Improving Public Accepance of Onshore Wind Energy Projets through Value-sensitive Design: A qualitative exploration

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Abstract

Wind Energy is heading towards playing a determinant role in the energy sector in the Netherlands, as it has emerged not only as the most economical way to add new capacity to the national grid, but as an important element in the country's energy transition. The extraction and consumption of traditional sources of energy such as gas and coal are planned to phase out before 2030, and onshore wind capacity in the country is expected to reach 6.8 GW in 2025 and a 9.6 GW capacity by 2030, with approximately 1500-2000 wind turbines to be installed. In a densely populated country such as the Netherlands, this implies a significant presence of wind turbines in the lives of citizens, with increasing numbers of on-land installations in the upcoming decade.

The aim of this thesis is to investigate the applicability of Value Sensitive Design (VSD) methods to address a very specific issue: the public acceptance of onshore wind energy projects in the Netherlands. The implementation of these projects is crucial for the future energy policy of the country, but has been hindered by low rates of implementation since the first commercially viable options, falling short on national targets consistently since the early 2000s.

Due to the impending urgency of more wind energy capacity in the Dutch grid, and the need for an orderly execution, researchers and policymakers have been looking into possible design techniques for the creation of peaceful pathways towards a common goal. Value Sensitive Design, a theory initially applied within the ICT sector in America, has found to be possibly applicable to the issue of public acceptance of wind energy projects.

The research starts by contextualising the development of wind energy in the Netherlands, from its first prototypes to the current days, focusing on the influence of the network of actors. It progresses with a review of the studies on public acceptance of wind energy, defining the notion as outcome of a collective process of adoption of the technology from a defined group of stakeholders.
The design tool of the Socio-Technical Value Map (STVM) is presented as part of the framework of Value Sensitive Design, and applied to the research problem. The process includes three investigations: a technology mapping, where procedural and technological designs are reviewed in their current status and alternatives, a stakeholder mapping, where the networks of influence present in the sector are analysed, and a value mapping exercise, where the underlying values of the sociotechnical system are visualised through Value Hierarchies. The five identified values that have interplay with public acceptance are: Trust, Fairness, Sustainability, Profitability and Well-being. The five value translate in norms and design requirements to be implemented in design initiatives (e.g. implementation of accountability frameworks relates to Fairness, thresholds for shadow-flickering to Well-being, etc.) The design requirements can be synthesised in three approaches to be implemented in process design for new wind onshore energy projects: Proactive Community Management, Public Tendering, and Co-Design and Co-Ownership.
These possible solutions are drafted with a value-perspective and address the issue of public acceptance of wind energy projects from a multi-stakeholder perspective. While far from perfect, these approaches are subject to the principles of VSD and aim to improve the dialogue between different groups of stakeholders, as key step towards a comprehensive approach to value-based design of wind energy projects in the country.

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List of Acronyms

ANT Actor-Network Theory

CBS Centraal Bureau voor de Statistiek

CLO Compendium voor de Leefomgeving

CLO Compendium voor de Leefomgeving

DfV Design for Values

ECN Energy Centre of the Netherlands

HAT Horizontal Axis Turbine

IEA International Energy Agency

LSEO Landelijke Stuur groep Energie Onderzoek

LTS Large Technical Systems

MLP Multi-Level Perspective

NMP Nationale Maatschappij der Pijpleidingen

NOW Nationaal Onderzoksprogramma Windenergie

OWEZ Offshore Wind Farm Egmond aan Zee

PA Public Acceptance

PBL Planbureau voor de Leefomgeving

RCN Reactor Centrum Nederland

RIVM Rijksinstituut voor Volksgezondheid en Milieu

RI Responsible Innovation

RRI Responsible Research and Innovation

SCOT Social Construction of Technology

SCOT Social Construction of Technology

SED+ Subsidie Duurzame Energie Plus

SEP Samenwerkende Elektriciteits-Produktiebedrijven

SER Sociaal-Economische Raad

SNM Strategic Niche Management

SST Social Shaping of Technology

STN Socio-Technical Network

STRN Sustainability Transition Research Network

STS Socio-Technical Systems

STS Socio-Technical Systems

STVM Sociotechnical Values Map

TIS echnological Innovation System

TM Transition Management

TSO Transmission System Operator

TT Technical Transition

VAT Vertical Axis Turbine

VSD Value Sensitive Design

WECS Wind Energy Conversion Systems

Introduction 1

Wind Energy is heading towards playing a determinant role in the energy sector in the Netherlands, as it has emerged as the most economical way to add new capacity to the national grid (IRENA, 2017) . The extraction and consumption of traditional sources of energy such as gas and coal are planned to phase out before 2030 (Rutte, 2019). Onshore wind capacity in the country consisted of 3.3 GW in 2018 and is expected to reach 6.8 GW in 2025 and a 9.6 GW capacity by 2030, with approximately 1500-2000 wind turbines to be installed onshore. In a densely populated country such as the Netherlands, this would imply a more invasive presence of wind turbines in the lives of citizens, with increasing numbers of on-land installations in the upcoming decade.

Considering the human-technology interaction from a sociotechnical system perspective, a powerful barrier has been identified in the achievement of renewable energy targets; namely, social acceptance (Wüstenhagen et al., 2007). Although the general public is typically in favour of wind energy (Ellis and Ferraro, 2016), local communities have expressed resistance towards the development of new wind turbines within close proximity of their households (Krohn and Damborg, 1999; Wolsink, 2012). The motives behind this opposition are predominantly due to the environmental impact of the turbines on the territory, particularly wildlife mortality, the shadow flicker impact, noise impact, and visual impact (Huber, 2010). More in general, a lack of transparency and involvement in the process has been identified as the primary concern of the public and has been the primary reason why multiple projects have faced delays, both in the Netherlands and other European countries(Agterbosch et al., 2007; Liu et al., 2019).

This graduation research tackles the problem of public acceptance of onshore wind energy parks with a multidisciplinary and explorative approach. Borrowing recently developed theoretical tools and applying them to sustainable technologies, the aim is to take in consideration the issues that act as a barrier for acceptance in the normative and technological design of windparks, and to provide actionable measures to foster public acceptance.

1.1 Research Description

Researchers and professionals alike have analysed the problem arising from public acceptance of wind energy thoroughly and multiple approaches have been developed to investigate the phenomena. These issues are often described as a conflict of interests arising from the various stakeholder groups (Agterbosch et al., 2007; Huber and Horbaty, 2010; Wolsink, 2012). In early 2000, a new approach had been developed and used as a possible means of reaching higher societal acceptance, this being: Value Sensitive Design (VSD). Derived initially from information and communication technology (ICT) applications, VSD is *'a theoretically grounded approach to the design of technology that accounts for human values in a principled and comprehensive manner'*. In accordance with the definition presented by Friedman and Kahn Jr (2002), founder of the Value Sensitive Design Lab at the University of Washington. This approach has been applied in recent years in a wide variety of fields, from robotics (Van Wynsberghe, 2013) to nanopharmacy (Timmermans et al., 2011), and important examples are further been presented in the energy sector (Mok and Hyysalo, 2018)

VSD materializes in the larger framework of Responsible Research and Innovation (RRI), a term used by the European Union's programmes which identify both and evaluate the ethical and societal aspects of technological innovations. The importance of RRI in European countries is significant, particularly in the Netherlands this programme has been developed by the Dutch Research Council (NWO) under the name of Responsible Innovation (RI). Literature regarding VSD and RI provides useful tools and methodologies which could be applied in exploring the conflict of interest between stakeholders since RI requires the process of innovation to be transparent, interactive and inclusive of a wide range of societal groups (Von Schomberg, 2012).

1.1.1 Public Acceptance

Public Acceptance is a broad concept, mostly regarded in policy literature as "societal acceptance". Multiple definitions are found in various scientific and academic papers, however, for this thesis the definition proposed by Wüstenhagen et al. (2007) is presented and adapted. As a combination of three distinct dimensions of acceptance; *socio-political acceptance, community acceptance*, and *market acceptance* the "triangle of acceptance" analyses how different actors interact and display attitudes towards renewable energy projects. This definition has proven to be widely used by institutions such as the International Energy Agency and other researchers, and has been found as the most suitable means relating to this project (Bout, 2019; Hampl and Wüstenhagen, 2012; Huber and Horbaty, 2010).

Socio-political acceptance refers to the most general level of acceptance, by means of including the public as a stakeholder. Such acceptance can be estimated through opinion polls, being the Eurobarometer (2003), and reflects not only the overall acceptance level but also to the degree in which policies have been effectively implemented by the relevant authorities. Examples of such policies include spatial planning systems which simulate collaborative decision making or the establishment of financial procurement systems (Wüstenhagen et al., 2007).

Market acceptance is defined as the rate of adoption or diffusion of innovation by the market. It is not only consumers which are considered in this definition but also investors and suppliers of energy. A notable example of the difference between market adoption from a more general acceptance can be found in the rise of green power marketing Bird et al. (2002) where households were able to switch to a sustainable energy supply without the need for physical implementation in their environment.

Community acceptance can be identified as the acceptance from local groups of stakeholders which reside locally near wind farms and may significantly siting decisions. It is necessary to manage these groups carefully due to a more highly detected *'Not In My Backyard'* effect (NIMBY) which may hinder wind park development and create negative attitudes towards local authorities. Though the definition of local resistance has also been noted as more complex (Ellis and Ferraro, 2016). The forthcoming analysis primarily focuses on community acceptance but includes findings from stakeholder groups relating to market and socio-political areas of acceptance.

FIGURE 1.1: The triangle of social acceptance of renewable energy innovation. (Wüstenhagen et al., 2007)

1.1.2 Responsible Innovation

Responsible Innovation (RI) is a term used to describe scientific research and technological development processes, incorporating potential impacts on the environment and society (Von Schomberg, 2012). The discipline stems from the literature on innovation and is difficult to define due to the variety of sectors in which it is applied. Recent work conducted by Ortt et al. (2020) from the Delft University of Technology and Erasmus University in Rotterdam explored the concept widely and suggested a definition in function of similarities between the distinct definitions. Innovation has shown to be *'responsible'* in virtue of certain criteria:

- An equilibrium between different values, not solely economic but social and institutional;
- Wide inclusion of stakeholders, considering not only innovators but also subjects of the implementation of certain technology;
- Comprehensive approach to innovation, considering impacts in the life cycle of the technology in its entirety and after innovation becomes obsolete;
- Multiplicity of perspectives and frameworks when considering an innovation.

RI is an emerging but important topic in research recently, as shown by the number of publications rapidly increasing in the last decade (Figure 1.2). Further evidence by the mobilisation of funds from the Dutch Government (NOW Responsible Innovation programme) and the European Commission (RRI in Horizon 2020). RI may be considered as fitting, albeit broad, approach for the research.

In the aforementioned publication by Ortt et al. (2020), a chapter is entirely dedicated to the exploration of RI in subsequent wind power episodes during three different stages of development and periods. These episodes of farm windmills in 19th century United States, Denmark's DC wind turbine and the modern AC wind turbine in the US are analysed and compared in terms of Stakeholders, Values, Innovation Approach, Entrepreneurship Approach, Institutions and Degree of Responsibility. The research provides a clear picture of how the relevant stakeholders are of value and time-dependent, exemplifies the important role of the institutions, and raises an interesting question highlighting the value conflict: *'How can we balance the values of low prices and welfare now, versus clean and sustainable in the long run?'*

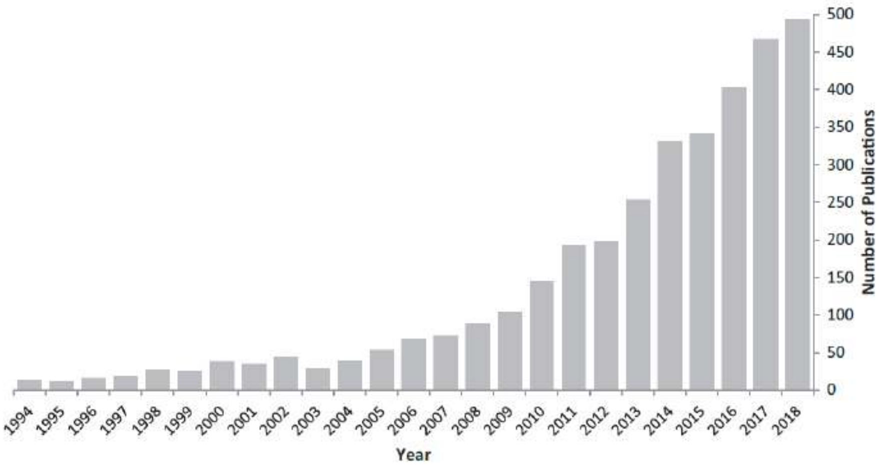


Figure 1.2: Number of articles published during the period 1994-2018 on the topic of responsible innovation (Ortt et al., 2020).

The authors suggest possible future research on how to match the economic values of entrepreneurs and other stakeholders, with diverse values from different groups, including societal values.

1.1.3 Design for Values

Design for Values (or value sensitive design, VSD) is a grounded approach which facilitates exploratory research on technology whilst addressing values implemented in the design of a specific innovation. Initially developed by Batya Friedman and other researchers at the School of Computer Science and Engineering of the University of Washington for ICT technologies, it rapidly revealed its applicability to various field of different technologies. VSD consists of three types of investigations: *empirical* (understanding stakeholders and their values), *conceptual* (formulation of relevant values and trade-offs) and *technical* (embodiment of values and value issues) (Friedman et al., 2013). An example of an applied framework of VSD related to sustainable energy installation and design is shown in Figure 1.3. In the case by (Mok and Hyysalo, 2018), the three stages of VSD are applied iteratively to a PV installation project in a cultural site in Finland: the authors use the conceptual investigations to reveal the value tensions and trade-offs of the stakeholders; the empirical investigations to explore the context ad measure how the stakeholder interact with the technology; and technical investigations to analyse the properties of the technology. The authors use the approach in a flexible manner to integrate value considerations with empirical investigations, and using the latter technical iterations to finalise the project design.

In literature, few but crucial examples have been found of the application of VSD in Wind Energy. A study from Oosterlaken (2015) explores the application of this methodology to better include key values in the design of wind turbines and parks, differing from common literature which proposes bottom-up approaches without addressing the technical object.
The paper explores various concepts, from the difference between acceptance, acceptability and support, and includes the notion of wind parks as part of a larger socio-technical system. Main findings by the paper from Oosterlanken which support this research are:

- The current research on public acceptance of wind energy treats turbines as 'black boxes', without addressing the causes of attitudes from stakeholders, and the

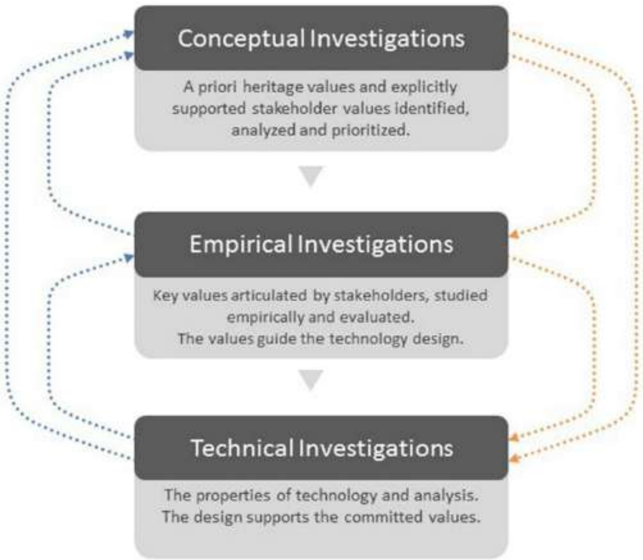


Figure 1.3: VSD Framework for a PV installation process (Mok and Hyysalo, 2018)

dynamic control in which these engineering artefacts are subjected to;

- Current literature on wind park and turbine design mostly focuses on engineering and technical features, without either implementing or considering values in the design process;
- Further research is needed on the topic, and this research should be interdisciplinary;
- Further research should include case studies considering design alternatives.

A further relevant source of inspiration for this research is an article published by Künneke et al. (2015) for the Environmental Science and Policy Journal. While not applying directly the VSD methodology, Künneke et al. (2015)'s work focuses on the existence of specific values conflicts, and how the analysis of these can lead to more purposeful designs. The paper explores the concept of purposeful institutional and technological design of offshore wind farms and applies a strong focus on values and implementation of those in the normative design, to develop a framework able to analyse possible interrelations between values. The research conducted is specifically related to offshore wind energy systems, however, many findings can be of inspiration in applying similar approaches to onshore systems. The definitions of objects and subjects of acceptability can be explored in onshore systems as it requires minimal modifications, and has already provided a good structure for the analysis, albeit from a normative perspective. A schematic representation of the framework is displayed in Figure 1.4. The combination of objects of acceptability (technical and institutional designs) and subjects of acceptability (community, market and general public, based on the work of (Wüstenhagen et al., 2007)) presents 18 possible categories of sociatal acceptability. The framework supports the understanding of the different dimensions of acceptance/acceptability and allows researchers to be more specific with respect to what aspects of the energy systems applies to which societal value.

The study emphasizes the need for coherent technical and institutional design, identifies relevant values in the process, and contributes to the delineation of a possible set of guidelines for future energy systems. While the article by Oosterlaken (2014a) presents direct conclusions to support this thesis, in Künneke et al. (2015) it is possible to notice how:

			Subject of acceptability		
			General public	Market	Community
Object of acceptability	Technology	Component			
		Subsystem			
		System			
	Institutions	Regional/ local			
		National			
		International			

Figure 1.4: Framework developed for a normative evaluation of offshore energy systems (Künneke et al., 2015).

- The value-centric perspective in a sector very similar to onshore wind energy system gives credibility to the topic of the proposal;
- Important definitions and analysis on acceptability in the research area is available and can be adapted and extended to onshore systems;
- A capability approach is suggested to address the dynamic features of the implementation of numerous values. It has been explored how Human Capabilities can be used in Design for Value to make the approach usable by designers (Oosterlaken, 2014b) and possibly an exploration on the concept could provide further development to the research.

1.2 Research Objective

In order to address the problem of community resistance towards onshore wind parks in the Netherlands, and contribute with a ethical discussion comprehensive of value analysis, this research project for a Master thesis in Sustainable Energy Technology explores the values embedded in onshore wind energy projects in the Netherlands and how could they influence social acceptance. The work aims to identify the key stakeholders' networks in the sociotechnical system, map the values associated with the projects that relate to public acceptance, analyse them and propose possible solutions to integrate the normative and technical design processes.
This research lays in the intersection of technology, innovation and ethics. Wind energy can be considered both as a sociotechnical system and as a set of defined elements (turbines, grid elements, control systems), and requires a multidisciplinary approach to be effectively implemented in the environment.
The aim of this research project is, through answering the research question, to explore new approaches to improve and evaluate public acceptance of wind energy systems. It is meant to investigate a different perspective on the topic of implementing ethics in design of sustainable energy projects.
As described in the Research Design (1.7) this thesis focus on the application of the theory of the Sociotechnical Value Map (STVM), developed by Pesch (2019) as an expansion of Rohracher (2002)'s work, in the overall bigger picture of Value Sensitive Design and Responsible Innovation.

The deliverable of this analysis is a comprehensive analysis of the wind energy sector in the Netherlands and a mapping of the values associated with development projects.

Insights and reflection points are highlighted and contextualized in a wider landscape, in order for project managers and researcher to implement initiatives to address these issues. A set of possibilities and alternatives regarding technical and normative design are proposed as starting point for enhancing participation and engagement within communities.

1.3 Academic Relevance

Concerning scientific relevance, this thesis is to contribute through investigating the adaptability of new techniques to the sector of onshore wind energy.

Applications of the VSD framework to sustainable energy have been explored in the recent years, but not extensively.
To confirm the statement from Oosterlaken (2015) that *"The VSD approach has so far not been explicitly applied to wind energy"*, two databases of academic publications have been briefly analysed: Scopus and Google Scholar.
The methodology of the analysis has been to identify the number of articles that treated the topic or applied the approach of value sensitive design, shortlist the ones that dealt with energy and sustainable energy, therefore identify the publications that could refer to wind energy.
The first analysis has been performed on the database of **Google Scholar**. While the owners of the database don't publish the size of the database, it has been estimated to contain around 389 million documents in January 2018 Gusenbauer (2019). Filtering the archive through specific search terms, the analysis results show a total amount of more than five thousand articles published addressing value sensitive design, in which 32% contained the term energy. The results are displayed in Figure 1.5 below.

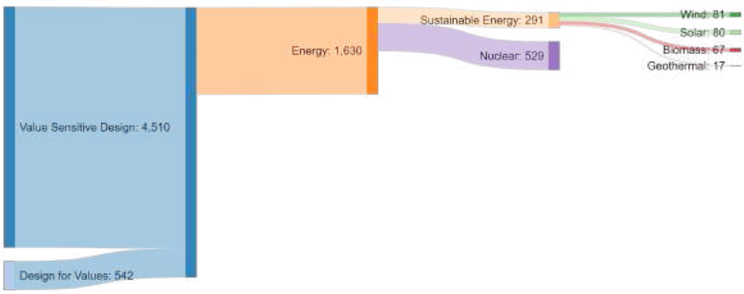


FIGURE 1.5: Scanning of the Google Scholar database with search criteria. Self-elaboration.

Google Scholar is not able to filter the database through keywords or words in the abstract. This resulted in many of the articles shortlisted in the analysis to be unrelated to VSD applied to sustainable energy, for various reasons. Many articles were only including the terms "value-sensitive design" or "wind energy" in the bibliography or irrelevant context. The scanning of the first database provided a good understanding of a possible quantitative division of papers per keyword, but it was not useful in shortlisting relevant literature.
A second analysis has been performed on the database of **Scopus**. Scopus covers approximately 36,000 publications, of which 34,000 are peer-reviewed journals, and features more advanced filtering options such as researching terms in the title, abstract or keywords of a paper. For the scope of this research, it has been considered more suitable than Google Scholar. The results are shown in figure 1.6.

The main difference in the methods of the two analysis reported is the option to filter for terms present in the abstract, title or keywords. Considering the outcomes, it is clear than a more refined list of papers has been found through the Scopus analysis. From the

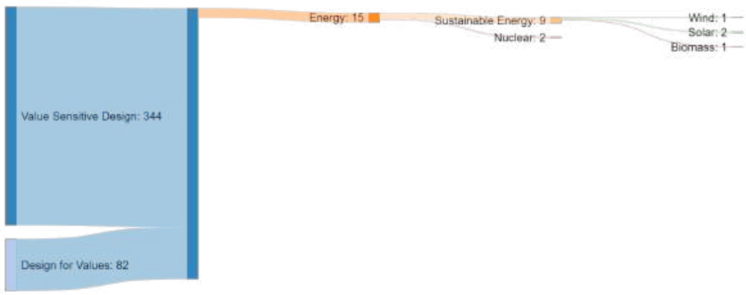


Figure 1.6: Scanning of the Scopus database with search criteria. Self-elaboration

408 non-overlapping articles treating VSD or Design for Values, only 15 were including the term "energy" in relevant sections, accounting for the 3.7% of the total. In comparison, 270 articles were covering Computer Science (66%) and 110 Social Sciences (26%), while engineering subjects were represented in 98 papers (24%). The research term "energy" and "sustainable energy" showed a very different range of papers, extending in different domains of research outside engineering practices. Considering the final result of the scan, it is confirmed that the application of VSD methodology to sustainable energy is a niche topic of research.
Since VSD and Design for Values have been used widely in social sciences in recent years and will continue to be a useful tool for social scientists (Friedman et al., 2015) a different search term have been tried to identify literature regarding acceptance and acceptability using the methods of VSD. Following the previous scanning procedures used, from the 408 Scopus articles considering VSD and Design for Values methodologies, apply the search criteria to include at least one term from acceptance or acceptability, 56 papers have been identified. An exclusion criterion for all the articles related to medicine has been applied, to sharpen the research to a thematic that did not address the health of individuals.
As expected, some articles between the two Scopus analysis (VSD and energy, VSD and acceptance) were overlapping. These articles have been considered suitable for a review considering the relevance of the topics treated. Other articles were not treating energy or sustainable technologies but have been reviewed nonetheless since they consider acceptance of technology innovations such as smart metering, autonomous driving or robotics.

The main results of this preliminary literature review are:

- VSD methodology has been applied for societal acceptance concerning different technology innovations;
- There is enough knowledge on the general framework itself to pursue further applications;
- Application of VSD has been found in sustainable energy technologies, but not in significant numbers;
- Only one publication covers the topic of VSD applied to wind energy, recommending further research.

Differently, literature on public and societal acceptance is more extensive and vaster than the one available for VSD. Relevant publications date back from when wind turbine technology started to get commercially implemented in Dutch society in the last decade of the twentieth century up until the present day. Considering the abundance of resources available, three main categories of publications have been investigated:

- Articles related to public/societal acceptance of wind energy authored by Dutch authors;

- Articles contextualising acceptance in the country itself;
- Highly referenced articles, which provides widely used concepts such as definitions, frameworks or important case studies;
- Reports from relevant research bodies such as the JRC and IWEA.

As identified above, with the analysis of the Scopus database, only a limited amount of this literature treats the topic of acceptance from the perspective of VSD. It is considered a valuable addition to the already existing literature to extend the work done from Oosterlaken (2015), building on the definitions provided by Wüstenhagen et al. (2007) to provide a new and fresh perspective on the topic of public acceptance of wind turbines in the Netherlands.

1.4 Societal Relevance

The integration of moral and ethical values into technological design is a responsibility for the correct and just existence of the technical artifact itself.
Engineers, when engaged in design or planning, are considering these activities as a value neutral task which has no more requirements than the functionality or efficiency of those devices. However the interaction with users, clients or external stakeholders, reveals through use that a technology incorporate moral and societal values (van den Hoven et al., 2015). Relevant examples include the "racist overpasses", designed to prevent busses to travel to specific areas of New York from poor neighborhoods (Winner, 2018), purposefully discriminatory tools, to misleading user interfaces in geographical data visualization (van den Hoven, 2007).
The correct and truthful representation of societal values into technology impacts individuals and communities through the interaction they have with the artifact. Considering buildings and habitations, the fruition of these from the residents will be in function of the values that are represented in the design, namely sustainability, inclusiveness, well being of inhabitants and others.

Wind turbines are not an exception from this analysis. While usually wind energy is associated to sustainable power production, and therefore in virtue of replacing more polluting conventional sources of energy (Eurobarometer, 2003), their interaction with the community and environment is full of controversy.
First of all, considering the trend of increasing hub height in modern turbines, the visual impact on a wide area is impacting the living experience of residents, together with more direct causes of nuisance such as noise produced by the generator, shadow flicker through the blades and other non-acoustic factors (Ellis and Ferraro, 2016; Wolsink, 2012). These instances have multiple negative effects on the population, interesting multiple aspects such as financial depreciation of households, decrease in the quality of sleep and therefore general wellness, fear (conspiracy tendencies) and general unease (Huber and Horbaty, 2010; van Kamp and van den Berg, 2018).
Secondly, how the communities are included in the decision making process is impacting the perception of the wind farm itself in the area. The feeling of not being taken seriously and the general unfairness feeling towards developers and institutions (**?**) fit clearly in the broader concept of Procedural Justice (van den Hoven et al., 2015). Design for Justice is a complex and ambitous task: to start, there is no agreement on the exact concept of justice and multiple definitions are to be taken in account. Fairness is not achieved in one attempt, this thesis will explore the difficulties in the process and evaluate possible solutions or mitigation measures.
Lastly, the trade off between different stakeholders group can be considered of public interest. As acceptance is defined in function of the target group (Wüstenhagen et al., 2007), one question of this thesis is to explore how to maximise contentment for diverse groups with different agendas and which one to prioritize. How these groups are clustered is also of interest: inside a larger cluster of "homeowners" different individuals have different priorities and attitudes, would prefer more financial benefits or environmental measures.

A more in depth analysis of the issue is covered in Chapter 2, where the concept of public acceptance is explored through literature and history in the Netherlands.

Power generation is crucial for our civilization, and sustainable energy has been found to accommodate this need with a relatively low impact on the environment. When generation intersects so narrowly the lifestyle of citizens, a deeper reflection on how this interaction is structured is needed. This thesis makes and attempt of enriching this analysis with newly developed tools such as VSD.

1.5 Industry Relevance

The discontent and protest against onshore wind parks are not a problem only for public groups and local authorities, as expected. Businesses and industry are concerned with the issue as much as other stakeholders group, as these instances are causing delays and impact the business continuity of their operations (Agterbosch et al., 2007). Moreover, with the rise of the concept of Corporate social responsability (CSR), businesses are implementing ethical-oriented decision making in their projects and products (Graafland et al., 2003).
In the Netherlands, a nation that is widely considered progressive in accommodating human needs in the living environment, engineering firms are making efforts to work closely to communities to include their needs in the developed infrastructure. Mayor firms developed corporate visions to act upon the values that are defined to be priorities: *People First, Integrity, Collaboration, Sustainability, Fairness, Accountability* and many more have been found to be relevant for their shareholders and employees (Arcadis, 2020; Deltares, 2020; Royal HaskoningDHV, 2020).
In the wind energy industry, considerable efforts are taken in order to address the issues with local residents and have a more comprehensive approach to project management of upcoming wind farms. In 2014 NWEA, the Dutch Wind Energy Association, counted around 300 members from the dutch wind energy industry, research and entrepreneurs, when it drafted its first *Code of Conduct* for acceptability and participation in the sector with Greenpeace, de Natuur- en Milieufederaties (the Nature and Environment Federations) and Natuur Milieu (Nature Environment). Later, in 2016, the code got updated and more parties joined (Nederlandse WindEnergie Associatie, 2016). The core of this Code of Conduct is that the stakeholders are involved in wind projects at the earliest possible stage. For each project, a participation plan is drawn up in dialogue with stakeholders and the competent authority (for example, the municipality), with which agreements about participation by citizens are established. The initiator of a wind project also appoints a point of contact for the environment. The aim is to distribute the benefits and burdens well and to involve local residents in wind projects at an early stage (**?**). The Code of Conduct binds the members of NWEA to a number of basic principles with regard to participation, communication and making a contribution to strengthening acceptance.

Efforts are conducted jointly, through NWEA, or individually, through actors of the sector researching individually on frameworks to engage the population in a more effective way and be able to build a reputation between the wider public. This research is mostly case-study based, evaluating which project was successful and which one wasn't, listing the reasons and estimate improvements of the process. A recent example is Blok (2018) research on partecipatory processes in Rijnenburg and Reijerscop for ENECO.

This research thesis is supported by Arcadis B.V., Global Design Consultancy firm for natural and built assets. The company has later researched a means of facilitating the acceptance of wind turbines by residents in many projects in the country (WindEnergieNieuws, 2018; Arcadis, 2017). The underlying approach from the company has been to increase the transparency of the process through informing the citizens about the upcoming projects, providing access to plans, and offering a constant flow of information between the wind turbine operator and the resident. It is believed that such a strategy may result in lessening public resistance (Caporale et al., 2020; Ellis and Ferraro, 2016;

Jørgensen et al., 2020). In the many years of field experience in consultancy, knowledge regarding nuisance factors has been identified and modelled. Noise and shadow flickering have been identified as the two main factors causing distress to residents living within the proximity of a wind site. Based on the assumption that less communication will lead to more discontent, reducing the nuisance would be a matter of keeping the residents informed. Arcadis has developed a mobile application which provides the residents with wind-noise and shadow-flickering forecasts, meteorological information, energy production insights and gathers feedback based on the level of nuisance perceived by the users. This research commenced with the fundamental ambition of understanding how the interaction between stakeholders may be facilitated, and how would be possible to solve the conflict of interests that arise in the process.

1.6 Research questions

Derived from the research objective (1.2) and the description of the research (1.1), a research question can be formulated in order to outline and guide the development of this graduation project. Considering wind energy from a sociotechnical system, and the network of actors involved as key participants in the process through interaction with the technology, this research will investigate the role of Values in social acceptance, using the VSD framework. Therefore, the main research question of the thesis is proposed as:

What are the values embedded in onshore wind energy projects in the Netherlands and how could they influence social acceptance?

In order to answer the main research question, a set of four sub-questions are formulated as it follows. Firstly, there is the need to define clearly what is meant for public acceptance. As mentioned earlier, acceptance is a concept that is highly actor-dependant, and therefore a study on the literature regarding acceptance is needed to explore the ramifications The definition of public is important, since different actors could have different behaviour towards a project, even within a small community. This is evaluated by answering the following research question:

***SQ1**: How is public acceptance defined in the context of wind energy?*

The first sub-question addresses the research domain in which this thesis is developed, while the second sub-questions focuses on adapting the research done in the environment in which this research takes place. The Netherlands presents a wide network of actors with different forms of interests in wind energy, and normative practices and policies in constant evolution. In order to fulfill the requirement for the application of the methodology described in 1.7, it is necessary to understand and map the participants of these processes, and this is be done by answering the second sub-question:

***SQ2**: Who are the stakeholders involved in onshore wind energy systems in the Netherlands?*

The methodology of the Sociotechnical Value Map introduced in literature has a strong focus on addressing the values that specific stakeholders (and technology) holds. While the actors have been identified through the previous research questions, more insights are needed in order to understand the dynamics between the process and identify the behaviours within roles. Values like profitability and well-being can be generally associated with specific groups, while sustainability is supposedly more shared within multiple networks. This investigation is done through addressing the research question:

***SQ3**: What are the values associated with public acceptance of onshore wind energy systems in the Netherlands?*

In the further analysis, it is important to describe how these values can be used as guidance for development of design requirements, normative processes and initiatives that can have an impact on the issue of public acceptance. Recent episodes shows both the virtue, for example of empowering of local initiatives through local cooperation, and the issues that can be raised. With a top-down perspective, using the tools and information collected through the previous research questions, the analysis will try to asnwer the fourth research question:

***SQ4**: What value-based design requirements and initiatives can influence social acceptance of future onshore wind energy projects?*

1.7 Research Design

This thesis project is designed to explore the application of VSD to wind energy specifically in the Netherlands. As such, the main methodologies used for it are *desk research* and *literature review.*

Desk research is a secondary research method, based on the use of already existing data. Secondary research includes research material published in research reports and similar documents. In this situation, various sources of documents will be investigated, for example:

- Scientific and Academic literature;
- Wind energy associations (e.g. NWEA);
- Municipalities and Provice's policies on wind energy;
- Government guidelines (Klimaatakkoord);
- Industry reports (Arcadis);
- European and Dutch surveys on wind energy.

Secondary research is more efficient and less time-consuming than collecting data directly, due to the availability of information on the topic, widely discussed in the media and in the business world. Less time of the research project will be spent on acquiring the data through surveys and more on the elaboration of the findings and further stages.

A disadvantage of desk research could be that, in a personal and user-centered situation as such as public acceptance, already elaborated data could include bias and distortion. Additional time was spent evaluating the authenticity and quality of data gathered.

A **Literature Review** investigates the concept of public acceptance and the current definitions found in literature. Starting from the definition used in 1.1.1 by Wüstenhagen et al. (2007), alternative definitions are considered and compared. An investigation on the methods currently used in evaluating and assessting acceptance is carried out. These concepts have been covered extensively in research since the 90s, with specific application to wind energy. A summary of relevant findings addresses the first research subquestion: *How is public acceptance defined and evaluated?*

Sociotechnical Value Map (STVM) is a framework proposed initially by Rohracher (2002) (in a limited form) and expanded further by Pesch (2019) that facilitate mapping a specific technology based on its embeddedness in a sociotechnical system. The framework is located in the context of Responsible Innovation in which it helps the implementation of relevant values for society in the innovation process. The STVM framework is not meant for direct implementation, but can help the formulation of new rules for technical or normative design, in the bigger framework of Value Sensitive Design (Pesch, 2019). The methods is composed in four different phases, as shown in figure 1.7 and described below.

The Technology Map, first step of the STVM approach, requires describing in depth the present technology, development and its characteristics. Due to the advanced stage of innovation in which wind turbines are situated, a brief overview from the Dutch wind energy sector is summarised in Chapter 2. The importance of defining the alternatives or technical choices is useful to discuss why certain parameters have been optimized, and if the trade-off between Return on Investment (ROI) and interaction with the environment

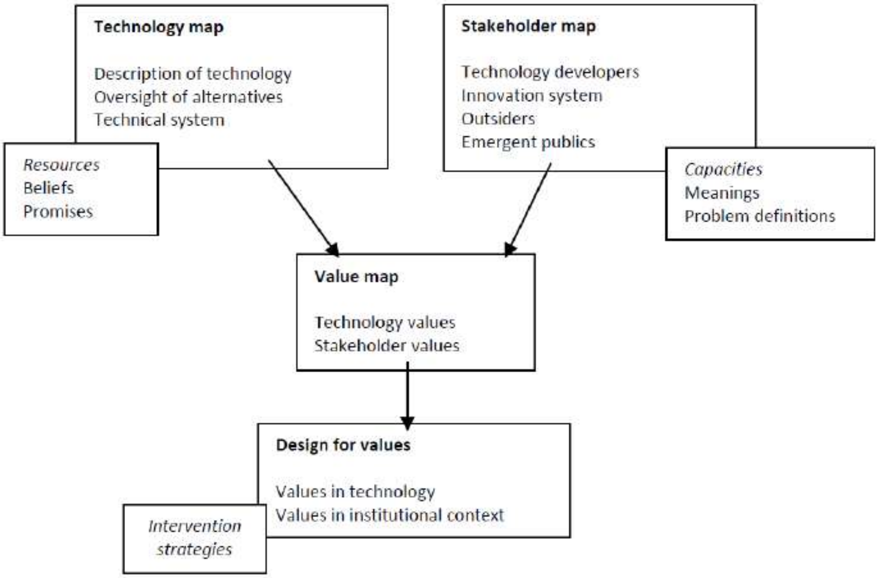


FIGURE 1.7: The Sociotechnical Value Map (Pesch, 2019)

is optimal.

The second step, namely the Stakeholders Map, investigates the role of societal actors that take part or play a role in the development of the innovation system. The found set of stakeholders are motivated first to dedicate resources to the technology, and a scope of this analysis is to investigate the motives and expectations that relies in their actions. How this wide range of stakeholders interacts will be simplified in categories with a determined set of characteristics, namely:

- *Insiders*: actors deeply involved in the technology. Investors, developers, advisors who allocate different kind of resources to it.
- *Outsiders*: actors who are not actively involved in the development. This categories is divided by Van De Poel (2000) in *outside firms* such as engineers and scientists, and *public pressure groups*, such as local committee in the case of onshore wind energy.

The further step, Value Map, identifies the values of the public mapped in the previous section. Not only it is needed to understand that technology comes inherently with values embedded, but that some groups endorse particular values based on their agendas. While the first two steps are mostly based on gathering empirical evidence and information, this step requires more investigation and there is a certain degree of freedom in how to accomplish the task.

The last step of this methodology has been got to know with the term of *"Design for Values"* within the scholars of the discipline. The application of the framework will be attempted by providing design requirements and value-based initiatives that can be applied to the normative framework, forms of project management and development, as well as spaces for co-design and co-ownership. According to Pesch (2019), this step requires a high level of creativity and specificity. Answering these question by vague suggestions will not solve the current issues, a certain degree of detail is needed in order to describe how the innovation system can be changed and adapted to accommodate to a more value-embedded design.

A balance of the methodologies described above is implemented in the thesis project, in order to attempt to answer the research questions and provide insights to the industry and academia.

1.7.1 Interviews with key stakeholders

Additionally to the research methods described above, interviews with representatives from different stakeholders group have been carried out between the months of January 2020 and March 2020. In table 1.1, an overview of the interviewees is provided. Throughout the manuscript, multiple times these interviews are referenced and provided as anecdotal support for specific claims. The accuracy and truthfulness of the content of the interviews carried out is not disputed, as the main objective of the research was to capture the sentiment, opinion and perspective of the different stakeholders. In the appendix 5.4, the summary of the conversations is provided.

Stakeholder group	Affiliation	Interviewee	Report
Research	University of Groningen	Frits van den Berg	5.4
Residents	none	P.	5.4
Residents	none	K.	5.4
Residents	none	J.	5.4
Residents	OAR[1]	V.	5.4
Authorities	Province Zuid Holland	Astrid Vlaminkx	5.4
Private sector	NWEA	Rik Harmsten	5.4
Consultancy	Arcadis	Erik Koppen	-

Table 1.1: Interviews performed for the research project.

1.8 Thesis outline

The thesis starts with a review of the academic literature regarding public acceptance of Wind Energy. Scientific articles and technical reports are taken in consideration while defining and discussing concepts as such public acceptance, societal acceptance, nuisance and environmental impact. In Chapter 3 a review of the current state of Value Sensitive Design is presented, providing the theoretical background needed to approach the further topics. A research on the applications of VSD on sustainable energy sources provides an overview on the possibilities and outcomes of the graduation project.
Chapter 4 consists an analysis of onshore wind energy systems in the Netherlands, following the framework of the Sociotechnical Value Map (STVM). Technology Map, Stakeholders Maps and Value Map are investigated through a 360°analysis of the sector. The outcomes of this analysis is later discussed in Chapter 5, whilst a comparison with the findings from scientific literature complements this analysis. In Chapter 5, the outcomes of the analysis are used to reflect on how to translate those in normative requirements and technological design specifications, and its implications on the overall public acceptance of wind energy projects.
In Chapter 6, conclusions are drawn. Gathering the outcomes from previous chapters, an overview of the discussion about public acceptance of onshore windparks in the country is enriched by the knowledge gathered and structured. Considering the multitude of stakeholders mapped in the previous sections, recommendations are summarised and made available. Further research advice and a personal recommendation concludes this thesis graduation research project.

Public Acceptance of Wind Energy in the Netherlands 2

To acquire the needed background for a comprehensive analysis, the research domain of the thesis is investigated in this chapter. The theories and frameworks that are a foundation to this work are investigated and contextualised in the context of the Dutch wind energy sector, starting from a timeline of the development of wind power in the country in section 2.1. Historical and political factors play a significant role in the community attitude towards energy projects, as the theory of sociotechnical systems explores extensively. Not only, but culture and society are also shaped and reciprocally shape the technology they are interacting with: therefore, against the backdrop of public acceptance, the relation between social groups and wind turbines needs to be investigated. A brief review of the main concepts and theories of *Social Shaping of Technology* (SST) and *Technological Transition* (TT) is carried out in section 2.2, including Social Construction of Technology, Actor-Network Theory, and concisely the Multi-Level Perspective of Geels. Society and Technology studies provide some relevant concepts for the overall analysis of public acceptance that are later incorporated in the methodology of analysis.

A review of the concept of *acceptance* follows, through literature study of the development of the notion through the years. While this analysis occurs in a stage of research maturity of the concept of acceptance, compared to the early stages described by Wüstenhagen et al. (2007), frameworks from other disciplines are useful to implement. A brief excursion on the role of cognition biases present in the public debate is presented, after reviewing the relevant literature of Public Acceptance. Implementing notions with a multidisciplinary approach from the history of wind energy, social theories of technology, evolutionary economics and sustainability transition, the first research question 1.6 *"How is Public Acceptance defined and evaluated?"* is answered.

2.1 Wind Power in the Netherlands

Imagining the future of wind power in the country would be foolish without considering its complex and sometimes controversial past. The Netherlands have been relying on wind energy since time immemorial. The first record of draining mills dates back to 1414 in the town of Reijerwaard (Burton et al., 2011), while is suggested that the technological artifact was already present in 1200. Deeply embedded in the landscape of the country, wind energy technologies were first investigated to produce electric power in 1923, applying cheap electrical motors to the already existing windmills infrastructure(Verbong, 1999). In 2018, 10.58 TWh of energy from onshore and offshore energy sources was generated, with a steep increase in the last two decades, as shown in Figure 2.1.

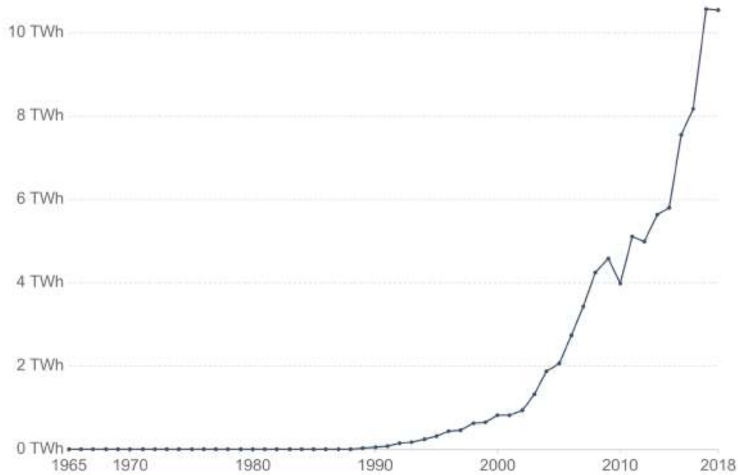


Figure 2.1: Wind Energy Generation, 1965 to 2018. (BP Statistical Review of Global Energy, 2019)

From the first wind turbine installed in the country, the 25 meters 300 kW HAT (Horizontal Axis Turbine) installed in 1977 by the Energy research Centre of the Netherlands (ECN) to the 4.2 GW installed in 2017 (IEA, 2017b), the country made important progress during these 40 years. Many RD projects, institutions, businesses and social actors took part in the development of a sector that has been intrinsically embedded in the Dutch society.

This section will evaluate the introduction and attempts to develop and scale wind energy in the Netherlands, from the oil crisis of the 70s up to recent years. Verbong (1999) in his work *Wind Power in the Netherlands, 1970-1995* provides interesting insights on the interaction between research programs, public reception and political support. Kamp (2008), while researching the roots of the contrast between the Netherlands and Denmark in terms of the development of wind energy industry, contributes with insightful findings through the analytical frameworks applied and identifies criticalities in the development processes. From 1995 onward, little literature has been found as explanatory and complete as the examples previously mentioned. Working reports from the government, industry data and international monitoring reports have been used to draft the path of development that the Netherlands has been following up to recent date. Insights from interviews and conversation with actors in the industry have also been used, when literature was not available.

2.1.1 1970-1985: First Research and National Debates

Two events kick-started the research in wind energy in the Netherlands *The Limits to Growth* by Meadows et al. (1972) and the first oil crisis of 1973, one of the most

impactful events in the energy sector of the twentieth century. The government and Dutch policymakers found themselves in charge of finding reliable alternatives to fossil fuels for the first time to cope with the energy crisis. While nuclear energy was considered a technological masterpiece that brought with it high expectations, considering the 1960s developments in USA and UK developing military and commercial products, it had high uncertainties. The issue of researching new energy sources and technologies needed an evaluation of a wide range of alternative power supply options.
In September 1974, the first Energy White Paper was published by the Dutch Department of Economic Affairs, announcing a change towards an active energy policy by establishing diversification of energy sources and energy conservation as key elements. A the time, lack of information and technical development of these new sources was a critical factor, but the fact that solar and wind sources could help diversify the energy portfolio of the country, together with nuclear energy, was clear (Lubbers, 1974).

One of the first steps taken by the Dutch government was the establishment of the National Steering Committee for Energy Research (LSEO, Landelijke Stuur groep Energie Onderzoek) and the involvement of the Energy research Centre of the Netherlands (ECR, previously known as Reactor Centrum Nederland, RCN). The first, formed with the participation of representatives from universities, research institutes and industry, had the task of outline a program for scientific research and technological development. In January 1975 the main goals of the program were laid out together with the available knowledge, establishing wind energy (together with geothermal and solar-heating systems) as one of the most promising sources. Uncertainty regarding the technology of the turbines, the impact of wake effect and the siting of units were critical research issues. It is notable that 35 years before the current date, LSEO recommended evaluating the construction of wind energy platforms in the national territories of the North Sea (LSEO, 1975), where today more than 400 offshore wind turbines are operating or in development phase (4C Offshore, 2020).
In 1976, as results of the promising analysis by LSEO, the First National Research Program on Wind Energy (NOW-1, Nationaal Onderzoksprogramma Windenergie 1) was initiated. One of the main goals of the program was to explore the differences between Horizontal Axis Turbines (HAT) and Vertical Axis Turbines (VAT), designing and constructing few prototypes such as the 25 meters high HAT turbine installed at the ECN site in Petten (shown in figure 2.2). Developed in late 1978, with the collaboration of a large group of companies and institution, the turbine run for three years and its operational measurement was later used to design more advanced models.
Further Technological developments were proposed in 1973 by Th. van Holden, a researcher at the Delft University of Technology, proposing to attach tipvanes to the rotor blades. After years of systematic research, the idea to create a flux through the rotor was considered a possible technological breakthrough and extra funds were allocated for the research, which never materialized in modern designs.

