Organizational Change with the Use of AI for Operational and Maintenance (O&M) Activities in the Wind Energy Sector

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IV. Abbreviations

AI: Artificial Intelligence

ANN: Artificial Neural Networks

APAC: Asia-Pacific

CMS: Condition Monitoring System

CoE: Costs Of Energy

CSR: Corporate Social Responsibility

DL: Deep Learning

DOE: Diffusion Of Innovation

EMS: Energy Management System

FDD: Fault Detection and Diagnosis

FDS: Fault Detection System

FOWF: Floating Offshore Wind Farm

GHG: Greenhouse Gas

GW: Gigawatt

ICT: Information and Communication Technology

IoT: Internet of Things

LCA: Life Cycle Analysis

M&R: Maintenance and Repair

ML: Machine Learning

MLP: Multilayer Perceptron

NN: Neural Networks

OEM: Original Equipment Manufacturer

OPEX: Operating Expense

PEOU: Perceived Ease of Use

PLC: Program Logic Controllers

PU: Perceived Usefulness

R&D: Research and Development

RBV: Resource Based View

RF: Random Forest

ROV: Remotely Operated Vehicle

TAM: Technology Acceptance Model

Executive Summary

Artificial Intelligence is no longer a buzzword and now forms the backbone of several businesses to facilitate efficient and advanced means of operations. The wind energy sector is one such industry that has and continues to benefit from the use of AI in its operational and maintenance (O&M) activities. These systems assist in the maintenance of large fleets of windmills with predictive maintenance capabilities and shorter turnaround times for fault detection and diagnosis. This, however, comes with challenges concerning the accountability of decision-making by the AI systems and the ethical use of the technology itself. The adoption of this new technology thus brings a fundamental shift in the way businesses define organizational priorities and future business prospects. Not many inquiries have seemingly been made to comprehensively understand this change in the wind energy sector. Based on this, this research asks the question: *What impact does the AI adoption for operational and maintenance activities (O&M) have in influencing organizational change in the wind energy sector?*

To explore an answer to this question, eight interviews were conducted with experts in the wind energy sector. Two sets of semi-structured interview drafts were prepared to study the technological and organizational impacts of AI adoption. The interviewees ranged from AI experts, wind turbine technicians, project managers, and academic experts who have worked extensively with AI systems in the wind energy sector.

Here, the Technology Organization Environment (TOE) framework has been utilized to assess the influence of AI adoption on organizations, considering the technological, organizational, and environmental perspectives. With the advent of AI systems, wind energy organizations have witnessed an increasing focus on upskilling/ reskilling activities, building robust cyber security systems, and growing investments in research and development (R&D) initiatives. There is also a growing consciousness towards the impact of using these systems on the employment of the human labor force, the emissions generated with their use, and the need for adequate policy measures and public support to be able to witness holistic and sustained growth in the industry.

Findings from the expert interviews have been collated with the literature review to comprehensively address the research question, and support further endeavors into the inquiries on AI-induced organizational change in the wind energy sector.

1. Introduction

1.1. Background

Sustainable Development has been an active part of mainstream discussions among policymakers, environmental activists, economists, and the larger public. In 1987, the Brundtland report gave the now most recognized definition of Sustainable Development, defining it as the ability to meet the requirements of the current generation, while not compromising the capability of future generations to do the same (Hariem Brundtland, 1985). The drive towards achieving sustainable development was further brought into active discussions with the adoption of the United Nations Sustainable Development Goals (UN SDGs). In September 2015, the United Nations accepted the list of Sustainable Development Goals (SDGs) in an attempt to structure the development of policy and actions across the world toward achieving a holistic idea of sustainability (B. X. Lee et al., 2016). These goals cover a range of aspects including quality education, gender equality, climate action, clean water, and sanitation, among many others. Although none of the goals refer to Information and Communication Technologies (ICTs) specifically, ICTs are a part of the targets that would accelerate achieving these goals. ICTs have the potential to catalyze the achievement of these SDGs, by fostering innovation and development (Wu et al., 2018).

The advantages with the use of ICTs have led firms to bring such technologies into their formal processes, in an attempt to accelerate their organizational goals. An industry-wide acceptance of the advancing technologies also leads to greater competition amongst organizations in terms of ICT adoption, its use, and integration into organizational structures (Murphy, 2002). This competitive environment in turn trickles down to firms across the economy to adopt the latest developments in technology and invest in ICT-based services (OECD, 2001). This flow of change brings a fundamental shift in the ways organizations are structured, and cater to the new business environment with changing ways of business operations.

Research continues to be done to study the developments with the coming in of ICTs, and their impacts on organizational structures. Moreover, attempts are being made to study how organizations build resilience and are preparing themselves for bringing in newer ICTs into their organizational structures.

1.2. Motivations

Organizations working towards environmental sustainability have shown a growing adoption of AI-based services for their operational and management services (O&M). The adoption of new technology impacts the traditional means of business operations. The existing structures of teams witness change, certain aspects of business operations get focussed more than others, new teams emerge, and collaboration between teams witnesses a change. This changing business environment leads to organizations gradually re-alining themselves, finding ways to incorporate this new change within their existing business operations seamlessly.

Organizational change impacts existing firms in ways, good and bad. While the coming of AI-based systems in organizations is by far inevitable, an assessment of the associated change is important to understand how it impacts the industry at large. For example, the increasing operational efficiency with these systems is a trade-off to its impact on the employment of the human labor force. This research aims to study the ways in which wind energy organizations are bringing a change to their existing organizational structures with the advent of AI-enabled systems, and the ways in which they are re-inventing themselves to better prepare for the incoming technology.

1.3. Objectives

The primary objective of this research is to understand the driving forces and barriers of wind energy organizations towards the adoption of AI-enabled systems. This will further help explore the ways in which this incoming technology brings a change to existing ways of business operations. The study will help identify these changes, and whether organizations perceive this as a progressive or regressive change. The research will also aim to understand if the organizations take any active steps in preparing themselves for such an advent of AI technology into their business operations, and the ways in which it aims to sustain these new changes to continue working towards organizational excellence. With academic inputs and discussion with industry experts, this research aims to provide a holistic view of organizational change in wind energy organizations with the incoming AI-based technologies.

1.4. Problem Definition

The initial literature review for the research helped identify some drivers and barriers in the adoption of AI by wind energy companies and further discussed their impact on bringing organizational change. The different aspects are listed below:

- AI systems help in *enhancing* the *operational efficiency* of existing modes of business operations. They help streamline operational activities, optimize turbine performance, and predict potential faults, thus improving efficiency and reducing operational costs.

- AI systems help in *enhancing decision-making* for wind energy companies. AI helps organizations derive meaning from vast amounts of data, thus enabling advanced decision-making.

- *New business models* can emerge with the use of AI in the wind energy sector. Predictive maintenance as a service or energy optimization as a service can be introduced.

- AI systems help in improving *the operational and maintenance (O&M)* activities of wind energy organizations. Efficient predictive maintenance mechanisms can help use resources efficiently and provide accurate and timely updates on the wind turbines for fault detection and diagnosis.