The outcome of NOW-1 was that wind energy offered sufficient long term prospects but more research was needed for large scale implementation. This unsatisfactory and vague outcome led to one of the first debates and conflict in wind energy: where to allocate more public funds? Would large scale applications be the future of this technology?
Since the beginning, representatives from the industry and research laboratories were contested for their exclusive orientation to large scale implementations. Alternative and anti-nuclear movements ideologically identified modern technology as a key aspect of the capitalist society, and rejected the use of renewable sources to benefit the utility companies. As clearly described by Verbong (1999):

> Their main opponents represented the anti-nuclear and alternative movements, who viewed modern technology -epitomized by nuclear technology- as a crucial part of the capitalist society they were rejecting in favour of a more 'humane' type of society. The promotion of alternative sources of energy, an example of environmental technology adapted to human size, was simply part of their strategy to reach their goal.

The debate concerning future applications of wind energy came at the time of a

Figure 2.2: A picture of the 25-m 300 kW HAT in Pettem, 1978. (Verbong, 1999)
.

second energy crisis and was one of the first and most interesting intersections between engineering, economics and partly ethics of wind energy technologies. The direction in which to develop such a promising technology was unclear and subject to the so-called "dilemma of control", which states that *"the social consequences of a technology cannot be predicted early in the life of the technology. [...] When change is easy, the need for it cannot be foreseen; when the need for change is apparent, change has become expensive, difficult and time consuming"* (Collingridge, 1981). The Collindgridge dilemma explains the importance of information at the early stages of development of innovations, and the difficulties in adapting a technology in its mature stages due to the gained momentum.

National politic also influenced the early debate on the direction of dutch energy policy. The government at the time was guided by Mr. Dries van Agt with a majority coalition of Christian-Democratic (CDA) and neo-liberal conservative (VVD) parties, advocating for nuclear energy as the only viable alternative to fossil fuels. In opposition, the Labour Party (PvdA) and other leftists groups challenged the statement and requested a national debate on the future of energy policy. The national debate proposal seems to have originated from small circles in churches, and after a preparatory phase, it took place between 1981 and 1984. The main outcome of the discussion was a general aversion from the Dutch citizens towards the development of nuclear power plants. The Lubbers government, successor of the CDA coalitions of van Agt and previously involved in the matter as Minister or Economic Affairs ignored the public sentiment and proceeded with the plans until the Chernobyl nuclear accident of 1986 happened and the sentiment of fear related to the risk of nuclear energy were too strong to be ignored.
Wind energy was a controversial topic in terms of how much potential could be achieved in the country, but still more appealing than the consequences of a local nuclear disaster. The various NOW groups that worked during the 70s on the research projects suggested an achievable power installed capacity of 5000 MW, for a maximum number of 34,000 50-meters turbines to be installed on national soil. The concerns that high cost was

involved in the development of these project (Lubbers, 1980) and the lack of storage capacity, combined with the issue of integrating wind power in the national grid, lowered the estimate to 2000 mW in the report of the national debate on energy policy in 1983. Not only researchers and policymakers were involved in the goal-setting of the government. Royal Dutch Sheel and the Gasunie, respectively private and public-private companies managing the harvesting and distribution of the natural gas reservoirs in the Groningen Province and north of the country, were actively involved in the discussion, and therefore their attitudes and interest were included in the target choose from the government. The final target to achieve 1000 MW of wind power installed by the year 2000 was finally set in 1985. It has been noted that those numbers were "*nothing more than educated guesses*" and often lacked justification(Block, 1985). Environmentalist groups and leftist parties were strongly against the reduction of the target and highlighted again the political importance in technology implementation and public debate.

The 1970s was a crucial decade for wind energy, and the actors that took part in the research, discussion and debates played an important role in what is the current situation. The role of the public opinion, starting from small church circles in the early 80s, sparked a discussion that involved the whole nation, and today still has its reflection in the current situation of renewable energy systems.

2.1.2 1980-1990: Competitors and Stall

While the research on more advanced types of wind turbines continued through the NOW-2 program (investigating wind parks, VAT designs, multi-rotor turbines and tipvane aerodynamic research) competition from other foreigner markets was pressuring the Dutch industry. While nationally there was still struggle in developing cost-efficient prototypes of small scale turbines (50-100 kW), in the United States a wind energy boom was taking place. In 1978, the U.S. government through the Energy Tax Act provided legal instruments to diminish the national dependence on oil, subsequent decision after the Arab sanctions and the Oil Crisis of the previous decade. From the only 150 turbines installed in 1981, the State of California could count on 4750 new turbines by the end of 1984. The American market was flourishing thanks to the active subsidies from the government, and another important set of players entered the global game of wind energy: the Danish wind turbine manufacturer. In 1985, they sold 2,000 turbines in California only (van Est, 1999), and established their groups as *global leaders* (Heymann, 1995).

Extensive research has been conducted retrospectively on the successful case of the Danish wind energy (Krohn, 2002; Sovacool et al., 2008; Klaassen et al., 2005) and on the comparison between the Dutch and Danish approaches (Kamp, 2008). What was clear at the time was a stalemate in the Netherlands wind power sector: NOW program developed technical knowledge in the design of turbines, but the few companies active in the field had no financial availability to improve their products and achieve the cost-effectiveness of Danish competitors. The government tried to involve the industry in the process, by assigning the design of a 10 MW wind park to the NV SEP (N.V. Samenwerkende Elektriciteits-Produktiebedrijven, a joint co-operating network of electricity producing companies). But the organization had no experience in wind turbines and actively supported the development of nuclear energy, therefore resulting in a lack of support and management from the electricity sector in this and similar projects. While an endeavour to develop a market was attempted through state subsidies, the potential buyers did not invest in turbines considering the options too unreliable and expensive. By the end of 1985, only 9 MW were installed in the Netherlands, while 60 MW of operating turbines were present on Danish soil. California had at the time 910 MW of wind power installed, 100 times more than the Netherlands, with a comparable coastal length and only 10 times the overall territorial extension.

One of the positive examples of the development of technology was the medium-sized company Lagerweij. Founded in 1979 by the 18-year-old student Henk Lagerweij, the company started producing small turbines with 75-80 kW two-bladed turbines and in by the end of the 1980s was one of the only three manufacturers surviving the crisis (or lack of development) of the Dutch wind turbine industry. Focusing on small scale implementation and using knowledge obtained by learning-by-searching through his personal contacts (Kamp, 2008), Lagerweij was one of the first to introduce the application of direct drive in gearboxes (Lagerwey, 2020). An example of a three-bladed 30 kW prototype is shown in figure 2.3. Despite the relative success of the company as a pioneer of the sector and entering the Indian and Japanese market, the struggled and filed for bankruptcy in early 2000, due to a difficult home market and the aforementioned competition with Danish manufacturers.

(a) Transportation of pillars in Barneveld, 1979.

(b) First three-bladed 30 kW turbine, 1980.

Figure 2.3: Small scale manifacturing of wind turbines by Lagerweij in the early 1980s. (Lagerwey, 2020)

The 80s were not a encouraging decade for Dutch wind energy. The few local experiences with wind energy, e.g. the Sexbierum 10 MW wind park first in the country and developed by SEP[1], were not particularly encouraging and the external pressure pushed for high governmental support in the only 50 MW of capacity installed by 1990. The ambition to reach the already downscaled goal of 1000 MW was threatened my multiple factors, one of which was the attitude of the "monopolistic" behaviour of the electricity sector's utility companies.

2.1.3 1990-2000: The Importance of "Sustainable Development"

The political agenda of a country changes over time, and with that its legislation and priorities. While in the previous decades the major driver for the development of wind energy was to diversify the energy portfolio of the nation with economically-feasible sources, in 1989 the paradigm shifted. The favourable combination of two different events such as the establishment of the National Environment Policy Plan (NMP, Nationale Maatschappij der Pijpleidingen) and the liberalization of the electricity sector through the Electricity Law, both in 1989, changed the national rules in which wind energy was considered.
After the agreement on the formation of the Lubbers-Kok government, it was stated in the NMP that "*environmental policy was to be the third main element in government policy*" placing the issue of reducing carbon dioxide emissions (and others, such as energy savings) high on the political agenda (Rijskwaterstaat, 1989).

[1]Samenwerkende Elektriciteits-Produktiebedrijven

Before the Energy Act of 1989, the Dutch electricity sector was characterized by vertically integrated monopolies (Damme, 2005), centralizing production in only four large regional companies (EPZ, EPON, UNA and EZH) who owned and operated SEP. The first step of the act was to impose licensing for new traditional generation exceeding 5 MW and to "separate" distribution and production, anticipating what in the future would have been described as the liberalization of energy markets encouraged by the European Commission. The Act made decentralized generation attractive to investors through a high feed-in tariff, therefore doubling the decentralised capacity from 2100 MW in five years (Damme, 2005). With the combination of market instruments and positioning withing the NMP framework, emerging distribution companies were now allowed to create profitable wind energy projects up to 25 MW.

Since the history of a technology is not just a chronological order of units of power installed, it is fair to point out that a possible milestone in the Dutch wind energy sector was the incorporation of wind turbines into *Nationale Molendaag*, the National Windmill Day in 1992 (Gipe, 1995). Held on the second Saturday of the month, on the 10th of May 1992 in the small city of Westkapelle two 250 kW 43-meter high Micon turbines were installed to celebrate the national recurrence (Stichting Cultuurbehoud Westkapelle, 2017). The small city is located on the island Walcheren in the Zeeland province, and it was part of the agreement made by the government with seven coastal provinces of the country to install 1000 MW by 2000. It was during the implementation of this agreement that one of the first national cases of resistance from local inhabitants was documented. While the study of the issue of social acceptance was only at the early stage, the voices of the residents were not taken in consideration during the siting and decision of suitable location for the projects, and it was proven to be a critical obstacle in the implementation (Verbong, 1999). The main factor of resistance identified was noise produced by the turbines and visual impact on the landscape. To accommodate those objections, the plans of the government were downsized considerably, proving for the first time that policy and technical conditions need to be accompanied by previous engagement of local actors, costing the national goal of 1 GW not to be met in the year 2000.

As shown in figure 2.1, there was little to no production of wind energy in the last decades of the twentieth century. The big increase of wind power capacity installed and energy produced came after the significant year 2000 when big technological development in the turbines allowed for bigger rotors to be installed and a more concrete and precise agenda in terms renewable energy sources exploitation. Nevertheless, the three decades covered in 2.1.1, 2.1.2 and 2.1.3 laid out the starting point for the milestones that the Dutch government managed to achieve by today. The small episode that happened in those years had long-lasting consequences: as Gipe describes in his book *Wind Energy: Comes of an Age*, published in 1995, RaboBank was suggesting in those years to local farmers to consider wind energy as a source of revenue to exploit the financial incentives offered. This "advice" is now present in the debate on the redistribution of financial benefits from operating wind farms in the country, where *windboers* exploit their land to install and benefit out of large wind farms, without taking into account other citizens in the area that would eventually be impacted by their decisions. The concept of Procedural Justice applied to wind farms will be discussed thoroughly in the following chapters.

2.1.4 2000-2020: Ambition, Targets and Implementation

With the advent of the new century, the Netherlands wind energy sector was facing the lack of achievement of power capacity targets, an increasing rejection of onshore projects due to the *not in my backyard* effect from local communities and under-competitive manufacturing industry. While the situation was far from ideal, the importance of developing low carbon intense source of energy was still high on the political agenda of the country, that tried to approach the problem from a different perspective, testing the well-known Dutch pragmatism.
If the implementation of wind turbines in a so densely populated country was difficult, why do not exploit opportunities where a citizen would be less impacted? In 1975 the potential of wind in the North Sea was already described in reports from the ECN (as

Figure 2.4: An example of wind turbines placed on farmer land property. Consisting of 19 Micon 600 kW turbines, in 1999 was the largest installation, exploited by a cooperation of six windboers (IEA, 1999)

.

described in 2.1.1), and the high wind speed of the offshore areas could have provided the necessary conditions to reach the 2,750 MW target of wind capacity set for the year 2020. As Eecen (2011) describes, the research in wind energy becomes focused on offshore applications in early 2000, and a first demonstration offshore wind farm was tendered. A consortium composed by engineering firms, banks and project developers called Noordzeewind outlined the project, while ECN was working on the very first wind resource atlas of the Dutch North Sea, published in 2005 and shown in figure 2.5.

This tool, created with a combination of numerical weather prediction models and weather measurements in the North Sea, shown that important wind speed was achieved while moving away from the coast and with its accurate 10 year predictions could provide useful information for the planning of offshore projects for the first time. The efforts of Noorzeewind aimed at *learning as much as possible from the near shore demonstration wind farm in order to better realize the future larger offshore wind farms that are necessary to reach the national targets* (Eecen, 2011). The demonstration project was a 108 MW Near Shore Wind farm, located between 10 and 18 km from the coast of the municipality of Bergen, it involved 36 Vestas 3 MW turbines with a monopile foundation and produced roughly 350 GWh per year, enough to supply 100,000 households (Noordzeewind, 2020). Using Danish wind turbines for the project was considered a wise choice, even though it meant the official "admission of defeat" in the competition with the Danes on wind energy: being the first Dutch wind farm, the Offshore Wind Farm Egmond aan Zee (OWEZ) came 14 years after the first Danish offshore project of Vindeby. Acquiring knowledge became more important than acquiring market dominance, and the Dutch excellence in research was concentrated in the wind energy department at the Energy research Centre of the Netherlands ECN and in the interdisciplinary DUWIND wind energy department at Delft University of technology. Together, these two are considered in the top-5 of international wind energy research groups (Eecen, 2011).

Thanks to participation of the Netherlands in the International Energy Agency Wind Technology Collaboration Programme (IEA Wind TCP), constant unbiased monitoring of the country performance is available for every year since 1978 through the IEA Wind Annual Reports. This grey literature provides a comprehensive overview of the national activities in the wind energy sector of all the member states of the association, with a summary of national policies, commercial implementation initiatives, deployment, challenges, RD initiatives and progress and many more aspects. While this and other detailed overviews are comprehensive of many technical aspects, they lack the social perspective and the sense of continuity and storytelling present in the work of Verbong reviewed

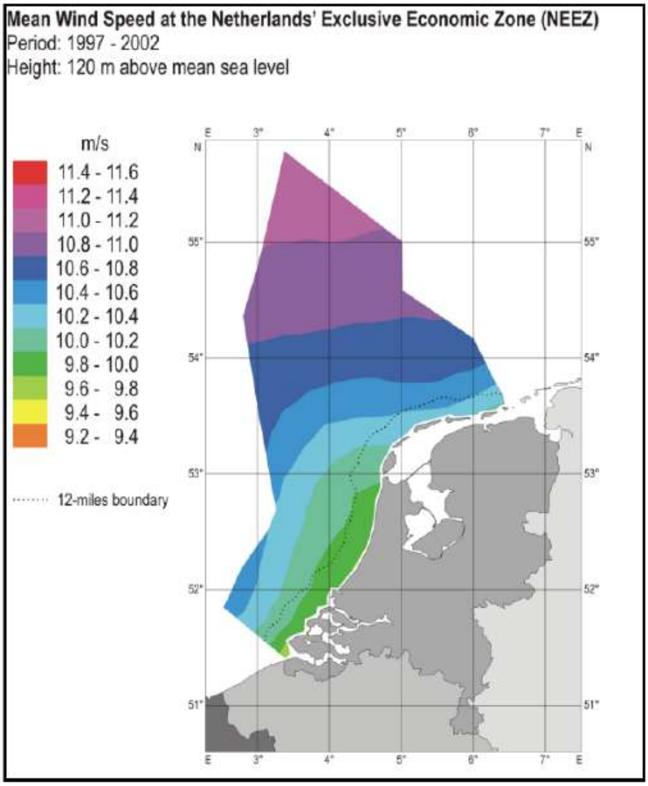
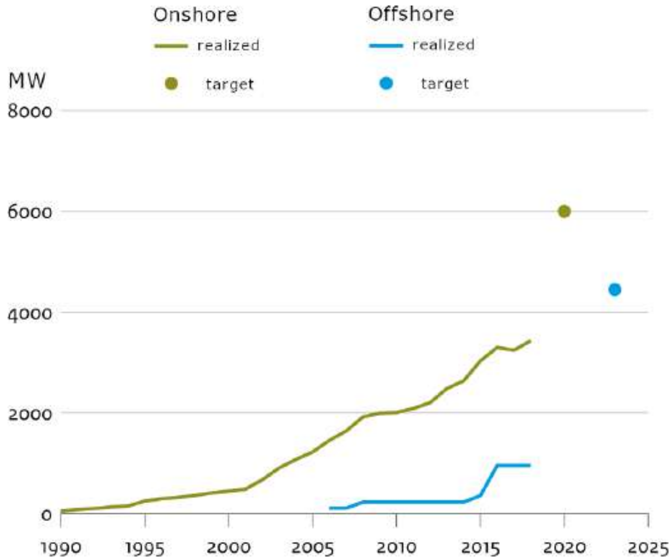


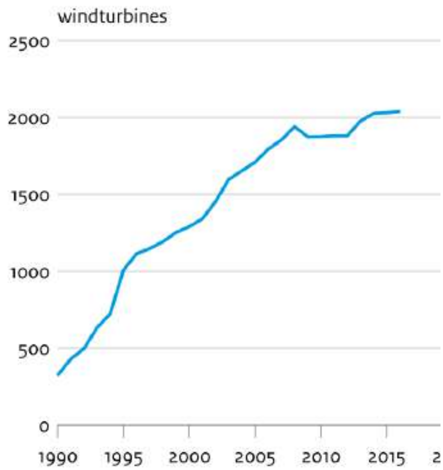
FIGURE 2.5: The publication of the wind energy atlas by the Energy Research Centre of the Netherlands (ECN) in 2005 was a crucial step in the development of offshore wind farms.

in the previous sections. Nevertheless, data can be used as an important reference to describe the development of the sector in the last 15 years. The Compendium for the Living Environment (CLO, Compendium voor de Leefomgeving), a cooperation between the Central Bureau of Statistics (CBS), the Dutch Environmental Assessment Agency (PBL), the National Institute for Health and Environment (RIVM) and research groups, is a project of data visualization that provides interesting insights on the distribution and phases of wind power capacity in the country.

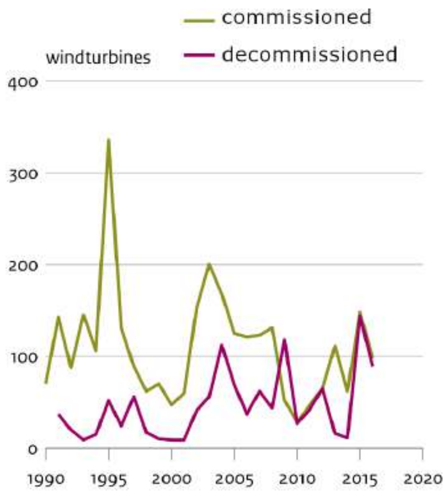
In figure 2.6a, it is possible to observe the cumulative capacity of installed wind power both onshore and offshore through the period of analysis. As described beforehand, the OWEZ farm was commissioned in 2006, followed shortly by the Princess Amalia Wind Farm (named after the Hereditary Princess of Orange) as the second operational wind farm in the country. With little capacity, the parks produced more electricity per unit of power than traditional onshore turbines because of the higher capacity factor but encountered expensive installation costs and difficulties in accessibility. Before the late 2010s, the cost of offshore wind power generation has always been high and generally not competitive against oil and gas (Lensink, 2013). The cost effectiveness of offshore wind energy has been a central topic in the strategy of the Netherlands in this period for R&D and fueled various entrepreneurial activities. Ampelmann Operations, a TU Delft-spin off start-up, was founded in 2008 to fulfil the need for safe access to offshore platforms, considered a bottleneck in the technology. The Ampelmann System, a motion compensated personnel transfer system, is the result of entrepreneurial spirit, pragmatism and the ability to seize the opportunities.



(a) Cumulative capacity of wind power installed and target, onshore and offshore (CLO, 2019).



(b) Cumulative number of wind turbines installed (CLO, 2018).



(c) Number of wind turbines installed and dismantled per year (CLO, 2018).

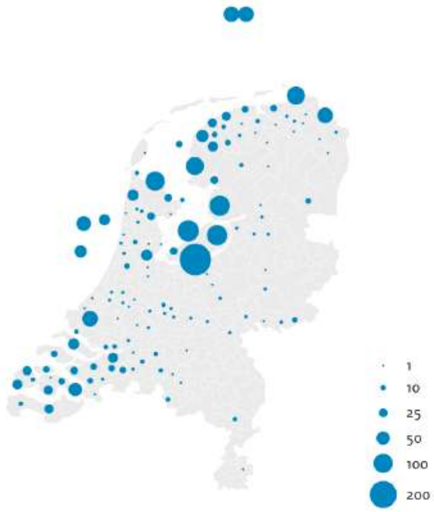
Figure 2.6: Capacity and number of wind turbines in the Netherlands from 1990 to 2017 in the Netherlands (CBS, 2018).

In 2013, the ambitious target of 4,450 MW was set for the offshore capacity to be installed by 2023 as part of the Energy Agreement (Energieakkord), about 20 times the capacity that was installed at the time of the goalsetting (SER, 2013). This rather arduous intent had been followed by the commissioning of additional 750 MW of capacity, with the wind farm Gemini being the second world's largest wind farm at the time of its commissioning in May 2017. The same year, the Netherlands moved from a tendering system with a single criterion to a system with a request for subsidy-free bids (**?**) and opened applications for the Hollandse Kust Zuide sites, located off the coast of Hague. In

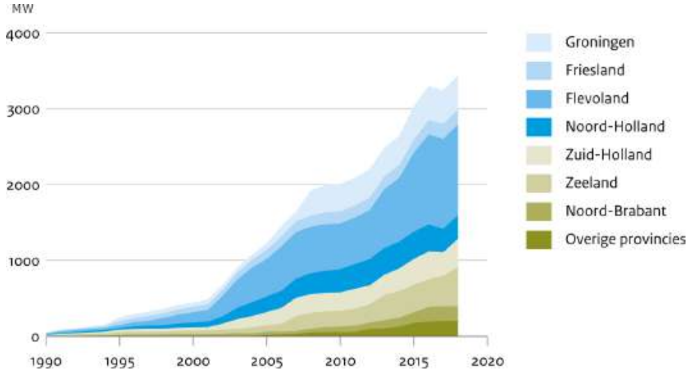
March 2018, the world first offshore subsidy-free wind farm tender was won by Vattenfall. The historical bid was a game changer event for the industry, where the prices per kW were constantly decreasing and highlighting offshore wind energy as a competitive option. Years of technical development, advanced risk management and joint efforts between the industry and the government resulted in the Netherlands being the first nation to host a subsidy-free wind farm. Vattenfall won the tender first for sites 1 and 2 of Hollandse Kust Zuide, and in 2019 for sites 3 and 4, for a total expected capacity of 1.5 GW (RVO, 2018, 2019). The Dutch government has high expectation for offshore wind energy in the future, and with the Coalition Agreement and the Climate Agreement (2019) the roadmap for offshore wind energy was traced to reach 11 GW by 2030 (Government of the Netherlands, 2020; Vermeulen, 2019) by combining sustainable energy generation with green energy storage technologies such as hydrogen. Five offshore wind farm zones have been defined and planned to be tendered between 2019 and 2025. TenneT, the Dutch TSO, is working in close collaboration with Gasunie (mentioned earlier in 2.1.2 for their involvement in the first national debate on wind energy in 1982), Energinet (Danish network operator) and the Port of Rotterdam to create a hub in the North Sea for a large scale offshore project to fulfil the 2050 vision of the Paris Agreement to secure sustainable energy supply and minimize environmental impact (North Sea Wind Power Hub, 2019).

Figure 2.7: Digital representation of the concept of the North Sea Energy Hub in the Dogger Bank, implementing wind, power-to-gas and power-to-hydrogen technologies. (TenneeT, 2020)

The idea of an international, power-to-hydrogen offshore wind energy hub (represented in figure 2.7) could have sound fiction not many years ago, and the consortium plans to have the first hub operational by the early 30s. The road from small 300 kW prototypes developed by the ECN (2.2) to this massive large scale projects is impressive, considering the difficulties encountered in these 50 years.



(a) Distribution of wind turbines in the Netherlands in 2017 (CLO, 2018).



(b) Cumulative wind power capacity installed per province (CLO, 2019).

Figure 2.8: Distribution and spread of wind power production sites in the Netherlands and contribution (CBS, 2018).

While offshore wind energy has received the majority of R&D investment from the Government since 2012 (IEA, 2017a), market development and implementation for onshore wind have not stopped. Onshore wind turbines were cheaper than the offshore models (Blanco, 2009) until the late 2010s, and overall provide a simpler installation, grid connection and maintenance. In the early 2000s, the was the urgency of speeding up the increase of wind energy in the national electricity share, to improve the learning curve of the technology and met the target of 6% of electricity produced from renewable sources, which was achieved (IEA, 2005).
As shown by the numbers of wind turbines installed in the country (2.6), steady growth in onshore wind power took place until 2008, as a result of the favourable conditions of the government subsidies. After a slight decrease before 2010, the number of turbines in the country has been constant for a few years, settling around 1800 units. While the number of installed turbines was very close to the number of decommissioned units (2.6c in 2015 148 turbines were built and 144 removed), the national capacity continued to grow due to the higher nominal power of new installation. These new and bigger turbines had an axis height around 130 meters and rotor blades diameter of 100 metres, they were more than four times bigger than the installation of early 90s. Residents were now facing almost 200 meter high technological installation sometimes only a few kilometres from their households, and it wasn't until the new century that Municipalities actively faced public resistance from their citizen.

The concept of social acceptance of wind energy is treated later in this same chapter (subsection 2.3). Researchers and policymakers in those years analysed the public response and the social issues that arose from the problem of integrating such invasive technology in the landscape of a densely populated country. Agterbosch et al. in 2007 mentioned that "*Ambitions towards wind power implementation disappear quickly if the City Council gets confronted with fierce social resistance. This holds especially when council elections are on the way*".
When in 2013, as part of the Energieakkord published by the government, the goal for onshore wind installation was to reach 6000 MW of capacity on land by 2020 (SER, 2013), the twelve provinces divided the objective and set their targets. As shown by the cumulative distribution per province and by the distribution of wind installation in the country (figure 2.8) the majority of turbines are located in the coastal areas and the Flevoland. It is interesting that not always the provinces with higher wind speed and potential are the ones with higher installed capacity, as socio-cultural backgrounds and implementation strategies are characterizing every province in a different way. The impact that these turbines have on the landscape and therefore social acceptance of wind energy (subsection 2.3) played a crucial role in the success rate of different provinces, as in 2017 Dhrente achieved only 8% of it while the Flevoland was at 75% (IEA, 2017a). The results of national policies were deeply impacted by the perception of onshore projects by citizen groups, and in 2017 the Rijksdienst voor Ondernemend Nederland noted that it is unlikely that the target would be achieved.
In particular, the provinces of Groningen and Drenthe were impacted by strong levels of resistance that escalated in actual violence episodes and collective threats. In September 2016, acts of violence against windfarms took place in the form of burning their properties. A journalist involved in public debate concerning a possible wind farm in Groningen was threatened to have their house burnt. 34 companies and NGOs involved in wind farms received a personal letter of threat in June 2018, signed by the "*threatened citizens from Groningen and Drenthe*". In January 2019 asbestos was dumped on multiple possible wind sites, raising many concerns for the safety of the environment and condemning the extremist group. (RTVNoord, 2019; The Northern Times, 2018). The national authorities associated these anonymous activist groups with "wind turbine terrorism".
While more capacity is added to the national grid from onshore wind energy systems, the entire sector is mobilising to address the issue of local resistance. Opposition can lead to delays in the project development, and since SDE+ subsidies are given only for a specific amount of time, important financial losses are associated with lower public acceptance. The Netherlandse Wind Energy Association (NWEA) worked on a common framework for acceptance and participation of onshore wind energy. This Code of Conduct binds the members of NWEA to several basic principles concerning participation, communication

and contributing to strengthening acceptance. The aim is to distribute the benefits and burdens well and to involve residents in wind projects at an early stage (Harmsten, 2020).

Wind energy in the Netherlands has gone through various iterations and overcame multiple barriers. From having small prototype assembled in the first Lagerweij garage to powering the entire rail network of the country (Business Insider, 2017), in the 50 years that have been briefly reviewed in this section wind energy became a substantial part of the national infrastructure. Not only technologically integrated, but wind turbines are now part of the everyday life of millions of Dutch citizens and become more and more part of the cultural identity of the Netherlands. In the next section, the relationship between society and technology will be investigated further.

2.2 Wind Energy as a Socio-Technical System

The aim to analyse public acceptance of wind energy cannot exist without the contextualisation of the technology within the broader environment of economics, politics and culture. As shown in the previous section, wind energy is not simply the results of research programs and industry R&D, but rather a series of collective efforts that resulted in the development of complex and innovative technology, able of harvesting power from a non-extinguishable source of energy. Wind farms could not exist in the forms in which they are today without the many interactions between social groups, industry leaders, research centres and politicians that shaped the direction of technological application. Vice versa, society affects technology in many ways such as providing legal, market, cultural structures with underlying strategies and interests. The interdependency of social context and technological development is a central element for the concept of public acceptance.

While recognizing the vastness of literature on the topic, the purpose of this section is to discuss the main concept of the STS (Socio-Technical System) theory through a brief but comprehensive literature review. The ambition to analyse the studies in their sociological depth goes beyond the scope of this thesis, that approaches these theories with a pragmatic approach. In order to provide a theoretical background to the methodologies used in further analysis, it is important to discuss the main concepts of the various theories, recognise the context in which they were developed and provide a solid justification of *why wind energy can be considered a Socio-Technical System.*

2.2.1 Technical Systems

Before diving into the theory and the various frameworks proposed for STSs, it is first needed to clearly define is the object of analysis discussed in the following sections and chapters. While it may sound self-explanatory, when referring to *wind energy* in this thesis is identified as the group of technical artifacts[2] that enable the harnessing of wind from the atmosphere. Wind energy indicates the conversion of kinetic energy of the air particle in motion into mechanical power through electric generators. As power is defined as energy per unit of time, when mentioning *power capacity* it is intended the nominal capacity of a mechanism to transform kinetic energy in electricity in any given moment of nominal usage.
Wind is described as the movement of air across the surface of the earth, generated by differences in atmospheric pressure. This pressure is commonly measured in millibars and varies from day to day resulting from the rotation of the Earth (causing Coriolis forces) and the incident radiation of the Sun in the atmosphere. As these characteristics differ geographically, different potentials for wind energy are available in the globe. Mapping wind energy potential is achieved through weather measurements, which are the input of advanced numerical weather prediction models to estimate the availability of wind

[2]The term *artifact* is commonly used in STS literature, and the same use as Bijker (1996) will be adopted. *Artifact* encompasses all products of technology, it denotes machines and technical processes, hardware and software.

resources over future time periods (e.g. the offshore dutch energy atlas shown in figure 2.5).
Concerning the definition of what are the technical artifacts that enable the conversion of wind into electricity, it is important to consider both onshore and offshore wind energy farms setups. While onshore turbines are rather simple to connect to the energy grid, offshore arrays of turbines need more technical arrangements which usually imply a higher degree of complexity and investment cost (Blanco, 2009). In figure 2.9 a schematic representation of those elements is presented. The term wind turbine is used commonly while referring to Wind Energy Conversion Systems (WECS), available in many typologies based on dimensions, number of blades and topology. Designs can include horizontal (HAT) or vertical (VAT) axis of rotation, presence or blades or bladeless configurations. Airborne wind turbines do not include a tower in their design and operate while being suspended off the ground. For the scope of the analysis, the turbines taken into consideration are HAT with three rotor blades, the most common model in nowadays large scale installations (Liserre et al., 2011).
The turbine itself is divided into three main components: rotor, generator and support structure. A rotor is composed of glass-fiber blades, which convert the wind in low speed rotational energy. The generator is comprehensive of gearbox and control electronics and can be classified based on the operational mode in which it can operate (fixed speed, variable speed). The support structure includes the jaw control mechanism and the tower of the turbine. While is not the aim of this section to discuss the design and operations of a modern wind turbine, aspects of the technology will be taken in consideration in a further analysis to develop a more comprehensive perspective of the interaction between individuals and technological artifact. The turbine noise experienced by many subjects in the vicinity can be analysed according to the operational parameters of a WECS, integrating the social implications with engineering analysis.

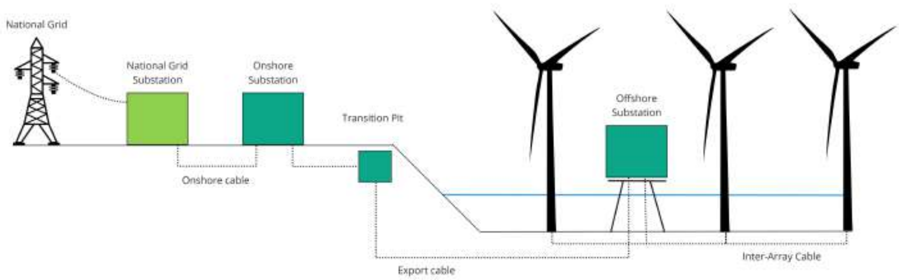


Figure 2.9: Schematic representation of technical elements for grid connection of offshore wind turbines.

As wind turbines produce electricity at low voltage (between 575 or 690 V), they are usually equipped with a transformer to step up the voltage to 20-30 kV for the connection within the wind farm. Lower voltages result in high transmission losses according to the quadratic relation between power and voltage described by Ohm's Law. For a large wind farm distant (more than 5 km) from the electrical grid, another transformer placed in a substation will step up the voltage to 100 kV. Electrical conversion systems and the related support structure for those (in case of offshore substations) are therefore considered part of the technical artifact used for this analysis. In the case of offshore platforms, it is interesting to include in the list of technical tools also transportation and logistics machinery, such as the Ampelmann devices mentioned in section 2.1.4.
The inventory of items listed above includes some of the major elements of connections before the national grid, in case of large scale grid-connected wind energy systems. The electrical network as a whole is not considered part of the object of analysis of this research, but the elements that provide this network electricity harvested from wind. This is considered *Techno-Structure*, and it is the most tangible part of the technical system.

The definition of technical system as superset of techno-structure is due to the need to outline what is clearly inherent information carried within the technology. Adopting the classification used by Rohracher in the representation of a generic STS (in figure 2.10), a technical system includes other important elements which core is strictly connected to the nature of the technology. Technical standards for wind turbines (such as IEC 61400 for general design requirements and the ISO 19900 for offshore structures) are considered part of the set, together with the price of electricity produced from these wind energy systems. While a feed-in tariff is a policy mechanism that originates outside of the technical system, the inherent cost of the electricity produced using a specific technology is the result of technical design and cost-reduction strategies in the manufacturing of the elements, together with many other processes. This inclusive use of the technical system is supported by literature in the STS discipline, such as *Of Bicycles, Bakelites, and Bulbs: Toward a Theory of Sociotechnical Change* from Bijker (1996)

2.2.2 Social Shaping of Technologies

The field of science and technology studies, multidisciplinary research is carried to investigate how society, politics and culture affect technological innovation. Within the discipline, one of the most prominent theories argues that technology development is influenced heavily by the social environment into which the novelty is introduced. Disputing the technological deterministic approach that assumes a one-way causality relation [3] between technology and society (Williams and Edge, 1995), *social constructionism* supports the interdependency of society and technology when addressing the development of innovation. The cluster of theories supporting this concept is known as *Social shaping of technology* (SST) or *Social construction of technology* (SCOT) [4]. In the last two decades of the twentieth century many scholars were producing substantial research on the topic, and three main approaches converged in what is in literature defined as social shaping of technologies: the social construction of technology (SCOT) approach, the Actor-Network Theory (ANT) and the theory of large technical systems (LTS).

The social construction of technologies has its beginning as the practical application of the aforementioned social constructionism, evolving into the sociology of science from epistemology. The origin of this perspective can be traced back to Friedrich Nietzsche's perspectivism ("Facts do not exist, only interpretations") but the first *use* of this approach in a publication was from Thomas Parke Hughes in 1983. Hughes, an American historian of technology, introduced a foundation for the SCOT approach while reviewing the development of the electrical grid and power systems in western societies highlighted how different actor groups external to the technological system had consistent shaping power. SCOT was described as "linking technical apparatus to engineering systems, and in turn these to manifold organisational, economic and political actors and structures" (Joergers, 1988). Hughes early works on the topic facilitate the definition of a sociotechnical system as a set that includes physical and technical artifacts (as seen in the previous section), organizations, scientific components and legal artifacts (Rohracher, 2002). This definition is relevant for many engineering systems, but particularly for wind energy because of the strong similarities between the wind energy sector and the large scale technological system on which the author focuses on.
In his subsequent work, Hughes (1987) highlights the importance of *system builders*, a category of actors that have the ability to gather consensus and set unity in the environment. System builders are responsible for creating and shaping the organizational forms of a system and are deeply involved in the initial phase of development of a technology. As for the previous historical analysis of the wind energy evolution in the Netherlands,

[3] Technological determinism also presume a *value neutral* vision of technology. This theory is nowadays rarely supported amongst STS students, nevertheless, it provides interesting discussion points. Wyatt et al. (1995) offers an in-depth and up to date analysis of the current role of technological determinism.

[4] It has been found in the literature reviewed interchangeable use of construction and shaping, as the theories mainly address very similar concepts. Rohracher defines SCOT as a subset of SSTs approaches, whereas Wyatt et al. and other publications do not even mention SST, but rather use the term SCOT to include the approaches.

the ECN could be considered a critical aggregator of knowledge and key actors able to define the structure and direction of the innovation.

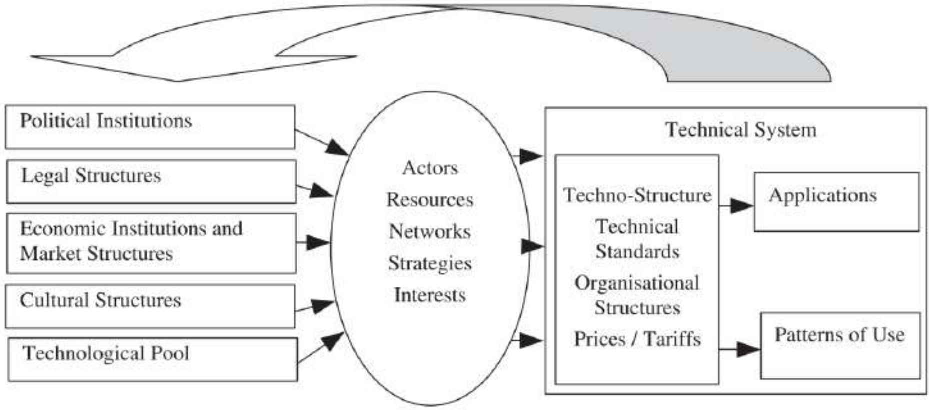


FIGURE 2.10: A representation of a generic Sociotechnical System, as ensemble of social and technical elements (Rohracher, 2002).

In a broader sense, Williams and Edge (1995) in their work *The social shaping of technology*, carried out a review of the literature published in those years on the subject. The social shaping of technology is presented as a critique of the traditional concept of technology, because of its determinism and linearity. SST is "seen as playing a positive role in integrating natural and social science concerns; in offering a greater understanding of the relationship between scientific excellence, technological innovation and economic and social well-being" (Williams and Edge, 1995). The literature reviewed by the authors insisted on the need to open up the *black boxes* of technology and allow socio-technical patterns to be embedded in the *process of innovation* (MacKenzie and Wajcman, 1999), a theme that is now incorporated in the field of studies. The SST approach also stresses the concept of *negotiability of technology*, for which different groups of actors with different interests and agendas are able to shape the development of certain technology and therefore obtain different outcomes. This is well explained in the famous example of the early development of the bicycle, cleverly narrated by Bijker in his historical reconstruction of the various iterations of bicycle design, but can easily be adapted in the example mentioned in section 2.1.1. Is the current scenario of wind energy the result of many *negotiations* that happened through history, such as the clash of interest between the neo-liberal oriented Dutch industry and the alternative anti-nuclear leftist groups? Was the power imbalance the weight that shifted the development of wind energy towards large scale applications, rather than the intrinsic nature of the technology itself? Embracing the SST theory, the answer is the former.
Negotiability of technology is closely related to one of the key concepts in the SCOT approach: *interpretative flexibility.* In Pinch and Bijker the principle is explained by proving that "there is flexibility in how people think of or interpret artifacts but also that there is flexibility in how artifacts are designed", and is highlighted to provide empirical reference in the social study of technology. Social groups are able to make their own interpretations and are subject to biases, therefore multiple designs are simultaneously plausible before the results of the social dispute. While opportunities are endless, the lack of closure of the SCOT approach has been the object of critique (Williams and Edge, 1995).

The Actor-Network Theory (ANT) has a French origin, as it was first developed by Bruno Latour and the staff of the Centre de Socologie de l'Innovation (CSI) of the Paris School of Mines. ANT features a less hierarchical approach than the American LTS theory of Hughes (1987), and does not have a clear division between social and technical realms, such as the British-Dutch SCOT theory of Pinch and Bijker (1987).

Nevertheless, the approach proposes the concept of autonomous networks guided by the objective of profitability into mechanisms of cooperation and integration. "The network notion ... has no a priori order relation; it is not tied to the axiological myth of a top and a bottom of society" (Latour, 1996) and therefore is suitable to adapt to various scales of technical development without the restriction of two dimensional dichotomy [5].

As the theory was discussed between scholars, interesting applications of those methodologies were published in the following years. The socio-technical networks (SNT) approach was proposed by (Elzen et al., 1996), incorporating in its requirements elements from both SCOT and ANT approaches (such as the interpretative flexibility and the heterogeneity of processes). The SNT approach was cleverly developed by pragmatically "chose" which principles to follow from which theory and applying them to a very specific group of technologies: the European Fighter Aircraft network. The conceptualization of *actors* (individuals or organizations), *intermediaries* (information or anything that passes between actors, such as scientific papers or software or money) and *technology* (actor-specific version of the artifact) is a rather simplistic but effective way to represent the object of the case study. An important characteristics of Elzen's networks was stability: "actors cannot randomly do what they want but are dependent upon incoming intermediaries. In this way, the network limits an actor's 'acting place'" (Elzen et al., 1996). The acknowledgement of a stable pattern of interaction within actors is a fundamental step in the recognizing and analysis of *pre-existing networks*. These paths of preceding synergy between stakeholders are a major reason of why there is expected behaviour in a social context, and why some innovation are more successful than others if incorporated successfully in a pre-existing network of interaction. Considering the Dutch wind energy sector, these networks can act *pro* or *con* a specific wind project, based on the political, cultural and historical background of a specific area.
The results of (Elzen et al., 1996) work is displayed in figure 2.11. The dashed contours represent the boundaries of the multiple STNs, the ovals are the actors of the sector, the arrows between actors the intermediaries and lastly the rectangles below the actors represent the *perceived version* of the artifact.

Another relevant application of the SST theories is Rohracher (2002) study on the adoption of biomass domestic heating systems in Austria. While not only contextualising the theory in the sector of environmentally friendly technologies, Rohracher summarize and explains clearly the main concepts of SCOT and ANT in order to provide a theoretical background to his mapping of sociotechnical systems actor and patters. The synthesis and clarity of his description were extremely useful and has provided a starting point for the writing of this section. The result of his analysis is a framework in which the analysis of modern domestic biomass combustion technologies focuses on a sociotechnical perspective, including actor constellations and central players and providing inputs for improving policy making initiatives recognizing the critical problems of the sector. Furthermore, a reflection on participatory strategies and interactiveness of actors is undoubtedly relevant in the field of public acceptance, as it will be investigated in the following section (2.3).
Not only technologies relate to the social and cultural environment, but they are interdependent between themselves. As wind energy systems cannot exist without a close relationship with the large national electricity grid, the military weapons described by Elzen et al. could not develop without mature radar technologies. The notion of *interdependence of technologies*, how relations between different technological systems can benefit or harm the innovation process, is deeply relevant in the context of the *situated character* of technological development (Rip, 1995): "the success of new artefacts cannot be understood and analysed if one neglects their linkages with other artefacts and infrastructure".

In this section, relevant concepts from technological transitions have been briefly reviewed. In the SCOT approach, the combination of different elements from sociology of innovation, institutional theory and economics attribute to the framework a multidis-

[5] "The notion of network allows us to get rid of a third spatial dimension after those of far/close and big/small. A surface has an inside and an outside separated by a boundary. A network is all boundary without inside and outside" (Latour, 1996). Latour uses the network notion described by Denis Diderot, including a strong ontological element into the theory.

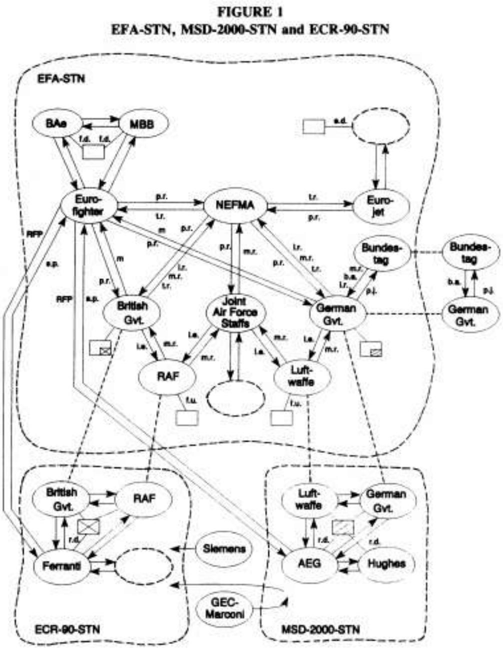


FIGURE 2.11: An application of STN approach: the European Fighter Aircraft's development networks (Elzen et al., 1996).

ciplinary modus operandi to approach sociotechnical systems. In the next section, the problem of acceptance of technology is discussed within the context of wind energy.

2.3 Public Acceptance of Wind Energy

Given the complexity of interaction between actors and technologies, the definition of acceptance of wind energy technology is anything but trivial. Considered one of the main challenges for the implementation of wind energy (Ellis and Ferraro, 2016; Wüstenhagen et al., 2007; IEA, 2000), studies on the topic began to appear in the late 1990s, evolving from "[...] a marginal and little studied point of discussion to be at the forefront of broader debates in the social sciences" (Fournis and Fortin, 2017).

While the subject of acceptance of technology can sometimes be associated with information system theory, it borrows many findings from diffusion of innovation studies. This section aims to outline and review its application to wind energy technologies and projects. A general introduction is given to the topic and an examination of the current literature covering acceptance (and acceptability) is reviewed in 2.3.1. Concerning the scope of this research, and the focus on *public* acceptance, the need to a common framework to address *SQ1, "How is public acceptance defined in the context of wind energy?"*, influencing factors and perceived impacts are going to be covered in 2.3.2.

When addressing the topic of public sentiment towards wind energy technology, literature has found a remarkable difference in attitudes(Elliiot, 1997). On a general level, high level of support for this specific source of renewable energy has been identified through multiple opinion polling (Eurobarometer, 2003; Walker, 1995) because of the perceived benefits for society and development towards low carbon technologies.
On a local level, many episodes of resistance have been influencing the implementation of projects, made it to the national headlines (RTVNoord, 2019; The Northern Times, 2018)

and polarized the public debate over many years. The widely noticed and documented juxtaposition of high level of general public support and frequent local opposition has been a central theme in literature regarding the social implications of renewable energy, and there is growing research interest in the field. Since 1970s, publications on the issue became more frequent and peaked in the recent years, Figure 2.12 shows how the relations between wind energy and communities continues to raise interest while many developed countries set targets to achieve higher onshore wind energy installations [6].

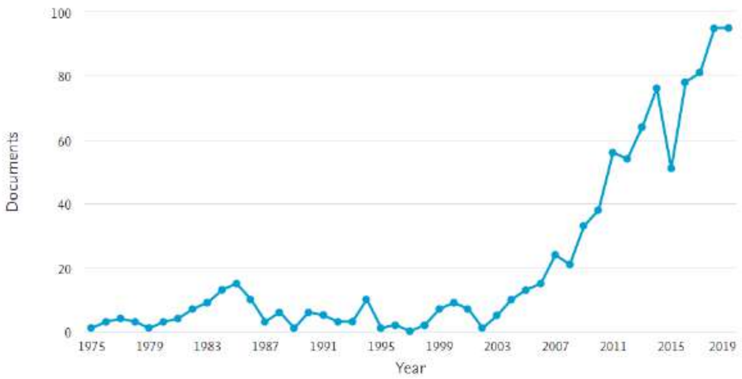


Figure 2.12: Publications addressing wind energy and community relation over the years (Source: Scopus).

In order to support the implementation of low carbon energy sources capacity, the research on public perception of these technologies has been addressed in many developed countries such as Canada (Omnibus Report, 1995), Denmark (Krohn and Damborg, 1999; Daugarrd, 1997), UK (MORI Scotland, 2002) and the Netherlands. The majority of early publications on the issue undertook the task as a way to identify and recognize barriers that justify negative attitudes from the local population, driven by quantitative survey tools that mostly listed discrete attributes of turbines. Many of these studies focused upon visual, environmental and technical aspects, and were guided by a rather deterministic view of human psychology: public opposition has often been assumed to be a result of specific physical attributes of the artifacts, rather than contextualized in a broader framework accounting for values, attitudes, intentions and outcomes.

The notion of NIMBYsm (Not In My BackYard effect) started gaining momentum around those years. NIMBY has been the most cited explanatory concept of negative sentiment specifically targeted against wind farms (Devine-Wright, 2005). The concept has been extensively used in non-scientific communication and it is sometimes still present in the public debate on the topic, while scholars moved past these simplifications. The concept found low empirical evidence and has been criticized by many (Aitken, 2010; Van der Horst, 2007; Burningham et al., 2015). Wolsink described the notion as "questionable as the reasoning behind the theory is faulty" and has been commonly recognized as unhelpful to address the issue (Ellis and Ferraro, 2016).
A common lack of conceptual foundations and general framework led to the early literature on the topic to be mostly led by opinion poll research and local case studies, generating rather specific and incoherent results (Devine-Wright, 2005).To establish a solid foundation for this research work, it is needed to review and adopt a clear and comprehensive definition of acceptance.

[6] This search was undertaken on 01/08/2020 using the search string '(TITLE-ABS-KEY (wind energy) AND TITLE-ABS-KEY (community))' which identified 948 outputs from between 1975 and 2020. This database search updates Ellis and Ferraro Scopus output retrieved in 2015.

2.3.1 Definitions and Available Frameworks

Although the term "acceptance" is widely used in practical policy literature, definitions are rarely given explicitly. The use of the nomenclature varies regarding the context, the technology, and the stage of diffusion, amongst other factors. A general definition conceptualizes acceptance as "an antagonism to the term refusal and means the positive decision to use an innovation" (Simon et al., 2001), presenting acceptance as a *lack* of resistance and the opposite of the notion being the true source of interest (Chataignier and Jobert, 2003).
While the definition of acceptance of technology in a broader sense is outside the scope of this research, the context of wind energy gives opportunities to investigate the main definitions used in recent literature. Fournis and Fortin (2017) reviewed a list of approximately 100 publications referring to social acceptance in the field of wind energy, addressing what was identified as *unprecedented accumulation of knowledge* on the topic.

As mentioned earlier, early research has been identified as providing a rather superficial understanding of acceptance. Fournis and Fortin classified this groups of definitions as techno-centric approaches, outlining social acceptance as "the more or less effective appropriation of a given *technology* by a *social body* that is inscribed in *space* and which is *politically instituted* and more or less mobilised to meet the challenge of energy issues". Contextualising this general approach, it is difficult to say that it is completely wrong. Wind turbines (the technology) can be more or less adopted and supported by a social body (the public and communities) inscribed in a specific space (the area adjacent to the wind farm site), which is politically instituted (the local and national framework for adoption of wind energy) and has tangible motives (the energy independence of the area, energy scarcity, quality of the air, etc.). The overly technical phrasing of this cluster of definition struggle to cover the bias and blind spots of the approach: the public is treated only in term of "residue" and "barrier" (Fournis and Fortin, 2017), treating the human behaviour as a deterministic reaction upon physical features of wind turbine projects [7].

As theories moved past this "childhood sickness" (Huber, 2010), new frameworks tried to incorporate a more comprehensive view on stakeholders and the different dimensions of acceptance. A widely adopted reference is the "triangle of social acceptance" proposed by Wüstenhagen, Wolsink, and Bürer, briefly mentioned earlier in section 1.1.1. The framework proposed includes three different levels of acceptance, namely Community, Market and Socio-political acceptance, which opens the focus on multiple sets of actors holding different interests.
Socio-political acceptance indicates the most general level of acceptance, by means of including the public opinion, politicians and other indirect but opinionated stakeholders in the paradigm. *Market acceptance* is defined as the rate of adoption or diffusion of innovation by the market, businesses and industry (not only consumers and suppliers but also the novel figure of the prosumers). *Community acceptance* can be identified as the acceptance from local groups, communities, local environmental groups and local authorities.
This definition has the virtue of introducing issues such as procedural and distributional justice, trust and most importantly an economic perspective in the discussion: not only communities are responsible of adopting new technologies in their environment, the market needs also to be ready to accept a novelty. Opening the problem to a higher rank of complexity is one of the main takeouts from this framework, that has been largely used in literature [8] and industry reports (Ellis and Ferraro, 2016; European Wind Energy Association, 2010).

A complementing approach has been introduced by Szarka in the same years: "an evolving social contract" about wind energy or renewable energy policy which implies

[7] Affinity can be found between the evolution of STS theories from technological determinism to social constructivism, as mentioned in section 2.2.2, and the initial deterministic views on social acceptance.

[8] The article in which the framework is described received more than 1080 citations at the current date (August 2020) and it is by far the most cited publication of the author

multiple levels of collective decision. The framing of the issue in terms of *contract* was already present in the Social License to Operate (SLO) proposed by Gunningham, Kagan, and Thornton (2004) but enriched under many aspects. Similar to the triangle, this social contract includes three different levels of interest-holders, which are taken into account in terms of *decisions*: (a) socioeconomic and technical choices, (b) options between different policy paths and (c) governance choices. In the perspective proposed by the author, acceptance is therefore a function of decision making and therefore access to information (Szarka describe the involvement of politics as a "process of social contract negotiation between parties having unequal access to expertise"). Dynamism and the notion of collective choice are important expansions in this definition, and therefore influenced further literature.

Building on this extensive review of definitions, Fournis and Fortin drawn their consideration and developed a further definition and framework. Considering the triangle of social acceptance unsuitable to take into account the "complex interplay of power relationships", and building on Szarka's concept of contract negotiation, the resulting framework provides a useful heuristics to navigate a broader, modern and relevant notion of *acceptability*. Social acceptance is in this model seen as one of the possible outcomes (against unacceptance) of the bigger process of social acceptability. The authors provide their vision as defining acceptability as "the process of collective assessment of a given project (understood as the specific embodiment of complex interactions between technology and society within a given socio-technical project), integrating a plurality of actors (stakeholders) and spatial scales (from global to local), as well as involving the specific trajectory (past present and future) of a political group or polity (community/society)" (Fournis and Fortin, 2017). Given the definition, the authors proposed their analytical framework, (unsurprisingly) based on three levels of acceptance:

- *Micro-social level*: the interactions and processes such as coordination and antagonism. Social interpretation and construction of attitudes play an important role in this level, where concepts such as place of attachment and identity allow for *emotions* to be taken into account (more on place of attachment will follow in section 2.3.2).

- *Meso-political level*: the governance of wind energy projects. How economic and political macro-parameters enter in contrast with micro-dynamic interaction lays in this complex yet well-researched level of analysis. Planning and institutional processes take place in this layer, associated with perceptions of procedural injustice or unfairness of the process.

- *Macro-economic level*: the (inter)national models and global trends. Providing context to market mechanisms for wind energy into a broader global landscape, this layer of analysis allows a comparison between different national approaches. The trajectories established by different countries (e.g. bottom-up for Germany and Denmark, top-bottom for Spain) converged in shaping the current global market for wind energy technologies.

A summary of the reviewed frameworks is presented in figure 2.1. The understanding of social acceptance evolved over the recent decades and developed thanks to the many scholars a deeper theory with relevant social implications. While different interpretations and frameworks are currently applied, the literature has converged towards a "crystallisation" (Fournis and Fortin, 2017) of the theory's principle. Social acceptability is recognized to be a highly complex, dynamic problem that features many different dimensions, layers and actors.

Author(s)	Synopsis	Structure	Considerations
Multiple sources (1970-early 2000)	. Techno-centric approaches. Acceptance as appropriation of a given technology by a social body (politically instituted).	No clear structure.	Deterministic approach, simplistic on how public is taken into account.
Wüstenhagen, R. Wolsink, M. Bürer, M.J. (2007)	**Triangle of Social Acceptance**. Multi-dimensional analysis, widely used reference both for academia and industry.	Three different dimensions of social acceptance: • Market Acceptance • Socio-political acceptance • Community acceptance	Introduces global/local perspectives and brings together different aspects of acceptance. May fail to consider highly complex power interplay.
Szarka, J. (2007)	Collective choice of an evolving energy - **social contract**. Acceptability as symbolic decision-making framework.	Three levels of decision making: • socioeconomic and technological choices • public policy alternatives • governance directions	Establish a dynamic dimension in acceptance and brings focus on the negotiation and access to information issues.
Fournis, Y. Fortin, M. (2017)	Social acceptance as result of **social acceptability**. Multi-actor, multi-scale and dynamic analysis built on review of previous frameworks.	Three layers of determining factors: • Micro-social level • Meso-political level • Macro-economic level	Comprehensive analysis including a wide range of factors. Integration of distinct processes that result in acceptance when convergence happens.

Table 2.1: Summary and evolution of the definitions and framework reviewed.

As per the scope of this research, the focus of analysis will be placed on the interaction between local actors and the technology. The outlining of different frameworks provides the core concepts that will support the methodology described in Chapter 3 and applied later on in Chapter 4, Value Sensitive Design. To avoid the oversimplification and fallacies revealed in earlier literature, a broader definition of social acceptability will be implemented in the analysis, while focusing on the micro-scale interaction layer.

2.3.2 Influencing Factors

While the previous section addressed conceptual and theoretical definitions, in the following pages the characteristics that enhance or diminish the actual acceptance of a project. Due to the empirical and relatively accessible nature of the task, the listing of factors that influence acceptance has been noted to be a recurring section of analysis of many reports. Data (gathered through interviews, opinion polls, media outlet and surveying) is widely available or easily collectable.
When analysing the factors that prevent (as the techno-centric approach suggests) barriers and low achievement of acceptance levels, professionals and researchers need to acknowledge these issues and their context, rather than actively challenge them. Kaldellis, Kavadias, and Paliatsos (2003) in one of the previously mentioned "early publications" undergone the task to review the main sources of concern for Greek citizens regarding future wind energy projects and to invalidate their objections. While it is admirable to rationalize and provide physical data to enrich the discussion and negotiations with the public, it is inherently wrong to approach communities as "irrational" and "uneducated" groups a priori.

Considering an open communication with these actors and engage in a discussion without judgement implies taken into account carefully every aspect that could impact acceptability.

Many categories of influencing factors have been identified and analysed by literature, and are proposed in multiple different classifications. The presented list is based on the comprehensive work of Ellis and Ferraro, which report was found to be one of the most complete published in the recent years. Inputs are also collected from the work of Huber and Horbaty (2010), which work features a detailed collection of the variables influencing social acceptance pre-2010.
As we move further the simplistic view of exclusively physical parameters to influence community attitude, in this section five categories of factors are presented: (1) quality of life, (2) financial factors, (3) landscape impacts, (4) trust and procedural justice, (5) personal predispositions.

2.3.2.1 Quality of Life

Impacts of the presence of wind turbines on health have been widely discussed in the public debate. Turbine operation causes the presence of shadow flicker, audible noise, low frequency noise and electromagnetic fields (EMF) that have been suggested to influence human health. (Knopper et al., 2014) reviewed and provided a summary of the main peer-reviewed publication on the issue, concluding that the environmental impacts of wind energy are unlikely to be related to impacts on human health. The Canadian government established the *Wind Turbine Noise and Health Study* [9] in order to monitor and review the impact of wind turbines on their citizen, probably one of the most noteworthy programs. The results of this research aligned with existing literature and did not identify causality between the artifact and personal health (Feder et al., 2015).

It is noted, however, how annoyance can be directly related to the physical manifestation of turbines in the surrounding of a household, and therefore impact the quality of life of an individual. Shepherd et al. (2011) investigated the relations between reported low quality of life and exposure to wind farms in New Zealand, and justified for these impact through a multi-level heuristic, shown in figure 2.13.

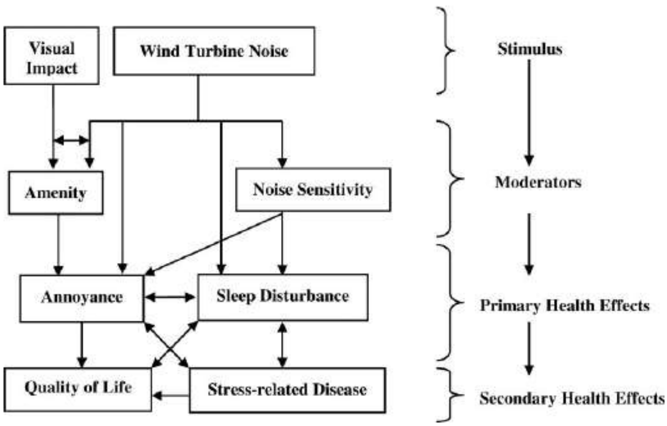


Figure 2.13: A schematic representation of the relationship between wind turbines and health (Shepherd et al., 2011).

While the impact of nuisance related to wind turbines is subjective, the frequency of complaints is a rather objective indicator of annoyance. In the UK, more than 20% of

[9] https://www.canada.ca/en/health-canada/services/health-risks-safety/radiation/everyday-things-emit-radiation/wind-turbine-noise/wind-turbine-noise-health-study-summary-results.html

the operational wind farms had been receiving formal noise complaints (Moorhouse et al., 2007). The presence of noise has been observed to be relevant in relation to other sources of disturbance, such as road traffic or the presence of airports Huber and Horbaty (2010). In lack of a definitive and objective model to account for individual perception, suggestions to handle noise and shadow flicker complaints include applying mitigating measures based on sound setback distances, limiting operational noise to < 40dB(A) and regular monitoring (Ellis and Ferraro, 2016).

2.3.2.2 Financial Factors

The economic dimension is closely intertwined with the perception of acceptance of wind energy, as it is for most of debates concerning energy policy. On a *landscape* level, the majority of the discussion focuses on the cost effectiveness of the technology (Sovacool et al., 2008; Sovacool, 2009) in comparison with other sources: intermittency of power generation, cost of unavailability, capacity factors and power density are recurring themes when it comes to general profitability of the technology. The claim that sustainable energy aims to replace and supersede traditional sources of energy poses the question of transition of the industry, employability of professional and significant capital investments in the current technologies (Smith et al., 2005).

Zooming in, the financial impact of a wind energy project on a community is suggested to be (a) depreciation of property values (Bond, 2010; Ladenburg and Dubgaard, 2007), and simply (b) the presence of benefits for residents. Studies have been carried across Europe and worldwide to investigate a possible correlation between property transaction and presence of wind farms, with important methodological challenge. Empirical research in US has suggested a "general lack of significantly negative effects" of turbine proximity on property prices (Vyn and McCullough, 2014), UK transaction analysis also confirmed a lack of causality (Sims et al., 2008).
Concerning the Dutch current situation, the 2019 report *"Wind turbines, solar parks and house prices"* was published: a study that was carried out by the Vrije Universitie on behalf of the Ministry of Economic Affairs in response to parliamentary questions about housing value decline and wind turbines. The report states that *" the house price development of houses within a radius of 2 kilometers from a large windmill (150m) will remain in the period after 2011 by an average of 5% behind compared to homes with no wind turbines in the vicinity.... In general, house prices are rising less rapidly within a radius of 2 kilometers from wind turbines than elsewhere, but higher wind turbines in particular appear to have a negative effect on house prices."*
While studies have been conducted on the topic, the nature of the analysis hinder the possibility to prove the hypothesis: differences in sales regions, market trends, inference with other factors are methodological challenges that have not been overcame at this day (Ellis and Ferraro, 2016).

Economic benefit for the community can be defined as direct (lower energy prices, payouts, financial support to local projects) and indirect (economic development of the area, creation of jobs). How to distribute said economic benefits can be cause of public opposition too, and it is usually analysed in the context of Distributional Justice. A summary of community benefits has been proposed by Munday et al. (2011), and it is reported in table 2.2.

Categories of community benefits
Conventional economic benefits: • the use of locally manufactured the use of locally manufactured content, and local contractors for construction, operation and maintenance; • land rental income to landowners and any royalties; • local business rates and/or taxes.
Flows of financial benefits to local communities: • some form of ownership/investment in the project among local people, either as equity or a form of profit share; • some form of community fund, with lump sum and/or annual payments, either focused on specific purposes (such as energy efficiency) or more open-ended; • cheaper electricity; • sponsorship of local events.
Contribution in kind to local assets and facilities: • to landscape and ecological enhancement measures, perhaps that mitigate or compensate for any environmental costs caused by the wind farm; • to tourism/visitor facilities.
Provision of other local services: • educational visits or other educational programmes.
Involvement in the development process: • various forms of liaison activity.

Table 2.2: Categories of community benefit, proposed by Munday et al. (2011)

2.3.2.3 Landscape

Visual impact of wind turbines has been cited as one the most relevant causes of opposition by many (Ellis and Ferraro, 2016; Wüstenhagen et al., 2007; Proka et al., 2018; Dion, 2019; Agterbosch et al., 2004), and the concept is closely tied with the notion of *place attachment* (Pasqualetti, 2011), *aesthetics* of wind parks (Oosterlaken, 2014a) and *identity* of the community (Huber and Horbaty, 2010).
Studies on the issue have been analysing the impact in two clusters:

- Tangible traits - design parameters such as height of a turbine, number of turbines per site, geographical context in which the site is located, distance from the observer and other visual factors such as colour, length of the blades (Maffei et al., 2013);
- Conceptual traits - attitudinal and emotional perceptions attached to landscapes such as beauty and environmental values, relationship between cities and land;

According to Wolsink (2007), the link between visual/landscape impacts and acceptability is "one of the most complex to understand", with many different perspectives on the issue. As other factors presented in this section, the impact has been found to be possibly mitigated by considering other solutions (such as financial benefits). Landscape impacts are also perceived differently according to a range of individual characteristics, such as general attitude to wind energy (Molnarova et al., 2012) and social differences (Zografos and Martínez-Alier, 2009).

Many of the mentioned issues will be covered from a value perspective, adopting methodologies of value sensitive design, in chapter 4.

2.3.2.4 Trust and Justice

The concept of trust and justice are complex problems that have a broader relevance into understanding how technology, polity and social engagement relate. Concerning the scope of acceptability of wind turbines, these values have often been analysed in terms of procedural justice (Fast and Mabee, 2015). Many dimensions of the issue have been idenfitied in relation to climate and energy policy by Rayner (2010):

- *credibility* - degree of truth in the claims made by different actors;
- *confidence* - degree of trust in the ability of actors in charge of the project;
- *integrity* - degree of honesty of an actor performing;

- *reliability* - degree of ability in meeting certain expectations from different groups;
- *compliance* - degree of scrutiny under which expertise or policy is subject from the public;

Trust has been analysed in a large number of recent publications and cases studies of contested wind farms (Caporale et al., 2020; Hall et al., 2013; Jørgensen et al., 2020; Liu et al., 2019), and is a rising issue in literature concerning acceptance. The concept has been expanded to new dimensions (e.g. intergenerational justice from Pellegrini-Masini et al. (2019)) and is continuoisly evolving to adapt to a dynamic perspective of acceptability Ellis and Ferraro (2016). However, a perceived lack of fairness has always been a central point in conflicts over wind energy projects (Gross, 2007) and different institutional designs, such as participation processes, has been proposed many times by scholars as a way to foster a legitimate outcome.

As a review of the notion of trust and fairness is outside of the scope of this research, the applicability of the concept to wind farms are investigated in chapter 4, and suggested strategies to grow trust and perceived justice are presented in chapter **??**.

2.3.2.5 Personal Factors

Studies on the attitude of the public on the concern of wind energy have been published since the late 1990s until nowadays, serving as a key body of literature that developed the current notion of public acceptance. In 2015, Ellis and Ferraro (2016) identified in Scopus at least 93 attitude studies, featuring standard quantitative surveys with open and closed questions, discourse analysis, Q-methods and other techniques (Langer et al., 2016).
The main finding of these studies can be as simplistic as it is: acceptance (at a micro-level) is a complex issue, and personal attitude makes a big portion of an actor's belief system. (Pellegrini-Masini et al., 2019; Fournis and Fortin, 2017). Working under the assumption that belief systems are formed and challenged by values and morals endorsed by individuals, the analysis of these individual attitudes is left to be treated in the following chapter.

In table 2.3, Langer et al. (2016) list the findings of his research in individual attitudes concerning Bavarian wind energy projects. As the survey-like methods used in this and many cases are able to capture a stakeholder beliefs, it has been noted that there is a limited understanding of how attitude relates to action (Bell et al., 2013), and how this overall impacts acceptance.
The personal factors presented by Langer et al. (2016) are derived from the literature study that the author conducted on the factors which form an individual's distinctive character. It features a list of "personal characteristics" such as environmental attitudes, gender, awareness, knowledge and experience with renewable energy, or political believes - factors that have been found in literature to influence acceptance of wind energy. A key finding from this review is that "*the more a person deals with the topic of wind energy, the higher its acceptance*" (Langer et al., 2016). The authors reviewed the recent literature on the subject and collected key findings, presented below on the right column of the table, such as the direct correlation between level of information on wind energy and the acceptance of the subject.

However, the findings presented are subject to a disclaimer: the influence and acceptance from personal factors is heavily dependent on the context to which it is subject. Walker and Devine-wright (2010) presents and explores the contextual factors such as place, community, regional and local policy and business. The findings from literature presented in the table 2.3 are therefore to be paired with each local context for the relative wind energy project.

In this section, a brief overview of the factors influencing public acceptance has been presented. Simplifications have been made in order to allow a fairly straightforward overview of the main literature concerning the complex issue of public acceptance. In the next sections, the notion of values will be first presented and then applied to the issue of wind energy projects. There is the expectation for this to provide a framework of methods to bring added value to the literature and research presented previously.

Factors	Relevant studies	Key findings
Environmental attitude	Wolsink (2007), Ek (2005), Devine-Wright (2007), Demski et al. (2014), Greenberg (2009), Hobman and Ashworth (2013), Ertör-Akyazı et al. (2012), Viklund (2004).	Studies indicate high levels of acceptance for energy policymaking which strengthen the goal of environmental protection.
Socio-demographic status	Ek (2005), Devine-Wright (2007), Greenberg et al. (2009), Hobman and Ashworth (2013), Komarek and Kaplowitz (2011).	On the individual level, socio-demographic characteristics such as gender, age and social status can have an influence on the acceptance towards renewable energies.
Place attachment	Van der Horst (2007), Devine-Wright and Howe (2010), Ladenburg (2008), Waldo (2012), Swofford and Slattery (2010), Jones and Eiser 2009), Firestone et al. (2015)	Emotional attachments to places can influence the acceptance of the population
Experience with renewable energy	Ribeiro et al. (2011), Devine-Wright (2007), Devine- Wright (2007), Mallet (2007), Aitken (2010), Ladenburg and Möller (2011), Borchers et al. (2007), Cica et al. (2012), Ladenburg (2010), Krohn and Damborg (1999).	Direct experience, such as having personally seen or visited wind farms may have influence on the acceptance towards wind energy.
Knowledge of renewable energy	Ellis et al. (2007), Aitken (2010), Luz (2000).	The higher the information level of the person about renewable energy, the more likely the person accepts them.
Normative beliefs	Hobman and Ashworth (2013), Huijts et al. (2012)	Studies suggest normative beliefs to be a strong, positive predictor.
Emotions	Hobman and Ashworth (2013), Cass and Walker (2009).	Positive emotions are associated with technology acceptance.
Political beliefs	Devine-Wright (2007), Karlstrøm and Ryghaug (2014).	Empirical findings suggest that political beliefs are correlated with acceptance of different low carbon technologies.
Attitude to traditional energy	Frantál (2009)	Acceptance of renewable energy can be related to opposition to nuclear energy.
Conservative attitude	Bidwell (2013), Eltham et al. (2008)	A conservative attitude has been considered to be a relevant factor with respect to theory of adoption of technology innovation.

Table 2.3: Personal attributes influencing acceptance of wind energy projects (Source Langer et al. (2016))

2.4 Conclusions

Chapter two of this thesis, "*Public Acceptance of Wind Energy in the Netherlands*" sets the scenery for the research by introducing the main research domain of the work. Taking a deep dive into the history of wind energy in the country, the roadmap to what is currently one of the most promising sustainable energy sources and only viable options to cut greenhouse gases in the power generation, provides important reflection points.

First of all, it shows how technological development is a collective, cumulative effort. Progress is made over time, with continuous and steady investment of resources, both of financial and of human capital. The first wind turbine installed in Petten in 1977 had a nominal power of only 300 kW, and 50 years later wind energy powers the majority railway system of the country.

Secondly, the history of the adoption of wind energy shows how energy in the Netherlands has many times been a public matter, and discussion on the topic have helped shape the direction of the country's energy agenda. The public consultations that have been held in the early 1980s on the future of the country power supply after the second oil crisis of 1979 share similarity with the process that led to the 2013's Climate Agreement: the

Dutch population has often taken an active role in developing the future national energy policies.

Thirdly, the issue of implementation of onshore wind energy, in relation to the Dutch population resistance to turbines, is not a recent problem. While in the recent years more cases of protests against wind turbines are organised, the public opposition to the technology has been found a relevant issue in the reports analysed dating back to 1995 (IEA, 1995), when local planning encountered many bottlenecks because of developers failing to address a problem that was not properly investigated yet.

The research question that this chapter answers addresses the nature of the issue described: *How is public acceptance defined*, in the context of wind energy? The question could seem trivial in the perspective of a single wind energy project, but has deeper implications that can result in the successful implementation of nation-wide targets on clean energy. First of all, the subject of the claim of "acceptance" needs to be defined. The epistemological question of the notion of acceptance is then briefly introduced, but focus has been shifted to the translation of the concept within the implementation: as this thesis has a pragmatic, underlying engineering background, it is of more interest to understand how to make use of the knowledge gathered. Finally, the influencing factors concerning public acceptance are presented.

To answer the research question and define the subject of acceptance, key elements of a socio-technical system are introduced: wind energy is presented in this research work not as the assembly of technical components such as blades, generators and towers, but as the wider network of actors, resources, culture and interests that shape the development, growth and implementation of the technology. A review of the proposed frameworks within the Social Shaping of Technologies (SCOT) field (2.2.2), highlights how the development of technologies is heavily impacted by the actors within the network and the *negotiability of technology* (Williams and Edge, 1995). Individuals, organisations and groups act according to specific interests (or Values), and are able to influence the development of a technology significantly. The reliance of the early wind energy pilots on the Dutch electricity utility companies of the NV SEP is reflected in the literature that shows the interdependence between radar technologies and the military R&D (Elzen et al., 1996). Tecnological Transitions (5.4) theories also contributes in the definition of the subject of acceptance. The Multi-Level Perspective framework brings in the dynamic view on technology adoption: wind energy is currently in a very different situation than it was thirty years ago, and is currently heavily influenced by the *sociotechnical landscape* rather than small niches. This position within a larger picture shows how actors are subject to different incentives, and how a larger group of subjects are impacted by it.

The review of these theories provides a theoretical background to understanding the complexity of the subject of public acceptance. In section 2.3, the studies focusing on the actual "acceptance" of the technology are reviewed with a focus on the sociotechnical elements highlighted earlier. The definition of acceptance in literature developed over time from "*lack of resistance*" (Chataignier and Jobert, 2003), through the simplistic NIMBY effect to consolidate around a multi-stakeholder broader perspective presented by Wüstenhagen et al. (2007). The review of publications on the subject by Fournis and Fortin (2017) provides with three possible approaches, each one with important considerations for the translation of intent into result:

- Wüstenhagen et al. (2007) introduces the Triangle of Social Acceptance, by providing a three dimensional perspective to acceptance. Three different stakeholders groups have different decrees of acceptance, and have different responsibilities and milestones. The approach has the merit of clearly defining three entities, decline them into practical objectives and has been widely adopted in literature and further research.

- Szarka (2007) pushes the notion of an evolving social contract between different parties. The overall decision making framework proposed by the author has a focus on interaction and choices in design and normative processes, of which acceptance can be the outcome when stakeholder's criteria are met.

- Fournis and Fortin (2017) further elaborate on the two definitions by proposing the concept of acceptability: a process of collective assessment that considers plurality of actors, spacial scales, and temporal dimensions. One of the possible outcomes of social acceptability can be social acceptance.

The main takeaway of this review is that defining public acceptance can be complex. The literature has now progressed to a point in which these complexities are translated into analytical frameworks considering many dimensions, and it is widely accepted that a techno-centric definition is no longer suitable to addressing the issue.
For the purpose of this thesis, and the translation of the concept of acceptance in practical (when possible) initiatives, a simple definition of public acceptance needs to be presented.

Social acceptability *is the process of collective assessment of different entities of a sociotechnical system, where multiple processes take place on three main levels (micro, meso and macro) and may result in the successful social acceptance of a technology.*
Public acceptance *is the outcome of these processes that take place on a micro-level, where the entity of interest is the social network of local actors. The impact of these processes can be analysed in terms of influencing factors.*

It is outside the scope of this research work to define the influencing factors of *social* acceptance of wind energy. While recognising and considering the interplay of the levels of acceptability in the local level, this thesis focuses on implementation of design and normative requirements that can foster *public* acceptance in a possibly pragmatic approach. Nevertheless, the notion of a multi-layered acceptability process has important implications on the local level, and these impacts needs to be taken into account when analysing public acceptance.

The Ethics of Wind Energy 3

As technology evolves and humans innovate, a new set of ethical questions was developed in parallel. The adaptation of moral philosophy to technological design issue came with a new set of problems for engineers, many of whom where most of the time unequipped to address.

In 2015, the first commercially viable models of self-driving vehicles were ready to be launched on the market. The possibility to automate the conduction of a car or truck came with clear benefits such as higher fuel efficiency, less environmental impact, higher road safety and less traffic, as well as many moral implications (Bonnefon et al., 2016; Borenstein et al., 2017). Many automotive manufacturers were not hiring only software developers and control system engineers, but ethical experts focused on understanding and testing ethical choices behind the design of autonomous control. In the Moral Machine experiment organized by MIT (Rahwan), 2.3 million people around the globe faced an advanced version of the trolley problem (Thomson, 1985): the choices that a self driving vehicle should be able to make in a situation where the conductor, a passenger or multiple pedestrians should be in physical threat. In the results of the experiment, Awad et al. (2018) report cross-cultural ethical variation, and show how differences in modern institutions and deep cultural traits affects our morality (Awad et al., 2018).
Self driving cars are a perfect example of the importance of ethics in technology, and one of its most accessible examples.
While apparently less controversial, technological innovation in energy generation implies moral and ethical choices as well, impacting the lives of millions of subjects in a similar way.

Renewable energy has often been perceived in a positive way amongst the wide population and associated with many terms referring to its low carbon emission: *clean, green, sustainable*. Sustainable energy is a broadly used term (both in literature and general use) for "energy that is collected from renewable resources, which are naturally replenished on a human timescale" (Ellabban et al., 2014) that features a moral implication in its definition. The term *sustainable* suggest a more conscious approach to the use of extinguishable resources (Tahiru and Bakare), a long term perspective on controlling the levels of emissions in the atmosphere (Kondili and Kaldellis, 2012) and the idea of intergenerational justice (Pellegrini-Masini et al., 2019), considering future generations as potential beneficiaries of the current technological choices. If this technology appears so ethical, how come it is currently subjected to the problems and discussion described earlier in Chapter 2?

(a) Protests in Santa Monica (CA) after the *Deepwater Horizon* Oil Spill in 2010, advocating for clean energy generation. Source: Gina Ferazzi - Los Angeles Times

(b) Demonstration against nuclear energy in front of TEPCO headquarters after the Fukushima-Daiichi nuclear disaster in 2011. Source: KYODO News

Figure 3.1: Civil demand for renewable energy has risen sharply since the early 2010s, following the environmental disasters that characterized the start of the decade.

The popularity of sustainable energy power generation has also risen in recent years as *alternative* against more widespread sources of energy, such as oil and gas combustion and nuclear power. Public perception toward nuclear has a long history of distrust and opposition, but the 2011 Fukushima-Daiiri nuclear disaster influenced heavily the perception towards the source (Kim et al., 2013). While the moral implication of nuclear energy are extremely complex and have been covered extensively in technology ethics literature since the 1980s, the rise of popularity in renewable energy (and therefore wind energy) in areas where distrust in nuclear power was reported, is an interesting correlation (Park and Ohm, 2014). In comparative studies, renewable energy (including hydropower) is the most commonly endorsed generation mean, in clear advantage against nuclear and coal, with many of the respondents citing environmental concerns regarding nuclear power (Ertör-Akyazi et al., 2012; Ellabban et al., 2014).
Nuclear power has clear environmental benefits such as low land use and production of carbon dioxide emissions, even when compared to wind energy or other renewable sources (McCombie and Jefferson, 2016). It shares most of the perceived benefits of renewable energy, but the perception of the environmental impact that episodes like Fukushima-Daiichi(2011) and Chernobyl(1986) created is still present in the public debate (Kim et al., 2013).

Similar to nuclear disasters, other events have influenced heavily the global perception of ethical energy generation: oil and gas spills. The *Deepwater Horizon* oil spill, often cited as one of the biggest accidental petroleum spills in history (The Telegraph, 2010), impacted and strengthen the sentiment against oil and gas multinationals in terms of impacts on the environment. The accidental spilling of 4.9 million barrels (780,000 m3) of petroleum in the Gulf of Mexico over 4 months was found to impact support for offshore wind energy development as a consequence of the event, with 82% of U.S. citizen favourable for the cleaner power generation alternative (Lilley and Firestone, 2013).
Meanwhile, oil and gas companies have been found more likely to pursue unethical practices in non-competitive markets (Gupta, 2017), the appropriation of oil supply causes aggressive foreign policy preferences and war (Colgan, 2011) and the environmental impact of the various conversion from oil to energy is significantly higher than renewable energy.

Compared to examples of traditional energy sources, wind energy supposedly gained momentum over the last decade as it seems to better embody ethical values such as *sustainability, safety* and *accessibility of resources.*

Wind energy has also been found to generate a high level of local protests in onshore projects (Devine-Wright, 2005; Wüstenhagen et al., 2007; Jobert et al., 2007; Agterbosch et al., 2004). As described in the previous section, residents report high level of stress, nuisance and sometimes decrease in the overall quality of sleep, factors that should therefore impact the ethical value of *health* of an individual. Depreciation of the value of the property is reported, and if no benefits are assigned to the residents, the idea of *fairness* is diminished. On a technical level, opposition against wind turbines often refers to the lack of *availability* of electricity generated by wind turbines, compared to the stability that can be obtained with thermal power plants.

The investigation of whereas wind energy is an ethical source of electricity is outside of the scope of this section. The aim of this chapter is to provide the theoretical framework in order to evaluate the relationship between ethics and wind energy. An introduction to the literature of Responsible Innovation (RI) will be presented in sub-chapter 3.1, together with the notion of values. Building on the framework of RI, the methods of Value Sensitive Design (VSD) is presented in 3.2, providing the theory to develop and execute the analysis presented in Chapter 4. Relevant applications of VSD to the topic will be discussed in this section, and the current literature that applies the method to wind energy will be presented in 3.4.

3.1 Responsible Innovation

The interlacement of ethics and technology has been relevant since the moment when the application of said technology started to change society. The design decisions included in the development of new inventions have been influencing not only the direct users of those artifacts but a much larger range of stakeholders, on different levels.

Considering social media: one of the most rapid innovations that are now extremely pervasive in society, as of June 2020 3.6 billion users are estimated to be active on social media platforms, with 2.5 billion active on Facebook (Statista, 2020), with daily screen time average of 72 minutes for just social media in the US (eMarketer, 2020). Design choices in the interfaces of the news feed, notification system and recommendation algorithms have been reported to have many concerning implications in terms of mental health (Conway and O'Connor, 2016), relationships and even perception of truthfulness(Li and Sakamoto, 2014) for users.

If technological development takes into consideration the potential impacts on the environment and in society, it can be considered "responsible" according to an early definition provided by Von Schomberg (2012). The notion responsibility is given here within the context of Responsible Innovation (RI), a framework that describes the field of technical research with high ethical standards, promoted by the European Union and the Dutch Research Council.
The number of scientific articles and journal citing the topic of RI has been growing steadily in recent years, as shown in 1.2 earlier. Ortt et al. (2020) suggests that responsible innovation has been existing long before the research interest growth, with precedents in literature concerning innovation and diffusion such as 'Complex Product Systems' (CoPS) and 'Large Technological Systems' (LTS). The study of CoPS (such as cellular mobile communication systems) and LTS (e.g. electricity networks) is deeply tied to the approaches described in section 2.2.2, where the involvement of vast groups of stakeholders determine the level of complexity and impact of a determined technology. Another precursor of RI is found in the publications addressing 'Technology Assessment' (TA). TA was an approach used by the American government to evaluate early stage technologies with potentially large implications on society to inform politicians and prepare policy options (e.g. supersonic transport or genetic screening).

Responsible Innovation theory differentiates itself from its predecessors with the openness and adaptability of the concept of a vast range of technologies, creating at the same time ambiguity over its definition. van den Hoven et al. (2015) reflects on the criteria that an organization (or process) would need to satisfy in order to be labelled with the term "responsible" concerning a specific innovation:

1. they would need to accumulate as much knowledge as possible on the consequences of their choices and on the alternatives available at the moment;

2. they should evaluate their options and outcomes in terms of moral and ethical values;

3. implied that 1. and 2. have been completed successfully, they should take those outcomes as requirements for the design and development of said innovation.

Ortt, van Putten, Kamp, and van de Poel, in the book *Responsible Innovation in Large Technological Systems*, propose a case based approach to identify resemblance in the approaches applied to a range of diverse technological systems in society. With limited harmony on a shared definition of Responsible Innovation, the baseline is drawn in the seven features that are identified in literature by the authors:

a Predictive and iterative - RI propose to anticipate potential impacts of a technology and iterates the innovation process with that information (Stilgoe et al., 2013; Owen et al., 2013);

b Helpful - RI, being aimed at improving society, focus on minimising the potential harms and maximising gains for society as a whole;

c Ethical - RI intends to integrate ethical values into the design and process of development of the innovation (Friedman and Kahn Jr, 2002; Van den Hoven, 2013; van de Poel, 2013a);

d Inclusive - RI encourages multiple stakeholders from different groups to take part in a participatory innovation method (Stilgoe et al., 2013);

e Impactful - RI serves and aims at solving problems and challenges that are significant for society as a whole;

f Responsive - RI is flexible in adaptation to societal expectations and should rapidly change if a new problem may arise with its development (van de Poel, 2013a);

g Transparent and open - the framework of RI allows for accountability of its participants through a transparent decision making process and research (Von Schomberg, 2012).

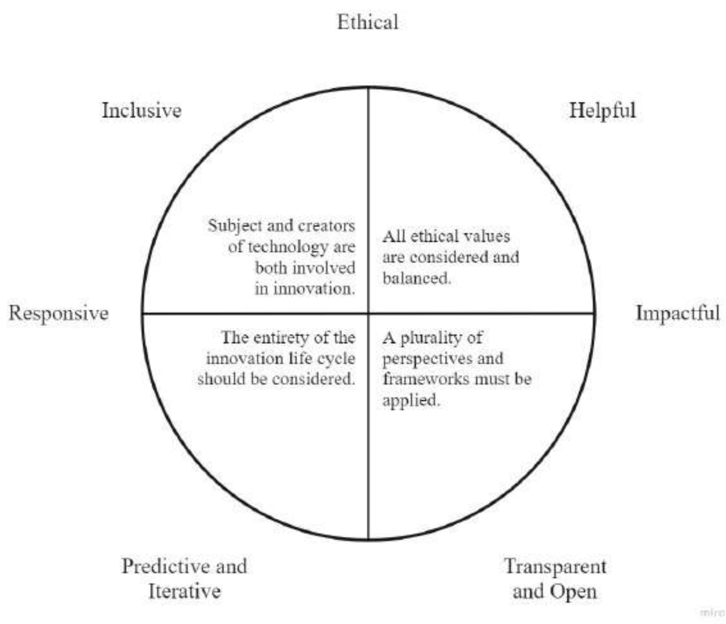


FIGURE 3.2: A summary of the common features (external) and defining traits (internal) of Responsible Innovation. Based on Ortt et al. (2020).

Evaluating these traits of responsible innovation to the nine case studies presented in their research, Ortt et al. come to the conclusion that the concept is highly dependent on the context of the innovation. In order to provide with a comprehensive, but not exclusive, definition of RI, the traits that characterise RI in Large Technical Systems are defined as it follows:

- Innovation should take into account and balance multiple values, not only the economic factors;
- Subjects and innovators of technology should both be included in the process, together with a wide range of stakeholders;

- Innovation should focus on the entire life cycle of the product and its impacts, considering a long enough time horizon;
- The process must include a plurality of perspectives, considerations and diverse methods to obtain the most amount of information possible about its implications.

The summary of these findings is reported in figure 3.2.

3.2 Value Sensitive Design

The argument that technology is intrinsically not value-neutral is possibly the main foundation of the discipline of Value Sensitive Design (VSD). As an objection to technological determinism, as shown in section 2.2.2, technological innovation has been described as the result of a complex process that includes a wide multitude of different systems, social groups, sub-processes and interests, that implies a *negotiation* of different interests (Williams and Edge, 1995). To repose on the example of social media described earlier, the features of certain platforms is explained through the existence of a particular business model, responding to the need of certain stakeholders. Not only, but the presence of targeted advertisement also incorporates the development of technologies such as machine learning algorithms and data mining services (Lee et al., 2010; Cui et al., 2018).

The notion that values were embedded in technological design raised the question if it was possible to reverse the dependency and if innovation processes could feed value-based decision making into the initial design. In the 1970s, at the University of Stanford, the idea of making moral values central to design and development of innovation was developed and first applied to studies in human-computer interaction of Computer Science (Van den Hoven, 2013). However, one of the first formalizations of the process is often attributed to Friedman and Kahn Jr at the University of Washington in the early 1990s, when a group of scholar started using the label of "value sensitive design" to describe a wide range of research projects that included a shared interactive design process and proactive approach towards including different values (other than efficiency and usability) (van den Hoven et al., 2015; Friedman, 1999). Subsequently, with the foundation of the VSD Lab and the affiliation of other researchers, numerous publications [1] started to use the term to describe the set of theory, methodology and methods that were used to account for human values systematically throughout the design process.
Similar approaches have been proposed under different nomenclature since then. At the University of California, Irvine, the "Value in Design" (VID) Lab [2] was founded by Geoffrey Bowker and Helen Nissenbaum in the early 2010s, with fundings from the United States government and partnership with prominent American private Information Technology companies. The VID research focuses on the privacy and ethical concerns of mobile internet applications such as GPS-based location (Knobel and Bowker). At the Delft University of Technology, the "Design for Values" (DfV) Insitute explores the relationship between values and technology from a seemingly more comprehensive design perspective: with a 21-century vision on technological development, the institute aims to incorporate ethical questions and debate into specific design requirements for a vast range of engineering applications [3].

Regardless of the application, it has been observed three majorly common themes and features between the approaches mentioned (Van den Hoven, 2013). Primarily, VSD, VID and DfV share the claim that values can be expressed in technology. In the highly cited article *"Do Artifacts Have Politics?"*, Winner outlines how design choices in urban planning can be made to discriminate certain social classes, with the famous example of "racist overpasses" designed to prevent buses (commonly used by the poorer black families) to access New York's beaches. More recently, discrimination can still be enforced by technology through algorithms, as racial bias has been found to be present in commercial

[1] https://vsdesign.org/publications/
[2] https://evoke.ics.uci.edu/about/values-in-design/
[3] https://www.delftdesignforvalues.nl/vision-why/

algorithms that are used in the US healthcare sector (Obermeyer et al., 2019). Next, if values can be displayed through technology, it is morally relevant to discuss and review the ethical implications and motives of the innovation used in a large group. While not strictly concerning only engineering designers, policy-makers, modern philosophers and economists are equally found to be important participants of a societal discussion about the moral implication of the products and services we use. Noted the relevance of moral considerations concerning technology, the last shared claim is that said discussion should happen early in the design process, at the moment in which value consideration can make a difference in the possible outcomes. As per described earlier in the predictive nature of Responsible Innovation by (Stilgoe et al., 2013), anticipation of the impacts of a specific technology is important in a way that can minimize the potential value failure in design (e.g. injustice or physical danger). Considering the power problem that arises when a widely implemented technology (that carries a complete socio-technical structure within) is found to have negative societal implications, it requires considerable effort and resources to change its design because of the multiple systems it is intertwined with. The effort could be substantially lower if said negative implications could have been detected earlier when the innovation process allowed more degree of freedom in the design. It arises then the Collingridge dilemma: information is scarce when it could be most useful. VSD and other frameworks seek to prevent the information problem by systematically incorporate moral evaluation at the early stages of the process of innovation (van den Hoven, 2007; Friedman, 1999).

3.2.1 Theory and Methodologies

The theoretical background of VSD stems from an elaboration of the empirical finding of studies in information systems technology and human-computer interaction. As foundation of the discipline, there is the claim that technology's influence on a user, group of users or entire society is shaped by (1) the features of its design, (2) the context in which is used and (3) the people involved in the use (van den Hoven et al., 2015). The interactional perspective of the nature of the technique is important: the design of an artifact itself is not pre-determinant of the value that can arise through its application. VSD rejects technological determinism described in section 2.2.2, which implies a "value-neutral" nature of technology (Wyatt et al., 1995), it refuses as well a simplistic causality between design and values. The theory of VSD embraces the notion that values are not embedded in technology, but are implicated through engagement. The careful identification and consideration of values in the design process are considered by VSD scholars and supporters able to improve the final use of the artifact. Ignoring the influence of a product over its user experience can cause negative impacts over the overall well-being of an individual, or even worse, over a large group of individuals (Nathan et al., 2008).

The fundamental methodology of VSD has been outlined in Friedman and Kahn Jr's work *"Human values, ethics and design"* 2002 as a triad of "investigations": conceptual, empirical and technical investigation. The process is described to be iterative and integrative, with the singular research activities meant to inform and overlap with each other, rather than a structured methodology (Friedman et al., 2006). *Conceptual investigations* consist in the retrieval of information regarding the stakeholders involved in the use of technology (direct stakeholders) and those influenced without direct use (indirect stakeholders). These investigations include also "mapping" the values associated with stakeholders groups: the identification and definition of values implicated by the use of said technology. *Empirical investigations* concerns methods such as surveys, interviews and workshops, aimed at observing stakeholders' "understandings, contexts and experiences" (Friedman et al., 2002). *Technical investigations* examine how a change in design parameters of a said technology, or the implementation of a different feature in the artifact can implicate a specific value or behavioural change in stakeholders.
Friedman and Hendry (2012) published over the years a wide range of methods to apply to VSD. Many of these methods involve the appropriation from a value-based perspective of standard social science methods, such as semi-structured interview, experimental designs or observations. Starting from *Stakeholder analysis*, one of the most common exercises used in project management, with the purpose it to identify individuals, groups,

organizations, institutions, and societies that might reasonably be affected by the technology under investigation. *Value Source Analysis* is an exercise to distinguish among the explicitly supported project values, designers' personal values, and values held by other direct and indirect stakeholders. In a later stage, *Value Dams and Flows* can be used as analytic methods to reduce solution spaces and resolve value tensions among design choices (Friedman et al., 2017).