- AI systems are regarded as *black boxes* and their decision-making cannot be fully relied upon.

This research focuses on understanding the driving forces and barriers to the introduction of AI in the wind energy industry, and how it brings organizational change. To study this, the research question is defined as follows:

1. What impact does the AI adoption for operational and maintenance activities (O&M) have in influencing organizational change in the wind energy sector?

1.1 What are the driving forces and barriers to the adoption of AI-enabled systems in the wind energy sector?

1.2 How are wind energy organizations (re)aligning themselves with the advent of AI-enabled systems?

1.5. Delimitations

One aspect of this research aims to study organizational change with the adoption and use of AI systems in the wind energy industry. For this study, the scope of AI is limited to the idea of self-learning machines. This was scoped out by the literature review, complemented by the industry examples that were used as part of the study. Organizations use Machine Learning, Artificial Neural Networks, Deep Learning, etc as part of AI technology, however, these will be studied with their ultimate objective of developing ‘intelligent’ machines.

Further, the research uses the Technology Organization Environment (TOE) framework to study organizational change. However, the focus of the study is on the ‘Technology’ and ‘Organizational’ elements. This is to make the study focused on the aspects that internally drive the organizations to bring change. The element of ‘Environment’ in the TOE framework is not explored extensively, since it consists of external factors that affect organizational change. Including the environmental aspect would have made this research broad, given that the current focus of the study is on internal drivers and barriers of wind organizations in bringing technological change.

1.6. Structure

This paper starts with an in-depth state of the art in Section 2 that includes literature on wind energy, Artificial Intelligence, its scope within this research, and the ways in which organizations are driven or limited to bring AI into their business operations. This is followed by section 2.2. which explores some current initiatives of organizations that have successfully implemented AI in their wind energy business operations. In Section 3, the introduction of AI systems in the wind energy industry is discussed via the lens of the Technology Acceptance Model (TAM), Resource Based View (RBV), and Sociological Institutionalism, in conjunction with the analytical framework for gathering a comprehensive understanding of the topic. Section 4 lays out the method of data collection and the details of the interview participants. Once the interviews were conducted, codes and themes were decided, which have been listed in Section 5.2. Section 6, lays the discussion of the findings based on the major themes within the research. These themes include the state of the industry, driving forces, challenges, and ethical concerns with regard to AI adoption, followed by organizational change, and the way forward for the industry. Section 7 discusses some of the limitations of the research, followed by the conclusion in Section 8.

2. State of the Art

In this section, the existing relevant research on the use of AI systems in the wind energy sector is discussed. Further, the driving forces and challenges for this adoption are explored, along with the elements of organizational change that are brought about with these changes. This is followed by the impact of external factors on bringing and influencing the change, and the ways it can bring a change to the ways of business operations. The section concludes with some current initiatives of organizations using AI in their wind industry sector.

2.1. Literature Review

2.1.1. Wind Energy and AI

2.1.1.1 Wind Energy

The energy industry is witnessing shifts in the ways it aims to reduce carbon emissions and maintain a balance in the supply-demand dynamics of the power grids (Engels et al., 2020). Energy improvement and efficiency have become a worldwide priority to ensure adequate energy supply, and address challenges related to global warming, carbon emission, biodiversity protection, and developments in renewable energy (Tchakoua et al., 2014). Wind energy is gaining prominence with it being a clean and renewable source of energy, serving as an alternative to traditional fuel-based energy systems (Sun et al., 2020). It is also a promising source of energy that plays an important role in reducing the global carbon footprint (Wang et al., 2018). The growth in the wind energy sector can be asserted by the fact that it constitutes the fastest-growing sector amongst other renewable sources of energy, in terms of installed capacity (Tchakoua et al., 2014). An increase in the acceptance of wind energy has been witnessed with a growing wind turbine installation globally over the last decade. It has increased sharply from 24 GW in 2001 to 651 GW in 2019, recording an almost 27 times increase (Tra, 2019). This installation is expanding across both onshore (on land) and offshore sites (on water).

Wind energy is harnessed using a wind turbine, which is defined as “a machine which converts the power in the wind to electricity” (Manwell et al., 2010, p. 2). The exceptional growth of the wind energy sector and the subsequent increase in wind turbine installations have been possible with the growth in technological advancements, enabling faster maintenance and operational activities as well as the reduction in the cost of operations. For this sector to continue witnessing growth, the increasing focus needs to be laid on optimizing the wind turbine controls, better forecasting of wind speed, and regular evaluation of wind power generation (M. Lee & He, 2021).

However, the operations of a wind farm are very different from conventional power stations. Wind Turbines (WT) are unmanned, remote power plants that are exposed to a high degree of variable temperature, wind conditions, lightning, hail, snow, and even mechanical stress (Tchakoua et al., 2014). This can lead to increasing financial investments to ensure regular monitoring and health check of these wind turbines. Operational and Maintenance (O&M) costs can account for about 10%-20% of the total cost of energy (COE) of a wind project, and this number can reach up to 35% over a WT for the end of life (Tchakoua et al., 2014). It is thus of critical value to invest in a prevention-centered maintenance strategy for these wind turbines in order to reduce costs incurred due to faults, mechanical stress, or shutdowns (Tchakoua et al., 2014).

2.1.1.2 Artificial Intelligence

The discussion of Artificial Intelligence was largely introduced with the Turing test in 1950. The test laid that machines could be considered intelligent if they could successfully pretend to be a human, to a knowledge observer (Monostori, 2014). Discussions then followed on the ways of designing intelligent machines and the means to test this intelligence (Turing, 2009). The idea of intelligent machines has evolved since then, with new fields of AI like Artificial Neural Networks, Machine Learning and Deep Learning emerging and becoming a commonplace. This growth in the adoption and use of AI systems can be attributed to the continually increasing computational power of computers, more focused application-oriented research, and the combination of different disciplines (Monostori, 2014).

AI systems help the wind energy sector with effectively managing the operational and maintenance support of the wind farms, streamlining business operations, and enhancing predictive maintenance capabilities. For the purpose of this research, the term AI will be used to convey the idea of self-learning machines/ intelligent machines that can perform tasks that would otherwise also require human interference. The idea of intelligence as conveyed by the term Artificial Intelligence, also encompasses an important element- prediction (Agrawal et al., 2018). This study will understand the idea of prediction as an important factor for its use in the wind energy sector, to reduce ambiguity and uncertainty in business operations. This scope has been established with the findings from the literature review, and discussions with industry experts that are using these systems in the context of the wind energy sector.

2.1.1.3 AI in Wind Energy

Digital technology and ICTs can play a critical role in streamlining the operational and maintenance activities of a wind farm. The knowledge of technologies like Artificial Intelligence can be coupled with that of renewable energy to capture growing opportunities (Sodhro et al., 2019). Artificial Intelligence and data analytics can effectively help in improving the performance of wind energy systems by increasing performance and building predictive maintenance capabilities (Ozcanli et al., 2020).