3.3 The Socio-Technical Value Map

The methods and tactics proposed by Value Sensitive Design researcher provide tools for intervention in the early stage of a technological innovation. As per requirements of the notion of Responsible Innovation described earlier, the early developers of technology have the duty to provide predictive perspective to their work, in order to address earlier the possible problem that can arise later in the use phase (Ortt et al., 2020). VSD additionally stresses the importance of anticipation of impacts through scenario analysis, action-reflection models and other useful techniques.
However, this preventive perspective on design is argued to be only implemented in early-stage technologies. Abiding to the Collingridge dilemma, changes are made possible earlier in the innovation process because of the dynamic nature of the process itself (Collingridge, 1981). Because of multiple reasons, including economies of scale, mass production, the establishment of formal ruling over a technology, mature systems are described by Hughes (1987) as *"independent from outside influences, therefore more deterministic in nature"*, less prone to change and innovation.
While it is clear that inclusion of values should take place at the start of the innovation process, elements of evolutionary theory suggest that the nature itself of technological development allows for growth and improvement during the whole lifetime of the systems. As described in Geels's Multi Level Perspective description of the innovation system, when a technology becomes part of a 'sociotechnical regime' it acquires dynamic stability and momentum, but it is still subject to pressures from the global landscape and can still provide 'windows of opportunity' to innovation to break through the regime. Automotive transportation can be described as a very large and solid technical system, with billions of users, incredibly pervasive in current law and institutions, with large key players in the sector. Yet, innovation and growth broke into the seemingly unchangeable system through the introduction of electric vehicles: the industry changed, laws adapted, the urban environment is slowly adapting to accommodate more EV charging stations and the electric grid needs now to consider different user patterns. It can be argued that EVs had a faster speed of development because of the pressures exerted from the global landscape, such as Climate Change (Åhman, 2006; Marcel et al., 2003).
Ortt et al. also support the idea that after the initial innovation process innovation and entrepreneurial behaviour remains important, to update and adapt the institutional system, decision-making and communication that revolves around the technical system. As values have been described to change over time their ownership with different groups of stakeholders (van den Hoven et al., 2015), if a technical system based on innovation needs to be "responsible", based on the iterative nature of RI, it will need re-evaluation and monitoring. A need for a framework for value-analysis of large scale, mature, technical systems is therefore needed.

The Socio-Technical Value Map (STVM) is a framework that combines the theories of VSD and Constructive Technology Assessment (CTA), proposed by Rohracher (2002) and further developed by Pesch. Considering technology based on its incorporation in the sociotechnical system and including a specific focus on values as part of the analysis, the STVM aims to serve the purpose of mapping complex sociotechnical systems. Proposed by Pesch as a "desk exercise", rather than "aimed at the direct intervention in the innovation process or the engagement of stakeholders", this framework incorporates the main takeouts of STSs theory, VSD and therefore RI. Contextualising the technology in an evolutionary perspective is convenient and not only applicable to early stage innovation, but to every technology that is *in* development.

The choice of applying the STVM to onshore wind energy in the Netherlands is motivated by multiple factors, on which it will be elaborated more in Chapter 4. Considering the knowledge on wind energy in the country, SCOT theories, RI and VSD frameworks, it can be outlined briefly in five reasons:

a Wind energy in the Netherlands can be considered a large and complex sociotechnical system, accounting for a broad range of stakeholders (Ortt et al., 2020), therefore requires a comprehensive framework of analysis;

b Wind energy in the Netherlands may be deemed as a mature technology due to the size and entanglement with the national electrical grid. However, in order to meet the national targets (CLO, 2018, 2019) significantly more capacity needs to be implemented. Formal and informal institutions can and need to adapt to this rapid increase in capacity;

c Support towards wind energy projects is often described in terms of "conflicting interest" of various stakeholders (Künneke et al., 2015; Wüstenhagen et al., 2007; Huber and Horbaty, 2010).

d The degree of implementation of wind energy in the Netherlands is not reliant only on the technology itself, but also on the social setting of it (Agterbosch et al., 2004; Kamp, 2008);

e The unsolved problem of public opposition to wind turbines in the country can benefit from the application of a methodology that is specifically designed to include participative design (Vermaas et al., 2010; van der Velden and Mörtberg, 2014), conflict of interest (van de Poel, 2014) and mediation (Spahn, 2014), topics often included in analysis on the issue.

Applications of STSs and VSD are presented in section 3.4.3, elaborating more on reasons a and b. In the following section, an overview of the "phases" of developing a STVM is presented, according to the methodology outlined by Pesch (2019). In figure 3.3, a summary of the four main components of the method are represented. *Technology mapping* (4.1, in red) and outlining a *stakeholder map* (4.2, in blue) are preliminary exercises that allow the formation of a comprehensive *value map* that includes both technology and stakeholders' values. Building on the understanding of the three maps, *design for values* can be enabled, bringing together the insights and creating a space for value-based innovation (3.3.4, in green). In the figure, the circles represent the entities to be mapped in the Technology and Stakeholder Map such as artefacts, elements of design, procedural alternatives, actors, groups, etc..., while the squares represent the values that motivates specific designs, technologies, ambitions and objectives.

3.3.1 Technology Map

Outlining the technical system of which the analysis is performed is a key step in the sociotechnical value mapping exercise. While it may seem trivial at glance, the definition of context, boundaries and alternatives requires a great degree of attention in order to produce useful insights for the further steps.
The first step of practice is to define the *character* of the technology: the stage of development, main value proposition (borrowing terminology from business studies), required resources and in general any information that can *define* the technology. In the case of EVs mentioned earlier, this section of a technology map would probably include a description of the electric engine technology, control systems, energy storage solutions, types of vehicles available to the public and other key parameters such as average range and price per mile, safety indicators and environmental performance. An overview of the development should be provided, giving context for the growth forecast in market share, and possibly information on the raw materials required for the components. Lithium constitutes the main component of commercial EVs' battery systems, therefore information about its availability constitutes relevant information when considering the

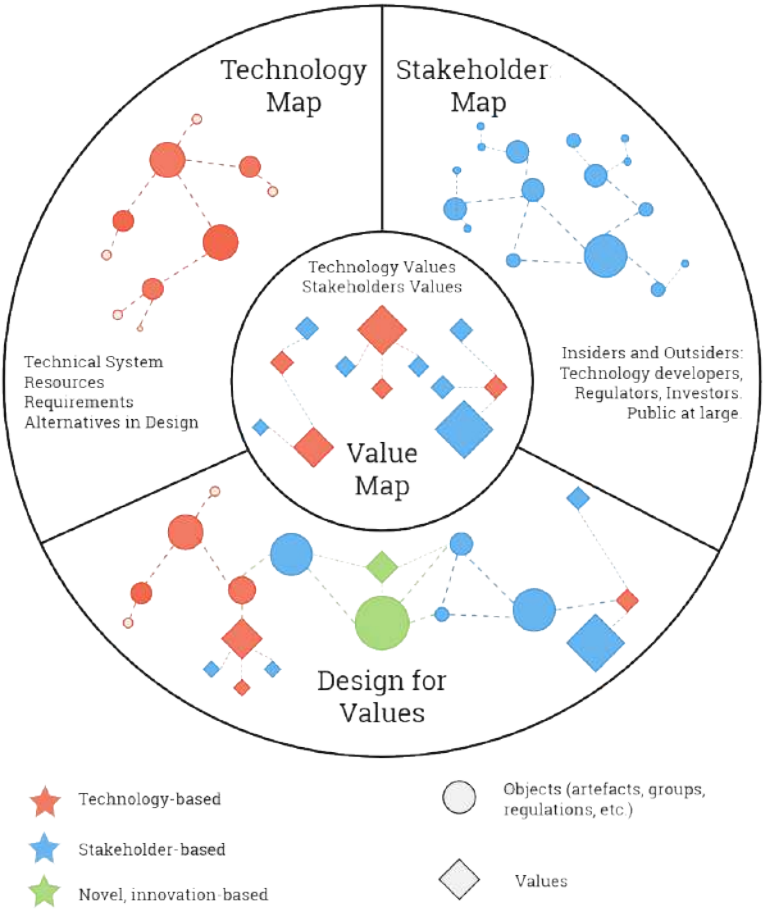


Figure 3.3: Socio-Technical Value Map (STVM) components. Adapted from Pesch (2019)

overall technical system.

Secondly, as implied by the evolutionary nature of the method, it is important to illustrate possible alternatives to the technology. While the availability of alternatives can depend on the use of technology, design choices or geographical preferences, it is suggested to define a variation environment that includes technologies that could *compete* with the one in analysis. For EVs, a benchmark comparison with the leading competitor, internal combustion engine "traditional" vehicles, should be accompanied with a focus on technologies under development such as hydrogen powered vehicles. Market share, comparison of performance indicators and availability of alternatives should be included in the mapping.

Finally, a conceptualization of the development of the chosen technology needs to be addressed. As described in STS-inspired research on technical systems, the regulations and formal relationship with institution constitute an integral part of the system. How do these relations influence the possible technology development, what key *barriers* may hamper the implementation and is there a specific forecast for said technology? Considering EVs, many barrier analysis have been performed since the early innovation phase. The role of national governments is crucial to enabling their diffusion, as well as the adaptation of electric grids to accommodate for a different demand profile from EVs' owners. The role of the carbon-free transportation system also needs to be contextualised in the perspective of decarbonization of the automotive sector to address Climate Change, with international bodies subsidising such technologies.

In order to address the right amount of information, a technology map can be adapted to a certain application of technology, or peculiar component. It is unrealistic to list all the technical alternatives to circuit boards inside an EV, the level of detail of the analysis need to focus on a specific scope. In chapter 4, the technology map of onshore wind energy systems in the Netherlands is presented. Without the ambition of analysing the entire wind energy technology, the focus has two main boundaries: (1) onshore systems, excluding all the sea installations and new technologies (such as floating foundations, higher capacity factors per turbine) and (2) systems installed in the Netherlands. Such constraints on the analysis are put to explicit the scope for which this analysis is presented, to investigate the public attitudes of Dutch stakeholders over the sociotechnical system.

3.3.2 Stakeholder Map

Stakeholder analysis has often been cited as a possible tool in VSD and CTA frameworks of analysis (Friedman et al., 2002), in the first of the 14 methods listed in table **??** developed by Friedman et al. (2017) direct and indirect stakeholder analysis brings the focus on the individuals *affected* by a technology as well, not only the actors directly invested in the development and use of said technology. The aim of this exercise is to provide reference for a more comprehensive analysis of interests and resources of individuals, organizations, groups, institutions or societies affected by the existence and use of an innovation, that could potentially bring further or impact negatively the development and adaptation of it. Allocation of resources, both financial and non-material nature, needs to be explored in order to understand the underlying reasons of involvement of a specific group. Interest can be translated in values, and the result of this practice is to provide a, possibly original, perspective on the development of a certain innovation. Three main clusters of stakeholders are outlined in this analysis: *direct* and *indirect* stakeholders, and *public-at-large.*

'Insiders', or *direct stakeholders* are the set of actors involved explicitly with an innovation process. Borrowing terminology from Geels's frameworks, the actors involved in the early stage of innovation ("niches level") shapes heavily the development of the technology and place on it a considerable amount of resources and influence. The group of technology developers, investors, mentors (in the case of start-ups), researchers, policy-makers and early networks can fall into this first category. When a technology is more mature and widespread, the composition of the group can shift to allow whoever is directly essential and involved in the operations, maintenance and decision-making processes of said technology. The stakeholder analysis of EVs would have appeared very different if mapped in the early 1990s and today. Actors enter and leave the sphere of influence of a technology regularly, and while the development proceeds and leave the protected niches of innovation, a broader group of actors become involved in the maintenance and existence of it.
The second group of analysis is identified in literature concerning stakeholder analysis within value-based perspectives: *indirect* stakeholders. 'Outsiders' of the innovation system of a technology are described as "outsiders firms, professional engineers and scientists, societal pressure groups" by Van De Poel (2000). Van De Poel argues that individuals not involved in the development, and therefore not subject to the "rules" that guide technological design, are important actors in enhancing democracy in technical development. The three groups of indirect stakeholders presented are then further analysed in terms of resources, involvement mechanism and interest. A summary of the analysis is reported in table 3.1, which provides guidance in this step of the STVM.

	Outsider firms	**Outsider professionals**	**Societal pressure groups**
Resources	Financial and managerial resources Engineering competence	Engineering and scientific knowledge	Influence over public opinion
Involvement mechanism	Entry of outsiders firms in new markets	Jurisdictional vacancies	Deligitimation detours Lead articulators
Interest and sphere of influence	Technical artifacts	Design tools and concepts	Functions, design criteria and requirements

Table 3.1: A taxonomy of 'outsiders' in technological development. From Van De Poel (2000).

When considering the societal pressure groups described, it is argued that the over formalization of opposition in terms of organizations and groups brings harm to the correct representation of societal dynamics (Pesch, 2015). The notion of *public-at-large* is proposed in this analysis to avoid overlooking of values, intentions and interests that could arise without formal representations through social institutions. Opposition, for example, shifted heavily in the recent years from organized groups that actively manifested their disapproval to online communities, thanks also to the advent of social networks and online activism (Earl and Kimport, 2009). While Van De Poel's outline is relevant to the year of publication, a broader adaptation of it needs to be up to date with the rapid development of societal and technical norms. The definition of this new category allows reflection upon the various roles of actors that are neither directly "linked" to the technology, neither officially inscribed in traditional forms of associations: which values and interests can have one towards a technology?
The definition is straightforward in terms of *users* or *consumers*. In the case of EVs, individuals who purchase and use said vehicle can bring interest and participate in the development without being invested in the development process. But applying the same rationale to sustainable energy technologies such as solar energy, how is it possible to "label" an individual that uses and simultaneously produces electrical power? The category of *prosumers* seems logical to be applied in a context which the national energy systems can be accessed bidirectionally (Brange et al., 2016; Gautier et al., 2018), but applies also to open source software and online knowledge/content creation and consumption (Hemetsberger and Pieters, 2001).
After the introduction of users, consumers and prosumers, other not traditionally organized actors can be identified in a context-based situation. As described in studies over public acceptance of technologies (2.3) public-at-large can accommodate groups of *protestors* and *supporters* that bring important value-based perspective to the public debate over said technologies. Self-organized groups have been reported constantly to oppose the construction of energy infrastructures, such as power plants and transmission lines, but the same opposition can be found in speed cameras and surveillance systems (Sandbrook et al., 2018). It seems intuitive that, when it concerns public opinion and personal values, actors that often are not involved in the internal processes of technical systems may need to be accounted for, according to the inclusivity principle of responsible innovation. The reasons and motives can vary on a personal basis, the identification of a shared behaviour and attitude towards certain technologies falls under the scope of the subsequent step of the STVM: the value map.

3.3.3 Value Map

The first two components of the STVM, technology and stakeholder mapping are essentially empirical exercises, collecting information and highlighting connections between various elements of reality through the use of guidelines, described in the previous sections. The value map aims at creating a coherent interpretation of the empirical results of those analysis (Pesch, 2019), in order to identify meaning behind existing formal (and informal) relationship between actors, technology, context and practices.

Values can be described axiomatically as the implicit act of placing importance over a specific matter and can be distinguished into two main categories: *intrinsic values* and *instrumental values*. Intrinsic values are generally defined as values that are good in themselves and are striving for their own sake (van de Poel and Royakkers, 2011; van de Poel, 2015, 2009). Instrumental values are mean to achieve intrinsic values and therefore pursued for the sake of other values (van de Poel and Royakkers, 2011; van de Poel, 2015). Applying the examples of values commonly associated with EVs, reported intrinsic values could be environmental sustainability, safety and human well-being (Axsen and Kurani, 2013), while instrumental values can be energy-efficiency, reliability or economic development (Han et al., 2017). Further elaboration of the etymological nature of values goes beyond the scope of this research project.

As portrayed in the conceptual representation of the process in figure 3.3, two main components are part of the value map: technology values, identified through the first exercise of technology mapping; and stakeholders' values, following the second component of the STVM. Concerning the foremost values, the claim that technology itself comes with values (Van den Hoven, 2013) is fundamental to the analysis. Artifacts are designed to accomplish certain goals and to fulfil specific needs, explicated through the functions. "Non-functional requirements" are great examples of implicit design values that can be collected through a meticulous review of the technology.

It is important to note that a value map does not necessarily need to be a schematic representation of the values involved in a technology/project/process. As per the previous exercises, the importance of this part of the analysis is to *identify* and *link* values from and within a context rather than presenting it through a visual medium. However, to visualise the results of the exercise, there are multiple frameworks. For the scope of this analysis, 'value hierarchies' will come useful: information will be presented in a layered structure to showcase the different levels of abstraction.

Values endorsed by the heterogeneity of stakeholders are the second main input of this exploration. As individuals are not reported to cite explicitly their alignment in a value-perspective, contrary to institutions or organized groups, often is possible to retrieve the information through a deductive process. The 'value hierarchy' is a tool developed by van de Poel (2013a) to retrace values, and aims as describing how values translate into *norms* and *design requirements* until they permeate society. Whilst fairly simple, the conceptual model is effective in supporting the task of tracing values from public debate and helps expand the terminology needed for the process. In figure 3.4 the model is illustrated.
If values are intended as the high-level conceptualization of *why* particular interest is kept by specific stakeholders over a certain matter, norms are the translation of *how* this focus should be implemented in society. Norms provide guidelines for action or restrictions, they are constituted of *objectives, goals* and *constrains*. For instance, if the value mapped by this tool would be sustainability, within the context of EVs, the second level of the hierarchy would possibly include the objective of "affordable transportation" (without specific target), the goal of "cut carbon emissions associated with road transport by half" or "improve air quality in residential areas", and finally some constraints such as "use of high environmental standards for battery durability, recyclability and performance".
When values are translated into norms, they are subsequently implemented in society in the form of design requirements, *what* measures are physically implemented into the technology or institutions. The choice of materials, internal components, life-cycle of batteries for EVs are examples of technical design requirements. Other design requirements could be described as "institutional", in forms such as subsidies, laws or policies enabled by the government. Other design requirements could be concerning the business model of a specific product, such as providing part of the profits generated through sales to carbon offsetting projects. Values translate in the sociotechnical systems in many different ways and the lower, wider level of design requirements indicates the ways in which this process happens.

For certain stakeholders groups, values can be suggested through *arguments*. Arguments

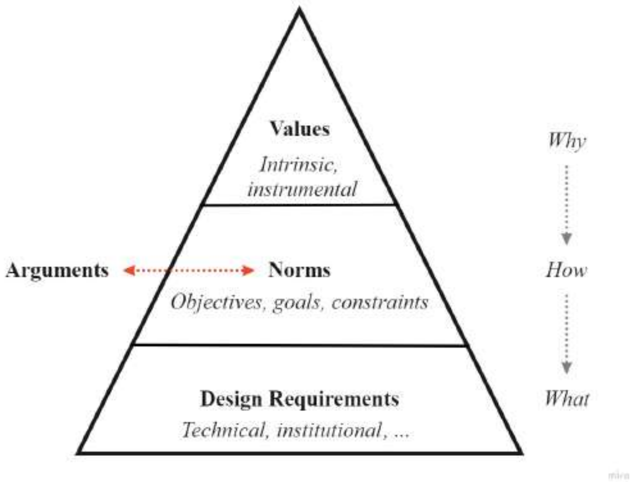


Figure 3.4: The Value Hierachy proposed by van de Poel (2013a).

have been noted from Dignum et al. (2016) to arise while social groups oppose or endorses particular norms. Specific values can be identified as they appear in public debate when political groups, institutions or other actors (often outside the innovation system) address an issue by providing context for said value.
The value hierarchy can provide an important analytical tool for mapping the value of a technology. Desk research and other common tactics can be implemented from social sciences and VSD. Deductive logic can assist the methods to establish a final and coherent mapping of different perspectives, as inclusive as possible.

3.3.4 Design for Values

The final step of the STVM is the formulation of specific *solutions* to translate the relevant values mapped into the technology or institutional framework. The broadness and openness to interpretation of this process include all the techniques and recommendations provided by Value Sensitive Design. Few guidelines are truly indispensable for this exercise, allowing innovation:

- Solutions should be *specific*, aiming to target precise value (or values) conflicts, gaps and issues identified in the analysis;
- Solutions should include *incentives* for stakeholders and the systems, to obtain leverage for implementation;
- Solutions should use a broad *design space*, including a variety of social structures (i.e. policy, law, organizational practices, social norms...);
- Solutions are not meant to be *definitive*, as the nature of responsible innovation is to be responsive to rapid value changes.

Generally, proposed solutions should reflect the traits of Responsible Innovation outlined earlier: ethical in addressing the values, helpful, impactful, transparent, open, predictive, responsive and inclusive (3.2). While Chapter 4 will adapt the first three steps of the STVM to the case of onshore wind energy systems in the Netherlands, Chapter **??** will explore methods and solutions to translate the results of the value analysis in design requirements, covering the final part of the methodology.

3.4 Applications to Sustainable Energy Technologies

Value Sensitive Design and its adaptation have been a vibrant field of research for more than 30 years. As Friedman et al. (2015) indicates, a steep increase of research interest has been experienced by the discipline: publications mentioning *"human values"* were only 20 in the year 2000, compared to the 113 in 2010 and 242 in 2020 [4]. VSD has been applied to many and diverse fields: robotics and healthcare (Van Wynsberghe, 2013), nanopharmacy (Timmermans et al., 2011), construction (Abraham et al., 2015) and even romantic relationships (Alsheikh et al., 2011). Nevertheless, research pursuing a value-based approach to address challenges within energy technologies is limited.

In a fairly recent graduation project within the Value and Technology department of the Delft University of Technology, de Geest (2016) explicitly investigate to what extend VSD can be applied to energy projects, and which added value the methodology could provide to them. While applying the framework to the case of public controversies concerning gas production in the Groningen province, de Geest argues that applying VSD can add a substantial value to his specific project. While this added value does not rely solely in the deliverable of the exercise such as value hierarchy or value mapping, VSD can provide value by focusing on specific and often overlooked segments in the design process:

- Conceptualization and definition of shared interest in form of values, in order to resolve ambiguity;
- Determination of stakeholders' expectations and benchmarking against proposed project measures;
- Support in the trade-off between risks and value of depleting natural resources.

Implementation of value-based design methods for energy projects, both for technological and institutional design, have been found in a limited but relevant number of applications (Mok and Hyysalo, 2018; Oosterlaken, 2014a; Dignum et al., 2016; Zomerman et al., 2018; Tuomela et al., 2019; Maxouri), some of whose are presented in this section. The aim of this review is to establish a starting point from where to develop the analysis presented in chapter 4.
A discussion of the presence of a value perspective in research on wind energy systems is presented in section 3.4.3, where the work of Oosterlaken and Künneke et al. provides significant insights for this research.

3.4.1 Photovoltaic Installation and Cultural Heritage

Value Sentive Design is a flexible tool, that can be used reconstruct both institutional frameworks such as participation schemes, policy and regulation, and actual technological design (Friedman, 1999), addressing different aspects of a sociotechnical system. The article from Mok and Hyysalo, "*Designing for energy transition through Value Sensitive Design*", focuses on the latter: from a designer perspective, The Finnish researchers investigate how to advance the use of solar photovoltaic technology within the heritage of an historical building. Using the VSD framework the author's work aims at carefully balancing the abstract values identified in the analysis and translate them into concrete project parameters. The outcomes presented are supported by a context that helps in clarifying the rationale behind design choices, but the project provides guidelines on the use of the methodology applicable for "energy transition" researcher and designers.

Mok and Hyysalo's efforts apply to the case studying of installing solar PV capacity in a specific building of the Aalto University's Campus, in Espoo, Finland. Integration of renewable energy in the national portfolio is relatively low, consisting in 0.06% of solar energy and 4.6% of wind energy capacity in the grid (Statistics Finland, 2018), with the government pushing initiatives for higher penetration of RES. Transitions literature

[4] This search was undertaken on 01/10/2020 using the search string '(TITLE-ABS-KEY (human values))' which identified 3,677 outputs from between 1975 and 2020. This database search updates Friedman et al. ACM Digital Library output retrieved in 2015.

(5.4) shows how system change needs innovation to be implemented in protected spaces (*niches*), where it can be tested and grow to be adopted in (or substitute) the incumbent regime (Geels, 2006); building capacity would help to establish a record for the price of installations of PV modules and create momentum in the adopting of solar energy in the country. Amongst Finland's barriers for more renewable power production is also a negative precedent of opposition against wind energy projects (Janhunen et al., 2014).
Concerning the case of Aalto University, four values were identified by the author during the conceptual investigation of VSD. Adapting the value hierarchies described in the previous section, it is observed that the *values* described by Mok and Hyysalo are more correctly addressed as *norms*: generic aims of direction in which the purpose of the design should lead.

a *Cultural heritage preservation*: concerning the fame of the Finnish architects that designed the building in 1960;

b *Campus prestige and identity*: addressing the interest of specific groups of stakeholders of establishing Aalto as a reputable and prestigious university;

c *Aesthetic quality*: fairly subjective, but relevant concern of the visual impact of the building;

d *Ecological modernization*: empowering the campus to appear modern and to generate a substantial share of the electricity needed autonomously;

e *Economic cost and energy efficiency*: key objectives that can influence the scope and ambition of the renovation of the building.

Value conflicts arise when a choice between two options for which at least two values are relevant has to be made (van de Poel and Royakkers, 2011). The pursuing of preserving the cultural heritage of the building seems to prevent any possibility to increase ecological modernity, not allowing solar technology addition to being applied to the structure. In parallel, choosing to maximise energy output from the solar system would imply the use of every surface available regardless of the aesthetics and heritage.
Additional issues can arise when different weight is given by different stakeholders to the values identified. The authors utilize a quadrant stakeholder map as analytical tool to identify and capture the importance and prioritization of both *direct* and *indirect* stakeholders of the project: Board of the University, solar technology providers, architect's professional organizations and finally end users of the facilities (professors, researchers, students) or alumni of the University.
Mok and Hyysalo performed additional field research surveying local stakeholders perspectives on the proposed value conflicts, collecting empirical findings on the historical evolution of the building and engaging with professionals such as architects and solar system engineers. They draw upon this analysis criteria to guide the technology design, while VSD was reported to help guide iteratively the process through the various steps.

The final design proposed by the author featured a design choice that is simultaneously guided by the values researched and supports said values: a *subtle visible* structure carefully positioned on site to be "practically invisible yet detectable" (Mok and Hyysalo, 2018), yielding meaningful energy. The design is shown in figure 3.5. It is presented as not the optimal solution to site solar panels on a heritage building (no data concerning electricity production is provided) but as the result of a broad design process addressing legitimate value concerns.

3.4.2 Natural Gas Extraction and Public Controversies

Elements of VSD and DfV theory have been applied to controversial energy cases of the Groningen gas controversy in (Mouter, de Geest, and Doorn, 2018) and, in a larger perspective, to the case of shale gas explotation in the Netherlands in (Dignum, Correljé, Cuppen, Pesch, and Taebi, 2016).
These cases are relevant to this research for three main reasons:

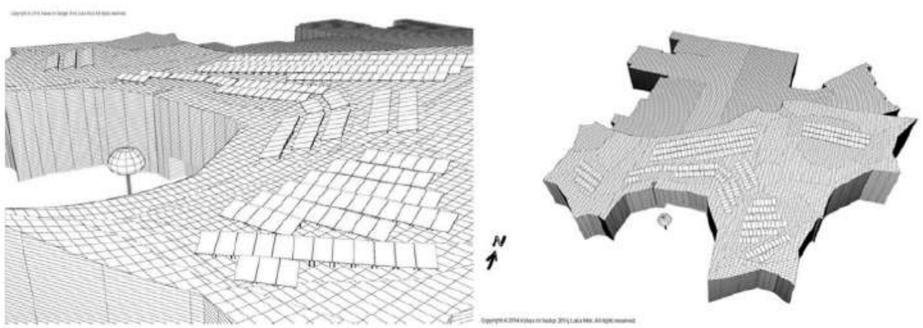


FIGURE 3.5: The solar photovoltaic system proposed by Mok and Hyysalo overcame the value conflict present in the project. Rendering presented in Mok and Hyysalo (2018)

- They introduce VSD terminology and methods in applications to energy systems;
- The geographical and normative context of the Netherlands;
- The assumption that acceptance of sociotechnical systems can be improved by *redesigning* technical, institutional and procedural artefacts (Mouter et al., 2018);

Considering the similarities of these cases with the main aim of this thesis: investigating how public acceptance of wind energy systems in the Netherlands can be improved with a value-based perspective (1.2), an overview of the methods used and approaches used by the authors brings added value to the analysis that is performed in chapter 4.
In "*A values-based approach to energy controversies: Value-sensitive design applied to the Groningen gas controversy in the Netherlands*" from Mouter et al. (2018), the work aims to explore the applicability of VSD in controversial energy cases, investigating identification of values, norms and design requirements according to the values hierarchies (van de Poel, 2013a) (described in section 3.3.3). The case study taken in consideration is the complex problem of public controversy the exploitation of a major gas field in the province of Groningen in the northeast area of the Netherlands. The gas field is one of the largest in Europe and over the years it has provided many benefits for the Dutch state: providing a reliable energy supply for the area, generating billions in revenue for the Dutch economy and employing thousands of residents over the period 1963-2013 (Minister of Economic Affairs, 2014). Over the years, an increasing number of earthquakes has been reported hitting the area, despite the distance from any tectonic fault line, and caused growing public discontent (van der Voort and Vanclay, 2015). A proven relationship was found between the rate of gas extraction and the seismic event magnitude (Mevr Muntendam-Bos and de Waal, 2013), and multiple activities were initiated by the Dutch government to manage the complex situation. The shocking claim that *safety* of the population was not taken into account in the decision-making process on gas extraction in Groningen until 2013 (Dutch Safety Board, 2015) led to public scandal and the official apologies from the government.

Mouter, de Geest, and Doorn (2018) focus on the construction of value hierarchies with a combination of top-down approach, and subsequent validation of the heuristics built with a bottom-up approach. Identification of relevant values was done through content analysis of many sources such as academic literature, newspaper articles, transcripts of political debates and interviews with stakeholders. The selection of sources aligns with the RI and VSD recommendations of considering a broad range of stakeholders (residents, employees of the gas extraction company, politicians and representatives of different organizations) and perspectives. Coding the sources to identify the values, norms and design requirements concerning the debate, the top-down approach provided an overview of the frequency of occurrences, shown in figure 3.6. In the Figure we can see the results of the scanning of newspaper articles and debates for the number of time each value was mentioned, per source. *Safety*, *Trust* and *Impartiality* appears to be the most detected values, and the most present in public debate. On average, in newspaper articles values were more often presented compared to norms or design requirements (326 vs 127 and 188 instances), while in parliamentary debates norms have a higher frequency (219 vs 50 and 112) (Mouter et al., 2018).

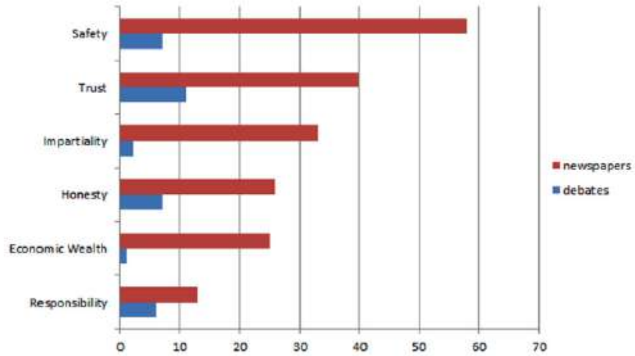


Figure 3.6: The results the content analysis of newspaper articles and parliamentary debates concerning the Groningen gas controversy, presented in Mouter et al. (2018).

The authors identified 716 norms and design requirements using content analysis, and clustered them in 64 categories. With a bottom-up approach, following the conceptual model of the value hierarchy, they traced back the categories to the values. The large majority of those (40 of 64) were concerning the value of *Safety*, and were used to trace the hierarchy of the value, presented in figure 3.7.

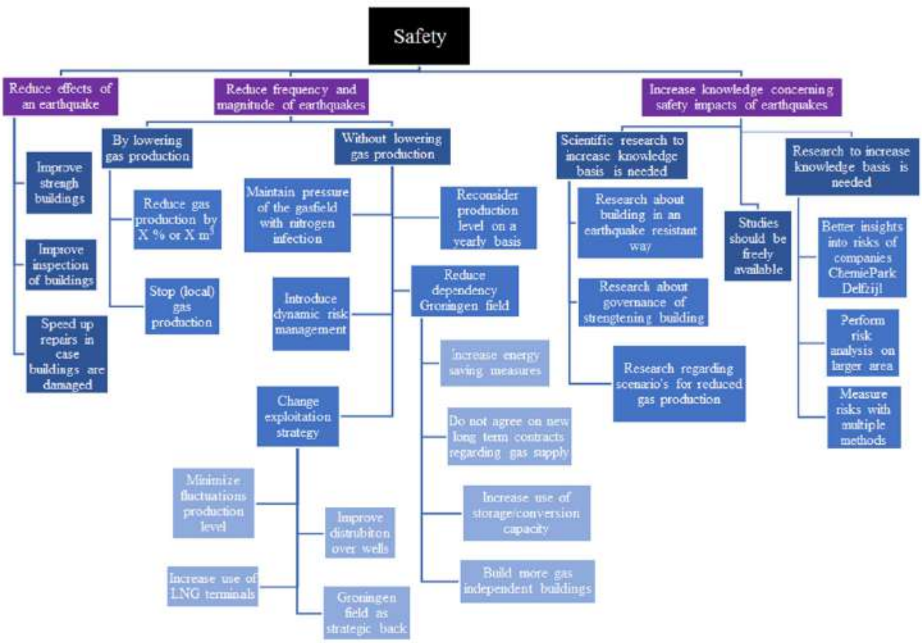


Figure 3.7: The value hierarchy of "*Safety*" concerning the Groningen gas controversy, presented in Mouter et al. (2018).

The study shows that is possible to apply VSD to identify relevant values, norms and design requirements in an existing socio-technical energy system, not only in the case of new radical technology (Mouter et al., 2018). While the authors did not apply the methodology to the broader plateau of energy cases, Dignum et al. (2016) provides a generalization of the methodology for the entirety of debates concerning the exploitation of shale gas in the Netherlands.

In the article "*Contested Technologies and Design for Values: The Case of Shale Gas*", Dignum, Correljé, Cuppen, Pesch, and Taebi investigates the incorporation of values for the design of institutions surrounding technologies and the design of stakeholder participation.
Observation and analysis of key documents from the National Government, NGOs, Industry and the Dutch Energy Council led to the formulation of 97 arguments present in the public debate, unequally distributed in opposition of the exploitation of gas resources (56) and in favor (41). The use of value hierarchies is adopted by this research article, which supported the identification of values derived from the arguments. 20 values were identified through the process, divided in *substantive* and *procedural* values.
Substantive values are described to refer directly to the technology of shale gas and the effects of the project(s) (Dignum et al., 2016), and are intrinsically linked to the Dutch national energy policy. Six substantive values in the debate were found, and connected both to the energy policy values and to the arguments identified of International Stability, Resource Durability, Environmental Friendliness, Aesthetics, Health and Safety, and Welfare (shown in figure 3.8a). These values are defined in relation to the case of analysis, for example, the argument "shale gas might have adverse environmental impacts on flora and fauna" traces back to the value of Environmental Friendliness.
Procedural values relate to the different aspects of the procedure concerning shale gas exploitation (Dignum et al., 2016). Shared themes were the unfair distribution of benefits and costs over different groups or generations. Three procedural values were found by the authors (presented in figure 3.8b) to be Accountability (legal and practical arrangements for safe practice and frameworks for responsibility allocation), Procedural Justice (timely and formal processes for participation of stakeholders), and Distributive Justice (allocation of resources and benefits for local populations and future generations). The procedural values relate to the desire for recognition and the ability to influence the process of decision-making (Dignum et al., 2016).

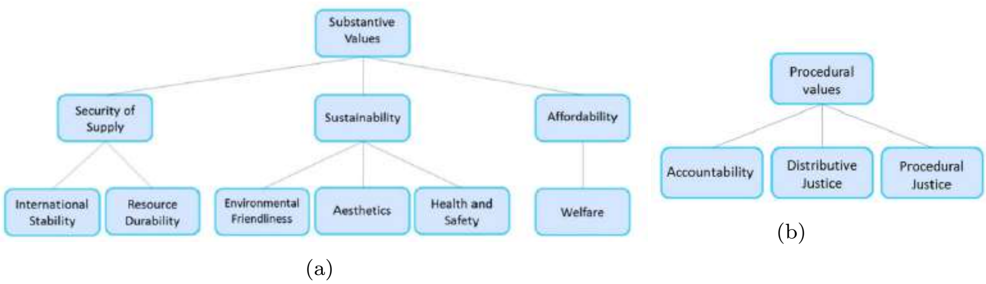


FIGURE 3.8: Substantive and Procedural values identified in the shale gas controversy by Dignum, Correljé, Cuppen, Pesch, and Taebi (2016).

The authors noted that all values identified were endorsed by both proponents and opponents, while the conflicts where in how these values where translated differently by different groups of stakeholders. For example, the substantive value of *Sustainability* was addressed by both pro-arguments mentioning how shale gas can offer cheap and relatively quick emission reductions, and counter-arguments that debated that natural gas is a fossil fuel and therefore cannot be considered sustainable.
The notion of *intra-value* conflict is then proposed to describe the situation analysed: values are not being debated one over the other, but rather in their operational interpretation. The article concludes that shared values in energy controversies (and possibly more

broadly) can hide conflict at the level of norms. This consideration, together with the methodology and national context, provides valuable insights when considering the issue of public debate addressing wind energy projects.

3.4.3 Wind Energy Sites and Public Acceptance

Wind energy projects have a long history of controversy and opposition from public groups, as highlighted in section 2.3. While VSD have been suggested in multiple recent applications to provide a valuable tool for institutional and normative design (Mouter et al., 2018; van den Hoven et al., 2015; Friedman et al., 2015), a surprisingly low number of publication apply the methods to the issue of public acceptance of wind energy. Out of 344 journal articles concerning VSD and relevant methodologies, only 15 of those cover technologies directly related to energy production and consumption, and one article investigates wind turbines as object of the methodology [5].
The direct application of VSD theory to the case of wind turbines was first explored by Oosterlaken in the article "*Applying value sensitive design (VSD) to wind turbines and wind parks: An exploration*". The work of Oosterlaken builds on the vast literature concerning acceptance of wind energy and the critique of a simplistic labelling of opposition as NIMBY: public sentiment is often more complex than selfish behaviour (Wolsink, 2012; Devine-Wright, 2005) and is closely tied to moral or public values (Oosterlaken, 2014a). Some of these values are identified in literature: *Trust*, *Distributive justice*, *Procedural justice* and *Place attachment* are reported to be key aspects in the case of Australian wind farms (Hall et al., 2013), *Aesthetics* (sometimes referred to as *Visual impact*) are described from Wolsink (2000) and Ladenburg and Dubgaard (2007) to impact significantly the extend of support for wind energy projects.

A fundamental hypothesis is that the application of VSD to wind parks and turbines could contribute to solutions that are more *acceptable* from a value perspective and therefore translate into a the general *social acceptance* of wind energy (Oosterlaken, 2014a). This fundamental assumption in the study is taken as an "hypotesis, the proof of which is beyond the scope of this paper" by the author, and aligns with the approach taken by others dealing with public debate and VSD (Mouter et al., 2018).
This claim seems to be supported by the heuristic of the technique, suggesting that implementing values shared by a large group of stakeholders would translate in positive impact, minimising value failure and negative societal implications (Stilgoe et al., 2013). However, for the scope of this research, the assumption is considered valid and the approach suggested is adopted.

While Oosterlaken does not apply the VSD framework to a specific set of project, two important considerations can be drawn from the literature:

1 Wind parks should be designed as sociotechnical systems, and "black boxes" should be opened. Engineering literature concerning design of wind energy systems often lacks inclusion of social elements, avoiding an integral approach towards values. On the contrary, research on social acceptance treats the central objects of controversy as immutable artefacts, missing concrete design alternatives. VSD position itself as a middle-level approach, able to build a bridge between engineering practices and social studies.

2 VSD is an outcome-oriented approach to values, that should not replace other process-oriented approaches. The research of participatory design provides meaningful tactics that should be complemented by a VSD approach, which is by definition focused on the acceptance of wind energy.

Compared to other applications, wind energy has relatively low adaptation of value-based perspectives that integrate more than one social aspects in the design process, with

[5] The flowchart of the Scopus analysis is shown in figure 1.6 and concerns a scanning the database using a combination of "VSD", "Value-sensitive design", "Design for Values" and "Values" combined with "wind", "wind energy", "wind turbine" in abstract, title or keywords. The results were retrieved in August 2020.

a few of notable exceptions. Künneke et al. (2015) proposes a framework for "purposeful design" in offshore wind energy systems based on a rigorous division of categories of acceptability, created by the combination of subjects and objects of acceptability (figure 1.4), and uses it to analyse embedded values in technical and institutional designs. The article has a rather practical approach to the topic compared to Oosterlaken, and follows the exercise of listing the moral values associated with offshore wind energy systems (*Security of supply*, *Sustainability*, *Distributional justice*, *Procedural justice* and others), defining the different realities of acceptability (based on the tripartition of *Community-Market-Public* proposed by Wüstenhagen et al. (2007)) and applies the designed framework to the cases.

While the analysis of value conflicts applies solely to the case of offshore wind energy, the article suggest strategies for the definition of a desirable solution space that can be shared by onshore projects.

The publications presented in this section contribute in different ways to the problem of implementing values in wind energy system design: Oosterlaken (2014a) explores the applicability of VSD to the subject and defines key recommendations for further research, whereas Künneke et al. systematically identifies embedded values and lists value conflicts related to social acceptability. In the next chapter, findings from both approaches (together with studies presented in previous sections) will function as starting point to develop an independent analysis of onshore wind energy systems in the Netherlands, following the framework of the STVM. Oosterlaken (2014a), work is implemented by providing a dual nature of the design exercise: process-oriented (encompassing the institutional design, participation schemes, etc.) and outcome-oriented (design specification, engineering and opening of technical "black boxes"). In Chapter 4, both these dimensions will be considered to provide a number of different approaches to the issue of acceptance of wind energy projects in the Netherlands.

3.5 Conclusions

Chapter three, "*the Ethics of Wind Energy*" does not answer a specific research question of this thesis, but provides the required theoretical background to further analyse the Dutch socio-technical system of wind energy with the appropriate value-based frameworks and tools.

In this chapter, the ethical implications of energy generation through wind turbines are introduced, and the domain of Responsible Innovation is presented as the first point of contact between ethics and technological development, for the purpose of this research. Responsible Innovation studies and publications shown the characteristics that an actor (organisation, business, individual) should follow concerning innovation for it to be considered "responsible": van den Hoven et al. (2015) introduces the duty to collect as much input and information as possible, and to process it in terms of moral and ethical values. Ortt et al. (2020) attempts to draw a definition of RI in large technological systems and define a shared set of characteristics within the literature: predictive and iterative, helpful, ethical, inclusive, impactful, responsive and open. The notion that *subjects* of technology should be included in the innovation process, and that a plurality of perspectives should be considered in decision-making and design processes, lay the foundation to the discipline of Value Sensitive Design.

Value Sensitive Design (VSD) is not the only discipline that actively implemented ethical values in engineering design processes, Design for Values (DfV) is the Dutch application of similar principles developed at the Delft University of Technology. Compared to the American approach which focuses mostly on ICT and software applications, the researchers at the Delft Design for Values institute favour a broad adaptation to the discipline in many different sectors that share one common characteristics: the focus on rapidly changing technology and innovation. In one of the key publications that supported the research for this thesis project, the "*Handbook of Ethics, Values, and Technological Design*" from van den Hoven et al., the theory, methodology and methods of DfV are first presented, discussed and applied in the context of different disciplines. The reading of the Handbook, together with the book "*Responsible Innovation in Large Technological Systems*" from Ortt et al. are broad-ranging publications concerning the application of the themes of Responsible Innovation and Design for Values for this research.

Within the literature reviewed in this chapter, a few publications stands out for the applicability of the issue of value-based analysis in wind energy systems and projects. The paper "*Applying Value Sensitive Design (VSD) to Wind Turbines and Wind Parks: An Exploration*" from Oosterlaken has strongly influenced the shaping of the research questions and provided an important introduction to the topic. Firstly, the author is one of the few researchers that applies the VSD approach to the issue of public acceptance of wind energy. Oosterlaken points out critical issues in literature concerning public acceptance, and explores the direction of using a VSD approach to solve the main challenges identified. From treating wind energy systems as "black boxes", with analysis that provide "little guidance on what concrete design alternatives" to foster acceptance of wind projects, to research that focuses "merely on a single value [...] rather than taking an integral approach towards values".
It is important to take into consideration that the author applies important conceptual assumptions to the problem, that can be adopted for a further exploration of the topic in this thesis. Oosterlaken does not draw a strong theoretical link between the concept of public acceptance and value-sensitive design.

[...] an interesting hypothesis for further research would be that a way to create long-term support for wind farms is not merely a more participatory process, but ensuring acceptability of the outcome in terms of key values.

The important interplay between ethical values and acceptability is suggested and cultivated in the paper from the author, that however leaves the proof for further research. This thesis project is not that proof: we take a similar stand in terms of suggesting that a value-based approach *could* provide possible higher levels of public acceptance, while taking into account that the process is highly case-specific. The outcomes of a value-based analysis could be perfectly applicable to a specific project and increase the overall success of of implementation, while the same recommendations could completely fail to deliver at only 50km of distance in a different project. This is because solutions need to be specific (3.3.4) and take into consideration the social fabric of a community, as per the principles of DfV and RI - specificity and impact can be an important tradeoff when considering the potential outcome of these analysis.

How can the application of DfV principles and methodologies be of any help if every wind project is inherently different, because of the very same requirements of DfV? The outcomes of a value-sensitive analysis could therefore be presented as a *set* of recommendations, to be as specific as possible but include a degree of flexibility to allow adaptation in implementation. To maximise impact over multiple projects, a deck of best practices and solutions can be identified through value-based analysis and then contextualised in the case-specific situation from project developers and local policymakers.

The positive experience of Mouter et al. in applying VSD methods to the energy controversy may be anecdotal, but combined with the initial exploration of the application for onshore wind energy systems by Oosterlaken, it provides a starting point for the adaptation to the methods to this research. The framework of the Socio-Technical Value Map, described earlier in this chapter, contribute to the research design by providing a phased approach to the gathering and elaboration of information.

A Value-based Analysis of Wind Energy Systems in the Netherlands 4

Since the first prototype installed in Petten in the autumn of 1978, wind turbines have come a long way in the Netherlands. After 40 years of research, discussion, debates, projects and strategies, the country is now looking at the future with a type of knowledge that could help contribute to solving the imminent global climate crisis.

The country does not hold its knowledge solely in technical expertise: the framework of Responsible Innovation, the theory of Design for Values and many contributions towards the Ethics of Technology were shaped by the contribution of Dutch scholars. Researchers from all over the country combined advanced technology with sharp and pragmatic reasoning - how to create innovation that is not only revolutionary, but that will bring society further.

The contributions from the numerous experts cited in the previous sections come together in this chapter in the context of a value-based analysis of wind energy systems in the Netherlands. First, the history of development of the technology described in section 2.1 provides background and context, together with an understanding of the stakeholders involved in the innovation system. Second, the theories of Social Shaping of Technologies (SST) (section 2.2.2) and Technological Transitions (TT) (section 5.4) constitute the theoretical foundation for this research. Wind energy is, and should be analysed, as a *sociotechnical system*, a dynamic complex network of interaction between stakeholders, technology and social structures. Third, the notion of Responsible Innovation (section 3.1), and the discipline of value sensitive design, introduce *values* as central building block as manifestation of human behaviour, presence and expectations in the interaction with technology. Lastly, the review of the literature concerning social acceptance (and *eacceptability*) presented in section 2.3 shapes the central question of this research, draws conclusions and explicates what are the key issue in acceptance of wind energy, what has been done until today and what should be pursued.

It is with this foundation that in this chapter a value-based analysis of wind energy systems in the Netherlands is presented, built on the framework of the Socio-Technical Value Map proposed by Pesch (2019) outlined earlier in section 3.3.

4.1 Technology Map

The first building block of the analysis presented by the STVM is a review of the technology of interest, in this case, wind turbines. It is important to define the boundary of analysis to concern the main object of research, the social acceptance of said technical systems.

In chapter 2, an outline of the technical system was given, describing the technology, components, and high-level configuration.
In this section, with a focus on the acceptability of technology, wind energy systems will be analysed in terms of *technical* and *process alternatives*.

4.1.1 Wind Turbines

The vast majority of wind energy systems installed onshore in the Netherlands is an array of vertical wind turbines, positioned either standalone or in groups, namely *windmolenparken*. At the end of 2019, 2029 wind turbines are installed, with a nominal capacity of 34534 MW, generating 6.6 TWh of energy. The largest share of capacity is installed in the province of the Flevoland, producing 27.4% of the national wind energy quota and hosting 31.7% of the overall number of turbines. The provinces of Groningen and North Holland follows, with 17.4% and 15.9% of the capacity installed. This is the results of a combination of wind energy potential and effectiveness of policies enabled in the areas (RVO, 2019). The target of 6000 MW of onshore wind energy capacity installed by 2020 set from the government has been down scaled in 2018 and postponed. In 2023, RVO () forecasts that the target could be met with an increase compared to previous estimates: 6796 MW to be installed after an acceleration agreement between the government and RVO.
As part of the reasons for which the achievement of the target is delayed is the notion that *"the Netherlands is densely populated and has high density of functions and interests. For new project with spacial impact, it is necessary to consult with parties with standing values and interests in the area or that must be aligned with competing ones"*. It is one of the mentions in official documents of conflicting interest and values, consistent with the scope of research of this thesis.
The traditional technical design of the two-bladed wind turbine, historically endorsed by Dutch manufacturers and researchers, has been replaced by the three-bladed design developed by the Danish industry. Various reasons are cited as the parameter of choice of a three-bladed design over a two-bladed one, when the reduced drag forces of a two-bladed model would yield higher energy harvest:

- structural issues - gyroscopic precession, the angular momentum of two bladed models causes wobbling (**?**);
- aesthetics - three bladed design appear more visually pleasing in rotation and stationary positions (Schubel and Crossley, 2012);
- optimization - according to Benz's method for optimal chord lenght 4.1, at constant lift coefficient, blades plan are a function of tip-speed ratio and number of blades. It is beneficial to decrease the materiality of a blade at low tip-speed ratios, to reduce cost and structural load (Figure 4.1) (**?**);

It is interesting to analyse the embedded values in the above decision criteria. The aspect of translating design requirements in shared values is covered in section 3.3.3. Concerning onshore installations, two-bladed turbines are installed in small numbers in the country (CLO, 2019). However, Dutch manufacturers as 2-B Energy and Seawind shifted the applications of their models to offshore installations.

$$C_{opt} = \frac{2\pi r}{n}\frac{8}{9C_L}\frac{U_{wd}}{\lambda V_r} \quad where \quad V_r = \sqrt{V_w^2 + U^2} \tag{4.1}$$

r = radius (m)
n = Blade quantity
C_L = Lift coefficient
λ = Local tip speed ratio
V_r = Local resultant air velocity (m/s)
U = wind speed (m/s)
U_{wd} = Design windspeed (m/s)
C_{opt} = Optimum chord length

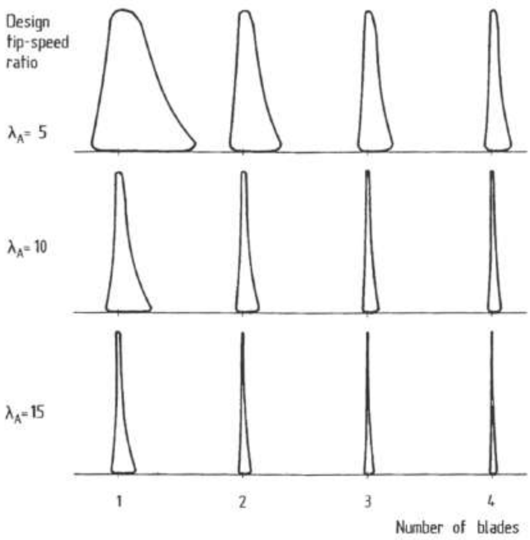


FIGURE 4.1: The number of blades in a wind turbine influences heavily the blade plan shape, at optimal lift coefficient. From **?**

Wind turbines can be often found in multiple arrays, to take advantage of the economy of scale associated with a wind energy project. The low density of the energy resource requires a large surface area, therefore the scalability of the size of the project increases profitability (**?**). While in 2019 a wind energy project can cost between 1 million and 1.5 million per MW installed (Blanco, 2009) in capital cost only, the order of magnitude of a single turbine installation is in the same order of magnitude of larger wind parks (in Dutch, *windparken*) (**?**). The cost of the grid connection, contractors, legal costs and electrical infrastructure can be shared between multiple units and creates the conditions for larger wind installations.
Nevertheless, many of onshore wind energy projects installed in the Netherlands consist of single installations and small wind parks of less than 10 turbines installed. This is due to the high spatial density of some provinces, such as South Holland. A conflict between the optimal profitability of a project and the availability of the areas allocated to wind energy arise from this high-level perspective.

4.1.2 Technical Alternatives

Wind turbines are not the only technology designed to harvest energy from the atmosphere, but one of the most established and successful in commercial terms. It is in the scope of this research to to explore the availability of other options from a technical and value perspective, to compare their implications and development.

As highlighted in previous chapters (2.2), wind energy artefacts are subject to the process of innovation as every other technology. It is incorrect to forecast wind energy systems to be rigid and stable in their current form and design, it is needed to *predict* (or make an attempt, based on Responsible Innovation principles) future developments, and take into account for values implied as early as possible. Technology evolves and undergoes many different stages of innovation and interaction, as the complexity of Geels's *sociotechnical landscape* changes according to different pressure.
The Netherlands in the recent years set many ambitious targets in offshore capacity, while at the same time lagging behind the more feasible accomplishment of onshore installation targets. Important investments of capital and expertise are done in the developing of offshore technology and partnership, such as the North Sea Hub. The trend suggests that

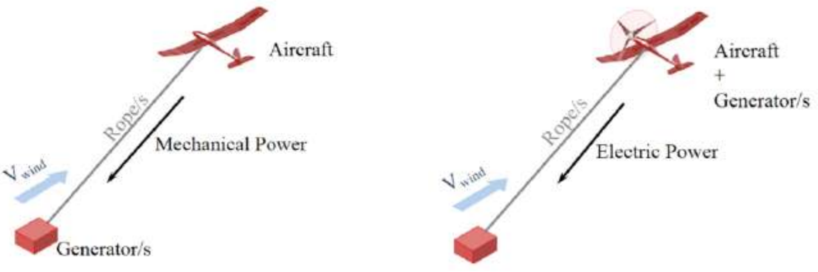
onshore installations, which are at the moment the *easiest* and most cost effective way to add significant renewable energy capacity to the national portfolio, may be limited or substantially *different*.
Considering the phenomenon of synergy is important as well. With the steep decrease in cost of PV installations and development in batteries technology, conditions for a decentralized energy generation paradigm in the Dutch energy sectors are explored by many key actors (Ministry of Economic Affairs, 2016; Stille, 2020; Topsector Energie, 2020; **?**). These conditions were not present in the 1970s, when the public debate regarding the future of wind energy in the Netherlands was taking place (2.1).

4.1.2.1 Airborne Wind Energy

The idea to generate energy with the help of a kite was conceived in 1980, in the seminal work of Loyd (1980). At the time, the technology was not far enough to actually turn the idea into a practical design, but the concept shown interesting and substantial advantages: Airborne Wind Energy (AWE) systems aim at capturing wind energy at significantly increased altitudes, in the order of 200m-10km, where the persistence of wind currents is higher than lower altitudes reachable by traditional wind energy systems. Moreover, AWES would potentially, if installed onshore, reduce issue on siting and cost of wind energy systems: the minor impact on visual landscape and a 95% reduced need of materials compared to a traditional wind turbine (Lempsink, 2020) would address many of the problems highlited in section 2.3. As described by Cherubini et al. (2015) in a throughout review of AWES, the systems configurations can be distinguished in *ground-generation* models, where the conversion to mechanical energy happens at ground level, and *fly-generation*, when electricity is converted on the aircraft (Figure 4.2). Aircraft components can change significantly across prototypes, from resembling a traditional kite or paraglider, to plane-like systems like the Glider developed by Ampyx Power (bottom left in Figure 4.3a).
In the decade 2005-2015, the sector experienced a growth in research and business interest. Research teams globally have started developing new design to improve control systems, aerodynamics and conversion systems. Several companies entered the market and registered hundred of patents in a relatively short amount of time. A sociotechnical network has starting to developing around the technology, with the establishment of global and international association: the Airborne Wind Energy Industry Association (AWEIA) [1] promotes an annual conference bringing together academia, industry and international agencies. Specific to the Netherlands, various companies and research groups are active: since 2004, when former astronaut professor Wubbo Ockels started a dedicated research group in the Aerospace Faculty of TU Delft, which has been developing different design. e-Kite was founded in the netherlands in 2013, active in developing a 50kW, ground generation prototype (e-Kite, 2020). Kitepower is a Delft-based startup aiming to bring a commercially viable product to the market, with a 20kW system developed in the research group of TU Delft (a 100kW system is currently under development). Kiteplanes and Tensairity Kites are research project jointly developed by TU Delft and ETH Zurich, aimed at increasing aerodynamic efficiency of kites.

The concept of airborne wind energy is not only interesting from a technical perspective, potentially achieving higher energy yields, stability in electric generation and other benefits, but from a value perspective it could potentially tackle some of the issues associated with public acceptance of wind energy. The concept of "plug and play", commercially described as mobile wind energy by KitePower (2020), aims at shifting the perspective from a static and capital-intensive wind turbine to a dynamic and affordable application that could provide electricity for small scale applications in off grid situations. To tackle the issue of scalability, some actors are now investigating bigger projects. KiteGen, an Italian research company who helds more than 40 patents for AWE concepts, developed Carousel, a combination of ground-generators installed on a rotating platform offshore.

[1] The group monitors the development of AWE around the world and publish updates at this link: `http://www.energykitesystems.net/AirborneWindEnergy/index.html`



(a) (b)

FIGURE 4.2: Airborne Wind Energy Systems: Ground generation (a) and Fly generation (b). From Cherubini et al. (2015)

The project is estimated to be able to produce up to 1 GW of electricity and reach heights of 1 km, theoretically [2]

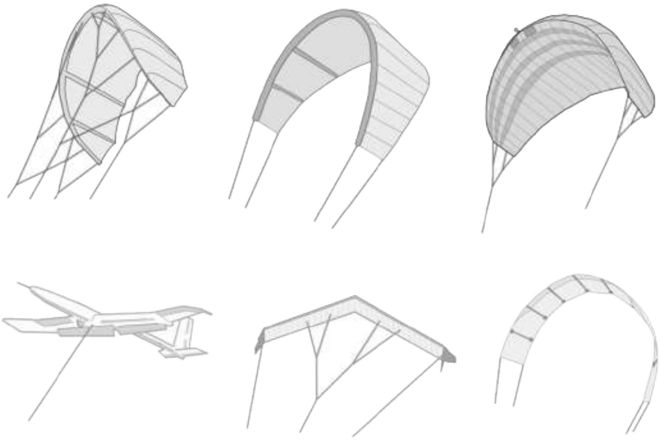
4.1.2.2 Urban Wind Energy

While residents tends to be very negative towards onshore large-scale wind energy in urban areas, not much is known about the social acceptance of small-scale wind turbines in urban areas. The rising number of applications of rooftop PV across the globe and in the Netherlands rose interest in the possibility to generate decentralized renewable energy with small wind turbines. The adapting electricity-grid could potentially provide the criteria for a profitable business case, but there are many other implications: relatively low energy yield, uncertainty about permits and aesthetic of the implementation in the built environment.

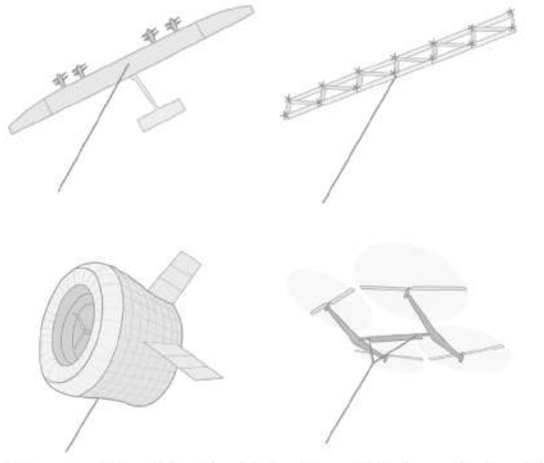
In order to answer the question *"What is the potential for urban wind energy systems in the Netherlands?"*, in 2018 the TKI Urban Energy Group of Topsector Energy (see 4.2.3) published an overview of the current situation of urban wind energy generation in the country (**?**).The potential of urban wind energy generation has often been advocated because it represents a yet unexplored potential, the report investigated which are the solutions commercially available for the issue, system efficiencies and costs (in Watts and LCOE (EUR/kWh)), technological development needed and unique Dutch capabilities.

Various options in terms of design were investigated, and the selected most-promising implementation choice was to install Darrieus Vertical Wind Axis Turbine (VAWT) systems (Figure **??**) on the rooftop of sites higher than 35m from the ground (the H-Darrieus design was investigated because its higher power coefficient (**?**)). The assessment considered the possibility to install 20,000 devices in 85 Dutch cities, for a potential annual energy production of 170 GWh (**?**). Clearly the calculation implies important assumptions (neglected turbulence, null generator losses, constant turbine performance over extended lifetime) but provides overall an idea of the order of magnitude of the project. In financial terms, the operation would cost between 150 and 330 million of euros, of which the cost of turbines would account for 67,3% of the total. The levelized cost of energy (LCOE) would result to be between 0.045 EUR/kWh and 0.091 EUR/kWh. This values are comparable with other technologies, as shown in table 4.1.
The expectation of the authors is that the full potential of urban wind energy could be exploited in the Netherlands within 15 years, if enough funding for research was to be provided to research consortia to develop a reliable and affordable Darrieus VAWT and to assess in detail the potential of urban energy resources.

[2] The company recently signed an agreement for production and development with SAIPEM S.p.A., Italian oil and gas company.

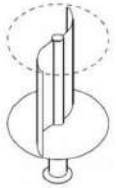


(a)

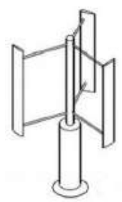


(b)

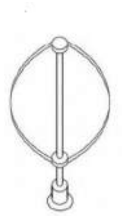
Figure 4.3: Different aircraft prototypes for ground-generation AWES: Ground generation (a) and Fly generation (b) From Cherubini et al. (2015).



(a) Savonius



(b) H-Darrieus



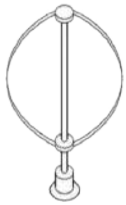
(c) Darrieus

(d) Helix

Figure 4.4: Different types of VAWTs could be suitable for urban energy applications. From (Castellani et al., 2019).

In table 4.1 below, a high-level conceptual comparison of the three technical design is presented, in terms of technology, types of installation, stage of development, estimated potential for the geographical boundary (Netherlands), LCOE and average noise level. Sources are reported in the table, and are as relevant as possible for the Dutch cases of application and research on the technology.
The implications of these designs in a value perspective is explored in section 3.3.3.

Table 4.1: Overview of technical alternatives

			
Technology	Two or three bladed HAWT	Darrieus VAWT	AWE Groud-Generator
Installation	Onshore	Onshore urban	Off-grid
Stage of Development	Well established, developed industry	Established but not widespread applications	R&D, start-ups
Potential(Netherlands)	70 TWh/year (Ministry of Economic Affairs, 2016)	170 GWh/year (Rezaeiha et al., 2018)	N/A
LCOE	24 - 54 EUR/MWh (IRENA International Renewable Energy Agency, 2018)	45 - 91 EUR/MWh (Rezaeiha et al., 2018) *(potential)*	25- 60 EUR/MWh (Cherubini et al., 2015) *(potential)*
Noise level	45 dB(A) *(recommended)* (Ogg, 2018) up to 70 dB(A) (van Kamp and van den Berg, 2018)	20-40 dB(A) (Rezaeiha et al., 2018)	Negligible (Loyd, 1980)

4.1.3 Procedural Alternatives

When mapping the wind energy sector, design alternatives are not the only different system configurations identified. In the broader perspective of a sociotechnical systems, alternatives were also found in the *process* that leads to a wind energy project to be set up. For the scope of the analysis, an overview of the current and best practices in terms of engagament, timeline, actors involved needs to be considered.

Top-down execution: the first and most common approach to streamlining a wind energy project planning appears to be the centralized execution of national and regional plans for renewable energy implementation. This process has been applied consistently to set up the majority of the onshore wind energy capacity installed in the country in the decade 2005-2010 (**?**), while currently has been put under scrutiny. In the top-down approach, the initiators of a wind energy projects are usually wind energy developers that identify business opportunities consulting the zoning plan (*bestemmingplan*) published

by provinces. The plan is a open document published on the webite of the province, where on a GIS map areas that are allocated to wind energy project development are highlighted. The project developers then approach (either by themselves or with the support of the authorities) owners of the land on which would be possible to set up a wind farm. These land owners are often farmers (hence the Dutch naming of *windboers*), and negotiate their annual land use fee based on their personal interest. Once an agreement is reached between the project developer and the land owner, the firms progresses with the outline of the project, creating a plan and evaluating the economical and environmental feasibility of the project. The plan is then presented to the local authority that is in charge of issuing a permit (*Omgevingsvergunning*) for starting the construction of the wind farm, if the national and local guidelines are respected. In most of the cases, if the projected site of the project is not included in the zoning plan, a consultation with the province can be opened to redefine the plan itself to accommodate the potential farm (Vladmiks, 2020). In is not until the permit is given that public consultation are usually initiated (Mertens, 2019; Dion, 2019). Local actors are informed about the upcoming plan of development of a new wind farm in their area, and from their reaction the project can either continue as planned or go through a series of legal actions, as in the case of the windpark De Drentse Monden en Oostermoe. The process is then concluded when the construction and grid-connection are completed, a Power Purchase Agreement (PPA) is established with the TSO (or other bodies who wish to purchase the generated power) and electricity can be generated from the operations of the park.
The application of this approach implies a minimal interaction with local actors, either after the issuing of the permit or just before. This can be done because of minimising delays and time to execution of a project, but has been reported to cause negative sentiment in resident's groups because of the lack of involvement (Residents, 2020). The notion of *transparency* and *involvement*, crucial in this process, are analysed according to the frameworks' Value Map in section 3.3.3.

Bottom-up initiatives: In opposition to the first approach, in the recent years a different concept of planning and execution of wind energy projects was partly applied in the Dutch energy landscape. Local groups of individual residents, or existing networks of local actors, took the initiative to develop wind energy projects in the areas they had been living or exercising their professions. Through a rather democratic progress, made of share participation in a *local energy initiative* and public assemblies, communities gathered to define how to invest in the well being and development of their areas. In close collaboration with local authorities, similarly to the previous approach, a provisional arrangement for a permit is made. When choice for siting and financial arrangement are completed, a wind energy project developer is reached and works in partnership with the community to execute the project. Arranging a PPA and financing are carried out in consultation with professionals, but the community (through a board of representatives) has the final say on every aspects of the project, empowering local actors and increasing significantly the involvement in decision-making.
This approach has been proven to be successful in particular situations in the Dutch sector (Proka et al., 2018), and currently more than 400 initiatives are active in the country. However, the lack of central coordination in the planning of renewable energy installation seems to hinders the achievement of a shared national target. A third approach has been proposed implementing key lessons learned by the recent development of local initiatives by the network of professionals of the Dutch wind energy sector.

Responsible project development: promoted through the Code of Conduct developed by the Dutch Wind Energy Association (*Nederlandse WindEnergie Associatie*, NWEA), this approach to project development and management of onshore wind energy projects creates a common ground between developing firms and public groups based on the shared interests.
In brief, the code of conduct (Nederlandse WindEnergie Associatie, 2016) regulates how the wind energy sector involves the community in a wind energy project:

1 The initiator is - in addition to the steps taken by the authorities during the spatial planning process - responsible for involving the community in the entire

project process (development, construction and operation). This happens as early as possible; the design of a project starts with participation of the community during the planning process.

2 For this purpose, initiators, in consultation with the competent authorities and stakeholders, draw up a participation plan prior to the spatial planning process of the project; within the project, the initiator appoints a contact person for the community.

3 The scope and contents of the participation plan are customised and depend on the project and outcome of the consultations with local residents and other stakeholders.

4 The participation plan describes the (non-statutory) participation: *Process participation* (for instance: consultative talks with stakeholders, setting up a focus group, organising discussions, public hearings or design workshops, setting up a proper and transparent system for the processing of questions and complaints) and *Project participation* (for instance: financial participation with shares/bonds, local fund, arrangements for local residents such as green energy at a discount, a discount on the energy bill or other (financial) compensation, creating local jobs).

5 Preferably, stakeholders are involved in the process of looking for participation options with the greatest possible social return.

Members of the NWEA are required to abide to the guidelines set by the code, and therefore implement more "responsible" practices in the top-down approach described above.

Public tenders: a fourth approach that has been suggested to be under development by the province of Zuid Holland, to apply the concept of public tender to the onshore energy sector (**?**). Already widely used for offshore wind energy projects, the process has as sole initiator the government authorities, who program an open auction for private and public players, that can submit a tender for winning the project. The concept is currently not applied, hence the requirements to "win" a project are not known, but may include the degree of public participation in a project, the minimum environment impact and energy forecast to be fed into the national grid. A process of tendering could be integrated with the *responsible project development* approach depending on the requirements. If paired with an objective and transparent decision making in assigning the bid, would possibly result in a better outcome for public groups usually whose interests are not usually taken into account in traditional approaches.

A summary of the process alternatives is reported in table 4.2, focusing on initiators of the processes, benefits and critical points.

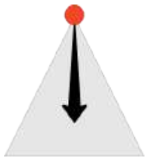
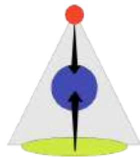
4.2 Stakeholder Map

As second building block of the SocioTecnical Value Map described in Figure 3.3, the Stakeholder Analysis provides the second piece of information needed for a comprehensive analysis of the sociotechnical sytems. Technology development is highly reliant on the inputs, motives and interest of the actors that interacts with the technology (section 2.2.2) and the Dutch wind energy sector has historically been involved heavily in the shaping of what the current situation is today (section 2.1).

The multitude of actors identified in the sector have been grouped in five different clusters based on their affiliations and interest towards wind energy: private sector, public sector (and government), research groups, NGOs and citizen. Forms of associations have been mapped, as well as interactions between groups of actors. Some entities as the TSO (Tranmission System Operator) and Energy Cooperatives are considered trans-sector, as per their public-private nature, and are described accordingly.

In Figure 4.5, the results of the mapping exercise are shown. The various quadrants are described in the sections below.

Table 4.2: Overview of process alternatives

	 Top-down	 Bottom-up	 Responsible project development	 Public Tenders
Initiators	Project developers	Local actors	Project developers and local communities	Provinces
Pros	Efficiency Established process	Participatory Democratic	Responsibility Inclusiveness	Fairness Transparency Coordination
Cons	Lack of inclusion Opposition	Lack of coordination	Complexity Lengthy Resource intensity	Requires solid normative process Possible corruption

It is important to mention that the map presented is not a comprehensive photograph of the entirety of the onshore wind energy sector of the Netherlands. The map exist and is developed in function to analyse the *public acceptance* of wind energy in the country, therefore focuses on relevant actors and stakeholders involved in the processes that characterise the issue. The map extends to subjects not directly involved because of the broader perspective investigated in this design exercise - research institutes do not directly interface with public groups on negotiation of better financial conditions, but are involved in the creation of better technological designs that may possibly have impact on the perception of energy from residents. However, many actors have been discretionary not included in the analysis. It is up for discussion the impact of the choice on the results of the analysis.

4.2.1 Private Sector

The networks of actors involved in the wind energy systems that falls under this group is a set of professionals, private firms, businesses and association of professionals that engage in the sector with the main motivation of profit generation. As integral part of their business model, and of the economics of wind power generation, profitability for a renewable energy project is a key requirement: these actors engage with eachother and other groups by bringing expertise, resources (human, financial, patents, expertise) into the process. Different firms bring different kinds of expertise: manufacturers, consults, contractors, financial institutions, energy companies and engineering firms are some of the involved groups involved. Most of these groups are represented by NWEA (see 4.1.3), the Netherlands Wind Energy Association, an association of professionals involved in the Dutch wind energy sector. Regardless of the size, both SMEs and more established firms can become member and be represented.

Manufacturing firms are responsible for designing and building the technical converters that harvest wind energy. As described in chapter 2, many efforst in the developmente of wind energy earlier in the days were put in research and development of a successful design alternative. Nowadays, a majority of turbines are imported from abroad, manufactured by Siemens Gamesa (Spain and Germany), Vestas (Denmark), GE Renewable Energy (United States), Enercon (Germany) etc. There are a number of Dutch manufacturers active, with a relatively small market share, fulfilling specific niches in which they are active. Lageryway, mentioned earlier in section 2.1, remains active with 40 years of expertise in developing turbines [3]. 2-B Energy, Seawind, WES and Fortis are other Dutch manufacturers, mainly focused on offshore turbines (Seawind and 2-B Energy) or small-scale applications (Fortis and WES).

Engineering firms are integral part of the process of developing new onshore wind energy projects. They perform calculation on foundations, wind resource assessment, soil-structure interaction and geological studies. Other firms are specialised in noise emission assement, or shadow casting assessment, important parts to include in the project plan to present to authorities to obtain a construction permit. Environmental compatibility studies are also performed by specific and certified players in the sectors.

Energy companies are a key group in the development of new wind energy capacity. In the Netherlands a few companies provide energy and electricity access to a large userbase, and acquire electricity from wind energy farms through PPAs or the Dutch electricity market, interfacing themselves with the Dutch TSO, TenneT. Essent/Innogy, Eneco, Vattenfall/Nuon and Engie are some of the main players.
Financial players provide funding and access to capitals for projects. The choice on how to finance a wind energy project is extremely important and can impact directly the profitability for secondary stakeholders. Dutch actors like banks (ING, RaboBank, ABN Amro) and investing firms have the role of procure profitable and secure projects for their investment portfolios. In the early 1990s, RaboBank procured many investments in wind energy by sending agents directly in target sites to engage with local farmers, initiating directly the project development and providing early access to the means to realize it.

The majority of these stakeholders are part of a network as members of NWEA. The association advocates for the interest of the sector in discussion with the Dutch government, supporting with the join expertise the strategic decision-making of the authorities and facilitating communication between public and private sector. NWEA hosts several committees that work on public policy in close collaboration with their members, on subjects as exports, communication, offshore and onshore policy. NWEA facilitated the debate with environmental association and industry, creating the Dutch Code of Conduct for public participation in onshore wind energy projects, described earlier.

4.2.2 Government and Public Sector

The two main branches of the Dutch government involved with wind energy are the Ministry of Economic Affairs and Climate Policy (Ministerie van Economische Zaken en Klimaat; EZK) and the Ministry of Infrastructure and Environment (Ministerie van Infrastructuur en Waterstaat; IW). The first is clearly involved in any decision making concerning energy policy, target settings and regulations of the energy market, while the latter has jurisdiction over spatial planning, land use and environmental impacts. The EZK regulates energy markets, business and consumers through the ACM, the Dutch Authority for Consumers and Markets. The agency regulates the energy market with respect to safeguard of *affordability, quality, continuity and accessibility*, facilitating fair competition and therefore has high authority over the entire top-left quadrant of the stakeholder matrix, through its influence over energy and utility providers.
When it comes to land use, the IW Ministry supports local authorities in creating guidelines for the local zoning plans (*bestemmingsplan*), which allows specific areas to be usable as sites for wind turbines. The criteria on how these zones are arranged are *wind potential, distance from residential areas, grid accessibility, preliminary environmental assessment, previous land use* and others Vladmiks (2020). It is not clear the weighting of these parameter, as the allocation is based on a case-specific situation. Zoning plans can anytime be consulted and amended, if reasonable motives are presented to the local authorities.

Permits to build a wind farm (Omgevingsvergunning) are issued by the governing body, depending on the size of the project proposed. For projects below 5 MW, the local munic-

[3] In 2018, Lagerwey signed a strategic partnership with Enercon, strengthening the position of the company and opening opportunities for the Dutch manufacturer (Lagerwey, 2020)

ipality can provide the permit, while for bigger projects up to 100 MW the responsibility falls on the province. It is common occurrence that municipalities offset the responsibility of issuing the permit, even for small project, to the province altogether, to avoid claims of responsibility from local protesters. For large projects with nominal capacity higher than 100 MW, the government needs to be consulted through the responsible ministry of infrastructure. The permit requires a specific number of documents to be presented on the evaluations of feasibility of the project, financing, electricity production and environmental impacts (noise, wildlife, shadow flicker, etc). The responsible agency for this is the NCEA, the Dutch Commission for Environmental Assessment. The Environmental Impact Assessment (EIA) is a mandatory evaluation that was introduced in the Netherlands in 1985, to ensure that the environmental and social consequences of proposed activities are incorporated into decision making.

4.2.3 Research

The Netherlands holds an international reputation in the topic of wind energy research and education, competing and cooperating at a high level in topics such as energy transition, offshore wind energy and turbine design, among many others. The Dutch RD sector is composed of multiple independent actors that focus on different aspects of innovation, jointly developing a network of knowledge nationally and abroad. In a publication by van Kuik and de Lange, a good overview of the research groups, topics and facilities is given for the nine Dutch institutes working on wind energy: Deltares, DUWIND, ECN, IMARES, MARIN, NLR, DNW, TNO and WMC. While some are specifically involved in the development of knowledge relative to offshore wind energy applications, others such as ECN and TNO are more generally involved in research on the Dutch energy transition, which involves an important amount of research in wind energy technology since the early 1980s. As shown in chapter 2.1, the Energy Centre of the Netherlands has been involved since the start with the first prototype of wind turbine installed in the site in Petten in 1975, and now consists in an hybrid combination of research (on aerodynamics, rotor design and om) and industry support (experiments and measurements).
ECN cooperates closely with DUWIND, the wind energy research institute od the Technical University Delft, on medium to long-term objectives such as maximising the reliability of wind farms, minimise structural loads and optimization of the supply chain. DUWIND is a multidisciplinary institutes that gathers its 50 researchers from five different faculties of the university, broadly encompassing aerodynamics research, structural analysis, power generation, system design and policy mechanisms.
On the more specific topic of social acceptance of wind turbines technology in the country, the research intersects with the fields of sociology and human psychology. Researchers from the TBM Faculty (Faculteit Techniek, Bestuur en Management) of TU Delft worked on the topic in the wider frame of ethics of technology (Oosterlaken, 2014a) or economics of infrastructure (Künneke et al., 2015), working closely with colleagues from the Eindhoven University and Twente University (Pesch et al., 2020). Publications on the different dimensions of acceptance have also been addressed by researchers at the Utrecht University (Agterbosch et al., 2004) in the context of "barriers to implementation", an early approach to the long-existing problem common in the country.

While the vast majority of institutions and research groups are funded and oriented to solve the technical issues of wind energy, generally there is no specific network developed to address wind energy acceptance research. Nonetheless, lack of acceptance was reported by international reports from 2005 to the current days (IEA, 2005, 2017a) as one of the main reasons for the country to lag behind the national target for many years in a row. It is unclear if the efforts of individual researchers (and small groups).

4.2.4 Associations

Other associations and groups are present and active in the network associated with the development of wind energy projects in the Netherlands. Within this stakeholder group multiple realities have been listed, identified with the colour green in figure 4.5: NGOs and citizens' voluntarily group are located in the bottom-left quadrant of the map, however other non-NGOs associations have been marked with the colour while being associated with other quadrants.

With the condition of being involved directly within the issue of public acceptance of wind energy projects in the Netherlands, three main groups of associations have been identified: environmental groups signatories of the NWEA's Code of Conduct (Harmsten, 2020), resident associations and authorities associations. A minor group of environmental professionals, the VVM, is active within the private sector as responsible for the implementation and oversee of the environmental impact assessment methodology renewed by the government in 2010.

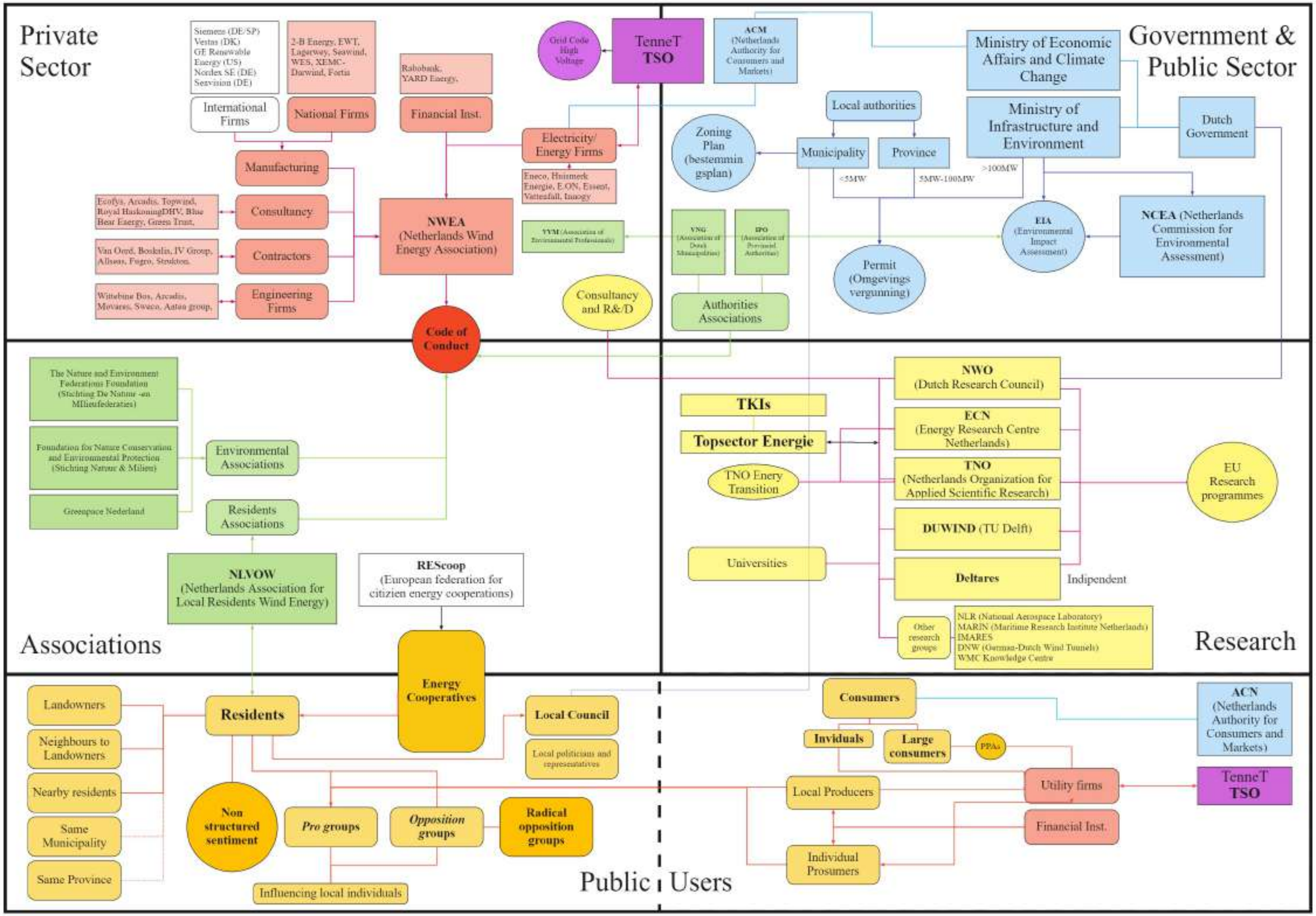
The different environmental associations and foundation that co-signed the Code of Conduct proposed by NWEA in 2014 have different perspectives and roles in the advocacy of wind energy. Natuur and Milieu has often and publicly advocated in favour of wind energy, while recognising the limitation that onshore development in the dutch densely populated country, and supports high government subsidies to support renewable energy sources. Other groups such as Greenpeace have often brought to attention wider environmental impacts of projects, such as the disruption of the natural habitats for species receptive to low-frequency sounds and increased rates of wildlife mortality in bats and birds, but generally align support towards wind energy as an important renewable source to ensure a sustainable future.
The Dutch local residents association has an important role in the process as it channels and collects some of the negative sentiment identified in articles, interviews and conversations collected in the research for this project. One of the available NLVOW (Nederlandse Vereniging Omwonenden Windturbines) press releases appeals to the Dutch minister for Economic Affairs to allow citizen to participate in the planning and decision-making of new parks:

For more than two years, the NLVOW has been trying to convince the government, and minister Kamp (the Dutch minister of Economic Affairs) in particular, that people living near (proposed) wind farms should be properly informed, should be allowed to participate in planning and decision-making and, if all else fails, should have a fair chance before a court of law. (NLVOW, 2015)
The statements of representatives from NLVOW has been considered as important perspective for the value-based analysis of this chapter. It is important to note that the NLVOW considered the Code of Conduct proposed by NWEA as "unacceptable" because of the lack of representations of their demands in the code and consultations[4].

4.2.5 Public and Users

[4] A revised code of conduct has been published on their website, but inaccessible to non NLVOW members.

Figure 4.5: Stakeholder Map of the Dutch onshore wind energy sector.



4.3 Value Map

The value map, as introduced earlier in 3.3.3, is a key component in the structured approach of the socio-technical value map, as it attempts to summarise and tie together the information gathered with the two previous pieces. Bringing a coherent interpretation of the values embedded in a technology and those brought forward by stakeholders, the value map aims to give concrete translations of these empirical findings (Pesch, 2019).
The identification of the main values that are analysed in this chapter comes through two main, and different, streams. The first, values associated with the technology, has its origin in the *intrinsic values* for which wind turbines have been designed and implemented in a social landscape. **Sustainability** is deeply embedded in the nature of these artefacts, and sometimes rather self explanatory. The implementation of wind turbines, one of the most low-carbon sources of renewable generations available at commercial scale, aims at multiple "objectives" such as grid decarbonisation, phase out of non-renewable sources and improvement of the air quality, qualities that have generally been associated with a long-term, sustainable energy strategy.

The second set of values that can are featured in this analysis, are those defined *instrumental* by van de Poel and Royakkers (2011): values that exist in function of other and aims at achieving the overall objective. In the context of this analysis, the instrumental values are defined and presented concerning the actors that carry them, otherwise named "stakeholder values". Profitability, Well-being, Fairness and Trust have been described implicitly in the entire literature on public acceptance of wind turbines (2.3), and fulfill the role of facilitate a successful implementation of a wind project in the context of a community (or any public group).
Stakeholder's values are not endorsed homogeneously by the very diverse network of actors that constitute the social groups described in 4.2. Many different groups advocate for different outcomes, choices, decisions and respond to very different narratives: while **Profitability** can be held dear by a project developer who operates on a low margin, **Fairness** can be advocated from a group of active citizens who wish to share the revenue of the newly planned wind farms in their area. **Well-being**, in the intrinsic sense of quality of life, is something intuitively associated with residents and their representation, that wish for the nuisance and visual impact of wind turbines to be minimised. **Trust** can be advocated by both project developers, who wish to build legitimacy in their projects and minimise unaccounted lead time, and policy-makers, that hope for a public recognition of the importance of increasing the numbers (and size) of wind parks, to meet the national targets.

Within the plurality of voices, narratives, conflicts and ambitions, it is unlikely that a wind energy project will satisfy all the shareholders, both direct and indirect. It is not impossible however to aim for a process that takes into account this multitude of views, and offers the possibility to create spaces of cooperation and compromise.

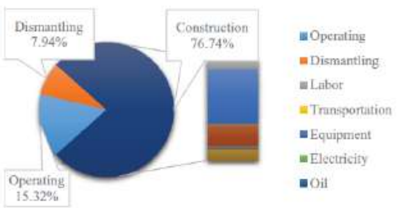
In this section, through the use of the tool of the value hierarchies proposed by van de Poel (2013a), the five identified values associated with the public acceptance of wind energy onshore projects will be analysed. The value-based analysis performed uses the hierarchies both as an *analytical tool* to comprehend the underlying reasons behind design choices, but mostly as a *design tool* to satisfy the need for value-based initiatives that could bring together divergent values into coherent design requirements (Pesch, 2019).
The number of values identified for this analysis resulted in the overlapping of a subset of norms and arguments, that can be equally associated with multiple values according to the value hierarchies structure. In 4.3.6, an adapted framework is presented to account for this plurality, and render the presentation of the values as a combined value hierarchy, rather than five individual elaborations.

4.3.1 Design for Sustainability

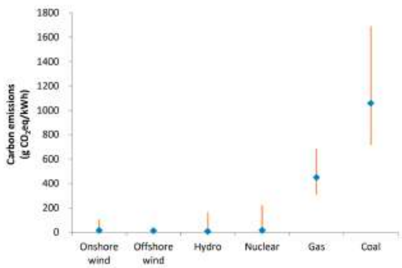
As the first value considered, deeply embedded in the nature of the technological artefact, Sustainability is itself a key component of this analysis. The task of decoupling

societal benefits and environmental deterioration is one of the main challenges for many professionals at the rising of risks associated with climate change and global warming. While the task of installing new wind energy capacity is itself a sustainability value-based initiative, the translation of the effort into action needs to take into account multiple issues. Not only the procurement of components and materials for the installation can be a concern due to the non-recyclability of many of the materials commonly used, but the impact of the turbines on the wildlife populating the surroundings has been a notable cause of opposition (Ellis and Ferraro, 2016).
In figure 4.7, the visualisation of the analysis is presented in the form of a value hierarchy, with the overall value crowning the nested norms and design/process requirements for onshore wind energy projects.

Within the broader value of Sustainability, four main objectives and norms have been identified as guiding principles of the design and development of projects. To *minimise local environmental impact* of a project is a key direction in which many engineering projects are expected to move forward: in the book chapter *Design for the Value of Sustainability* written by Wever and Vogtlander (2015), the importance of sustainable design practices is highlighted and presented by the authors with a collection of holistic sustainable design approaches. While many of these are rather product-oriented, such as Life-Cycle Assessment (LCA), Circular Economy, Cradle-to-Cradle Approach, or Biomimicry, the key governing principles can be applied in the context of a larger socio-technical system perspective.
Of the impacts for which a wind energy project can impact the surroundings, installation and technology-associated effects on the environment can be optimised by sustainable procurement practices such as the choice of low-carbon intense construction materials, minimisation of installation time and associated transports (wheel-to-tank GHG emissions) and procurement of wind turbine components based on LCA data where available. The estimated 21 years life-time GHG emissions associated with a wind turbine are of 14,490 tCO2e (Ji and Chen, 2016), not negligible if considering that 76,74% of the emissions are due to construction (figure 4.6a). Important considerations can be taken in reducing the emissions associated with the dismantling of the turbine, where a revamping project could therefore bring further GHG savings and avoid the emissions associated with both components and installation.



(a) Carbon footprint of the process inputs of a wind turbine (Ji and Chen, 2016).



(b) Comparison of carbon emission intensity for different energy generation sources.

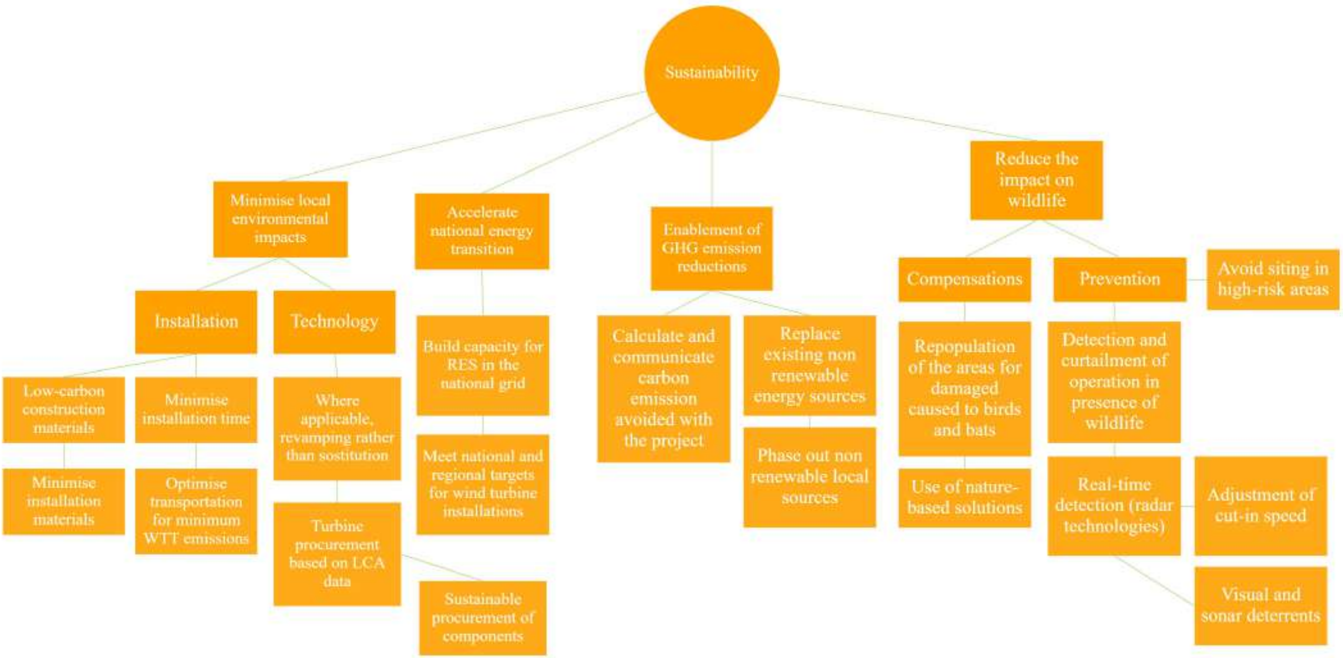
Figure 4.6: The impacts in terms of GHG of a wind energy project

As the interpretation of the value of Sustainability can depend on the stakeholder involved, for actors and professionals in the public sector and Dutch government the installation of a new wind farm translates in *acceleration of the national energy transition* (**?**). The increase in renewable energy capacity in the national grid has important implications from a governance perspective: it builds confidence that a nation is on the path to achieving its national targets, it lowers the grid emission factors of the country (therefore impacting a large number of other associated activities) and overall it shows the fruitful collaboration between private parties facilitated by policy put in place to achieve sustainability targets.

Thirdly, the objective of *enable GHG emissions reductions* is further embedded in the nature of the application of wind energy: a reliable, commercially-scalable, low-carbon renewable energy source. In the current energy mix of the Dutch sector, in 2018 electricity generation came primarily from gas (52%) and coal (27%). Moreover, energy from renewable sources accounted for only 7.4% of total final energy consumption (TFEC) in 2018, the third-lowest share among IEA member countries and well below the IEA median of 12.1% (IEA, 2020). The replacement of existing non-renewable and carbon intense energy generation sources in the country will both generate higher demand for wind turbines and keep the nation on track to meet the expectation of peers and other IEA members. It is suggested, on a local level, to calculate and communicate the enablement of reduction from the projects and how they translate into national KPIs.
Lastly, from a broader approach to the value of Sustainability, the objective of *reduction the impact on the wildlife* is presented. Directly analysed from the literature and reports published on the issue, the impact of wind energy on bats and birds (in the Netherlands and globally) has been widely taken into consideration by environmental activists groups, NGOs, associations and by a share of a environmentally-conscious public. Behavioral modifications, habitat loss, general disturbance can cause a higher vulnerability to collisions with wind turbines, and result in population decline across multiple species over the years. Multiple mitigation measures have been researched and tested because of the growing number of wind energy sites globally, but the evaluation of the efficacy is still currently under research (Arnett and May, 2016). Multiple strategies over the key families of preventive and compensation measures can be found, and some are presented briefly as high-level implementation of a wider research branch in this topic. Various compensation measures interestingly suggest to apply nature-based solution to repopulate and displace fauna from high-risk sites, and fit in the wider trend of exploiting natural mechanisms in engineering, for biomimicry and resilient systems Wever and Vogtlander (2015). Preventive measures are usually preferred, with complete avoidance of project siting in high-risk areas for the local fauna being the more often recommended approach. However, as trade-offs are essential while developing complex projects, preventive measures to detect wildlife (with sonar or radar sensors) and curtail operation have also been explored. Increasing cut-in speed of 1.5 m/s have been proven to reduce bat fatality by 50% on average in various studies in Canada (Arnett and May, 2016), and a low speed idling approach with blades pitched 45°, reported similar rates of avoided fatalities.

In conclusion, designing for the value of Sustainability for wind energy projects aims to exploit the intrinsic low-carbon nature of the technology, but requires a focus on procurement approaches, environmental management and communication. It requires a very diverse set of expertise and backgrounds to be successfully implemented in a project, and should be considered a key design process at the early stages of siting and resourcing.

Figure 4.7: Value hierarchy of Sustainability



4.3.2 Design for Well-being

Deeply connected with the value of Sustainability, designing for the value of Well-being is an exercise that considers the quality of life as object of the analysis. The value has been rarely associated with technology in design literature, but has deep implications in the context of public acceptance, as highlighted in the earlier literature review (2.3.2), and central to many of the debates polarising opinions against wind turbines. To design for Well-being can, in the context of this analysis, be defined as the lack of mental and physical pain and discomfort (Brey, 2015). This is a highly-simplified view on the issue, but for the limited scope of the application of the value hierarchies approach and the definition of practical design requirements, has been assumed as suitable. In the book chapter, *Design for the Value of Well-being*, Brey (2015) describes in detail the most current and comprehensive techniques for this specific design, together with the larger philosophical implications.