Traditional models of energy production, distribution, and planning can no longer support the growing economy (Jha et al., 2017). This is where AI and ML can help bridge the gap. AI systems help give meaning to data enabling better decision-making and prediction capabilities (Agrawal et al., 2018). Moreover, AI capabilities help in predicting wind power generation and power demand that further enable smart grids for storing and transmitting power effectively (Carolin Mabel & Fernandez, 2008). Since wind energy is a variable source of energy, wind turbine producers and manufacturers have integrated advanced technologies like Artificial Intelligence, robotics, and advanced data analytics, to regulate power production and distribution (Stetco et al., 2019). The use of AI in wind energy can be categorized under 3 areas: (i) forecasting of wind speed and wind power, (ii) optimization of operation and maintenance

(O&M), (iii) optimization of the operation of wind farms (M. Lee & He, 2021). AI and ML-based systems help in predicting wind power based on the wind speed, and potential faults in the turbines, and help better manage resource availability in case of fault diagnosis and repair.

Artificial Intelligence is particularly powering energy supply, trade, and consumption dramatically (Ahmad et al., 2021). The production of wind energy is directly linked to economic outcomes. However, since this production itself depends on a lot of factors (variable wind speed, temperature conditions, etc), it is important to use tools that help estimate the amount of energy that would be produced, which in turn translates to economic outcomes. Innovation in AL and ML can help in improving wind farm operations by about 10 percent by making effective use of the vast amounts of real-time data captured at the wind turbines (*Artificial Intelligence and Big Data – Innovation Landscape Brief*, 2019). Also, advanced AI capabilities can help in the early detection of faults through predictive maintenance capabilities and help improve the overall turbine performance (Ren & Bao, 2010). AI can also be used for turbine control, power system management, load tracking, and maintenance of wind farms (Colak et al., 2012). Furthermore, Artificial Neural Networks (ANNs) have shown better prediction of wind power, compared to other physical methods of prediction like human data analysis. ANNs are perhaps one of the most common AI techniques for monitoring data, optimizing operational activities, data forecasting, and subsequent decision-making (García Márquez & Peinado Gonzalo, 2022).

The wind power generation system broadly consists of 3 components: a control system, a condition monitoring system, and a SCADA (Supervisory Control and Data Acquisition) system. Among these, the SCADA system helps in enabling an efficient means of managing wind farms (Z. Lin & Liu, 2020). SCADA is not a full control system, but focuses on the supervisory level. It is a software package that is positioned on top of the existing hardware infrastructure to which it is interfaced via Program Logic Controllers (PLCs) (industry controllers used for automating specific processes or product lines) or similar commercial hardware modules (Daneels & Salter, 1999). The SCADA system captures extensive data from the different WT subcomponents through sensors that are attached to the anemometers (used for measuring wind speed and wind pressure), thermocouples used for measuring temperature), switches, etc (Tchakoua et al., 2014). SCADA systems help to analyze the overall operational status of the wind farm. Moreover, the data generated from these SCADA systems, combined with AI capabilities, can help accurately predict the amount of electricity that will be produced by the wind farm (M. Lee & He, 2021).

Since the reliability of the WTs depends on several factors, including weather, temperature, wind turbine age, size, etc there is a need for efficient maintenance systems to be put in place so potential faults can be highlighted well before any major financial or resource loss occurs. This is being leveraged with the use of AI-enabled systems in the wind energy sector. Artificial Intelligence is used in power prediction by optimizing yaw angles[1] and minimizing wake effects[2] in wind farms (Sun et al., 2020). Another data-driven approach used for fault detection is that of training a Normal Behaviour Model (NBM), where predictions of variables (such as wind speed, and temperature) are compared against the actual measured values. A residual between these two values is then calculated and the time series of this residual value can help predict abnormalities in turbine health and give alarms for potential failures (Helbing & Ritter, 2018). Research has also been done on using linear regression models and Multilevel Perceptron (MLP) to establish a SCADA-based NBM for detecting bearing damages and temperature anomalies in wind turbines (Schlechtingen & Ferreira Santos, 2011). Moreover, Deep Learning (DL) has applications for predicting faults across various WT components. Artificial Intelligence techniques like fuzzy logic (FL) and artificial neural networks (ANN) have greatly helped the energy sector by building capabilities for simulations, estimations, fault detection, and diagnosis (Bose, 2017). It is also being employed for efficient energy storage, real-time data analysis, and high grid stability, among many others (Ahmad et al., 2021). Thus, the role of AI is only increasing across various aspects of the wind energy sector making it efficient and effective in capturing the wind energy.

For this study, the use of AI in the wind energy industry will be studied to understand its use for operational and maintenance activities, including its use in predictive maintenance. This has been done to gather an overall understanding of how the operational and support business activities are impacted by the adoption of AI. Moreover, the wind energy organizations in consideration are the ones that have an initial understanding of the use of AI for their businesses, and are looking to expand their scope of operations with this technology.

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[1] Yaw angle refers to the angle between the wind direction and the axis of the wind turbine rotor.

[2] Wake effects is a phenomenon where the airflow downstream of a wind turbine is influenced by the presence of the turbine itself

2.1.1.4 Data Lifecycle Model

The use of AI systems is largely determined by the use of quality data that the systems can use to derive meaning from. With the increasing amount of data being generated, captured, and used to train these AI models, it becomes important to manage the vast amounts of data to be able to use it to its full potential. The Data Lifecycle model provides a comprehensive framework that helps manage data right from its inception to the final stage of data archival.

In the context of this research, several weather-only satellites have been placed in orbit around the earth, collecting data on cloud and wind patterns, weather conditions, and the like (World Meteorological Organization, 2010). These large amounts of continuous data streams coupled with advanced digital technologies, have the power to bring significant changes to how organizations perceive and use this data for business operations. The advent of Internet of Things (IoT) has furthered this data availability and accessibility. It has brought improvements in the quality and accuracy of the data being collected, enabling a better and enhanced system for weather forecasting (M. Lee & He, 2021). Artificial Intelligence is becoming a key enabler in developing a data-driven energy system that helps increase operational efficiency in the highly competitive energy industry (Ahmad et al., 2021). This data is of importance for the wind energy sector, as wind turbines operate in highly uncontrolled weather conditions, and a forecast of weather helps operators to monitor and maintain a check on the operations of the wind farms.

The Data lifecycle Model here will be used to understand how the data originates, is captured, stored, processed, analyzed, and ultimately archived. For the wind energy sector, SCADA systems help capture the data regarding the different aspects of the wind turbines, weather conditions, etc through external sensors (Zaher et al., 2009). This is a continuous, high stream of data that gets stored mostly on cloud-based platforms (Qian et al., 2019). The raw data is then refined through different software, and with human and machine intelligence to be able to derive meaningful insights from. This is also when the data is fed into the AI systems, to build better and advanced capabilities in understanding the data better and making its use in building predictive maintenance capabilities (W. Zhang et al., 2019). Finally, data archival ensures data integrity and accessibility of historical data, to ensure and track progress over a period of time. This process will also be studied and traced through discussions with industry experts.

2.1.2. Operational and Maintenance (O&M) Activities

Opearational and Maintenance activities encompass the fundamental activities that ensure well functioning and supervision of business processes. They form a vital competent of business operations, by ensuring effective and efficient operations of different business assets and processes (Sullivan, 2010).