Design for Well-being, in this analysis, needs to address a first important question: for the well-being of who? Considering the overarching theme of public acceptance, the answer is firstly the well-being of residents, communities and local public actors involved and effected (in different ways) by a wind energy project. Secondly, because of the inclusive nature of the exercise and relevance in the public debate, well-being of the wider ecosystem can be considered. Opening the boundary of the analysis to non-anthropocentric perspectives enables the evaluation of broader measures to address the entirety of interests from different groups (such as environmental groups).
Reducing the impact of the project on wildlife is an objective shared with the previously analysed value, Sustainability. In the circular representation of value hierarchies in figure 4.13, the two hierarchies are aligned to highlight the overlapping of the shared objective. A more in depth consideration of the adaptation of the framework is presented in section 4.14.

To minimise the nuisance, annoyance and other negative sentiments that directly impact the well-being of residents, this analysis incorporates elements of the literature on social acceptance reviewed earlier (Wolsink, 2007; Molnarova et al., 2012; Feder et al., 2015). Associated with *reducing the annoyance of visual impacts* due to the siting of wind turbines, the objective is suggested to be achieved through the involvement of the community into siting choices. Recognising that there are clear engineering choices behind the rationale of siting a wind park (foundation, soil, grid access, transportation and logistics, wind profiles) one of the most effective ways to address the everlasting issue of visual nuisance in residents has been suggested to be to involve representatives of the community of residents in the siting choices, based on the positive (but anecdotal) experience of local energy cooperatives (Proka et al., 2018). Under the suggestion of experts in communication with the public, project developers are encouraged to create visual representations of the various installations to support the consultation process, while restricting the positioning of turbines to a finite set of options.
Nuisance experienced by residents associated with the subproducts of wind turbines operations, noise and shadow flicker, are other value-based parameters to be minimised in the design for the community well-being. While numerous studies have been conducted on the impacts of wind turbines on human health (van Kamp and van den Berg, 2018; Shepherd et al., 2011; Knopper et al., 2014), due to the mainstream notion of "wind turbine syndrome", there no clear correlation has been found between the sound propagated by turbines and health impacts, even in the case of low-frequencies. Surveys have shown nevertheless that stress and frustrations, for many different reasons and emotions against wind turbines, can decrease the mental well-being of residents and therefore impact the standards of life. In the case of both shadow flicker and noise, the most straightforward has been suggested to be the most efficient (van den Berg, 2020), to plan schedule downtime for turbines to halt the operations. This can be either scheduled from the operator's side, or more effectively be negotiated with the nearby community. Currently a similar system is in place to limit the impacts of shadow flicker: when the turbine is forecast to be in opposition of the sun, casting the blades' shadows over residential areas, the operations are temporarily ceased. However, this mechanism and calculations have been described to be often inaccurate (van den Berg, 2020) and therefore a solid modelling system is

suggested as design requirement to minimise nuisance.
Other design requirement involve siting, and closely related to both visual impacts and noise nuisance. Current regulations in the Netherlands expects projects developers to respect:

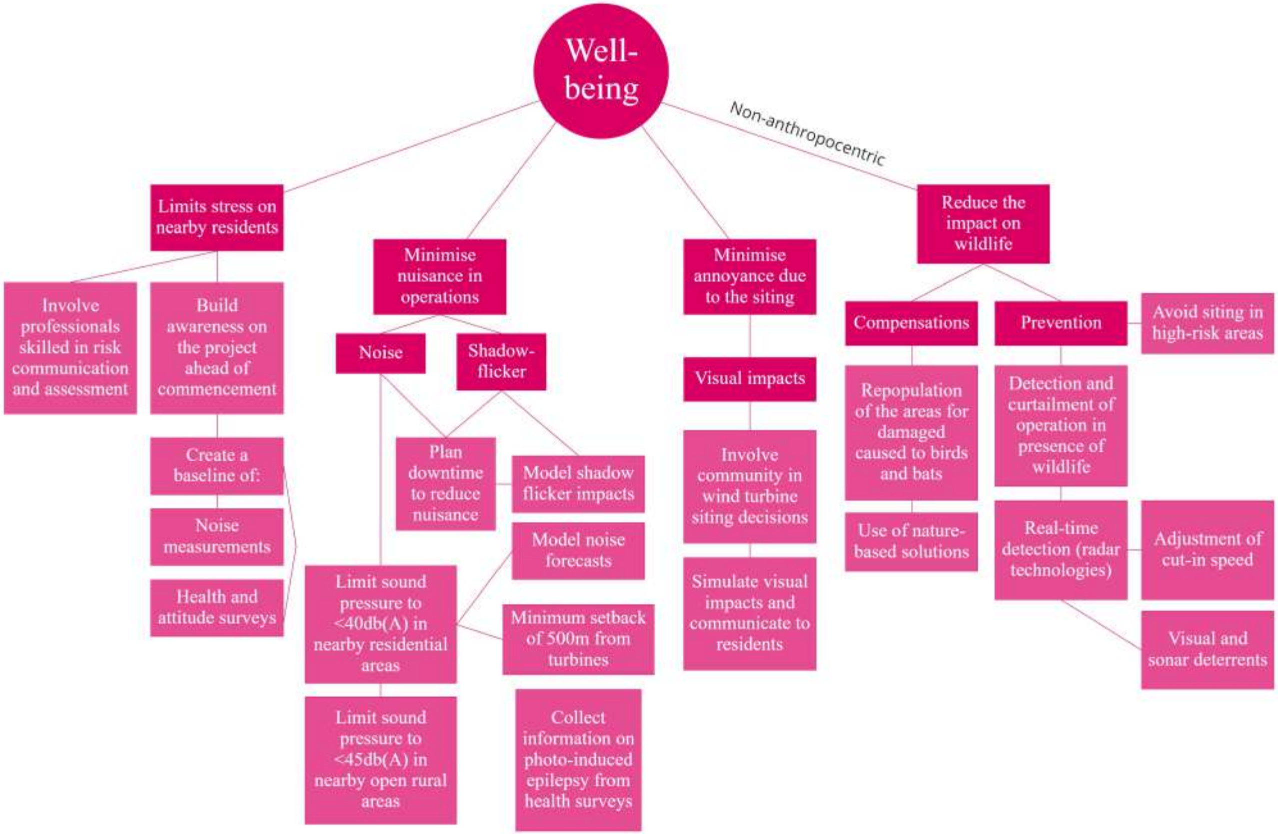
- A minimum of 500m of setback from residential units;
- A limit of sound pressure of 40 db(A) for turbines close to residential areas;
- A limit of sound pressure of 45 dB(A) for turbines located in open rural areas;

However, these guidelines have been indicated by residents not satisfactory and cause nevertheless annoyance, indicating that the operations of the turbines themselves can be a cause of the problem. Additionally, the sound pressure perceived at the dwelling is calculated on a yearly average that is not representative of the correct nuisance, experienced in particular conditions. Noise is perceived higher when in absence of secondary sounds (at night or early mornings) and in specific weather conditions (peak wind speed). The noise modelling should therefore be improved by taking these factors into account.

One last objective to translate the value of Well-being identified in this analysis focuses on *reduction of the stress associated with the process* of development of a new wind turbine. There have been numerous instances that the negative conditions associated with the introduction of a new wind energy project in an area have been amplified by the complete lack of communication with residents of that zone. This may have happened because of the lack of a clear communication plan and involvement of the community, something advocated by the Code of Conduct for wind energy developers published by NWEA (4.1.3). The involvement of professionals with a background in risk assessment and communication is suggested to prepare communities, inform and communicate, as well as facilitate the discussion and provide a point of contact between developers, authorise and communities. In order to improve future research on the effectiveness of these measures, it is suggested that a baseline is created for multiple social dimensions within the community such as health and local attitudes, to identify changes within the project development. Noise measurements are also suggested to ensure comparison pre and post installation of the turbines.

To improve the quality of life and well-being of residents the process designers and project developers should have a mindful approach to accommodate for perceived impacts rather than observed nuisance, while defining opportunities to cooperate with local groups on siting. The negotiating power of communities is considerably lower than the ones of the project developers, therefore external motivation to include Well-being into the design parameters should come from indirect stakeholders of the projects.

FIGURE 4.8: Value hierarchy of Well-being



4.3.3 Design for Profitability

Designing a system for the value of economic (and financial) Profitability is common exercise in the majority of professional services: the underlying assumption of every new wind energy installation is to have a profitable business case. The optimisation for maximum *profit* and minimum resources allocated can be found in every engineering project, and it is not a breakthrough for it to be applied to onshore wind energy projects in the Netherlands. What differs from the traditional analysis is the constraints that are usually applied to these calculations: rather than be the key parameter and output of analysis, profits in a multi-value analysis like the one undertook in this section is one among four other equally important variables.
The importance of a project to be profitable is a fundamental outcome for the majority of the stakeholders involved, but this analysis is designed under the assumption that *every value is equally important in the trade-off.* For a project to facilitate a solid level of trust between different stakeholders group is as valuable as generating the expected revenues, under this hypothesis.

Another important perspective of the exercise of designing for the value of Profitability is the heuristics behind the economic dimension of projects: a value-based perspective that focuses on *accessibility of financing* and the timings associated with the buy-in from investors, local communities, decision makers and the TSO, amongst other aspects.
Five objectives, or norms, have been identified on a high-level to render a project profitable. The analysis carried out is simplistic compared to the large amount of publications and research (Blanco, 2009; Kusiak and Song, 2010) and entire textbooks on the subject (Hau, 2006), but wishes to provide a comparable exercise to integrate the design of other values.

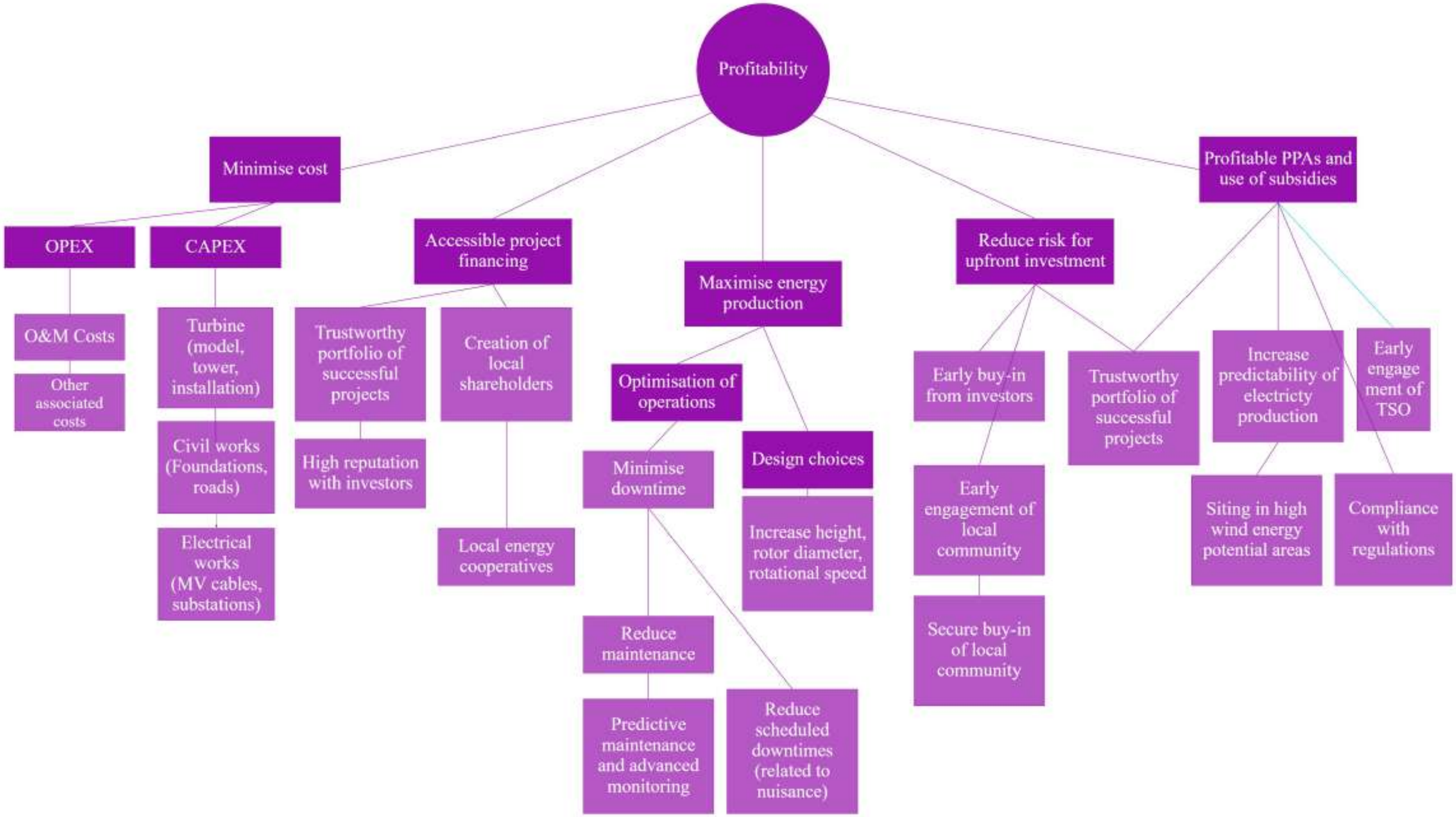
Concerning the financing of a wind energy projects, providing the required capital to cover the investments, we can identify multiple entities such as the owner of the project, the operator (legal entity) and the financial entity that provides the capital: traditionally a bank or a financing company (project company). Each project has a different business case based on a high number of parameters and possible situations, and is therefore impossible to create a general rule for financing of a wind project (Hau, 2006). Nevertheless, traditionally, the borrowed capital from the financier has an associated interest rate to be repaid to the lender, predetermined in the contractual phase. In case (exceptionally) of equity-financed projects, the business case associated with the investments will have a return in equity to the investors and minimum interest rate associated: this is one of the cases of the Dutch local energy cooperatives (Proka et al., 2018). With the creation of a user base of thousands of citizens that commit to consuming the energy that will be produced by the turbines, the investment cost is divided between many single actors that can therefore reduce the risk associated with the project financing, allowing developers to minimise interest rates and work closely to the community. Sharing the risk of the project with the community of residents (and other private actors has been proven successful in various cases in the Netherlands, an example is the windfarm Krammer from the local energy community Deltawind. Windpark Krammer is the largest citizens' initiative in the Netherlands, with nearly 5000 members that have taken the initiative to develop this wind farm on and around the Krammersluizen. The 34 Enercon E-115 wind turbines together generate 102MW of energy that power more than 30,000 households. In 2018, the members of these initiatives were given the opportunity to invest in the realization and operation of Windpark Krammer through a bond loan. In 2019, the first dividends were given and the bondholder day (Obligatiehouderdag) was organised.

The creation of local shareholders, as highlighted in other sections of this analysis, does not only reduce the risk of project investments but increases participation in decision making, redistributes benefits and generally increases the acceptability of wind energy projects. Windpark Kramer is an anecdotal validation of this statement, but the research on local wind energy initiatives has confirmed some of these takeaways (Hufen and Koppenjan, 2015; Heras-Saizarbitoria et al., 2018; Schreuer and Weismeier-Sammer, 2010).

Within the norms and overall arguments against wind energy, most of the nuisance

experienced from residents and the general public are related to the translation of Profitability-associated values: higher wind turbines benefit from better wind profiles (and therefore a cubic increase in power output) but have higher visual impacts, wind turbine noise is a function of rotational speed that is a key parameter is modern turbine control systems, and downtime results in important economic losses and longer pay-back times. The conflict between a profitable wind energy project and acceptable wind energy projects is what in VSD literature has been described as *conflicting values* in design trade-offs.
A summary of few of design parameters that directly impact the profitability of a wind project (and have strong ties with the concept of acceptability) is shown in the value hierarchy for the value of Profitability 4.9. A discussion on the clash between these values and their translation in design and process requirements is carried out in Chapter 5.

FIGURE 4.9: Value hierarchy of Profitability



4.3.4 Design for Trust

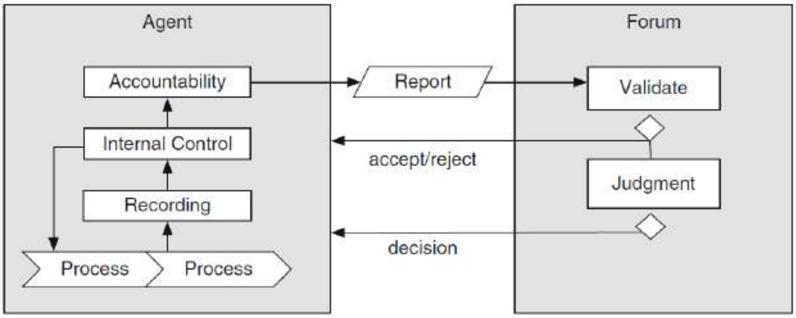
An introductory definition of Trust as an influencing factor has been given earlier in this thesis as influencing factor in the acceptability of wind energy projects (2.3.2.4). Rayner (2010) identifies 5 different dimensions of trust within stakeholders: *credibility* of the claims and degree of truth associated with it, *confidence* in the actor's ability to perform their duties, *integrity* associated with an actor's honesty, *compliance* with regulations and general legitimacy of the actions, and *reliability* in meeting expectation towards different actors.
Designing for Trust is a process that aims to establish trustworthiness across these different five dimensions in a **specific stakeholder** (e.g. project developer), and it is closely tied with designing for the value of Fairness (4.3.5), that deals with creating trust in a **specific process**.

Within the domain of Trust, the associated norms to the value are the *transparency* of decision-making and communication, the *accountability* of key stakeholders and the ability to *engage* with the community of residents. Shared between the domain of trust in the process and actor, the facilitation of *participatory design* processes, is presented.

The concept of accountability and transparency has been analysed in the context of Design for Values by Hulstijn and Burgemeestre (2015) within the context of regulatory compliance, but the elaboration provides important implications for the wider concept of Trust in an organisation (and individuals). From the experiences of residents involved in project development within their community (Residents, 2020) the lack of a single point of contact has been proven distressing and hindered the relationship with the project developer: with a large network of actors involved and the apparent lack of coordination (in the case of contraction workers, for example) residents experienced distress in the lack of accountability for the decisions made and the inability to communicate complains directly to the responsible role. The suggestion to implement within the process a higher degree of accountability of single actors and decision makers is to create a clear framework of responsibilities within the companies involved are subject to review and scrutiny from the public, collecting and channelling the negative sentiment that often is formed against specific decisions but overflows towards the higher processes in place. A model for accountability is provided by Hulstijn and Burgemeestre and displayed in figure 4.10 based on agent-forum relationship, this model is suitable for compliance reporting but can generally be extended to an overall idea of "validation" of decision making by a public forum in a structured method.
An agent (project developer) is expected to keep clear records of the actions and processes in place, to review them regularly (QA processes), assign responsibility to a specific role and then submit a summary of these internal processes to the forum (in form of a regular report, update, town-hall). The forum (local council, representatives from communities) has therefore the responsibility to validate the processes in place against previous communication, interact with the assigned spoke person to clarify possible outstanding issues, provide feedback and direction for future developments and then formulate a decision on the operation of the agent. The model assigns relevant power to the forum over the continuity of the processes of the agent, that has the duty and obligation to comply with the judgement of the forum.

Key to this process, but not exclusively associated with it, is transparency within the communication. Sharing information with residents is often associated with the importance of timely communication (often suggested *before* the commencement of a project) by the code of conduct from NWEA, but the completeness and availability of information over time is equally important for residents. Within the suggested framework described above, reporting is not possible without correct recording and collection of relevant information. It is suggested that said information shared timely and completely with key resident groups.
Transparent and open public meetings have been used by project developers of wind farms extensively in the Netherlands in recent years, but often with little benefit to the overall process or community (van den Berg, 2020). Opening consultations for upcoming projects and disclosure of design options without a clear request for "feedback" from

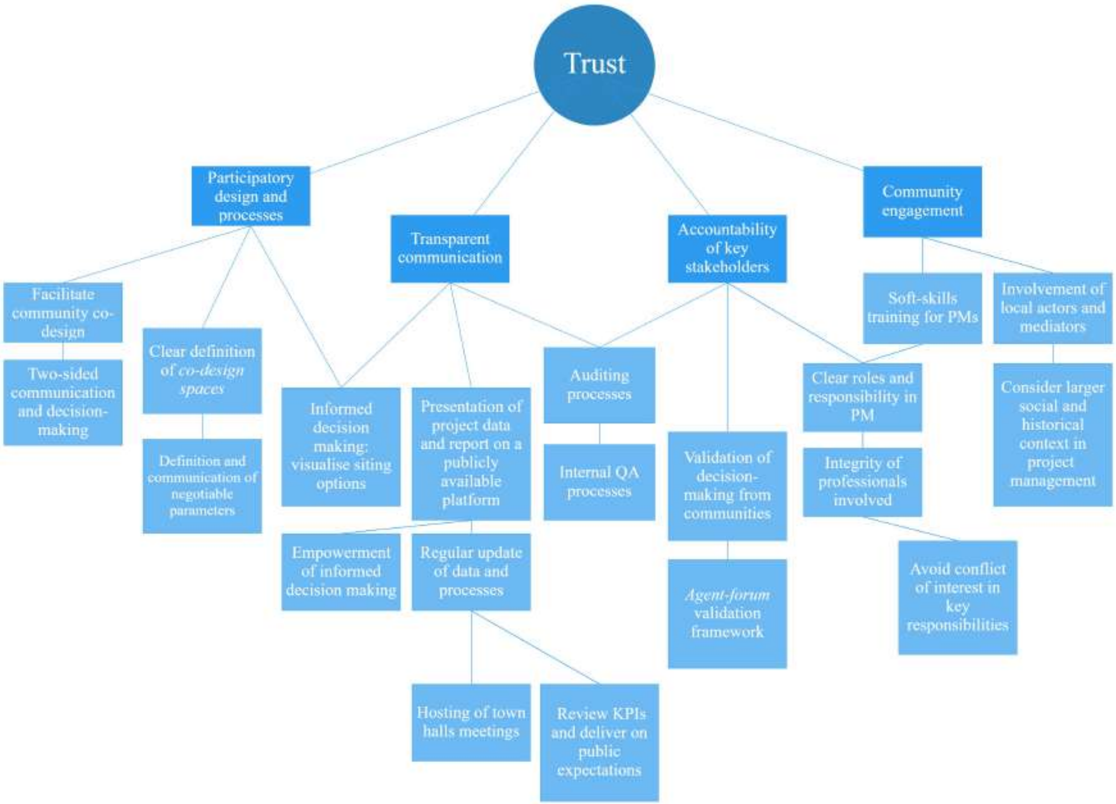
Figure 4.10: Simplified agent-forum accountability framework. From Hulstijn and Burgemeestre (2015).



the community is counterproductive, as the sessions sometimes tend to deviate from "questions and answer" to the only channel for communicating distrust in the decision making (as in the case described by the research assignment of Blok (2018)). Recently, consultation has opened for the construction of a new onshore wind energy project near to the city of Amsterdam, and a similar pattern of distrust has been observed in various manifestations and online consultations (Het Parool, 2021).

The communication can and need to be more transparent when informing about project development, but cannot be one-sided. If residents are only "talked to" and updated on the progress or possibility of plans, without any perceived impact on the outcome of the consultation or approval, the feeling of mistrust can increase and be internalised in the process for years to come. The communication has to be therefore two-sided, where both agent and forum communicate sincerely, as a first step in the process that VSD theory formalises as co-design.
Empowering a community in making part of the choices that will influence them has been identified as a potential beneficial step to include in the project development for further onshore project development. While the "owner" of the project has the responsibility of defining a co-design space in which stakeholder can propose solutions for a *finite set of design elements* (siting, for example), the community is therefore required to participate proactively and constructively to the consultation, with external moderators and mediators to create an environment of mutual trust.
Project developers are required to trust communities by giving away part of their decision-making power over design criteria, and communities would need to trust the process and take ownership of the solutions co-created. The definition of co-design spaces, correct involvement of public communities and complex project management and financing of these projects are important open research questions, that can benefit from the experience of local energy initiatives, VSD-based co-creation workshops (Friedman et al., 2015), and the long-standing experience in involving Dutch citizen in public consultations in the Netherlands.

FIGURE 4.11: Value hierarchy of Trust



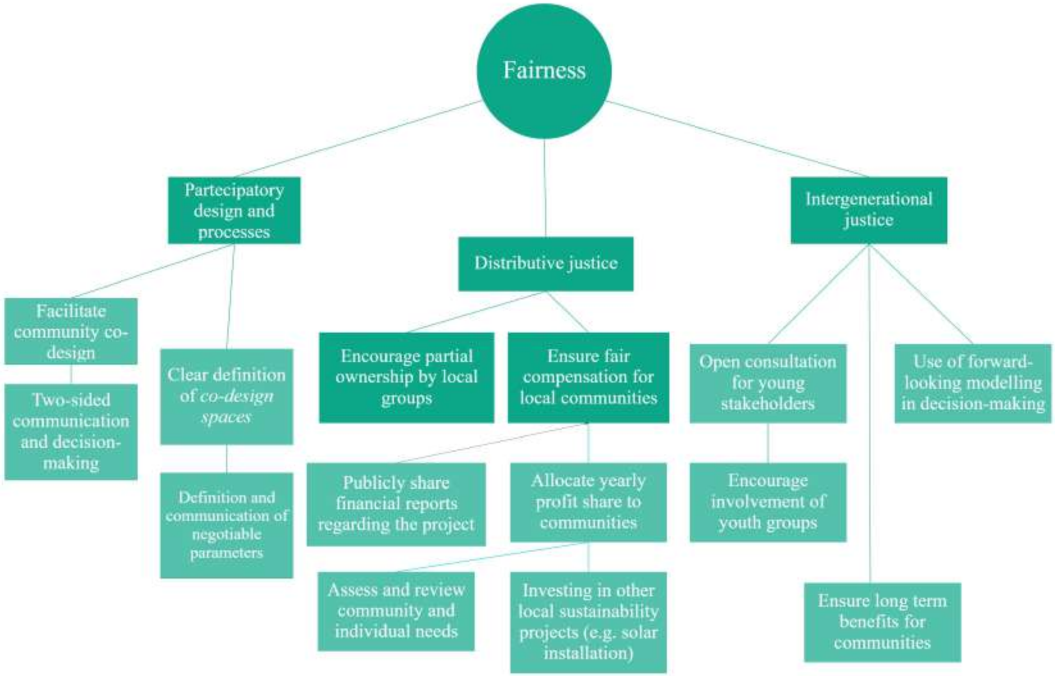
4.3.5 Design for Fairness

While, for the purpose of this analysis, Trust is intended as respect and accountability towards a single or group of actors, design for the value of Fairness projects the similar values towards the process, object of analysis. Fairness is therefore intended in terms of distribution of decision-making power, economic outputs, risk, between different groups of stakeholders (present and future) to ensure acceptability of the outcomes of the process.

Closely tied with the design of participatory processes in the previous sections, design for Fairness is an important exercise that aims at citizens to acknowledge their importance of their contribution to obtain a fair division in benefits and responsibilities. No group, in good faith, would purposely allocate benefits and outcome of a project that they consider "not fair". What is considered fair is different from the concept of "equality": different actors have different exposure to risk and allocate different resources to a project, therefore must be remunerated differently. The complexity in accounting for impacts such as the exposure to noise, discomfort or similarly the use of natural resources like wind is a problem described in the well-known *tragedy of commons* in economics. It is suggested that, by providing negotiation power to public groups, the decision on a "fair" price for the community to pay and remuneration to receive can be agreed upon, following group decision-making frameworks and findings from game theory, tested in the field of RES (Haralambopoulos and Polatidis, 2003; Soltani et al., 2016).

An important element of analysis, directly derived from Responsible Innovations, is the importance of taking into account future generations in the stakeholders' group impacted by the project and technology. This value translates in the general norm of "intergenerational justice" that is often mentioned in the literature but rarely in public debate and decision-making (van den Berg, 2020): not considering the long-term benefits and impacts of a project that extends over decades within the overarching theme of energy transition, is short-sighted and biased. Wind energy projects not only play an important role in the short term for a community (in terms of clean electricity access or impacts on wildlife) but medium to long term effects need to be considered while making decisions (landscape and identity of a region, phasing out of non-renewable sources of generation). There is no empirical evidence that negative sentiment against wind turbines decreases over time (Devine-Wright, 2005), but negative sentiment has been shown to be mitigated with careful consideration of the multidimensionality of the issue: it is important that the negotiated benefits and ownership of the community is ensured over time, to ensure a commitment from both parties to pursue a long term agreement. Involvement of young members of the community is a suggested requirement for an intergenerational just outcome: youth groups are generally underrepresented in the political end economic decision making, while paradoxically the outcomes will impact them longer and cumulatively, consequences would affect their futures more than other stakeholders.
It is difficult to quantify future impacts in economic quantities: the general disagreement on the social discount rate is at the center of many economist's debates concerning climate change. It is even more complex to quantify for future non-economic impacts, that are subject to a multitude of personal factors. In ensuring the long term benefits for communities, to design for the overall value of Fairness, it is important to adopt a flexible and open mindset, empowering groups to consider multiple future scenarios.
In figure 4.12, a short visual representation of the value hierarchy for Fairness is shown.

FIGURE 4.12: Value hierarchy of Fairness



4.3.6 Circular Value Hierarchies

The framework of value hierarchies has been discussed and introduced earlier in this research in section 3.3.3 as a conceptualisation of the nested nature of design requirements in the context of a value-based decision making. In the article "Translating Values into Design Requirements", van de Poel (2013a) presents the structure as a logical architecture to either analyse current situations with a focus on the discovery of underlying values in technology (bottom-up, analysis approach) or design systems meant to represent the overarching values within the implementation (top-down, design approach).
His work set a milestone and provided a simple schematic to analyse complex issues, and has been widely adopted in the discipline of design for values.

When considering the applicability of the structure to the research on public acceptance, the need for a multi-dimensional approach to the issue of designing for many different stakeholders' values suggested the adaptation of the architecture of the value hierarchy. Therefore, in this section, a brief overview on the *circular* value hierarchies are presented and analysed in terms of applicability to the research.

Public acceptance of wind energy projects has been proven historically to be a challenging problem for decision makers and process managers because of the different dimensions in which it extends (Vladmiks, 2020), it cannot be circumscribed to a simplistic definition such as NIMBY (Devine-Wright, 2005) and has a multiplicity of influencing factors that have been an object of research for many scholars (2.3). In the context of a value-based analysis, these influencing factors have been traced back to five different values appropriated by the technology and different groups of stakeholders: Sustainability, Well-being, Profitability, Trust and Fairness. Each of these values implies different translations into design (and procedural/normative) requirements and interpretations, for each one of the stakeholder groups involved. The hierarchical structure of the analysis extends therefore not only to multi-values dimensions, but to multiple stakeholders' interpretations dimensions. If a temporal dimension was to be added (value and stakeholder groups change over time), the complexity of the analysis would increase further.

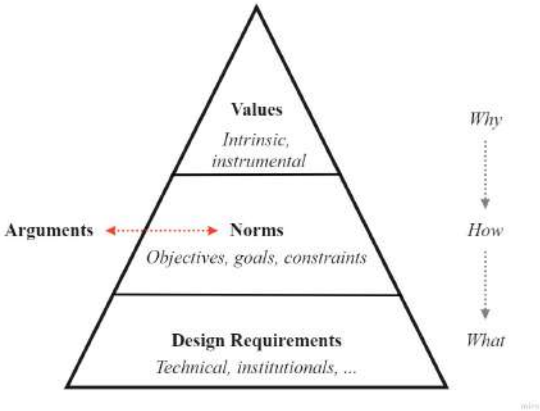
The problem of designing for acceptance of wind turbines from the public of residents cannot be optimised by focusing on one single value-dimension and stakeholder group at the time, value conflicts (van de Poel, 2014) are to be encountered and the proposed solutions would prioritise one over the other based on the constraints of the initial problem. Additionally, the translation of different values sometimes can overlap in shared objectives: to achieve the value of Well-being, objectives can be shared with the design of sustainable futures for the community, while to ensure a fair process design, trust in authorities can be positively reinforced as an outcome.

Three main characteristics are part of the framework of the circular value hierarchies presented in figure 4.13b:

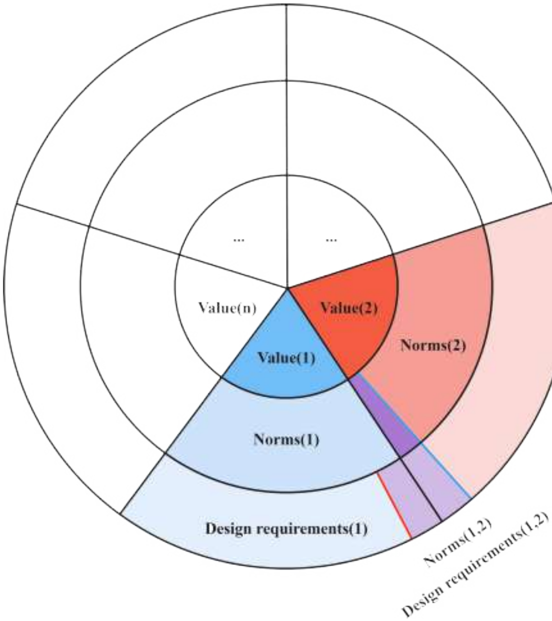
- to account for multi-value based analysis
- to account for overlapping in norms and design requirements within different value hierarchies
- to support in the identification of multiple value conflicts
- to support in the visualisation of multi-dimensional value analysis

While the first two features of the framework proposed are intrinsic of the disk-shaped, equally divided structure, the supporting role in identification and visualisation are proposed in relation to the use of the value hierarchies.
The circular value hierarchies are deemed suitable to display the result of a value-based analysis of a technology/system/process and assist in the identification of conflicting values.

In figure 4.14, the value hierarchies presented earlier are combined following the structure of the the proposed circular value hierarchies. The five identified values are



(a) The Value Hierachy proposed by van de Poel (2013a).

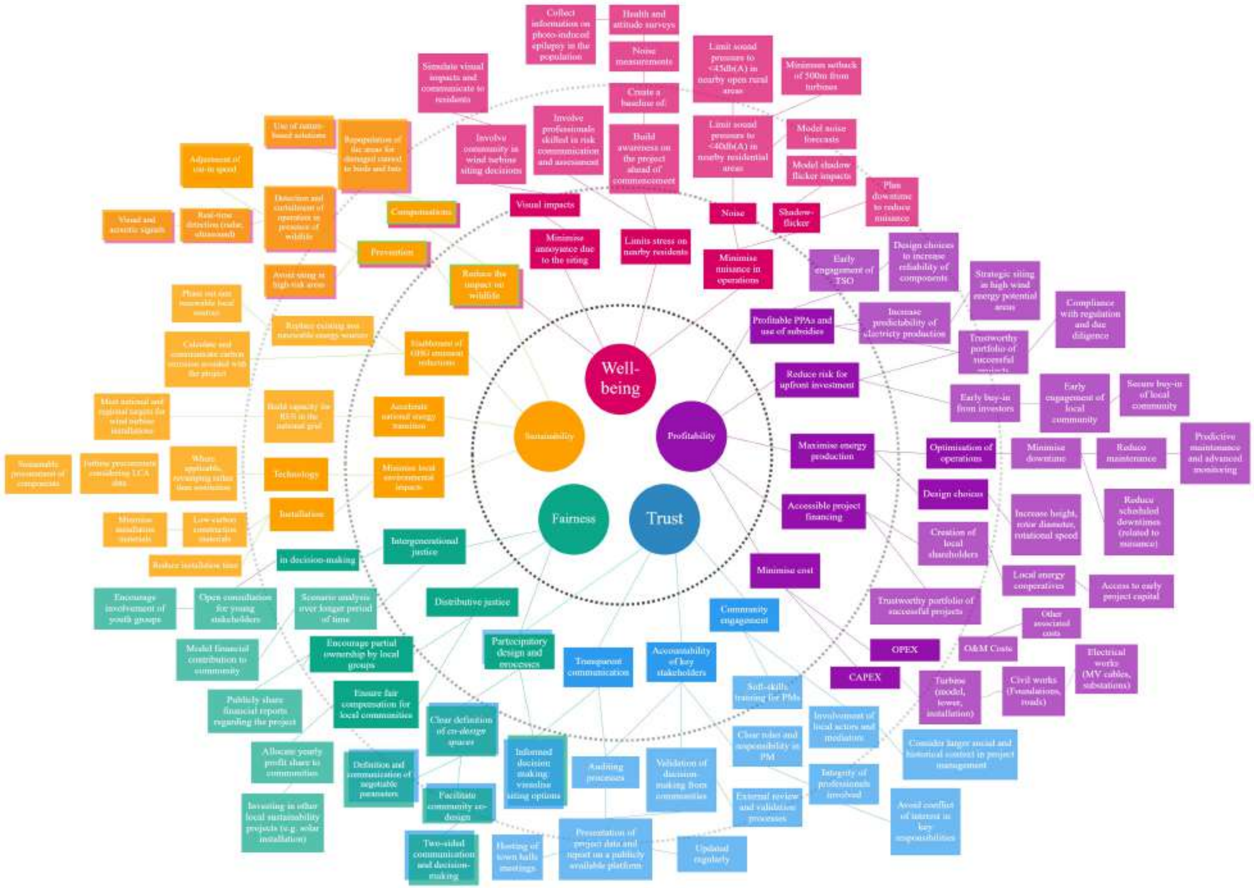


(b) The proposed circular value hierarchies approach

FIGURE 4.13: Comparison between the original framework of value hierarchies with the expanded proposed approach.

included at the centre, while the translation into design and normative requirements expands towards the borders of the circular sections. The results of the value-based analysis of public acceptance of wind energy systems in the Netherlands, comprehensive technology map, stakeholder map and value hierarchies, is discussed in the following chapter.

Figure 4.14: Circular value hierarchies for public acceptance of onshore wind energy projects.



4.4 Conclusions

The fourth chapter of this research is titled "*A Value-based Analysis of Wind Energy Systems in the Netherlands*", as it provides the main piece of analysis contained in this research project. This chapter proposes the adaptation of the methodology of the Socio-technical Value Map (STVM) presented in chapter 3 to the issue of public acceptance of onshore wind energy systems in the Netherlands, introduced in chapter 2. This chapter brings together the literature and studies reviewed in the previous sections with the application of value-based methods with the purpose to identify design requirements to enhance public acceptance (defined in 2.4).

This chapter aims to address multiple research questions for the scope of this thesis. Two main components of the STVM facilitate this by providing a space for answering these: in section 4.2, the Stakeholder Map is presented to answer the research sub-question "*Who are the stakeholders involved in onshore wind energy systems in the Netherlands?*", while in section 4.3 "*What are the values associated with public acceptance of onshore wind energy projects in the Netherlands?*" is addressed. The entire chapter provides content to answer the last sub-question "*What value-based design requirements and initiatives could influence public acceptance of future onshore wind energy projects?*", which is further elaborated in the concluding chapter of this research.

To effectively answer said research questions, we will start by first considering the stakeholders, then moving to the values involved and complete the analysis by considering effective and actionable recommendations.

4.4.1 Stakeholders

Considering the identified stakeholders involved in the Dutch wind energy sector, a landscape analysis has been carried out to identify all the potential relationship and networks that can influence the development of a wind energy project. This is, as described by the STVM methodology and by the underlying SCOT theories (2.2.2) important to identity the incentives, motives, expectations and beliefs from actors - translating in the values associated with stakeholders. This approach expands the mechanisms described by the Actor-Network Theory of chapter 2, where groups of stakeholders fall into self-regulating cooperation mechanisms by pursuing the shared objective of profitability (Latour, 1996). Within this approach profitability is only one of the main purposes of the groups, and the self-actualising cooperation mechanism will most likely not happen if not properly facilitated, as per the issue of conflict between groups.
Networks of cooperation form within the map presented in this chapter, the example of the Netherlands Wind Energy Association being the most relevant example. While profitability may not be the only parameter needed for this organisation to form, the private sector often relies on this kind of networks to facilitate knowledge sharing, connect private actors, expand business development opportunities and face common challenges together. As in the case of public acceptance, the various parties involved developed a formal commitment to solving the problem with the best of their intentions, the Code of Conduct for onshore wind energy development. Besides the NWEA, further network effects form within other quadrants of the map. Local energy cooperatives represent the union of multiple local actors driven by different incentives but shared goals (or values). The topic of local energy initiatives has been discussed thoroughly in literature in recent years (Dóci et al., 2015; Lepping, 2014; Luteijn, 2016) because of their rising role in the energy transition, and the fortunate examples present on the Dutch territory.

The landscape analysis carried out to answer sub question two, "*who are the stakeholders involved in wind energy systems* (and projects) *in the Netherlands?* translates into the stakeholder map displayed in figure 4.5. The visual elaboration of the analysis provides a high-level description of the actors that cooperate, interact and shape the sociotechnical system of the Dutch onshore wind energy sector. The "Private Sector", composed of archetypes of firms involved in development, operation and financing of wind energy projects is juxtaposed to the actors involved from the "Government and Public

Sector" - a list of the main bodies involved in approving, regulating and facilitating the implementation of said projects.
"Research" provides an important but less connected quadrant of the map, as the institutions and research centres listed (e.g. NWO, ECN, TNO, universities) does not directly interact in the development or management of the project often. It was shown, however, in section 2.1, how these institutions played a key role in generating the required knowledge and technical understanding that now is the foundation of every wind energy projects. RD is still a crucial part of the strategy that is guiding the transition of the Dutch energy sector, and therefore the joint efforts of the private sector and these organisation is a relevant part of a landscape stakeholder analysis.
Important for the value-based analysis, a group that is often considered only marginally is the residents and actors (van den Berg, 2020). While the firms and government bodies can be identified on a landscape level, subsets of actors are heavily case-specific. The historical background of communities in specific areas is to be taken into consideration. In villages of South Holland, pre-existing local cooperation networks have developed since the early 1950s to foster agricultural partnerships (Vladmiks, 2020) In the northern provinces of Groningen and Drenthe the sentiment of distrust towards the central government is historically rooted and retrace back to issues with territorial claims between the Netherlands and Germany (van den Berg, 2020).
For a relevant analysis of the local situation, we need to shift from the notion of *lanscape stakeholders* to *project stakeholders*. The information is captured in the stakeholder map with the listing of actors archetypes: we do not expect every case-specific project to have the same subset of residents or groups, the information listed in the map provides guidance for an external assessor with the structured information relevant to identify and map the participants of the process.

To provide more information to the research exercise on the acceptability of wind energy, a more focused approach needs to be taken. In regards to the issue of public acceptance of wind energy projects, different actors have different levels of *involvement*: it is not expected a wind turbine manufacturer to be involved in the issue as it would be the local council of a municipality facing social unrest. Similarly, the degree of influence of actors is determined by the power they are able to exercise on decision making: a single resident may be highly concerned with the upcoming wind park coming in their area, but has limited influence over the outcome of the project compared to the investors financing the project.
For this reason, the conceptual tool of the *influence-interest* matrix can be useful to map the different groups of stakeholders directly involved in the issue and the degree of importance they have in the situation. In Figure 4.15, below, the result of the prioritisation is shown. This brief exercise shows the clear asymmetry in power when it comes to comparable levels of interest: different groups such as project developers and residents have different "negotiating power" (connecting to Szarka (2007) social contract notion of acceptance) and therefore outcomes that favour specific groups are more likely to happen. The idea of an inclusive, value-based design exercise aims to flatten the inequalities established by a preexisting allocation of decision-making power. The implicitly expected outcome is that, with a more inclusive design process, the overall sum of the benefits distributed between a wider group of stakeholders will be larger than the benefits associated with a single (or a few) entity(ies). The prioritisation matrix can provide a snapshot of the current situation, useful for designers and decision makers to identify the underrepresented group and foster their involvement. It is recommended that similar exercises take place both on a landscape level, when designing new policies and regulations, and on a local level, when defining the roles and responsibilities of an upcoming wind energy project.

4.4.2 Values

To increase social acceptance, Value-Sensitive Design (VSD) aims to incorporate the values of all relevant stakeholders in the design process (Koops et al., 2015). Once the main project and landscape stakeholders have been identified, as the framework of the Socio-technical Value Map (STVM) suggest, it is possible to trace back the shared objectives and aims to map what is referred to as "values".

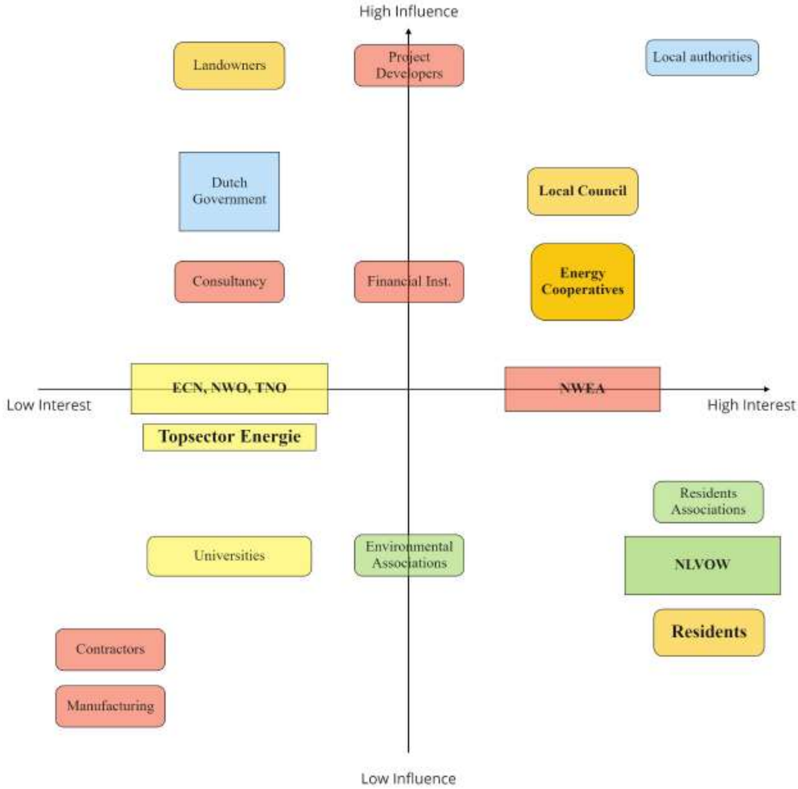


FIGURE 4.15: Influence-interest matrix for the relevant groups of mapped stakeholders, when considering public acceptance.

The identification of these values is a holistic process that relies on deep knowledge on the issue, familiarity with the involved actors and conceptual investigations [5] The identification of the relevant values relevant for the issue of public acceptance of onshore wind energy projects has been an iterative process during the analysis that resulted in chapter 4 of this thesis - initially only one value was identified and mapped following the literature review of public acceptance publications and research. As the process evolved and continued in this work, the need to bring the perspective of multiple stakeholders familiar with the problem was clear: multiple interviews with representatives from the industry and the local communities were incorporated in the research. While many of the sources from the scientific literature initially analysed were not specifically relevant for the Dutch situation (e.g. Ellis and Ferraro (2016)), adding perspectives and sources from Dutch stakeholders and publishers resulted in a more relevant value selection for the issue. In figure 4.16, a visualisation of the sources taken into consideration for the holistic value mapping is presented. The order of the values, in the figure displayed vertically, is not representative of any logical arrangement as each one of the five is considered to be equally important in the analysis, it is a visual adaptation.

The sources presented in figure 4.16 shows how different perspectives place priority

[5] Friedman and Hendry (2012) presented 14 methods for value sensitive design, in their 2012 publication. These are summarised in table ??, and for this exercise methods, 1,2,3 and 6 have been considered.