Operations refer to the daily activities and processes to ensure businesses run as intended. These include executing the standard operational procedures, ensuring real-time adjustments, quality control, risk evaluation and assessment across the key performance indices, to ensure optimize the performance of operations. This is important to ensure business targets are met, compliances are adhered to, and that business outputs are as predicted, while managing safety during all business activities. On the other hand, maintenance refers to the range of proactive and reactive measures to ensure the functionality and reliability of business processes. It involves scheduling regular servicing and inspections to prevent any potential faults or accidents, regular data backup and recovery, and routine checks. Such processes ensure a regular check on the assets of operations, track potential faults, extending the life of critical assets and allocated resources effectively to reduce the risk of any major financial losses in the future (Li et al., 2020).

For the purpose of this research, the adoption of AI will be studied with respect to the operational and maintenance activities in the wind energy sector. Here, AI capabilities help in bringing predictive maintenance capabilities (Ren & Bao, 2010), ensure fault detection and diagnosis (Colak et al., 2012) and streamline business operations (García Márquez & Peinado Gonzalo, 2022).

2.1.3. Drivers of AI Adoption in Wind Energy

The adoption of AI systems by wind energy companies may be driven by several factors. These could include that AI systems bring efficiency in the ways of business operations, reduce costs of operations, reduce potential risks to the human labor force, or assist in building a competitive advantage for the firm, over others. These factors are discussed in further detail below:

2.1.3.1. Operational Efficiency

Energy generation is highly dependent on assets of production, which can be optimized with the use of AI models to improve energy production. AI systems have brought vast improvements in the energy sector, with their use in predictive maintenance capabilities, optimization of supply chains, enhancing computational efficiency, etc (Ahmad et al., 2021). AI is being used in the renewable energy sector for different tasks, including forecasting, data analysis, and efficient power system operations (Kow et al., 2016). More specifically, building AI capabilities at the wind farms can increase energy production, by providing the right means of communicating real-time with the wind farms, and understanding data across different parameters like wind speed and wind direction (Ahmad et al., 2021). These aspects help streamline operational activities, reducing the turnaround time for taking action and bringing enhanced decision-making.

The scope of the renewable energy industry is only increasing with the use of digital technologies. AI systems here help with better operational and maintenance activities, improved monitoring of power infrastructure, provision of more secure system operations, and building new market designs (*Digitalization and Energy*, 2017). For the wind energy sector, AI helps companies bring meaning to the vast amount of data collected through wind turbine sensors. This brings value to the data and brings meaningful conclusions on energy generation, supply, and consumption. Moreover, AI-based systems enable the sharing of condition-based data with the control center, making it easier to pragmatically assist in fault detection (Ahmad et al., 2021). Thus, the use of AI capabilities can help wind energy organizations better their business prospects through improved operational efficiency compared to traditional means of operations that were largely dependent on human interference.

2.1.3.2. Cost Reduction

The growing cost of energy is always a concern for consumers, governments, and policy makers. In the case of wind energy, AI systems and the use of smart grids can help reduce the cost of energy by balancing the energy supply and demand, and efficiently managing energy distribution (Ahmad et al., 2021). With predictive maintenance capabilities, AI systems have the power of notifying potential faults and risks that may be encountered in the near future (Merizalde et al., 2019). This helps in allocating and planning resources, thus reducing any unforeseen financial losses when the actual fault occurs. AI systems also can optimize operational and maintenance costs, and increase efficiency and the operating life of the equipment, thus reducing financial investments over a period of time (OECD, 2017). Moreover, the use of AI systems and robots helps reduce the cost of energy by performing redundant tasks in much shorter periods, compared to them being done manually by the human labour force (Khalid et al., 2022). This ensures that redundant activities are completed on time, mitigating the risk of any potential downtime because of such activities, and the resultant risk of financial investment at the time that the fault occurs.

2.1.3.3 Reduced Human Dependence

The use of AI systems can help in mitigating safety hazards that the human labor force may be exposed to, when working on the wind turbines. Offshore wind farms are set up deep into the water bodies, with harsh and unpredictable weather conditions. This exposes the human operators working on these wind farms to such conditions and increases the risk of accidents. The possibility of risks has only increased with newer technologies, like the Floating Offshore Wind Farms (FOWF). A FOWF involves installing wind turbines over a floating support structure, thus ensuring that the wind turbine is installed irrespective of the water depth and seabed conditions (Tong, 1998). Installation and maintenance of FOWF poses additional constraints as they are at a further distance from the onshore facilities (Khalid et al., 2022). Such operations may be carried out efficiently by AI-enabled robots, which would reduce the health and safety of the human operators that may be involved in these tasks otherwise. More recently, there has been a focus on unmanned aerial vehicles (UAVs) and remotely operated vehicles (ROVs) for assisting wind turbine inspections, thus reducing the possibility of human accidents (Bernardini et al., 2020). Moreover, these drones are being built with AI capabilities that ensure quality of inspections and maintenance work being carried out by them.

2.1.3.4 Competitive Advantage

AI has a big role in transforming traditional business operations. For the case of wind energy, it helps firms bring operational efficiency, cut down costs on human labor, and helps prevent the risks of human accidents over traditional means of operations. This helps organizations digitally transform themselves and witness growth in the industry. Greater willingness to adopt AI systems, efforts in upskilling employees, and investment in R&D activities, all help an organization gain competitive advantage over similar firms in the industry (Tchakoua et al., 2014).

As the need for uninterrupted energy supply increases, organizations look for efficient and cost effective means to continue business operations. AI helps bring in those capabilities and ensures seamless operational activities. Utility companies believe that the use of AI systems give a considerable advantage to firms, accounting for about 33% in competitive edge against other firms in the industry (Henzelmann et al., 2018). AI has, and will continue to have its impact in this transformation, and play a key role in the future energy market (Ahmad et al., 2021). Policy makers have also realized the competitive advantages with the use of AI in the renewable energy industry, and are bringing in new ways of funding, and research and development to boost this growth (Fujii & Managi, 2018).

2.1.4. Organizational change with AI

Change is an ever-present aspect of organizations, be it strategically or operationally (Burnes, 2009). Change management has been defined as 'the process of continually renewing an organization's direction, structure, and capabilities to serve the ever-changing needs of external and internal customers' (Moran and Brightman, 2001: 111). It becomes important for firms to invest in organizational change given the dynamic and evolving market conditions and competition within the industry. Organizational change primarily consists of 3 factors:

- Production processes- Quality management, lean production, business re-engineering
- Management processes- Teamwork, training, flexible work and compensation
- External relations- Outsourcing, customer relations, networking

Firm performance is enhanced with a focus on some of these processes, which is furthered with the use of ICTs (Murphy, 2002). This research will focus on understanding organizational change through the 3 factors listed above. The use of AI in the wind energy sector brings in capabilities of streamlined business operations, upskilling/reskilling initiatives, technical skill outsourcing, investment in R&D activities, etc. These elements will be studied in this research, as part of the discussion on organizational change.