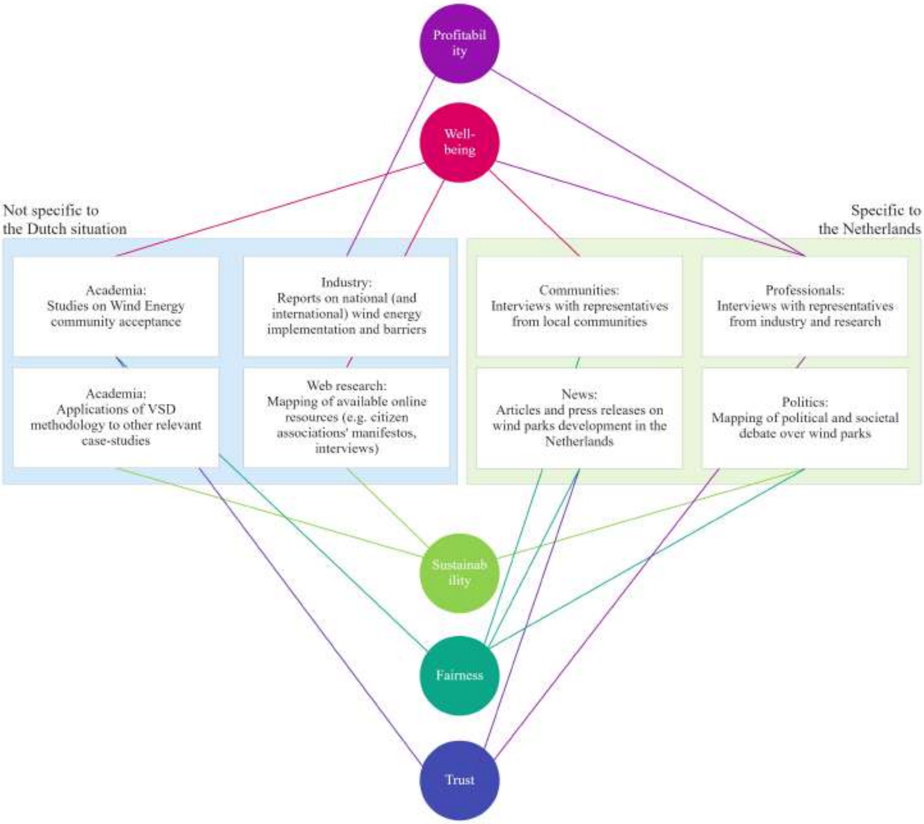


Figure 4.16: The various sources consulted to identify the appropriate values for the analysis, and how they relate to the five identified values.

over certain values and emphasise more aspects that directly impact their interest: the interview with residents from the windpark De Drentse Monden en Oostermoe showed depth and thoughtfulness in aspects that relate to the values of Well-being and Fairness. Similarly, the news article and press releases consulted and available on the web place interest on the concepts of rust and Fairness, while reporting the narrative that is affecting communities in many villages of this country. Industry reports such as the IEA (IEA, 2017a) have a clear angle on profitability and cost-effectiveness due to the purpose of the publication. Academic literature should have the most comprehensive angle on the issue, and while it usually encompasses all the different dimensions of public acceptance, many articles discussing public acceptance fall short on discussing the implications for Profitability (covered mostly in more technical literature).

The process of identifying the values has been a continuous exercise that is due to the number of sources, quotes and considerations present in this and in the previous chapters of this thesis. The mapping of these values is presented below, in table 4.3, listing a short definition and main sources that led to the identification [6].

Value	Definition	References and sources
Profitability	Aim to obtain a profitable case-study for the overall project development and operations of a wind turbine, for every shareholder.	(Huber and Horbaty, 2010; Künneke et al., 2015; de Geest, 2016; van Est, 1999; Blanco, 2009; van den Hoven et al., 2015; Agterbosch et al., 2007; Vladmiks, 2020; Harmsten, 2020)
Well-being	Aim to maintain and improve the mental and physical state of individuals living in the proximity of a project.	(Ellis and Ferraro, 2016; Fournis and Fortin, 2017; Williams and Edge, 1995; Koops et al., 2015; Ortt et al., 2020; Wolsink, 2012; Mertens, 2019; van den Berg, 2020)
Sustainability	Aim to preserve the natural resources and environment of a specific area with a long term perspective.	(EEA, 2016; de Geest, 2016; Botin, 2004; Dignum et al., 2016; Schreuer and Weismeier-Sammer, 2010; Pesch et al., 2020; Ministry of Economic Affairs, 2016; Kemp and Loorbach)
Fairness	Aim to ensure a fair and just process and distrubution of value between every stakeholder.	(Pellegrini-Masini et al., 2019; Ellis and Ferraro, 2016; Vermaas et al., 2010; van den Hoven et al., 2015; Fournis and Fortin, 2017; Residents, 2020)
Trust	Aim to foster a relationship of mutual respect and understanding between every stakeholder.	(Vermaas et al., 2010; Residents, 2020; van den Berg, 2020; Harmsten, 2020; Luteijn, 2016; Huber and Horbaty, 2010; European Wind Energy Association, 2010; Devine-Wright, 2005)

Table 4.3: The values idenfitied as relevant for the stakeholders involved in the public acceptance of onshore wind energy projects in the Netherlands.

4.4.3 Design requirements and initiatives

One of the ultimate aims of this research is, together with expanding the theoretical and methodological application of VSD to onshore wind energy projects, to provide actionable content and measures to improve the public acceptance of the technology on the Dutch territory. The majority of the literature analysed on the topic provided valuable insights on the theoretical applications of value-based analysis, but often fell short of providing tangible suggestions for stakeholders. While the goal of articles such as "*Applying value sensitive design (VSD) to wind turbines and wind parks: An exploration*" from Oosterlaken is not to influence, or even convince, professionals working in the field of wind energy development, this research attempts to bridge the gap between scientific literature and guidance documentation.

An important consideration that is necessary before introducing the outcomes of the research is that: it is very *difficult* to provide actionable content for each stakeholder in every project. Even when defining the boundary clearly to local, Netherlands based projects, the specificity of every situation applies and increase the complexity of a comprehensive analysis. Every project is different, because it includes different stakeholders, has a different historical background and networks that formed over the decades, different

[6] The list reported in table ?? is not exhaustive. It refers to some of the papers, publications and sources used in the mapping, but as described above the process followed a more holistic approach and includes conversations with various professionals consulted for the research, discussion with colleagues and professors, pieces of information collected from many different internet pages and manifestos.

technical specification for the project (number of turbines, distance from residents, fauna, etc.) and interaction between stakeholders.
Similar projects can bear completely different outcomes in terms of acceptance, when factoring in these aspects. The relatively subjective notion of acceptance does not simplify the discussion. Outcomes and process' perception can vary depending on who you ask: the multi-stakeholder, time-dependent and abstract nature of the problem has been challenging for the analysis.

To provide structure and a solid methodological framework for the task, the value hierarchies were adopted as support for answering the last research question. Value hierarchies (figure 3.4) are a conceptual tool widely used in value-based analysis (3.3.3) that facilitate the connection between high-level, abstract values and practical design requirements. They can be used interchangeably as a design tool - when defining normative and technical design requirements starting from general value to pursue - or as research instrument - when conceptualising and mapping value starting from evidence and requirements (van de Poel, 2013b).
Value hierarchies have been used in different settings in the Dutch energy transition, such as illustrating the translation of the value of Safety in the context of the controversy regarding shale gas exploitation (de Geest, 2016). The outcome of the use of this tool, for each one of the five identified values, is shown in figures 4.11, 4.12, 4.9, 4.7, 4.8. These design requirements are highly context-dependent, and defined according to the guidance provided by van de Poel regarding the use of the hierarchies.
The number of value analysed and applicability to the issue of public acceptance revealed an overlap between hierarchies. Design requirements from Sustainability and Well-being overlapped due to the common thread of preservation of the environmental wildlife and how the notion of well-being identified is wider and applies to the ecosystem surrounding a windpark. Trust and Fairness's translation of values into norms also shown some overlapping - when proposing participative processes as a way to increase Trust from residents and ensure a mechanism for the design of just redistribution of benefits.
Because of this overlapping, the visual representation of the hierarchies has been made circular, in figure 4.14. The figure communicates a larger set of information and suggests the hierarchical division through circular bands, similar to a topographic map with isometric curves.

In total, the use of the value hierarchies provided 5 separate values with 18 associated norms, which translates into 93 process or project design requirements. Following the methodology provided by the STVM, these initiatives and context-based solutions can be the building blocks for the generation of value-based solutions to tackle the issues mapped. Many of the design requirements shared similarities and could be grouped in sensible categories focusing on different aspects of project management and normative design: **siting**, **financing**, **communication**, **planning** and **operations**.

There are different degrees of how these building blocks could be integrated into a comprehensive strategy or recommendation. For the purpose of presenting a clear and actionable result of the analysis, the 93 design requirements have been grouped in the five described categories, and then implemented in three main proposed pathways. These schemes are presented below, in figure 4.17, and progressively implement stronger recommendations from the identified design requirements and suggestions. From pathway 1, *"Proactive Community Management"*, through pathway 2, *"Public Tendering"* to pathway 3, *"Co-Design and Co-Ownership"*, the involvement of communities in the project increase and the weighting of implementation of the value-based analysis outcome is higher.

Proactive Community Management (PCM) can be described with the implementation of more proactive practices in community engagement from wind energy project developers. It does not significantly transform the current governance structure or planning of projects, but suggests implementing many "good practices" of community management. The recommendations developed by NWEA and presented in their Code of Conduct falls in this objective.
Developers would be required to engage as early as possible with local groups, to ensure that communication is established earlier on in the scoping phase of a project. Visibility

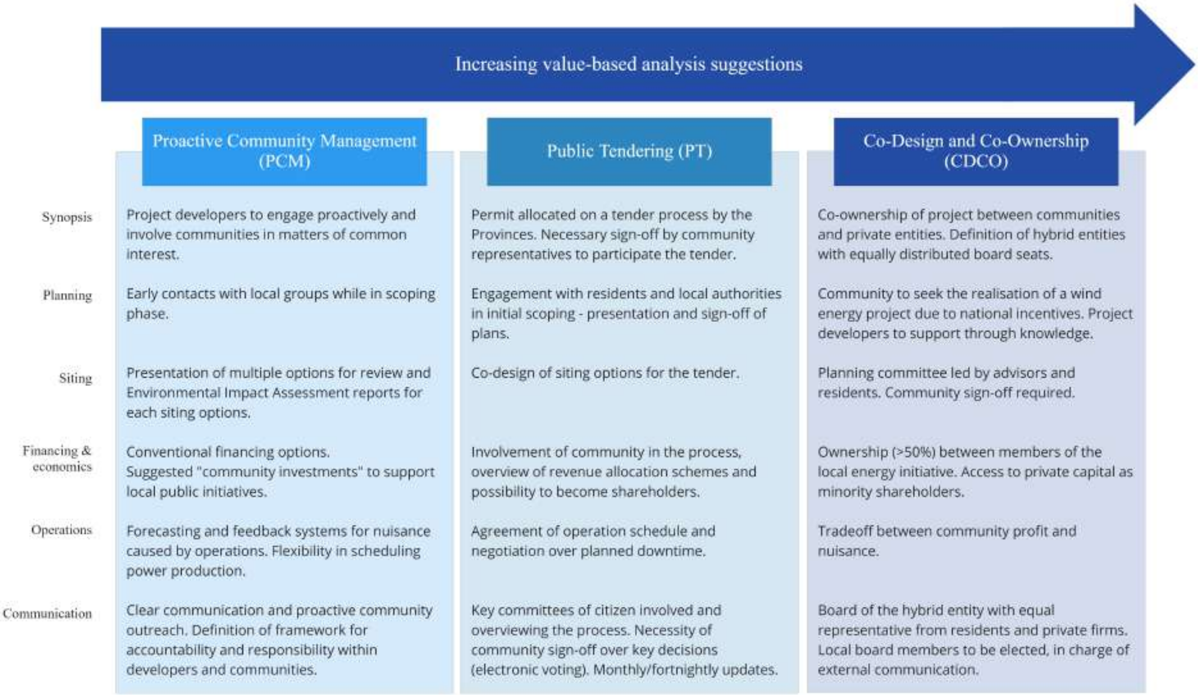


FIGURE 4.17: Three pathways to summarise the design requirement and suggestions generated by the value-sensitive analysis. Design for Values.

over possible future issues, conflicts and key areas may be provided as early as needed, and this could feed in possible options for siting. Environmental Impact Assessment (EIA) are already required to be presented to authorities for approval of the plan and issuance of a permit, within the current situation. Following the design requirements defined within the value hierarchy of Trust, the presentation of this documentation for multiple options of siting would possibly improve the transparency of the siting process. At this stage, it would not be required a formal sign-off by the members of the community. Improvements could be made in terms of prediction of the nuisance and to provide flexibility in the scheduled downtime for turbines: as nuisance related to noise and shadow flicker are significantly associated with concerns over the well-being of residents, scheduling more time than the minimum required by regulations is a sign of goodwill.
One key aspect of PCM is to foster communication and respect between the community and developers/operators of the wind park. The main recommendation provided by this pathway is to hire relevant resources and communication experts to manage a proactive information campaign towards community, with clear and updated channels of communication (e.g. webpage, social media, newsletters), opportunities for discussion (open forums, town halls) and a feedback system. To recognise the peculiar situation of every project, it is recommended that part of these professionals have a good understanding of the social background of the area (former public employees, experienced advisors and community champions) and existing good relations within the community. Overall, PCM aims to anchor the authorities as part of the social system of a community and willing to be flexible towards their need, while maintaining the current general practices of project development and governance.

Public Tendering (PT) would imply the allocation of a permit for the development of a wind park in specific areas of the zoning plan based on an open, competitive bid

system managed by the Provinces. The ranking of the applications would be designed to, among other factors, demonstrate the involvement of communities in the project, with a required endorsement of the residents.
Public tenders are already a common method used for allocation of permits for offshore wind energy projects, and it is currently in the discussion to extend the approach to onshore projects (Vladmiks, 2020). Compared to offshore wind, onshore projects have less defined siting options, but the involvement of communities in the siting decision would possibly facilitate the definition of suitable locations. A centralised approach to the allocation of the permit would allow to Provinces to evaluate the impacts of possible projects while considering alternatives and plan in advance for additional capacity to the grid.
While adopting the normative framework for tenders, there would be the possibility to embed resident's needs in the scoring criteria. The approach proposed by the value-based analysis would suggest requiring a formal endorsement of a project from a community to be considered suitable for a permit. The sentiment is already shared between roles in some Provinces, as Astrid Vlaminkx, coordinator for wind energy projects in South Holland mentioned: "*We want to work with firms that share the concerns of the public*". To formalise the aim of government into the public tendering process would foster collaboration and create early collaboration between both public and private sector in respecting residents' needs when proposing a project to authorities.

Lastly, **Co-Design and Co-Ownership (CDCO)** implies a higher degree of adoption of the suggested design requirements from the value hierarchies - up to completely redistribute the ownership models of wind parks. Taking an approach to project development similarly adopted within local energy initiatives (Proka et al., 2018), CDCO suggests to empowers communities to become major shareholders of the wind projects that will be developed over the surrounding areas.
Compared to PCM and PT that conceptually stem from the current status quo, CDCO takes inspiration from the positive experiences and case studies of local energy cooperatives such as Windunie. To facilitate the transition from the current models, the suggested approach propose participation schemes that include players from the private sector to obtain minority shares in the cooperatives. This is brought forward with the establishment of a separate entity (*Stitching*) and executive board to oversee the project development and execution, with seats allocated to representatives from both public and private sectors. The board would then provide sign off for decisions regarding the development of the park, and through the majority of shares held from community representatives, the interests of historically underrepresented stakeholders would be ensured relevant.

The three pathways described above and in figure 4.17 summarise briefly possible future developments of onshore wind energy project planning and development. The implications of each are ramified and the impacts on the stakeholders are yet to be determined. While a "softer" solution as PCM could ease the most immediate issues in calming the residents suffering from severe stress due to the nuisance, it may not solve the longer term issue of lack of participation in decision making. By providing means and opportunities to local stakeholders to join and share the success of the project, a stronger sense of ownership can be created to enable further progress in the energy transition.
Similarly, a radical passage to a more "intense" pathway as the CDCO may lead to a lack of preparation in the planning and execution of projects. The process has historically been owned by a specific set of private firms, who at the moment have most of the intangible capital (networks, access to financing, know-how) and financial means. New players from the residents' group would have little to no time to navigate the difficult internal dialogue within the community and the situation could hinder the needed added onshore capacity.

It is not a surprise that, as today, there is an animated discussion on the topic of onshore wind energy between the public and their political representatives. Both at the local and national level, different parties have completely different approaches on how to manage the policies and strategies for the implementation of wind energy projects in the country. While it is not in the objectives of the research, in the final chapter of this thesis, the conclusions will discuss the recommended pathways and their implications for stakeholders and the wider public.

Conclusions 5

In this chapter, the conclusion of this graduation project are presented to the reader. First, the findings from the research are displayed in relation to the initial problem statement. Secondly, reflections from the author are presented in relation to the methodology and applicability of Value Sensitive Design (VSD) methodologies in different context. Recommendations and further improvements in regards to the research problem are then formulated, and separate sections capture the key takeaways for researcher, policymakers and professionals interfacing themselves with the issue of public acceptance. Finally, the author elaborates on his contribution in terms of knowledge in the field, from the application of the VSD framework to the gaps highlited in the literature review. An afterword concludes the manuscript.

5.1 Answers to the Research Questions

The aim of this thesis has been to investigate the applicability of Value Sensitive Design (VSD) methods to address a very specific issue: the public and societal acceptability of onshore wind energy projects in the Netherlands. The implementation of this project is crucial for the future energy policy of the country (Ministry of Economic Affairs, 2016), but has been hindered by low rates of implementation since the first commercially viable options, falling short on national targets consistently (CLO, 2019). The issue of low acceptance from local population has been a widely studied problem, with many notable authors researching on the complex issue through extensive surveying of population samples, case studies, interviews and focus groups over the years. Since the 1990s, researchers analysed the issue of acceptance by initially focusing on the deterministic antagonism between individuals and the physical features of the wind turbines. The well-known "Not In My Backyard" effect (NIMBY) stems from the simplistic view that reduces the problem to an interaction between a resident and the technological artefacts (Van der Horst, 2007). Since then, analysts have realised that the situation is more complicated than that, and it involves multi-leveled networks of stakeholders, each holding different objectives and motives.

With the advent of the 2010s, the severity of the problem has increased rapidly. From one side, the effects of climate change are increasingly noticeable and governments have started defining trajectories for the decarbonisation of their energy generation sectors, and are desperately in need of low-carbon electricity production to meet their national pledges. On the other hand, with the advent of social media, increase in global wealth inequalities and a variety of local issues (such as the controversy on gas extraction in Groningen), local communities have become more hostile towards external implementation of wind energy projects, sometimes radicalising and acting violently towards project developers

(RTVNoord, 2019).

Due to the impending urgency of more wind energy capacity in the Dutch grid, and the need for an orderly execution, researcher and policymakers have been looking into possible design techniques for the creation of peaceful pathways towards a common goal. Value Sensitive Design, a theory initially applied within the ICT sector in America, has found to be possibly applicable to the issue of public acceptance of wind energy projects.

VSD's building blocks are so-called "values", loosely defined aims and objectives against wish various stakeholders base their decisions and behaviour. The theory features three key "investigations" to first define the values and stakeholders (*empirical* investigation), define how they interact and relate to each other (*conceptual* investigation) and how they are embedded in the artefacts or technology (*technical* investigation). The framework has been applied to photovoltaic installations in Finland (Mok and Hyysalo, 2018), the previously mentioned gas controversy in Groningen (Mouter et al., 2018), and other energy-related issues, together with wider research on how to apply the methodology to various energineering problems (de Geest, 2016; Maxouri; Iivari, 2019).

The main research question of this thesis, "**What are the values embedded in onshore wind energy projects in the Netherlands and how could they influence social acceptance?**", was answered through the four subquestion analysed during the manuscript. The subquestions have been designed to follow the methodology of Designed for Values, each providing a key piece of information required in a comprehensive analysis of the relation between values and public acceptance of wind energy projects.

1. How is public acceptance defined in the context of wind energy?

As analysed in chapter 2, the notion of public acceptance has evolved significantly over the years and reached maturity in recent publications. The initial approaches of a utilitarianistic concept of acceptance, of the sentiment from a well defined single group of individuals towards a single technological artefact, evolved to encompass a wider range of stakeholders, sentiments and processes. In order to answer this research question, to take into consideration how wind energy can be described as socio-technical systems is crucial. Socio-technical systems, as presented in 2.2 are more than an ensemble of technical elements (blades, generators, transformers and electrical connections) but a wider network of actors, resources, culture and interests that shape the development, growth and implementation of the technology. With the analysis of the history of wind energy in the Netherlands in section 2.1, it is clear how the progress and implementation of the technology has been influenced heavily by groups of citizen, knowledge hubs, individual politicians and even historical backgrounds of geographical areas. The national debate of 1981-84 (2.1.2) and the Energieakkord of 2013 (2.1.4) are clear, defining moment when in recent history numerous actors where involved in the shaping of the direction, scale and acceptance of wind energy technology in the Netherlands.

In section 2.3, the main analysis on the concept of public acceptance is presented. The studies presented in the section focus on the actual "acceptance" of the technology are reviewed with a focus on the sociotechnical elements discovered in the literature review on sociotechnical systems. The definition of acceptance in literature developed over time from "*lack of resistance*" (Chataignier and Jobert, 2003), to consolidate around a multi-stakeholder broader perspective presented by Wüstenhagen et al. (2007). The review of publications on the subject by Fournis and Fortin (2017) provides with three possible approaches, each one with important considerations for the translation of intent into result:

- Wüstenhagen et al. (2007) introduces the Triangle of Social Acceptance, by providing a three dimensional perspective to acceptance. Three different stakeholders groups have different decrees of acceptance, and have different responsibilities and milestones. The approach has the merit of clearly defining three entities, decline them into practical objectives and has been widely adopted in literature and further research.

- Szarka (2007) pushes the notion of an evolving social contract between different parties. The overall decision making framework proposed by the author has a focus on interaction and choices in design and normative processes, of which acceptance can be the outcome when stakeholder's criteria are met.
- Fournis and Fortin (2017) further elaborate on the two definitions by proposing the concept of acceptability: a process of collective assessment that considers plurality of actors, spacial scales, and temporal dimensions. One of the possible outcomes of social acceptability can be social acceptance.

Defining public acceptance can be complex. The literature has now progressed to a point in which these complexities are translated into analytical frameworks considering many dimensions, and it is recognised that a techno-centric definition is no longer suitable to addressing the issue.
To answer the first research question of this thesis, using the theories, frameworks and instruments reviewed, a definition is therefore to propose a distinction between two different but complementary concepts: Social acceptability and Public acceptance.

Social acceptability *is the process of collective assessment of different entities of a sociotechnical system, where multiple processes take place on three main levels (micro, meso and macro) and may result in the successful social acceptance of a technology.* ***Public acceptance*** *is the outcome of these processes that take place on a micro-level, where the entity of interest is the social network of local actors. The impact of these processes can be analysed in terms of influencing factors.*

It is outside the scope of this research work to define the influencing factors of *social* acceptance of wind energy. While recognising and considering the interplay of the levels of acceptability in the local level, this thesis focuses on implementation of design and normative requirements that can foster *public* acceptance in a possibly pragmatic approach. Nevertheless, the notion of a multi-layered acceptability process has important implications on the local level, and these impacts needs to be taken into account when analysing public acceptance.

2. Who are the stakeholders involved in onshore wind energy systems in the Netherlands?

In section 4.2 of chapter 4, a landscape analysis has been carried out to identify all the potential relationship and networks that can influence the development of a wind energy project, as highlighted by both the methodology of VSD (3.2) and the studies on public acceptance of chapter 2. This is, as described by the STVM methodology and by the underlying SCOT theories (2.2.2) important to identity the incentives, motives, expectations and beliefs from actors - translating in the values associated with stakeholders. The landscape analysis outcome is a stakeholder map, presented earlier in the manuscript in figure 4.5. The graphical elaboration provides a high-level description of the actors that cooperate, interact and shape the sociotechnical system of the Dutch onshore wind energy sector. The "Private Sector", composed of archetypes of firms involved in development, operation and financing of wind energy projects is juxtaposed to the actors involved from the "Government and Public Sector" - a list of the main bodies involved in approving, regulating and facilitating the implementation of said projects.
"Research" presents an important but less connected quadrant of the map, as the institutions and research centres listed (e.g. NWO, ECN, TNO, universities) does not directly interact in the development or management of the project often. It was shown, however, in section 2.1, how these institutions played a key role in generating the required knowledge and technical understanding that now is the foundation of every wind energy projects. RD is still a crucial part of the strategy that is guiding the transition of the Dutch energy sector, and therefore the joint efforts of the private sector and these organisation is a relevant part of a landscape stakeholder analysis.
Important for the value-based analysis, a group that is often considered only marginally

is the residents and actors (van den Berg, 2020). While the firms and government bodies can be identified on a landscape level, subsets of actors are heavily case-specific. The historical background of communities in specific areas is to be taken into consideration. In villages of South Holland, pre-existing local cooperation networks have developed since the early 1950s to foster agricultural partnerships (Vladmiks, 2020) In the northern provinces of Groningen and Drenthe the sentiment of distrust towards the central government is historically rooted and retrace back to issues with territorial claims between the Netherlands and Germany (van den Berg, 2020).
For a relevant analysis of the local situation, we need to shift from the notion of *lanscape stakeholders* to *project stakeholders*. The information is captured in the stakeholder map with the listing of actors archetypes: we do not expect every case-specific project to have the same subset of residents or groups, the information listed in the map provides guidance for an external assessor with the structured information relevant to identify and map the participants of the process.

To provide more information to the research exercise on the acceptability of wind energy, the conceptual tool of the *influence-interest* matrix was presented to map the different groups of stakeholders directly involved in the issue and the degree of importance they have in the situation. Presented earlier in the manuscript in figure 4.15, the exercise presents an asymmetry in power when it comes to comparable levels of interest: different groups such as project developers and residents have different "negotiating power" (connecting to Szarka (2007) social contract notion of acceptance) and therefore outcomes that favour specific groups are more likely to happen. The analysis of stakeholders sets a first step towards the adaptation of the VSD framework to wind energy projects, that is further progressed in the next research sub-question.

3. What are the values associated with public acceptance of onshore wind energy in the Netherlands?

To answer this research question, multiple segments have been analysed in this research thesis. In chapter 3, a selected number of frameworks and theories that include values as key element have been presented and analysed, introducing first the interplay between ethics and technological development. It is later studied how these theories can apply to wind energy, and in chapter 4 the value-analysis of Dutch onshore wind energy systems is presented.

Responsible Innovation (RI) is the first domain introduced and encompasses as a broad umbrella term the studies and publications shown the characteristics that an actor (organisation, business, individual) should follow concerning innovation for it to be considered "responsible": van den Hoven et al. (2015) introduces the duty to collect as much input and information as possible, and to process it in terms of moral and ethical values. Ortt et al. (2020) attempts to draw a definition of RI in large technological systems and define a shared set of characteristics within the literature: predictive and iterative, helpful, ethical, inclusive, impactful, responsive and open.
This is further explored when presenting the frameworks of Value Sensitive Design (VSD) and Design for Values (DfV), disciplines with similar names and similar underlying assumptions. DfV, compared to its more ICT-oriented counterpart, has been developed by Dutch authors and has found to be applicable within the context of emerging technologies or niche applications of it. The question of the applicability to an established, increasingly implemented energy technology like wind turbines is valid, and therefore discussed further in the reflection of this thesis.

One of the main takeaways from chapter 3 is the research tool of the Socio-Technical Value Map (STVM), developed by Pesch (2019) based on the initial framework proposed by Rohracher (2002). Considering technology based on its incorporation in the sociotechnical system and including a specific focus on values as part of the analysis, the STVM aims to serve the purpose of mapping complex sociotechnical systems.

The value map, third component of the STVM, is the main approach chosen to an-

swer this research subquestion.Th value map is used to summarise and collect together the information gathered by analysing the technology, landscape and stakeholders in sections 4.1, 4.2, and earlier in 2.1. Bringing a coherent interpretation of the values embedded in a technology and those brought forward by stakeholders, the value map aims to give concrete translations of these findings (Pesch, 2019).
The five identified values, being drivers for most of the behaviours of the stakeholders involved in onshore wind energy systems in the Netherlands are:

- **Profitability**: the aim to obtain a profit for the overall project development and operations of a wind turbine;
- **Well-being**: the aim to maintain and improve the mental and physical state of individuals living in the proximity of a wind project;
- **Sustainability**: the aim to preserve the natural resources and environment of a specific area in a long term perspective;
- **Fairness**: the aim to ensure fair and just process and distribution of value between stakeholders;
- **Trust**: the aim to foster a relationship of mutual respect and understanding between stakeholders;

These values have been identified through literature review (sources presented in table 4.3), interviews with stakeholders (Appendix A 5.4) and the technology and stakeholder mapping carried out in section 4.1 and 4.2.

The results of the value analysis are presented graphically for each values in figures 4.7, 4.11, 4.12, 4.9, 4.8, in the format of a Value Hierarchy. Value Hierarchies are vertical representations of a specific value and its underlying norms and design requirements. To summarise the results of these five values, a circular value hierarchy has been created and presented in figure 4.13, to provide the basis to answer the last research subquestion of this research project.

4. What value-based design requirements and initiatives can influence social acceptance of future onshore wind energy projects?

The answer to this (fairly ambitious) research question is equally a combination of the design requirements identified in the design requirements of the value hierarchy presented, and the understanding that came with the literature research on the concept of public acceptance: that there is not an unique solution for the problem. Every project includes different stakeholders, has a different historical background and networks that formed over the decades, different technical specification for the project and interaction between stakeholders. The attempt of generalising the problem is discussed later, but it is important to note that public acceptance, as one possible outcome of social acceptability, ca be fairly different for each project. Outcomes and process' perception can vary depending on who you ask.
While it may seem initially disappointing, and the limitations of this research are further discussed in the Reflection section, some initial solutions are drafted in this research and presented.
Three approaches are presented at the end of chapter 4: Proactive Community Management (PCM), Public Tendering (PT) and Co-Design and Co-Ownership (CDCO). These are not to be intended as ready-made solutions, but rather initiatives and approaches that can be considered and studied to work on specific values of the analysis presented earlier. The three approaches have been obtained from the combination of various design requirements and recommendations from the value analysis, and are presented in figure 4.17 in increasing order of distance from the current situation.

- **Proactive Community Management** can be described with the implementation of more proactive practices in community engagement from wind energy project developers. It does not significantly transform the current governance structure or planning of projects, but suggests implementing many "good practices" of community management. The recommendations developed by NWEA and presented in their Code of Conduct falls in this objective.

- **Public Tendering** suggest the allocation of a permit for the development of a wind park in specific areas of the zoning plan based on an open, competitive bid system that includes and priorities the plans to include local residents into the decision making.
- **Co-Design and Co-Ownership** suggests to completely redesign the ownership models of wind parks, providing the legal, financial and governance frameworks for local actors to co-own the energy projects that are operated in their area. Taking an approach to project development similarly adopted within local energy initiatives (Proka et al., 2018), CDCO is the third and fairly more radical redesign approach suggested by this thesis.

The three pathways proposed above and in chapter 4 are the result of the top-down design exercise that used the Socio-technical value map as its main tool, the theories of Responsible Innovation and Design for Values as guidance and the literature on public acceptance in wind energy as overarching compass for execution.
While this work provides an initial answer to the research question, it is equally important (if not more, for this work) to recognise the limitations to these answers. The factors that could hinder the successful implementation of a wind energy project are many, and this thesis work does not intend to show these three proposed approaches as final solutions, but rather as examples of value-based solutions to be taken into consideration. Bringing a value-based sociotechnical perspective into design can advance progress towards a more sustainable, fair future of wind energy project development.

To summarise the answer to the main research question: the five values found to be instrumental in onshore wind energy projects in the Netherlands are Trust, Fairness, Sustainability, Profitability and Well-being. A value-based perspective applied to the design of solutions and processes is suggested to be potentially helpful in addressing the key issues of public acceptance. More work is due in analysing how individual actions and initiatives, if designed with a value-based perspective, can influence acceptance from residents.

5.2 Reflections

In this section, complementary to the answer of the research questions, a reflection on the methodology and on the results of this research is presented. This will lead to formulation of recommendations for further research and other stakeholders, concluding the scope of work of this graduation project.

5.2.1 Reflection on the methodology and recommendations for further research

Considerations regarding the methodology, frameworks and theories used in this research problem are the first imperative to be discussed. In the introduction to the problem, in chapter 1, the relevance of Responsible Innovation and VSD are presented together with the increasing uptake that these theories are experiencing, in term of numbers of citations (figure 1.2). While it is undisputed the relevance of these disciplines, a fair question is if these frameworks are well-suited to serve the problem of analysing public acceptance in wind energy.
In section 2.2 is clearly discussed how wind energy systems are to be considered not only as a set of finite artefacts, but rather as a network of actors, tools, policies and shared expectations towards a technology that is clearly more than a rotor and a steel structure. As IC technologies are more than a user and a device, wind energy systems are more than an user and an energy source. The relevance of the ethical dimension to wind turbines is

further developed in that chapter, where issues towards the acceptance of implementation of wind energy is presented with a handful of cases from literature.
While the link between wind energy and the need for more than a technical analysis is strongly defined there, the question of which framework can be applicable to the situation still stands. Has the choice for application of the DfV methods, including the STVM, been suitable for this work?

The evidence, before this work, has never been indisputably strong. Only a limited selection of previous work focused on wind energy and values. Oosterlaken (2014a), in the work "*Applying value sensitive design (VSD) to wind turbines and wind parks: An exploration*", has been the first to test the hypothesis that this methodology could be applicable to wind turbines. In the recommendations, the author recommends to further study this method an application to sociotechnical systems such as wind farms, and that more case studies would have been useful for the analysis. Following this challenges, this research thesis looked at the case study of the De Drentse Monden en Oostermoe wind park, whose residents and stakeholders were interviewed. An additional aim was to expand the boundary of analysis from a single wind installation, to a farm, to the entire Dutch onshore technological and social landscape. Fairly ambitious from an academical perspective, to be taken on board in a single graduation project. A first, intuitive recommendation would be to follow Oosterlaken's advice and gather more case studies and data for a more comprehensive analysis, that was not taken into consideration in this work for reasons of brevity.

The presence of only one publication that clearly mentions the application of VSD to wind turbines is not a strong evidence for why this should not have been scope of work for this research. The opportunity to explore the framework and expand on previous work, was supported by the results of another publication on the applicability of VSD to energy systems from Mouter et al. (2018). The research states that *"that it is not only possible to apply VSD in the design of technical artefacts of a new technology, but also in an existing socio-technical energy system"*.
However, the lack of more work done on the framework in regards to wind energy led to the results of this work to be more exploratory than what it could have been.

Following the brief reflection on the applicability of VSD theory to wind energy projects, an interrogation of the suitability of the use of the sociotechnical value map is needed. Pesch (2019) states that *"the only restriction for choosing a technology is that the STVM has to address a technology that is in development"*. The definition of "in development" technology is fairly subjective, and the author himself remarks that *"it will in general be clear whether the societal uptake of a technology has reached a stage in which any further intervention in its trajectory seems senseless"*. This comment, and the clear gap to target in the national implementation strategy of wind capacity (CLO, 2018), define the reasons why wind energy has been considered, for the scope of this work, a technology in development.
However, the application of the STVM tool would have been considerably easier in the context of a technology *more* in development, with more specified niche markets, considerably less numbers of stakeholders and a less complex issue of acceptability. In order to model the issue of acceptance of wind energy through the STVM, many assumptions and simplifications have been done throughout this thesis work, such as the boundaries of the stakeholder map. However, the mandatory simplification hinders the successful analysis of social acceptability, that has been demonstrated to be a complex, multi-layered issue in section 2.3.
While defining the methodology for this research, no other frameworks were identified to be suitable for the analysis, as much as the STVM. The framework fit well with the issue of many different perspectives and voices that were found critical in the issue of public acceptance of wind energy. However, there is to be recognised that possibly different frameworks may be more suitable for analysing a technology that is already so well-developed and integrated within the social tissue of a country like the Netherlands. Or, more instruments and theory must be brought in to support the modelling of complex human behaviour. The research on public acceptance of wind energy needs to be

multi-disciplinary (Oosterlaken, 2014a), and possibly more expertise and theories need to be drawn from other subjects.

Secondly, a reflection is needed on how the data has been gathered for this research work. While the majority of the information that has been gathered for this work has been through desk research, a limited number of interviews have been carried out with a number of actors involved in a wind development projects in the north of the country. These interviews were not recorded, but notes have been taken and reports are added in the appendix. This was due to the nature itself of the interviews, more conversational than structured, and the language barrier that arose in some cases [1]. In similar research work that has been analysed, data from interviews follows a defined structure, is recorded and transcribed clearly and is accessible, as best practice for obtaining primary evidence. This was not possible for this work, and therefore interviews are not used as well as they could have.
Another identified issue is the sample size of the primary data gathered. While impossible to interview all the stakeholders of a wind energy project due to time constraints, the selection of the sample was more based on the limited availability of interviews than on a rigorous research method. In future work, if following the same methodology and with the intention of relying more heavily on primary data, it is suggested to increase the sample size and cover all the groups of stakeholders in analysis. For this work, a representative from the government, one from research, one from cross-sector organisations and four from the residents were interviewed formally. The small number of individuals and the lack of representations from the private sector are an important improvement point for further work.

Due to the issues listed below, this research mainly focuses on secondary data and information, gathered through desk research. This is deemed suitable for the scope of the work, and provided enough material to answer the research questions when combined with the limited primary data, but a more systematic approach could have been used that is worth discussing here.
When mapping the values to answer the third research subquestion, the five identified principles were retrieved from literature. Numerous reports and cases of public acceptance were identified in the Netherlands and other countries, and the analysis has been possible with an informed review of existing materials.
In similar work, for example the VSD analysis of smart grid systems in the UK from Maxouri, data has been collected directly from primary sources such as national newspapers. The methodology allows for the collection and analysis of large quantities of data, therefore allowing for possibly more solid results. However, as the author herself reflects on the subjectivity of the journalist of the news sources analysed and suggest to include a broader range of stakeholders. The codification approach is however suggested to be considered for further analysis on the topic, as a way to obtain a primary dataset to support the value mapping.

5.2.2 Reflection on the results and recommendations for stakeholders

In this section, a short discussion over the results of the application of the framework is carried out. The aim is to provide context for the exercise carried out, justify and evaluate the assumptions and discuss the applicability of the work for professionals involved in the wind energy sector, such as project developers and policymakers.

The initial objective of this research has been to facilitate a discussion between different perspectives towards a common problem, that is causing diverse issues for a large groups of stakeholders. Initially, the research problem was developed while carrying out research for one of the leading Dutch engineering consultancies, that has contracted major work in many wind energy projects in the country. The initial perspective has been from

[1] In two instances, the interviewee did not speak fluent English. With the thesis candidate not speaking fluent Dutch, this led to the interview being facilitated by a third party. This concerned only a limited number of interviews.

a project developer, that aims to provide meaningful, high-quality work that is not only profitable for the firm but bring positive impact in the community. When faced with resistance, not only private firms experience significant delays in project delivery, but often fail to respond properly to other stakeholders. There is a lack of accountability for the shared responsibility of the project development, that often in signed off from the local authorities.
This project was started with the initial perspective to add value to the private sector by define frameworks for action over non-financial impacts of project development, such as local resistance and other aspects of stakeholder management.

While analysing the issue within the broader perspective provided by the literature on public acceptance, it is clear that it is an issue that cannot be approached effectively by working with a single group of stakeholders. An intervention from the private sector can possibly be productive in a specific case, but it will be ineffective if it does not influence the wider network of actors.
Therefore, the scope of this research work was expanded to encompass other major actors in wind energy development in the Netherlands, such as local, regional and national authorities, and academia. The conclusions of this research need to take into account solutions that can be useful in a wider, societal perspective. The aim of this research, as stated in the problem description in chapter 1, is to provide *actionable suggestions* for stakeholders to manage the issue of public acceptance of wind energy.

Whether this has been achieved, is up to discussion. This cannot be verified in a simple manner. In chapter 4, suggestions have been brought forward for a redesign of the processes and facilitate a more just approach to governance and development of wind energy projects. These three main pathways, together with the value hierarchies presented in the same chapter, are the result of a theoretical research exercise, and therefore subject to simplifications that offsets the theoretical model from the reality of a situation. The suggestions brought forward, as per the tile of this research work, are the results of an *exploration*, and four main considerations need to complement them.

1 The issue of public acceptance has numerous dimensions: it expands over a large number of stakeholders, different values or objectives, potentially limitless courses of actions and a temporal dimension where past initiatives can influence future development. Therefore, there is not one fit-for-all solution that can be brought forward.

2 For the same reasons, even if it existed one sole solution to the problem, it cannot be actioned by one single actor in the network. Solutions need to represent multiple actors involved in the issue, to act upon the multiple facets of acceptance and leverage the different interests involved in the system.

3 The possible solutions may imply redesigning completely the current systems and processes, facing therefore various levels of internal opposition. This challenges the time and resource constraints that are often present in the private sector, and existing norms and regulations from the public sector, often slower than the private in changing its modus operandi.

4 It is virtually impossible to propose a solution that will satisfy every single involved individual or organisation. The aim of a possible solution is to increase the implementation by increasing the acceptance of wind energy projects to a degree in which is possible proceed without major disruptions. While possibly all the perspectives need to be taken into account, a solution brought forward will need to address the majority of them, without systematically ignoring the needs of one stakeholder group but accepting individual "acceptance outliers".

The first three considerations above are consistent with the principles of Responsible Innovation presented earlier in section 3.1, while the fourth one aligns with the literature

on public acceptance reviewed in chapter 2.3 [2].
The framework of Value Sensitive Design, and the results from this thesis, are recommended to be subject to this four considerations when applied to public acceptance of wind energy projects.
Therefore, three upshots are brought forward following the above considerations:

1 To be aware of the context and to develop a reasonable understanding of the social landscape in which the problem is taking place;

2 To facilitate dialogue between different groups of stakeholders, and where possible create cooperation. When conflict arise between the underlying objectives of different groups, the opportunity to discuss the true nature of disagreement should be encouraged;

3 To be open to change, redesign and collaboration;

5.3 Contribution

This research project aims to explore the applicability of the Value Sensitive Design frameworks in the implementation of onshore wind energy projects within the national context of the Netherlands. The thesis provides a comprehensive analysis of the sector following the VSD methodology, using the Socio-Tecnhical Value Map tools to map the processes, technology, stakeholders and values that influence the public acceptance from residents. This research is unique as it brings forward the first-of-kind value analysis of wind energy projects, backed by an in depth research on the sociotechnical background, including frameworks for public acceptance and historical analysis of the sector. Additionally, the conclusion of the project brings forward actionable approaches for fostering implementation, based on the outcomes of the analysis according to the theory's principles.

The work originates from a literature gap identified in the review of the applications of VSD theory to energy systems: only one publication is currently addressing the issue of public acceptance in wind energy using this promising frameworks. It was found relevant material concerning the application of VSD to other similar fields, such acceptance of smart grids (Maxouri), gas extraction (Mouter et al., 2018), PV installations (Mok and Hyysalo, 2018), to have a solid standpoint and enough foundation to justify the further exploration of wind energy acceptance. This work expands significantly the first exploration carried out by Oosterlaken (2014a) of the problem statement, where the theory is only presented and discussed: in this research thesis the framework of VSD is presented together with an in depth review of the theories concerning public acceptance, a significant amount of context provided into the historical development of wind energy in the Netherlands, and finally applied in its entirety to the problem. From a review of the relevant frameworks, the methodology is applied to analyse and create solutions to address the issue, in the first-ever attempt to use the methods to design new approaches to increase social acceptance.

This attempt builds on different segments of theories that have been brought together, in a multi-disciplinary approach:

- Literature on public acceptance of wind energy;
- Literature and theories of Socio-Technical Systems (STSs);
- Historical background and social context of wind energy in the Netherlands;
- Literature on ethics of technology;

The main conclusion of this thesis are obtained by applying the methodology of the STVM, by mapping the procedural processes, technological design, stakeholders and

[2] And from the experience of various professionals interviewed for this research. It has been referred as "common sense" when dealing with large groups from the public.

values identified in relation to the problem statement. The contribution to research from the author goes beyond the successful use of the instruments provided by the theory, but further adaptation of established notions to fulfill the needs of the research. The concept of Value Hierarchies, widely used in literature, has been adapted to satisfy the need to take into consideration multiple values simultaneously, introducing for the first time a circular variation that presents the interplay and interdependencies between different values' norms and design requirements.

The author's conclusions are presented summarising the results of the extensive analysis that went into the process. However, recognising the limitations due to both the complexity of the problem and the nature of the methodology, the conclusions are accompanied by further considerations for stakeholders. The aim of the thesis is to provide actionable content for readers, and the hope is for readers to have obtained an understanding of the complexity of the issue of public acceptance, learnt about the various dimensions on which it can be measured and tackled, observed one of the possible frameworks that can be of use in dealing with the issue, and finally adopted a value-based mindset to be brought in their professions.

5.4 Afterword

The problem statement of this graduation project was initially drafted in December, 2019, in collaboration with various professionals that work on a daily basis on the issue of public acceptance of wind energy in the Netherlands. It has been then refined and went through multiple iterations, after consulting with professors from the Technical University of Delft, both from the Wind Energy Institute and the Technology, Policy and Management Faculty.

Since 2019, the approach taken towards public opinion in the Dutch wind energy policy implementation has changed slightly, but key issues remain in plain sight. The debate surrounding new wind energy projects reached new levels in 2020, when a public consultation took place for the development of new energy projects around the area of Amsterdam (NOS, 2021). Due to the COVID-19 pandemic, the meetings took place online, where citizen could express themselves freely and local authorities where not prepared for the backlash that followed. In May 2021, in the middle of a national health crisis, large groups of citizen voiced their protests toward the project, collecting almost 20,000 signatures to stop the development. It can be argued that that number of signatures is small compared to a city with more than 820,000 taxpayers. However, the public protests and news mentions indicated the relevance of the issue.

There have been, however, interesting developments regarding the solutions analysed in this research work, in particular focusing on Co-ownership of energy projects. Under the European Green Deal, the European Union has put significant emphasis on community energy, with a directive stipulating that all member countries enact laws that make community energy possible in their markets (Hockenos, 2021). The European Commission estimates that by 2030 citizen-run energy cooperatives could own 17 percent of installed wind capacity, and is suggesting to do so by enabling the same financial incentives for both corporations and groups of citizen.

In the Netherlands, the issue of public acceptance of wind energy has become largely discussed within the context of the national election, held in March 2021. Representatives from different parties of the Dutch political spectrum agreed on the importance of wind energy, while disagreeing on how to reach the ambitious targets set for the country. Without going into the details of which parties where supporting which policies, major groups in the election where championing the concept of co-creation and ownership of public wind energy projects, encouraging public consultations to discuss not only the single projects' development, but the wider Dutch energy strategy.

On the 30 June 2021, zoning plans for onshore wind developments in the Netherlands will require a more comprehensive environmental analysis that includes noise and shadow flickering, two main influencing factors of public acceptance, as described in section 2.3.2. The judgement from the Administrative Jurisdiction Division of the Council of State follows an European Law introduced one year earlier, and specifically concerns the zoning plan 'Windpark Delfzijl Uitbreiding' and the environmental permit for the construction of sixteen wind turbines in Delfzijl, in the north of the country (Windpower.nl, 2021). While this is to be considered significant progress towards the inclusion of aspects that could influence the well-being of residents in the vicinity of a wind farm, there is still uncertainty in how these environmental assessment will be regulated in the future.

As of today, the Netherlands missed the national target of 6,000 MW by 2020, achieving only 70% of the scheduled capacity. Progress has been made towards a value-based approach to wind energy projects development, but major challenges are still ahead of the country in regards to its sustainability objectives.

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Appendix A: Interviews with stakeholders

The following interviews have been carried out during the period of my graduation internship at Arcadis, under the supervision of Erik Koppen, Senior advisor of Noise and Air Quality.
The following interviews were not recorded, no audio file of the conversation is available. The interviews were not structured, the approach chosen has been of a open dialogue between interviewer and interviewed, in order to obtain their unique point of view. Notes were taken during the conversation, with the approval of both parts, and the following summaries hve been written after the interviews took place.
All the information reported in this appendix are based on the aforementioned notes and external sources provided by the interviewer. The accuracy of the information is not discussed or analysed.
The summaries has been sent to the interviewers for approval of the content, phrasing and detail level.

Appendix A1: Residents of the area surronding windpark De Drentse Monden en Oostermoe

The results of this interview have been anonymised to protect the quality and accuracy of the statements.

A1.1 First interviews

Friday, 7th of February 2020
Gieterveen, Aa en Hunze, Drenthe.