The use of ICTs has become essential to bringing organizational change (Murphy, 2002). Depending on the size of the organization and its resource availability, different firms can have varying adaptability toward ICT adoption. Larger firms that are exposed to international competition may invest more in bringing ICTs into their business operations, thus bringing in organizational change. Firms are constantly evolving, with greater incorporation of digital technology, advancements in ICTs, skill dissemination, and the overall ways in which the firms are organized (Arvanitis & Loukis, 2009). This change is important for the firms to reap maximum benefits from the use of technology, particularly ICTs (Brousseau & Rallet, 1998).

The need for change is brought in by increasing competition among the firms with changes to the global economy, technological landscape, and also consumer-side preferences. This competition forces the firms to bring changes to the organizational structures to sustain, and position themselves well in the market. The change may be also driven by the firm's interrelated strategies regarding productivity, profitability, and market shares (Murphy, 2002). Firms are shifting focus to better harness human skills, knowledge, and technical capabilities. The growth in technology has been witnessed with increasing importance towards human skills and expertise to use this technology. Thus, a shift can be seen from the traditional scope of organizations focussing on plan, equipment, products, towards that of information, employee skills, and knowledge (Murphy, 2002).

One of the key implications of the use of AI in the wind energy sector is bringing in lean ways of operations. Making a system lean essentially means eliminating all sources of waste, including inefficient working methods, loss of resources, loss of working hours, or inefficient management of inventory and other business processes (Murphy, 2002). With AI capabilities, wind energy companies can bring faster decision making, predict faults, and efficiently manage fault diagnosis. The involvement of technology helps businesses re-engineer themselves, by focussing the creative tasks to be taken over by humans, while that of the redundant tasks by the AI systems (Wilson & Daugherty, 2018).

The use of ICTs in organizations also has implications on its knowledge management and employee skills. Organizations are now focussed on making the best use of the intangible assets, like employee skills and competencies, to complement the working of the digital systems. This brings a change in how organizations invest in their workforce, through upskilling and reskilling initiatives. Employee training programs have shown to improve the quality of output, thus necessitating its need especially when a new technology is introduced (Kling, 1995). The right set of training material and dissemination can help employees gain valuable skills and enhance productivity at work. It has also shown to help employees gain computer skills and bringing in technical expertise within the staff (Black & Lynch, 1996). Bringing in specialized skill requirements with the ICTs, also leads to some people joining organizations for a shorter period of time, to bring in the specialized knowledge and skills. This brings in non-traditional ways of employee engagement, where a certain section of people are employed "full-time", while others may be involved "part-time" or on a contractual basis (Murphy, 2002).

Another aspect that may be influenced with the use of technology is an organization's ability to outsource resources. With specialized technologies coming in, firms start outsourcing as a business strategy, in order to connect with external suppliers and free up their own resources (Murphy, 2002). Outsourcing helps the organizations to use state-of-the-art capabilities, without having to invest into research and development or associated risks in developing those capabilities. For the case of wind energy companies, data analysis, or infrastructural capabilities may be outsourced to make effective use of data and derive meaningful insights from it.

2.1.5. Ethics of AI in Wind Energy

2.1.5.1. Environmental Sustainability of AI Systems

As the use of ICTs to further sustainability gains prominence, the production and consumption of these ICTs also increases. In order for the net impact from the use of these ICT based systems to be positive, it is important to ensure that the production of these ICTs is made sustainable (X. Zhang & Wei, 2022). The AI systems aimed at creating sustainable business practices may contribute to rising emissions and increased energy usage, in turn compromising with the quality of the environment (S. Zhao et al., 2022). As newer technologies are introduced in making organizations ‘lean and green’, the increasing hardware churn rates, computational capabilities, and carbon emissions have a huge impact on environmental sustainability (Hilty et al., 2011).

For the case of the wind energy industry, AI systems help in predictive maintenance of faults that might potentially develop in the wind turbines. This is possible by training advanced AI/ ML models that use large volumes of training data to make these predictions. This analysis however consumes large amounts of energy, eventually leading to a high energy demand by the systems. The cycle follows, with the greater use of energy ultimately leading to increasing emission of greenhouse gasses and a negative impact on the environment (Belkhir & Elmeligi, 2018). Building efficient and optimized codes for training AI models could help reduce the need for high computational power, thus reducing the impact of these systems on the environment. Other concerns also arise, with the increasing use of hardware equipment required to integrate AI systems into wind energy systems. This concerns equipment like sensors that are placed on the wind turbines for data collection. The eventual use and disposal of these equipment can lead to environmental damage, thus increasing the overall Greenhouse Gas (GHG) emissions but also the environmental damage (Salahuddin et al., 2016). To account for this impact, a thorough Life Cycle Assessment (LCA) of such equipment must be done to correctly evaluate the impact of bringing AI-enabled systems into business operations.

The concerns regarding the use of AI systems include their negative impact on the environment, with high energy consumption, material use, and waste generation. Overall, the emissions with the use of AI systems themselves is a tradeoff that an organization makes for the outcome of overall improved operational efficiency and reduced emissions compared to traditional energy sources (Moyer & Hughes, 2012).

2.1.5.2. AI as a Black Box

AI-based systems are perceived as a black box, given they lack transparency at the consumer-end regarding their operations. For the purpose of wind energy, the right technical expertise is required to cross-validate the decisions made by the AI systems. For this, it is important to gather an understanding on how the system was trained and the ways in which it is evolving, so as to monitor its decision making. This can be done by bringing transparency in the AI/ ML training models and using interpretable and explainable tools to ensure greater understanding of such systems, enabling a sound decision-making process (Machlev et al., 2022).

Additionally, it is important to bring stakeholder engagement when introducing a new technology to existing business operations. For the purpose of introducing AI systems in the wind energy sector, local communities, technical experts, and regulators can come together to discuss their concerns and share insights to ensure a positive impact with the adoption of technology. This can ensure that the introduction of technology takes place in a fair and transparent environment, and leads to overall sustainable development (Lange & Hehl-Lange, 2005).

Moreover, grid operators have access to personal information like household electricity consumption, or patterns of energy usage across different locations. This is sensitive information that must be secure, and that the consumers must be made aware, if at all, this data is used for purposes apart from their intended use. Data encryption and authentication tools can also help here in securing personal data and prevent any potential data leak (Adekanbi, 2021). There must also be focus on regional information sharing and compliance measures, like the GDPR in Europe, to ensure that any personal data is not used for purposes that the data provider may not be aware of.

2.1.5.3. Concerns over Accountability

“Accountability refers to being answerable to somebody else, being obligated to explain and justify action and inaction” (Bovens et al., 2014). The use of AI brings concerns over the accountability and responsibility of its decision-making. In the context of this research, the use of AI systems leads to it taking crucial decisions on the repair, maintenance, and operational activities of the wind farms. These decisions are financially and resourcefully intensive, thus high stakes when taking action in accordance with these decisions. Incorrect decisions can not only lead to loss of resources and man-hours, but also raise concerns over the accountability of those actions. Thus, high-impact decision-making must be done with due human checks in place, to ensure that the AI ecosystem can function well for the long run without concerns over its accountability (Berscheid & Roewer-Despres, 2019).

AI systems are trained through training datasets that may not be fully accurate or complete. This may lead such systems to make decisions that are incorrect or biased. For the case of the wind energy industry, such systems could potentially prioritize efficiency of the wind farms over safety. However, the system itself is designed and trained in complex ways, and it could be difficult to understand the motivation for its decision and ensure that these decisions are ethically sound (Jobin et al., 2019). Any potential accident or an unforeseen event cannot be put to blame entirely on the AI systems or humans, since they have been developed jointly by the two. Thus, there needs to be greater transparency in the ways that the systems are designed and trained. This can help understand the decision-making processes better, thus helping address the challenge over the accountability of the decision itself.

2.1.5.2. Impact on Human Employment

With smart decision making and faster turnaround times with the use of AI systems, the human labourforce witnesses a shift away from its traditional engagements (Frey & Osborne, 2017). AI enabled robots can help detect faults in the turbines, carry out regular inspections, assist in image processing of the turbine blades, painting the blades, etc. These processes become more "efficient" with the use of the robots as they considerably reduce the investment in terms of human man hours. This essentially translates to cutting down the employment of the labourforce for such operational and maintenance activities.

Another aspect of the introduction of AI systems may be seen with the increase in the need for a technically competent labourforce. In this way, there will be a shift in the kinds of human skills required by the organizations. The reduction in the demand for manual labourforce, will be complemented with an increase in specific technical competencies within the working professionals (Mykhailychenko, 2019). This may also lead organizations to invest in reskilling or upskilling activities for its employees.

Yet another prospect that may be witnessed would be simply a re-arrangement in the tasks and responsibilities being shared among the humans and AI systems. This would mean that the responsibility of the regular and redundant tasks could be taken care of by the AI systems, while the human workers could become more invested in the complex and creative aspects of the tasks, thus working collaboratively with the AI systems to deliver the best results (Wilson & Daugherty, 2018).

2.1.6. Challenges with AI in Wind Energy

Fault detection and diagnosis continues to be a major challenge for energy systems at large (Guo et al., 2019). Issues related to data security and incomplete data are also some of the challenges faced in the energy industry (Y. Zhao et al., 2013). Moreover, the use of Artificial Intelligence systems for the wind energy sector and its grid operations continues to have its set of challenges, despite rapid advancements in the technology (Puri et al., 2019). In the wind energy sector, challenges arise with the use of AI, especially given the large amount of data being collected by sensors installed on the wind turbines. These challenges range from the lack of quality data, to inadequate infrastructural capabilities, technical expertise, compliance issues and legal issues. Some of the challenges are discussed below.

2.1.6.1. Cyber Attacks

The wind energy industry faces a larger threat from vulnerabilities and unauthorized access, as compared to other energy industries (Y. Zhang et al., 2017). The increasing use of AI in the wind energy sector has exposed the reality of growing cyber attacks in this industry (Sani et al., 2019). Such attacks can not only lead to the destruction of the infrastructural capabilities, but also incur huge economic losses (Ahmad et al., 2021). Vulnerabilities in the cyber systems can be exploited by hackers to intrude the SCADA systems of the windfarms and take control over one or multiple wind turbines. This could compromise with the overall reliability of the wind turbine, and lead to energy disruptions with eventual financial implications. Moreover, attackers could maliciously take control over the Energy Management System (EMS) and modify the operations of the wind turbines to possibly operate at lower efficiency than its normal operations (Y. Zhang et al., 2017).

Given that energy data is a high-impact data and holds high financial value, attackers are particularly interested in getting hold of this data. Also, with the increasing penetration of wind farms, a malicious attack on the energy systems has the power to disrupt the energy supply of a considerable section of the society. Intruding the SCADA systems of the wind farm also has the potential to possibly impact the different physical components of the wind turbine, and compromise with its operational activities (Y. Zhang et al., 2017). Once the intruder gains access to the system data, they could use it to sell information, disrupt the voltage and power supply, or shut down the systems altogether.

2.1.6.2. Technical Expertise

The right technical skills and ethical considerations are the backbone of designing efficient and ethical AI systems. Organizations may not be willing to invest in advancing technologies, given high financial investments associated with it, risk of data mismanagement, or the managerial investment in changing business processes. This is especially true for the energy industry where the stakes of data leak, data loss, poor data configurations, or unauthorized data access could lead to major financial losses (Ahmad et al., 2021). Thus, technically competent staff is important for organizations to invest in, in order to ensure safety against such incidents. The lack of technically competent staff also leads to delays in developing advanced digital capabilities, thus slowing the growth of an organization in the increasingly competitive market. Moreover, with a limited talent pool of people to work on bringing such technologies, there is a competition in acquiring these resources. This may bring competition among the industry to attract the best talent.

Organizations now realize this resource gap, and are investing in reskilling/ upskilling their employees. This takes place through online training programs, employee participation in R&D activities, seminars and sessions on the latest technological developments, etc. These attempts are made in an effort to keep one's employees up-to-date with the latest technological developments, and eventually close the skill gap. Since the use of AI in winfarms is evolving, there is a need for people to continuously upgrade themselves, learn new technologies and ways of problem solving. Additionally, the technical skill development within the individuals needs to be coupled with ethical compliance in order to ensure sustainable development of the industry at large (Hagendorff, 2020).

2.1.6.3. Funding

Developing smart systems and bringing them into existing ways of business operations is a high financial investment. Adequate funds are required for the entire duration of bringing this change, through software design, configuration, modifications, maintenance and management (Ahmad et al., 2021). Moreover, digital technology is a highly dynamic space, and new technologies get introduced very often. This translates to the need for organizations to build advanced capabilities for continuously adapting to the changing technologies. Adequate government funding in such cases could be useful for organizations to bring in the technology, and further invest in Research and Development (R&D) for the most efficient and sustainable means of technology adoption.

Research in the field of the use of AI in wind energy needs considerable funding to support the development of different AI models and algorithms. This requires high financial investments to bring greater computational power, data storage capabilities, and onboard technical experts. Since the use of AI in wind energy has transformed business operations compared to how they were carried out traditionally, investors may not be willing to put large financial stakes into the industry. Additionally, the need for compliance and adherence to regulatory measures with the use of AI, could deter investors for long-term financial investments. In such cases, government funding can help boost the research and also encourage private investors to invest in R&D in this sector.

2.1.6.4. Data Quality

In order to ensure reliability and accuracy of the energy being produced by the wind farms, it is important to accurately predict the power outcome and energy production. Wind turbines collect large amounts of data through sensors, weather stations, etc. Here, data quality is of critical importance to ensure that the AI systems are trained well. The quality of data determines the training data, which in turn would impact the predictions and forecasts that the model would make. For the case of wind turbines, the data collected by SCADA systems may contain incomplete/ missing values owing to sensor failures or communication congestion (Li et al., 2020). It thus becomes important to ensure that quality data is being captured, given that the turbine is exposed to noise, humidity, dust, and extreme temperature conditions, which could compromise the data quality.