P. and K. are living in a house they purchased in 2006 after moving from Utrecht, looking for a quieter lifestyle in the countryside of Gieterveen. Around 2010 they discovered about the plans of developing a wind farm project next to their residence, and followed the process until now, winter 2020, when the construction of the site is starting.

Process

In 2010, the regulations for building wind farms in the Netherlands changed, reducing the possible distance between wind turbines and households to a minimum of 500 meters. Less distance is possible if the household belongs to a Wind Farmer (owner of the land in which the wind turbines are placed). After this change in regulations, 3 different groups of farmers contacted the authorities in order to set up three different wind energy projects in the area of Drentse Veenkolonien, in the municipalities of Borger-Odoorn and Aa en Hunze.
They reached out the authorities without informing or asking the local community about their inputs on the project.
The authorities foreseen the problem that this projects could have caused with the resistance from local communities, and advised the farmers to combine the project in a single wind park, in order to reach the threshold of >100MW and assign the responsibility of the approval to the national government.
As today, the project consists in 45 Nordex N131 wind turbines placed in the area of 50 squared kilometers, as shown in figure **??**. The axle height of the windmills is 145 meters. The rotor diameter is 131 meters. The tip height - the highest point of the mill when a wick stands upright - is 210.5 meters. The size of the whole project should be of around 171 MW.
According to Dutch Law, residents should be informed when the assignment of a specific area of the territory is labelled as “Search Area” for wind energy project, before starting planning. This did not happen for this area. Moreover, the farmers and the authorities were trying to keep the project secret, in order to make progress without resistance from the local population. As example, one of the current residents, in 2012, bought a house in the area; before finalizing the contract, authorities were interrogated about the possibility of future projects in the area. The municipality stated that nothing was in the plan of the development, and the property was bought. Three months later the new residents found in their mailbox a flyer informing about the plans for the new wind park. This happened because the plans for development were not in the municipality plans, but on a national level documentation, highlighting a total fragmentation of information and critical misunderstanding between population and authorities.
As mentioned, in 2012 the first contacts were initiated with the residents through flyers in the mailboxes. An informative session was organized to inform the population, but the message conveyed from the owners of the land and the developers was that there was nothing that the resistance could do, since they were supported by the national government. This negative attitude upset the attendees of the event.
Since many residents had an insurance that covered legal actions, they started a crowd action toward the project. Various crowd actions backed by lawyers took place in the area, collectively organized.
In March 2018, the final decision from the High Court of the Netherlands was that the project would have happened, rejecting the case created by the residents. According to various interviews, this is due to the fact that the court checks the compliance with laws

and regulations, without taking in considerations the social aspects or claims from the population.

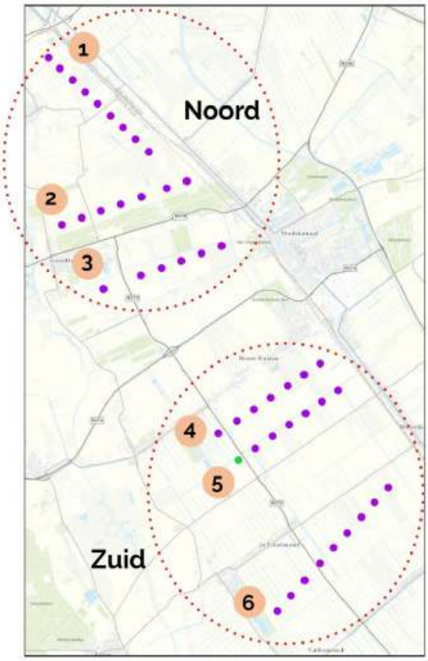
OmgevingsAdviesRaad (OAR)

The OmgevingsAdviesRaad (OAR) is an council formed with the participation of local residents, in order to represent the interest of the population and supposedly inform them about the developing plans of the wind park. Misunderstanding of the role of the council has been identified in various interviews, for example when the municipality was asked to inform the population about the transportation routes for the concrete for the site. The municipalities stated that this task was in charge by the OAR, while this was not the situation.

The OAR is also in charge of receiving financial funds for the community to compensate them for the existence of the wind park. These financial support has various streams, which have been identified in:

- Fee payed by the wind farmers (approx. 0,50 EUR/MWh, minimum)
- Support from the municipality
- Support from the Province
- Support from the National Government

The amount of financial availability was not disclosed during the interviews.
The idea of using this funds is to compensate the residents living close to a turbine, due to the depreciation of their assets, build walking alternative walking routes that won't be impacted by the wind park and plant new trees, in order to reduce visual and noise nuisance.



The windmills are in six rows. Green dot is the first built pilot project

Issues identified

Interference with ASTRON

Due to the low radiation and quietness of the area, the Dutch Institute for Radio Astronomy (ASTRON) is performing observations and measurements through high technology systems that could be impacted by the low frequency. These measurements are part of a Europe-wide network of thousands of highly sensitive radio antennas researching the universe. Electromagnetic radiance from the wind turbines generator could impact the quality of the measurements, causing noise and interference. The manufacturer, Nordex, assured that their generators are protected and will produce a minimal level of electromagnetic interference, which is physically impossible.

Visual impact

The high number of elements of the wind farm and the closeness of the turbines to the households will impact the landscape view from numerous windows. Moreover, since most of the houses have gardens, the view of the wind turbines will be always present. The closest house is around 350 meters from a wind turbine (owned by wind farmers, allowed by regulations). P. and K.'s residence is approximately 900 meters from the closest wind turbine. In figure **??**, below, a graphic simulation of one of the views from the village of Nieuwediep, close to the icon "1"in top left, in figure **??**.

Simulation of landscape from Nieuwediep, available on the website.

Sound level assessment for regulation

There are concerns on how the sound level for the permits is calculated, and how the local authorities monitor the noise production. According to one of the residents, the assessment is done by averaging the noise level on a year time span. This is not optimal in the resident opinion since it would be misleading and not representative of the true situation that will occur after the turbine is installed. No validation of the simulated data is reported.
Another concern is regarding the monitoring of the sound levels from the local authorities, that supposedly are collecting electricity production data from the operator and calculating once a year the noise level that the residents experienced. There is no transparency on the process and no trust from the residents that the authorities will enforce the regulations on the operator. A compensation fee is given to the local authorities by the operator per hour of higher noise than allowed, allowing the turbine to break the regulations in order to maximize the energy production, at the cost of a fee (no information on the value of the fee was found).

Low Frequency Noise

Both the residents of the house described their fears for low frequency noise impact on their health. Various examples of experiments on the human health have been narrated showing concerns for headaches, unusual tiredness, lack of concentration, irritation and loss of sleep. Examples were reported from Germany, where a subject of the experiment was faced with nuisance from LFN even from 2.5 kilometres from the turbine. This concern is caused by the discrepancy of different sources, that carries different information: some publications agree on health effects, some others not.

Property depreciation

A great monetary loss has been reported by the residents in terms of depreciation of the property bought in the area. According to the authorities, this depreciation would be of around 2.5% of the value of the house and land before the wind park would be built. Disagreeing with this estimate, the residents believe the depreciation is between 2.5% and 9% of the initial value. An investigation is currently being done by an external agency, and the results should be ready in the second week of February. More data will be added when the number will be communicated.
Some residents of the area moved out in the last years, selling their properties if possible. Numerous houses are currently on sale in the interested area, with low prices due to the project being executed soon. Few examples of houses that are impossible to sell have been reported, due to the extreme nearness of wind turbines.

Military flight zone and radar interference

It has been mentioned that the area where the De Drentse Monden en Oostermoe wind park will take place is a military flight zone, with the problems that with the implications that this could have on the military of the country. Another problem that has been mentioned is the possible interference of the wind turbines with the radar systems used by various groups.

A1.2 Second interview

Friday, 7th of February 2020
Gasselternijveenschemond, Aa en Hunze, Drenthe.
J. is the third interviewed resident of the area interested by the De Drentse Monden en Oostermoe wind park. She lives with her family few kilometres from P. and K., and she is not part of the OAR group. She bought her property around 2011 and the distance of her house from the closest wind turbine is around 600 meters.

Process

More than the aforementioned process of the planning and approval of the wind farm, J. emphasised on the total lack of communication from the side of the farmers or the municipality regarding the project. Her main source of information was a local newspaper printed by the municipality, where a page is allocated for communication from the authorities to the residents. The nature of this mean of communication is outdated and not effective, due to the limited reach, short sighted and unidirectional nature of the information.
When information reached the resident and her family, various attempts of contacting the wind farmers were done, without response from their side. The lack of real communication between the owners of the project and the community made her establish contact directly with the developing company that were hired by the wind farmers to develop the wind farms. She has been in contact with the project leader and the manager of the logistics and transportation, in order to clear some lack of information regarding the road usage next to her property. When communication was established with the developers, a more proactive environment was created.
Due to the proximity of her house to the main road where the construction materials

would be transported, she was able to obtain information regarding the transportation schedule, number of vehicles, frequency and safety information, in order to ensure the well-being of her family. This happened only because she asked for the information.

Issues identified

Lack of Transparency, Tension

Similar to the previous interviewers, a lack of transparency was noticed in the planning and executing of the project. The wind farmers have shown a lack of good communication, possibly due to the tensions created between the community and the owners. In other wind projects in the Netherlands, in situations alike, violence and threats have been addressed towards the farmers and their families. It is in the common interest of everyone to keep the situation under control and make the best out of it, but she described the relationship between the groups as broken.
When confronted with more information from the developers, even if the project is going to damage her property, she described a feeling of relaxation from more transparency. In the situation where nothing can be done to alter the plans, more information and communication can lower the feeling of anxiety and fears in the community.

Traffic and Logistics

One of the main concerns for the resident is the use of the road that will be used for transportation of the concrete and elements of the wind turbines. This road is very close to her household, and not wide enough to allows the passage of two vehicles at the same time without using the terrain on the side. Without communication from the project leader, she was unaware of the frequency of transportation, schedule and routes, as probably most residents are.
The communication during the development phase of the project is important to ensure the minimum amount of nuisance and safety of inhabitants. This information should be communicated to schools and residents close to the traffic site.

Personalized Information

The amount of information needed differs by receiver. Two residents living in different areas of the wind farm are subject to different needs, situations and needed information. The overloading of information could be as damaging as the total lack of it, creating a lack of involvement from the population.
J. mentioned she is not a member of the OAR because the association represents the whole area, while her interest is more specific. She stated that the closest residents should have access to more information.

Other issues

This interview as well brought up common points discussed previously, like concerns regarding low-frequency noise health effects, loss of sleep, unfair revenue distribution and general lack of trust in the process. Nevertheless, a positive and proactive attitude in the discussion with authorities and developers could lead to reduce negative feelings and maximize the benefits for the residents.

A1.3 Third interview

Friday, 7th of February 2020
Nieuwediep, Aa en Hunze, Drenthe.
V. is the the fourth and last resident interviewed during this day. He is also the one living the closest to a planned wind turbine (around 500m) as shown in figure **??**, below. He is a member of the OmgevingsAdviesRaad (OAR) and has been living in the house from few years, since he moved in with his family. The house was a property of his father, whom was very involved in the negotiation for the wind farm, when it first started with the first plans, in 2004.

The interested road for logistics highlighted, shown with the resident's property

From other residents I got to know that he is very involved in the negotiation with the OAR, and he is an intelligent man who is trying to achieve the best for his community. He proposed some detouring of the planned logistics in order to have minimum impact on the community, but his proposals were not accepted by the developers.

Location of the three houses in comparison with approximate locations of Noord wind park. P. is 900m distant, J. is 600m and V. is around 500 meters

Issues identified

Remuneration Inequality, Lack of Trust

As member of the OAR and directed interested of the depreciation of the property, V. stated that the financial compensation given by farmers and government is not going to be even for the loss.
The wind farmers can gain from their land around 80 thousand euros per year while other residents are left with nuisance and almost no benefits. The idea of having a shared benefit with the residents could consist in free access to the electricity produced by the wind turbines, profits from the sale of energy or more subsidies from the government. The population should share the same profits as the company, since the resources used are common.
A deep lack of trust towards authorities and politicians has been found a critical aspect of the communication. Political representatives have been invited multiple times to visit the site and understand the situation, but they refused the opportunity and failed representing this share of the population, in order not to damage their career.
The information event that happened regarding the wind park development were reported to have taken place in a further village, not in the interested one (Nieuwediep) because of the fear of local tensions.
Overall, if the communication was more transparent and the responsible more honest, the situation would now have been less difficult.

Adjustment of the wind farm size

Initially, the turbines decided for the site were much smaller (hub height around 67 meters). When the project progressed, a new suitable model was identified, the Nordex N131, that had more nominal power and lower sound emissions. This news was perceived as positive from the population, that assumed the area would then be quieter due to the characteristics of the new turbines.
This did not happen, since in the objective of maximizing energy yield from the area, the number of turbines was increased, and the sound level kept at threshold level. This shows once again how the design choices for these wind farms are made with lack of empathy for the residents.

Conclusions and takeaways

The situation in the area of Gieten has been described as example on how *not* to develop wind energy projects.

A broken relationship between residents and authorities, as mentioned in various interviews, has impacted the wellbeing of most of the residents in the area, that now look for conflict with the authorities or maximize their own benefits. A general feeling of powerlessness has spread since March 2018, when the legal cause against the wind park was rejected, and the morale of the population went down.
The resistance group, now without the possibility to change the plans of the project, has decided to shift their focus to improving the quality of life of their neighbors, planning on how to adapt their lifestyle next to the wind park. A general feeling of anxiety and anticipation was found: various residents mentioned that they don't know what to expect from these turbines next to the houses.
Even if now it may be too late to help this community, relevant information can be extracted from this example on how to properly communicate with the residents, the importance of planning, the inequal financial redistribution and the polarization of the debate around possible health effects.
Three common aspects have been found in all the four interviews:

- Low frequency wind turbine noise concerns
- Lack of communication with developers and authorities

- Inequal financial compensation

When the financial support should be addressed by policymakers and politicians, the communication and transparency seem to be the true issue in this scenario. Low frequency noise is a topic that can easily start an endless debate between different sources, as usual happens with controversial topics that try to gain momentum based on people's fears, more than actual scientific work.
In one of the four subjects a high interest in the prediction of wind turbine noise has been revealed. This could be due to the scientific background that gave the resident a more in-depth knowledge about the issue of noise.
One of the four subjects pointed out the importance of communication during the development phase and specific information channels, possibly due to the nearness to routes used for the transportation of materials.
A possible revenue model for the service has been identified in the funding that the local population gets from the wind farmers. Further investigation needs to be done on the amount of contribution they receive, and about the ethics of the business model.

Appendix A2: Environmental sound advisor, Frits van den Berg

Monday, the 20th of January, 2020.
Enschede.
The meeting started with a brief introduction about the graduation project, the various stakeholderss involved and the market relevance of the problem addressed, the public acceptance of wind energy projects.

Process of developing a new wind farm in the Netherlands

In the national plan of the Netherlands there is a needed additional capacity to be installed from sustainable sources, this means subsidies and fed-in tariffs for new wind and solar energy projects. Regarding wind, various areas in the country have been classified in the country as potential wind projects development areas, based on the potential of wind speed, assessed through the wind energy atlas and other parameters.

1. Involvement of the landowners

The initiative to start a wind energy project could come either from landowners (usually farmers) or from a business, that could then contact the owners directly. The main reason why farmers are interested in these projects is the good economic benefit they gain out of it, consisting in a yearly fee from the operators.

2. Drafting of the project

A draft of the project needs to be prepared by either the farmers or the wind turbine developers. This draft needs to include various information, such as the number of turbines, estimated generated capacity, location and feasibility studies

3. Presenting to authorities

When a proposal is ready, it needs to be presented to the respective authorities in the area. It is interesting that the authorithy changes based on the size of the project. For less than 50 nominal MWs, the municipalities handle the permission, while for between 50 and 100 MWs it concerns the Province. For projects bigger than 100 MWs, the interest is national.
It has been noted that, the higher the responsibility goes (from local to national), the less there is empathy for the local residents. The local politicians (city council) is voted from the impacted community and usually is more efficient in representing small groups of individuals, while on a broader scale (province and national) the decision is more based on the compliance with the existing regulations (usually this kind of decisions can be considered "cold" from the population, reducing the feeling of trust towards institutions).

4. Public presentation(s)

Information events are then organized from the municipality in the format of info-evenings. The aim of these events is to invite the local community, inform about the upcoming plan and put them in contact with representatives of the project. Usually various groups are present in these meetings:

- Developers of the project
- Local authorities
- External experts (noise, shadow flicker, visual)
- Community of residents

One of the issues in these events is usually the attitude that the groups have related to the project. It is not unusual that the community perceive the explanation of the event as something they have no stake or power in. The practical concerns are usually ignored

by developers.
Another relevant issue is that the meeting is open for the population, but usually the reach of the event is limited, as it is promoted mostly in local newspaper. Sometimes it is advertised in a flyer left in the letterbox, but mostly in a radius of 1km from the site. The fact that the reach is limited to municipality level (newspaper) lead to a mayor part of the population left out and a general feeling that the plans are trying to be kept secret.

6. Public discussion

After the meetings, it is possible that the public debate ignites, and the question reach national level. Not only in the community there could be hard opinions against the wind turbines, for a broad variety of reasons, but also on national level there are groups that tries to oppose the development of wind energy projects.
It is possible that these groups try to reach directly the community, or that the residents contact them looking for more information. As the discussion can easily be polarized based on the emotional impact that the development of a wind farm could cause next to the household of someone, these national groups in various occasions tried to instill fear in the population. Nonscientific research, fake news and examples of bad implementation of energy projects can easily reach the emotional core of the inhabitants and shift the focus of the dialogue from the factual point of view to the emotional, causing polarization of the debate.

7. Drafting of a definitive plan and submission to authorities

In case during the period of the public discussion (that could last 6 to 12 months) changes are proposed to the project and approved (relocation of turbines, change of the turbine model, etc.) the plan is updated and submitted to authorities.

8. Allocation of a permit

A permit needs to be allocated by the competent authorities, based on all the relevant information for the project (environmental impact, appropriate sizing, feasibility and development plan. . .) and a vote from the city council.
It is interesting to note that the city council members are elected to represent the interest of the citizens and could be reached to answer doubts or questions on the implications of the project. They are usually required to gather feedback from the population and can play an important role in the giving of the permit. Provincial plans are usually more successful in receiving a permit, since representatives are more distant from local communities and they need to consider the benefits to the entire province, same thing as national plans. Their goal is usually to reach a certain amount of electricity production.

9. (Possible) Legal dispute

In some cases, after the allocation of a permit, local groups can consider starting a cause against the authorities/developers, if they believe regulations have not been followed or the project is harmful for the community, like in the situation of the Oostermoer wind park. This could lead to even more fragmentation of the relationship between community and project owners.

10. Development Operational phase

When all the beforementioned steps are done, the development of the wind project can physically start. Preparation of the site, building of foundations and installation of turbines will take place, and in few years the wind farm can be considered operating. At this point, the community can receive funds based on the electricity production or based on their proximity to the wind park, if this was discussed with authorities beforehand.

Transparency and engagement

For people to be engaged with the project, or receive it positively, they want to be taken seriously. Top-to-bottom decisions have a bad impact on communities, that feel external dominance in their own territory, threatening the lifestyle they spent years building through work and sacrifices.
A possible approach in this could be to change the focus of the information meetings described above to a more open minded roundtables, where it is possible to show the population the reasons why the wind turbine has certain designs and locations, manage relations with the community and involvement them in possible modifications to the initial plans.

Economic benefits

As payment for the nuisance and impact on their lifestyle, it is possible that wind farm operators give benefits for the local communities impacted. This compensation can be of various nature, for example:

- Una-tantum payment
- Yearly amount (usually for the lifespan of the turbine, sometimes less)
- Reduced cost of electricity
- Sponsorship of local initiatives

A remarkable example is the Noordoostpolde wind park, in the Flevoland province in the central Netherlands. There, the wind farm has set up various ways to support the local residents, through financial participation in bonds and shares of the wind park, a yearly amount of 10,000 EUR to five surrounding villages for the societal development, a resident's scheme for reimbursement of the energy bill and support to regional research initiatives. More information can be found at this link.
Literature highlighted how in particular situations an economic incentive can enhance the public acceptance of the project, as it gives back to the community means to increase their quality of living. Most importantly shows that the developers care for the wellbeing of the residents.
It is important to handle the communication carefully if an economic reward wants to be given to the community, in order not to make it look like a bribe, or that it is inclusive enough and not a pay-out to few individuals.

Windpark De Drentse Monden and Oostermoer

When describing situations of tension between action groups opposing wind energy projects, an example was brought up, of a planned wind farm in the north of the Netherlands. In the province of Drenthe, municipality of Aa en Hunze, a wind project has been planned from 10 years, and it is polarizing the local debate without starting the construction yet. The project is including 3 municipalities, around 45 turbines of 3 MW each and it consist of 2 wind farms very close to each other. The size of the project brought the permit to be a national-level decision and the community is disappointed with the project, it brought high tension in the residents and made them start a cause against the owners.
They lost the cause, and the building will start later this year. The action group of residents asked for a health study to be performed in the area, afraid of low frequency wind turbine noise. This fear is found in multiple groups of residents living close to wind turbines and it is possibly instilled by misinformation and national-level groups opposing wind turbine development in the country.
A possible solution for this kind of problem is, since the small size of the community interested, to have a mediator between the authorities and the citizens, someone that could show empathy towards their problem, knows the regulations and could negotiate the interest of the community in the project. Monitoring complaining is something that needs to be addressed, or a feeling of powerlessness will remain in the community, that will either disconnect from the authorities or act as a negative sponsor in future wind energy projects

Atmosphere stability hub height

Regarding the product of Arcadis, Dr. van den Berg shown enthusiasm and approval, he was already in touch with the developer of the product, and he approves on research to try to find a solution for this situations, to improve the quality of life of residents and provide better insights to developers about complaints.
However, few points were made on the model for noise calculations. One question was how to accurately predict the wind parameters at hub height. Logarithmic law can not be used to scale the quantities from the data to hub height, he stated, due to the inaccuracy of the law itself. He mentioned that from the data used for the model cannot now predict the accurate hub height data, in his opinion.
On another subject, a small discussion was held regarding the atmosphere stability and if this was implemented in the model. If the atmosphere is stable, so it discourages the vertical movement of air particles, there could be way higher sound level on the receiver ends. It was noted that on a field test, once there was a mismatch between prediction and measurement of +10 dB.
In his opinion, atmosphere stability needs to be included in the model, if it is not already.

Conclusions and takeaways

This interview provided important information in terms of the process of developing wind energy projects in the Netherlands. Dr. Frits van den Berg helped me understand and explained clearly the various steps part of the timeline of the development of onshore wind farms.
Overall, I believe this interview was a starting point for me to understand the wider problem of public acceptance, gather few examples and develop a critical reasoning towards bad implementation of wind energy project. In the focus of maximizing social value for all the stakeholders, developers and residents, we want to achieve something that needs to take in account all the steps and their criticalities.
This interview gave me a sense of direction, that was later finalized in the interviews with the residents of the area of the wind park De Drentse Monden and Oostermoer. Please refer to that document for other findings.
Regarding the product from Arcadis, we saw some improvement points, both on the technical and business side. We should understand how to fulfill the market need, taking in account a highly complex multi stakeholder system, where emotions and communication take part of the process as much as wind speed and decibels. A challenge that makes this work worth of a try.

Additional informations

- Wind farm noordoostpolder
- History of wind turbine sound assessment and policy

Appendix A3: Process manager at Provincie Zuid Holland, Astrid Vaminkx

Thursday, the 12th of March, 2020.
The Hague, Provincehuis.
The interview with Astrid Vlaminkx, process manager for onshore wind energy projects in the Province of Zuid Holland, took place in order to understand the role of authorizes in the country and their attitude and expectations towards resident engagement in wind energy projects. Being responsible for the permit allocation of new wind farms in the province and years of experience in the sector, the interviewed represented the point of view of a conciliator, between public and private interests.

Standard process

The first part of the interview was focused on understanding the standard procedure used in the majority of wind energy projects in the Netherlands, or at least the ones set up between 5 to ten years ago. Most of the content overlaps with other interviews, like the one with Frits van den Berg [1], but it is important from the Province point of view to mention their preliminary studies on the wind energy potential and spatial planning.
The outcome of the trade off between political choices and technical studies is the Omgevingsbeleid, that practically translate in the spatial planning of the possible sites for wind energy in the province. This map is publicly available on the website of the province, at this link. The maps include the areas that are suitable for wind parks development onshore and it's developed through a GIS system. Looking at the public maps, wind energy companies can reach out owners of the land (possibly farmers, or the authorities if the municipality owns the area) and start the negotiation in order to start a new project. The initiation can be also the other way around, with landowners reaching a developer if they see potential in the usage of their assets.
Depending on the size of the project, the legal responsibility falls under different authorities:

- Less than 5MW: Municipality
- Between 5MW and 100 MW: Province
- Over 100MW: National Government

Sometimes the municipalities don't have the expertise or prefer to delegate the responsibility, to the Province can take over the project and manage the process in their interest.
It is important to note that the "easiest" sites available in the spatial plans proposed by the Province may be already in use, because of the more favorable conditions or initiative.

Recent developments

The approach described above has caused many problems in the process of developing new wind energy projects in the country. In the recent years, many public committees lamented not being engaged in the planning or communication regarding the new sites being developed close to their residences. A mix of misinformation and lack of understanding between the various parties brought a lot of resistance from local communities and general dissatisfaction towards the authorities and landowners.
The problems identified rooted in few critical aspects:

- Lack of involvement in the process
- Lack of understanding of mutual needs
- Lack of benefits for residents
- Miscommunication between parties

These problems were identified by the authorities that started taking action on how the processes was handled locally and nationally. Some measures were included in the Klimaatakkoord, that sets guidelines on the process to involve the public in the sector of wind energy.
One of the ways to reduce the resistance from the public is to empower residents into taking ownership of wind energy projects in their areas. The formation of public initiatives is encouraged, and the accord aims for different forms of local energy cooperation, where public initiatives and wind energy companies co-owns wind farms and share risks and benefits.
A great example of this is the windfarm Kraamer (link of the website). Windpark Krammer is the largest citizens' initiative in the Netherlands. The nearly 5000 members of the Zeeuwind and Deltawind cooperatives have taken the initiative to develop this wind farm on and around the Krammersluizen. The 34 Enercon E-115 wind turbines together generate 102MW of energy. An interesting documentary about the project can be found at this link.
One peculiarity of this project is that, since it was a public initiative, different features were implemented in the operations and execution of the project. A notable one is that a wildlife radar was developed and implemented in the farm, in order to protect the environment surrounding the project. The wind turbines are hereby halted when bats are active or when birds are nearby. Anything so as to cause the least damage to nature. Another interesting initiative or additional feature is that the turbines will not have the intermittent flashing red and white light to signal their position, starting from the end of 2020. The flashing light has been observed to be a nuisance factor for the residents and has been reported in literature as a determining factor for public opposition, based on the almost constant reminder of the presence of turbines, even during the night. A feasibility study has been carried out by Pondera Consulting showing that is possible that the lights will turn on only when in presence of a low-flying aircraft, thanks to an active radar monitoring.
These measures are not regulated by authorities but decided by the local energy initiatives. The tradeoff between revenue and quality of life (and environment) is different for these kinds of stakeholder, that still need to fulfill a business-case, but have more freedom and motives to implement new technologies.

Reputation and Criticalities

One of the focus of the interview was to understand which phases of the project development are critical and what are the expectations of the Province towards wind energy developers.
As stated in the interview, in order to represent better the interest of the residents in the area, various municipalities in Zuid Holland now apply a new approach to new wind energy projects: *"If the developers don't cooperate with the citizen, we won't cooperate with you"*.
As trivial as it may sound, this politically motivated rule has been applied in the municipalities of:

- Rotterdam, as stated in page 9, section 1.3 of this document
- Region of Voorne-Putten (Brielle, Hellevoetsluis, Nissewaard – Bernisse, Westvoorne and Nissewaard – Bernisse), as described on this website

Possibly more municipalities are involved but during the interview, only these were mentioned.
Developers are realizing that reputation plays an important role in the industry. Reputation not only towards costumers, suppliers or competition, but also towards public and authorities. This is not just a matter of PR or marketing, but it implies an assessment of the internal practices and the approaches used while engaging other stakeholders in a project.
Eneco and Nuon (now Vattenfall) have been proved to care about this concept and to apply it in their projects in the Province of Zuid Holland, mentioned Astrid.
Building a reputation among civil groups means establishing numerous relationships of

trust between your company and citizen involved. The clearer the communication, the more successful the project, the higher the chances to cooperate again with other groups because of the previous work you did. But connecting with local groups can be difficult in various zones of the country, because of the multitude of actors to involve.
Multiple developers reported to find difficulties in understanding the relationship between actors and the social structure underlying the relationship in the area. These factors are important in terms of effective engagement and can be tracked down historically. If in an area there is a strong cohesion on these initiatives, a successful project is more likely to be developed (example Krammer windfarm), while where the community is shattered and the interest of the citizen clash without mediation, the resistance to the project can be stronger (example windfarm Spui).

New Tenders of Onshore Parks

One of the biggest problems of developing a new onshore wind park from the point of view of a developer is also the resources spent before the actual allocation of a permit. A project could take considerable effort in the planning phase and preparation of the preliminary studies, environmental assessment and other practices.
In order to help companies with this issue and have more control over the location and planning of future windfarms, the authorities are considering changing the process through which new onshore wind parks are going to be assigned. A tender process, similar to the one used for offshore wind parks, could be the standard for future parks.
In figure **??**, below, an example of a simplified graph shows the main steps of the assignation for an offshore wind farm. The request is initiated this time by the authorities themselves, that propose the project to many companies. These companies will then compete for the proposing the best project, under different aspects, and only one will have one actual contractor.

The development is to apply the same tendering process also for onshore wind farm, allowing the Rijkswaterstaat to propose a suitable location and the farm and to engage with the citizen from the start of the process, having more control on when to start the communication stream.
There has been an example of some wind turbines developed already through this process in the province of North Brabant.

Simplified tendering process for an offshore wind farm.

Appendix A4: Policy and participation expert at NWEA, Rik Harmsten

Tuesday, the 24th of March, 2020
The interview with Rik Harmsten, Onshore wind energy specialist at the Dutch Wind Energy Association (NWEA) took place online, through Microsoft Team, considering the health situation that the Netherlands were going through at the time. The interview lasted approximately 45 minutes.

As a representative of NWEA, the interview took place in order to understand the industry point of view regarding the topic of Public involvement in wind energy onshore projects in the country. The role of the interviewer is to be in communication with the government and provinces to represent the interests and position of the members of the association in policies and decision making. His presence in the shadow flicker and noise committee and participation working group made him a suitable candidate in order to understand the efforts made in the industry in engaging and communicating with local residents.

Code of Conduct

In the recent years, NWEA in collaboration with its members worked on a common framework for acceptance and participation in the onshore wind energy. The core of this Code of Conduct is that the stakeholders are involved in wind projects at the earliest possible stage. For each project, a participation plan is drawn up in dialogue with

stakeholders and the competent authority (for example, the municipality), with which agreements about participation by citizens are established. The initiator of a wind project also appoints a point of contact for the environment. The aim is to distribute the benefits and burdens well and to involve local residents in wind projects at an early stage.
The Code of Conduct binds the members of NWEA to a number of basic principles with regard to participation, communication and making a contribution to strengthening acceptance. The nature and environmental organizations and the energy cooperatives are also committed to strengthening support by signing the code .
The earliest version of the Code was signed in 2014 by NEWA, Greenpeace, the Natuur- en Milieu federations and Natuur Milieu. A second version was published in 2016, and more parties signed the code (Milieudefensie and ODE Decentraal). A new version will be published in Spring/Summer 2020, with possible participation of 2 more partners.

Public ownership

In the recent period (10-5 years ago) a new development has emerged in the industry. The concept of local energy cooperation, a series of initiatives and projects where a cooperation between energy companies and groups of residents established in order to lower the public resistance and empower the citizen by sharing risk and revenues.
The Klimaatakkoord, presented in 2019, aims for a equal participation between local initiatives and energy companies, of 50% each.
This percentage could refer to the number of turbines installed (50% of the w.f. is owned by the citizen) but also to the capital invested and in the revenues, but this may change case-specifically.
Considering that 80% of the onshore wind energy market in the Netherlands is shared between few large energy companies (Vattenfall, Eneco, Innogy, Pure Energie), a high impact can be reached through the involvement of a limited amount of stakeholders. All of the major actors are currently invested in cooperating with local communities for new projects. The percentage of participation can vary significantly, from 30-70 to 60-40, but the aim is for the 50-50 projected by the Climate Agreement.
Different companies can have different approaches in the cooperation. An example is Pure Energie, that requires the local community to participate in the initial investment for the wind park. This investment is usually covered through bank loans, but a 20% of the cash-flow still needs to be provided by local actors. In case of a large wind farm, this can mean high risk, high reward investment, with a possible cost of 2-5 million euros from the residents. This can be a problem or not, based on the kind of community and the location of the project.

Criticalities

Part of the interview focused on understanding the point of view of the wind energy developers, in their trade off between generating revenue for their company and engage the local community with benefits for having a wind park next their residences.
To the question "what is for developers the most critical phase of a project?", the answer was clearly the period before receiving the permit for the wind farm. It is a complex problem to deal with all the actors involved in the process and convince them. A source of uncertainty is the fact that local board in municipalities are elected, and their decision on the project can sometimes be of political reasons. The election of a new board can easily represent a threat for a wind energy project, since an unfavorable vote of the board could bring down a project where already a couple hundreds of thousands euros have been spent already.
This is one of the reasons why local energy cooperation has been implemented recently, in order to maintain local support even through changes in the administration.

Turbine control technologies

During the conversation, the example of the Krammer Wind Farm in the province of Zeeland came up as successful implementation of local initiatives. More than 5000 members of Deltawind and Zeeuwind cooperatives come together to discuss the initiative to

develop this wind farm around the Krammersluizen.
Regarding specific applications developed through public request, the bat and wildlife radar is a good example on how the community can find innovative ways to use technology to improve the quality of the implementation of a wind park in the environment. A similar application has also been developed by Vattenfall, for another wind project in the country (Princess Alexia Windpark in the Flevoland), where a radar system is being used to preserve wildlife due to the closeness of the park with the Narutistencamping Flevo Natuur. Out of 33 wind turbines, three of them are equipped with a wildlife detection system based on radar technologies that can help identify potentially dangerous situations. The system slows down the respective turbine for a 15-minute timespan, and the operational rotational speed is restored when the fauna is far from danger. The initiative was approved and endorsed by the local authorities, that could not force the protocol over Vattenfall, but opted for transparent communication and common goal setting with the company, over conflict

Shadow Flicker and Noise

Generally, dealing with Noise is more complicated that dealing with Shadow Flicker from the perspective of a wind turbine operator.
Since noise regulations are legally binding for the project, high attention on the topic is posed during the planning phase. While dealing with complaints and nuisance, operators usually prefer to consider the issue as case-specific: dealing with local citizen that specifically complain directly to them.
Dealing with specific resident can sometimes lead to special arrangements made for them, for example slowing down the turbines during nights or stopping it in specific days of the year, for example summer when the wind speed is lower and the nuisance experienced could be higher. No actual data is used for this process, mostly personal connection between wind farm managers and residents.
There is the will to adapt to the public, but also the need to respect a business case and have revenues from the wind park. This leads to difficulties in the decision making on the subject, finding a trade off.
While noise is a problem that incurs through the whole year, shadow flicker is more limited in time, and easier to predict. A high number of projects implement calculation of the shadow flicker in their analysis, to comply with the law that requires not to exceed a determined number of hours per year.
In order not to cause nuisance of shadow flickering, the easiest option is to calculate when the shadow will impact the residents and stop the turbine for a required amount of time. Clearly, this option is expensive due to the cost of loss of electricity production and less operational time. When calculating the business case, companies find themselves in front the choice of equipping the farm with such a system in order to prevent the flickering from happening, but then subtracting the cost of lost revenues from the financial benefits that they would provide to the community. This loss is estimated to be around 2% of the total energy production, an important amount considering the operational time.

Appendix B: Theory on Technological Transitions

From the review of SST literature the interconnectedness of society, technology and politics have been analysed in a rather *static* perspective. It is fundamental to define concepts such as negotiability of technology and system builders to then introduce a more *dynamic* approach to the analysis. This section will introduce the concept of Technological Transitions (TT) and briefly provide insights on the Multi-Level Perspective (MLP) theory as crucial tools to understand and analyse the trajectory of technological development. As before, it is not the aim of these few paragraphs to review extensively the literature on the subject, but reasonably provide insights on the methodologies that will, later on, be mentioned in further chapters.

When embracing the notion of negotiability of technology, a fair question can be raised: how do we choose one alternative over the other? If many versions of the technical artifact exist for how many actors observe the technology, which one is the one that will prevail and develop?
Evolutionary economics can provide useful insights concerning those questions. As suggested by Dosi and Nelson (1994), this approach to mainstream economy has inspiration and similarities with evolutionary biology: a *variation* set of genotypes and possible phenotypes, juxtaposed to the *selection* process in which certain characteristics survive or extinguish. Building on this analogy, the competition between different technologies can be described as innovators, scientist and prototypes that interact and connect with each other, before a selective process of regulations and market mechanisms decides which alternative is 'successful' and survives. A straightforward example can be found in digital applications for smartphones: countless products can be found in the variation environment of Google Play Store. These products are results of a business effort to approach the digital market or the idea of a young entrepreneur to revolutionize a niche market, they are results complex of sociotechnical interaction between many actors and networks. Many examples can be found, form Rdio music streaming platform (extinguished' after Spotify acquired its market share) to anonymous messaging apps like Yik Yak (which market value collapsed in only 3 years), due to a deep flaw in the technology or simply because they could not compete against other products (The Verge, 2015, 2012).

Clearly, the analogy of the biological model is an oversimplification of the complexity of evolutionary economics theory: technological evolution is not simply a process of trial-and-error, technologies are *selected* by the environment by the actors themselves. Based on a heuristic series of interactions, reviews, expectations and competition, society selects these alternatives. As noted in the previous section, the existence of pre-existing networks and patterns of interaction influences the development of a technology because of the need for stability of a sociotechnical system. Therefore, society reinforces this selection process by enforcing similar choices over technology many times: this is the origin of the notion of *technical regime* (Dosi and Nelson, 1994).

> A technological regime is the rule-set or grammar embedded in a complex of engineering practices, production process technologies, product characteristics, skills and procedures, ways of handling relevant artefacts and persons, ways

of defining problems; all of them embedded in institutions and infrastructures (Rip and Kemp, 1998).

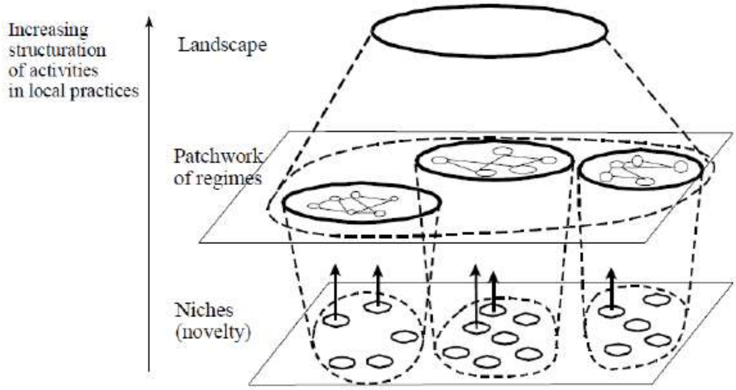
The notion of regimes was firstly introduced by Nelson and Winter to describe the cognitive routines of engineers while researching for innovation as an explanation for the lack of diversity in technical choices: the R&D efforts of professionals was guided by experience and an expectation to find suitable solutions in a specific direction, therefore being a bias in their cognitive framework. The meaning of regime was later on expanded to the comprehensive definition provided by Rip and Kemp (1998) above, but the commentary on the human pattern of choice is still relevant for the analysis. The study of regimes and their impact on the dynamics of technological development was furthermore expanded to be part of Geels's Multi-Level Perspective (MLP) framework.

Shaped heavily from a branch of evolutionary theory focusing on technological development (Dosi and Nelson, 1994), the MLP framework is a great tool to further conceptualize the interrelation of society and technology in a dynamic context. This perspective was first introduced by Rip and Kemp and later refined by Geels [3] with a strong orientation to apply system innovations for solving societal and environmental problems through policymaking.
The MLP distinguishes three layers of novelty: micro, meso and macro level. The former, constituted by *technological niches*, is defined as the "protected space" in which innovation can emerge and experiment. Niches are introduced as incubation rooms in which technology is protected by subsidies and investments, and in which is possible to deviate from the rules of the incumbent regime. Uncertainty about design requirements and lack of social structure allows for negotiation and interpretation of technology, and allow space for learning processes.
The meso-level is composed of a multiplicity of *sociotechnical regimes*, sometimes referred to as 'patchwork of regimes'. As described earlier, regimes can be considered sets of rules embedded in engineering and societal practices, and 'damper' the system providing stability through an established pattern of interaction. If in evolutionary economics the niche can be considered the variation environment, the regime act as selection mechanism: orientation and direction are given to technological innovation through the structure of the system.
Lastly, the macro level is formed by the *sociotechnical landscape*, analogy of the wider environment in which a technology operates. World wide issues such as climate change, long term societal issue and migration are accounted for in this layer, that provides a slowly paced direction to development of innovation.
In figure 1a, Geels illustrates the hierarchy of the core constituents of the approach. Differently than the ANT theory, this approach has a strong vertical analytical topology that accounts for a more LTS perspective of networks.

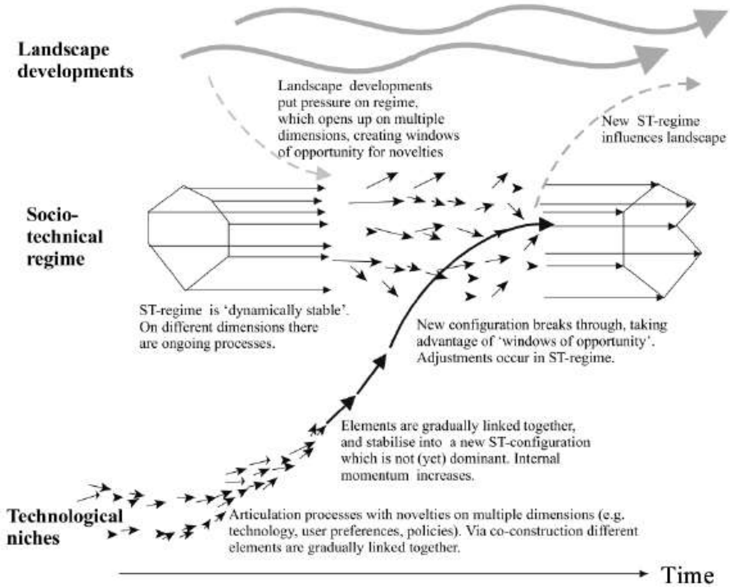
While the meso level provides stability, creating inertia and possibly lock-in in energy systems, it is crucial to define how these three levels interact. Geels identifies four temporal *phases*, summarized in figure 1b. In the first phase, problems present in the landscape and regime materialize at the micro level to be addressed from niches. Actors (and system builders) engage in prototyping, trial and error processes and learning to understand the user's needs. In the second phase, small niches start to form their own structure: market, network of interaction and practices are developed in this stage. As the outcome of this process, a dominant design is expected to emerge, and specific organizational forms are built.
The breakthrough into the established regime is addressed as third phase. This can happen if the niche product exploits a *window of opportunity* (such as negative externalities or technical problems in the established technology) or substantial *drivers* are found in the technology (such as cost/performance improvement or gaining of social momentum). It is an important notion to accept the multiplicity of those drivers and opportunities, to

[3] Johan Schot has also been found to be a notable author in the field of TTs that helped to shape MLP. The current research interest of Schot os Deep Transitions with the aim to develop a new version of the MLP framework for sustainability transitions (Kanger and Schot, 2019).

reject the deterministic paradigm of innovation and to embrace the interplay of multiple actors in it.
Finally, when the technology is mature and accepted, the replacement of former technology takes place. This fourth phase has a slower pace than the previous because of the higher impact on the pre-existing regime. Organizations, standards, patents and business models need to adapt to fighting the *sunk cost fallacy*. If multiple regimes are able to accommodate innovation, the meso-level can interact with the higher sociotechnical landscape, resulting in the fulfillment of a constructionist utopia. Impact studies address these long term transformations.



(a) The nested hierarchy of MLP levels (Geels, 2002b).



(b) The dynamic perspective of MLP on system innovation (Geels, 2002c).

Figure 1: The Multi-Level Perspective framework of analysis.

The Multi-Level Perspective frameworks dive into many concepts belonging to science and technology studies and other theories. Described by Geels (2006) as "building blocks", a wide range of disciplines are included in the background of this approach to innovation system transition. Sociology of technology inspired the formulation through the concepts

of closure and stabilization of interpretation from the SCOT approach (Williams and Edge, 1995), while ANT and LTS research highlights the interrelation between elements of emerging technology that gradually brings co-evolution (Latour, 1996; Hughes, 1983). Another relevant concept for the MLP framework are Hughes system builders, that have an important role in the notion of novelties (niches): they weave heterogeneous elements into a working system (Geels, 2010). In figure 2 a schematic representation of how multiple social groups interact to form a generic sociotechnical system is presented, according to Geels interpretation.
Institutional theory and Evolutionary economics played as well an important role in the theoretical background of MLP. The definition of regimes presented earlier in this section from Dosi and Nelson and cognitive routines create a stable pattern that over time stabilize into a *regime*, concept expanded from Geels into the *socio-technical regimes* constituting the meso-level.

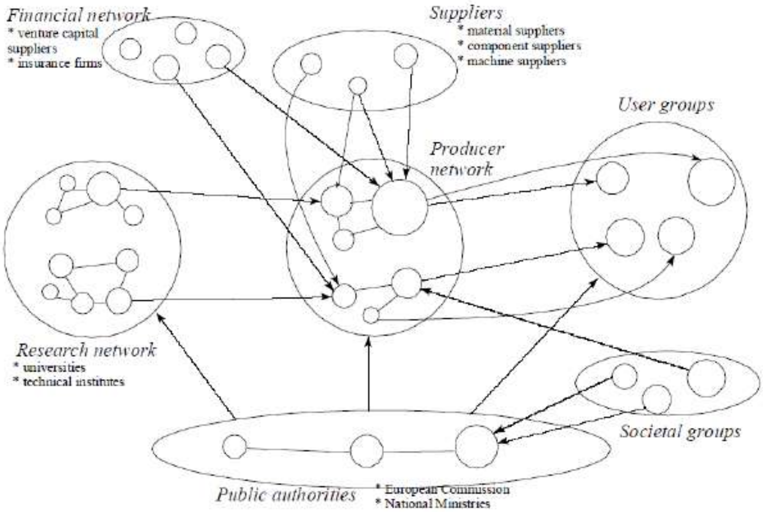


Figure 2: In Geels (2002a) depiction, different common social groups interact forming sociotechnical systems.

The use of the MLP approach applied to case studies has grown over the years, being applied to a different range of problems. In 2013, 7 publications featured the use of MLP, applied for example to the Dutch food sector (Spaargaren et al., 2013), aviation innovation (Nakamura et al., 2013) or expanding the theory (Papachristos et al., 2013; Hansen and Nygaard, 2013). In the first six months of 2020 alone, current date, 36 publications featured the MLP framework applying the concepts to a variety of case studies from China, Nicaragua, Norway, Israel and many more [4]. The three-layered approach has found interesting applications in the agricultural and food sociotechnical system, a sector which deals with many issues on sustainability: El Bilali (2019) conducted a systematic review of 57 publications addressing the issue.
Considering the broader subject of sustainability transition, in which the MLP is one of the prominent frameworks together with the *Technological Innovation System* (TIS), *Strategic Niche Management* (SNM) and *Transition Management* (TM), the research interest grew significantly, reaching 500 publications alone in 2018 (Köhler et al., 2019).

[4] A simple Scopus analysis provided these data. The analysis was not systematic but focused on the search term "MLP" combined with "Multi-Level Perspective" in the title, abstract or keywords, to avoid results related to the homonym class of artificial neural networks, "Multi-Layer Perceptron". The number of publication is most likely not to include many articles that reference or mention MLP, but it is considered to be satisfactory for the example.

In the extensive review and updated research agenda published by the main authors of the Sustainability Transition Research Network (STRN) Köhler et al. stress the fact that, despite the increase in studies on the topic, the main societal challenges of sustainability remain unsolved.