Data preprocessing must be carried out, so quality data can be used for training the AI models. The traditional means of filling data gaps can be classified into four categories: interpolation-based methods, regression-based methods, similarity based methods, and parameter-estimation-based (Liao et al., 2022).

1. Interpolation-based methods: These mainly include linear or cubic interpolations (Q. Lin & Wang, 2014). The missing data is filled by constructing polynomials whose parameters are developed using the information around the missing data. However, the correlation among the different surrounding variables is not accounted for, thus limiting the scope of this method (Hu et al., 2019).
2. Regression-based methods: These include recurrent neural network (RNN) and back propagation (BP) techniques (Yoon et al., 2019). Compared to interpolation-based methods, regression-based methods make use of correlation among attributes, making it more accurate and thus widely applicable.
3. Similarity based methods: These have limited scope since they study the data surrounding the missing data, but do not study the correlation among the attributes .
4. Parameter-estimation-based methods: This includes point estimation and interval estimation (Wang, 2018). Missing data is filled here through the maximum likelihood estimation.

2.1.7. Future Prospects

The use of AI in the wind energy sector comes with its set of opportunities and challenges. While organizations continue to reap benefits from its use, they must be mindful of the challenges that its use accompanies. For this, it is important to have a long-term plan of assessing the adoption of the AI systems, in order to ensure there is an overall positive impact with its use. In this context, some of the future prospects of the use of AI in wind energy are discussed below:

- *Algorithmic optimization*: The AI algorithms currently used for predictive maintenance, fault detection and diagnosis are complex and expensive (Ahmad et al., 2021). These algorithms could be made more efficient so the energy use and the computational power of these algorithms is reduced or managed in a way that it is optimized compared to its current energy use.
- *Infrastructural capabilities*: The boom in big data and advanced data analytics has put constraints on the existing infrastructure to support such computation. The IT infrastructure now needs to be improved in terms of network transmission capacity, data

storage capacity, data processing capability, data exchange capability, data visualization capability and data interaction capability to better support energy production and management (Ahmad et al., 2021).

- *Ethical implications*: Ethical considerations must be increasingly built in technological systems. This could be made a part of the Corporate Social Responsibility (CSR) initiatives, and also internal organizational discussions. Priority must be laid on securing the data channels that store information on household energy consumption and patterns of energy consumption, to ensure that the data is not leaked, or used maliciously (McDaniel & McLaughlin, 2009). Considerations must also be made to understand the energy consumption of the AI systems themselves, and the emissions that their use generates.

- *Policy and regulatory measures*: Policy and regulatory measures must be updated in accordance with the growth witnessed with the use of AI systems. Regulatory approval for newer products and systems should be made seamless, cheaper, and faster, given the pace of AI adoption in organizations (Ahmad et al., 2021).

- *Participatory discussions*: As the wind energy industry and also the technology industry continues to grow, it is important to bring different stakeholders together and have discussions about the future of these industries. The use of AI in wind energy helps organizations and businesses, but it also impacts households that use this energy. Moreover, the energy production and distribution is regulated through policy makers who need to be kept abreast of the technological developments in this sector. The installation of wind farms also impacts the natural landscape, which may or may not be agreed upon by the society at large. Moreover, there must be active discussions among organizations, consumers, and also policy makers to discuss their ideas and apprehensions towards the use of technology, and the ways that it may impact these individual groups (Lange & Hehl-Lange, 2005).

- *Professional Skills*: The field of AI is continuously evolving. For professionals to continue working in the industry, it is important to constantly upgrade themselves in terms of professional skills and expertise. Organizations must invest in the skill development of their employees through training programs, seminars, knowledge sharing sessions, etc. Courses on data analytics, computer science, energy science can help train individuals in complementing their skills to the advancing growth in AI capabilities (Ahmad et al., 2021).

2.2. Current Initiatives

This section takes a brief look at some of the wind energy organizations that have adopted AI systems in their business operations. A review of their operations helps to understand how organizations are adopting this technology and building the necessary skills among their employees to innovate and create opportunities for sustainable development.

2.2.1. Vestas

Vestas is one of the largest wind turbine manufacturers in the world. The organization has witnessed vast changes in the growth of wind energy and its associated use of technology, since its operations began in the late 1980's.[3] The geographical scope of Vestas spans across the globe, with about 85 countries that continue to use their wind turbines. The focus of the organization is now moving from just building wind energy systems, to ensuring that these systems help optimize wind energy.

More recently, Vestas collaborated with Microsoft and Microsoft partner minds.ai, in successfully using Artificial Intelligence to generate more energy from the wind turbines. They achieved this by optimizing the wake steering[4] in the wind turbines. The amount of energy being generated by the wind farms can vary greatly owing to the external temperatures of changing wind and weather conditions. By working on the wake effects, Vestas made an attempt to bring technology (AI) in ensuring that the wind farm energy production can be optimized.[5]

Wake effect is an important aspect in the working of wind turbines. When wind flows through a wind farm, the turbines in the front disrupt the wind flow, creating a wake of slower-moving air behind them. This phenomenon has implications for the performance and efficiency of wind

[3] https://www.vestas.com/en/about/this-is-vestas/history/from-2009-2020 (Retrieved on May 28, 2023)

[4] Wake steering is the process to manage the trail left by each turbine where wind speeds are reduced

[5] https://news.microsoft.com/europe/features/winds-of-change-how-one-of-the-worlds-largest-wind-companies-is-using-ai-to-capture-more-energy/ (Retrieved on May 28, 2023)

turbines in the downstream. As a result of this, the downstream wind turbines are impacted by turbulent and reduced wind, compromising with the energy that could be produced by them otherwise (Porté-Agel et al., 2020). This also affects the wind turbines by increasing their fatigue against the turbulent winds, leading to performance degradation and a lower than optimal output.

Vestas and Microsoft collaborated to use AI and other high performance computing in designing reinforcement learning models that helped mitigate the impact of wake effects. With such a design, energy could be recaptured by turning the turbine rotors to point away from the incoming wind, and deflect the wake. Vestas makes use of this technology to take appropriate actions based on inputs from the wind farm environment, for example, adjusting turbine yaw in response to wind direction, speed, and wake effect to mitigate wake effect and increase wind farm efficiency and yield.[6]

2.2.2. ONYX Insights

The wind energy sector has been evolving over the years, with the data collected by the industry increasing considerably. With this, a greater understanding of these data sets need to be made to derive meaningful outputs. This brings in the need for advanced computational capabilities and data analytics to understand different data sets. ONYX Insights has built AI capabilities to bring together different data sets to enhance decision making and eliminate data silos.

With the traditional ways of operations where human technicians gather the data, the data gets stored in spreadsheets or offline means. With technology making its way now, ONYX Insights has launched the AI Hub to centralize critical data and ensure data analytics and data interpretation is done smoothly. AI Hub currently has different modules to integrate data from different wind assets:[7]

- Pitch Bearing Monitoring: Having advanced analytics and online sensor capabilities to make predictions for potential faults

[6] https://customers.microsoft.com/en-us/story/1430379358742351454-vestas-energy-azure-hp (Retrieved on May 29, 2023)

[7] https://onyxinsight.com/software-analytics/ai-hub/ (Retrieved on May 29, 2023)

- Advanced analytics and online sensor solutions to detect early warning signs of impending pitch bearing failures.

- Blade Drone Analytics: Use of drones for blade defect detection across the fleet and conducting repairs.

- Case Management: Bringing collaborative working with efficient means of data centralisation and communication.

- Lost Energy Intel: Machine Learning powered SCADA analytics identifying issues causing the most lost energy and reliability problems.

These aspects of the AI Hub help to improve the accuracy of the Operational and Maintenance (O&M) activities, and also reduce the additional operating expense (OPEX) that might have been caused otherwise. A centralized data repository also helps in conducting efficient data analytics and predictive maintenance of the wind farms. Moreover, the AI Hub promises to reduce the Levelized Cost of Energy (LCOE)[8] for its customers by up to 12%. In addition, it also promises to save up to 30% in maintenance costs, with efficient and accurate risk management.[9]

2.2.3. Hitachi Power Solutions

With the growing environmental consciousness and the push for renewable sources of energy, Japan is looking to move towards a target of net carbon neutrality by 2050. Wind energy is now a major investment in this regard, and there are facilities and infrastructure being built to capture wind energy. The Hitachi Group has been investing in building the wind farm infrastructure in Japan. The organization is now moving forward with AI technology as a part of this investment, with the use of drones for wind turbine blade maintenance.

As wind power gains prominence, its maintenance activities also need to be looked at with due considerations. The turbine blades may rotate at very high speeds that may reach up to 300 km/hr.[10] With such high speeds, the blades are vulnerable to damage, along with wear and tear. In

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[8] LCOE is a metric used in the energy industry to evaluate the cost of producing electricity from a specific energy source over the lifetime of a power plant or energy project.
[9] https://onyxinsight.com/software-analytics/ai-hub/ (Retrieved on March 29, 2023)

[10] https://www.hitachi.com/products/energy/portal/case_studies/case_008.html (Retrieved on May 29, 2023)

addition, extreme weather conditions like lightning or typhoons, could further damage the turbine blades, making the repair and maintenance to be made timely and proactively.

Hitachi Power Solutions made an attempt to address these challenges with the use of AI enabled robots for conducting regular maintenance with seamless operations. The organization worked collaboratively with a drone manufacturer, to use automatic drone-based image capturing. They have now reported a clear advantage with the use of these drones, over manual technicians who performed these tasks otherwise. The turnaround time for inspection of the turbine blades has reduced drastically, while the quality of the inspection has improved. Manual inspections for a particular site in Japan took place every 6 months, which meant technicians had to manually inspect and gather turbine health data across 1800 blades over the year. This was fairly human labor intensive, and required considerable time to keep track of the blade conditions.

Moreover, when capturing images from a telephoto lens camera earlier, the technicians had to rely on natural light to get a quality image of the blade. This could be hampered with the back light, thus compromising with the image quality. The use of drones has helped the inspection with ease of access to the turbine blade, and capturing high definition images from all angles. Gathering this information from the images, helps to study the blades closely and take proactive measures against any damage that could be observed developing.

2.2.4. Siemens Gamesa Renewable Energy

With the increasing scope and installation of wind turbines across the globe, there is an increasing need to cater to relevant operational and maintenance activities of these wind turbines. This work has been carried out traditionally by human technicians. It involves technicians scaling up the huge turbine heights, in an attempt to closely monitor and make notes of the faults. This would also include humans to conduct such operations some times far into the sea, with harsh weather conditions. Another way of monitoring and maintaining the wind turbines would happen with people on ground capturing pictures via telescopes or cameras to document and study faults that might have occurred on the turbines. This is a rather manual and time-consuming task, especially if any repair or maintenance activities are required within a short span of time. Moreover, in order to ensure regular checks, technicians would need to spend hours climbing up/ down the large turbines across the wind farms on a regular basis.

However, this process of timely maintenance and inspection is witnessing a shift. Siemens Gamesa Renewable Energy has made such an effort, by using AI-enabled robots to conduct these activities.[11] They have transferred the entire operational and maintenance process with autonomous drones and a digital solution called Hermes. Hermes is a digital solution based on the Microsoft Azure Cloud platform and Azure AI, that helps in data analysis. The drones can reach the heights of the wind turbines relatively easily, and can capture high-resolution images in a much shorter span of time. This data is then analyzed with Hermes, enabling a safer, faster and more accurate inspection.

Bringing in advanced AI capabilities is helping Siemens in streamlining blade inspections, in turn pushing for a more affordable source of renewable energy. In 2019 already, Siemens had expected to inspect about 1700 turbines by these drones, with capabilities of capturing about 400 images of a turbine's three blades in 20 minutes. Bringing in Azure AI capabilities helps to greatly speed up the inspection process by image recognition that can stitch images into an accurate model of an entire rotor in 34 seconds. The same task could take a human about 4 to 6 hours, with possibilities of errors.[12] Photo reviewing by softwares can help easily detect cracks and faults from, say, bird droppings and thus speed up the process of inspection, fault directions.

2.3. Conclusion

This section built an understanding of the ways in which the wind energy sector is gaining prominence, and the role of AI in the overall growth of the sector. A push towards cleaner and greener sources of energy is an incentive for wind energy organizations to invest in keeping up with the latest digital technologies. AI-based systems have been put to use across several aspects in this sector, including enhancing operational and maintenance activities, predictive maintenance capabilities, and reducing the turnaround time for fault detection and diagnosis.

Wind energy organizations have shown acceptance and eager adoption of this technology to improve business operations. This has been possible with AI systems helping in bringing down

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[11] https://www.siemensgamesa.com/en-int/products-and-services/service-wind/blade-services (Retrieved on May 30, 2023)

[12] https://news.microsoft.com/source/features/digital-transformation/siemens-gamesa-renewable-energy-wind-power-ai-cloud/ (Retrieved on May 30, 2023)

the cost of performing redundant activities, and reducing the risks of human accidents who would climb the wind turbine heights otherwise for fault detection and diagnosis. Moreover, early adoption and use of the latest technologies lends a competitive advantage to the firms within the industry. This adoption of technology trickles down to organizations bringing changes to their business strategy. This can be witnessed with an effort in upskilling and reskilling activities for thier current employees, investment in R&D for better use of the technology, and greater possibilities of collaboration between humans and machines to ensure the best outcomes.

While this technology adoption seems to greatly benefit the organizations, the issues and challenges associated with its use were also discussed. The literature review makes an attempt to explore the ethical challenges with the use of AI in the wind energy sector. This ranges from assessing the environmental impact and emissions that the use of the AI systems themselves generate, to the questions over the credibility of the decision making by these systems, and their impact on the employment of human labourforce. These discussions can slow down the pace of technology adoption, and raise concerns over its use. At the same time, organizations may face challenges that restrict technology adoption. For the case of this research, these challenges could include the threat of cyber attacks on the wind farms, lack of technical skills and competencies to work with the technology, limited funding opportunities for technology adoption, or the lack of good quality data to be used by the AI systems.

Thus, technology adoption in any organization needs to be looked at holistically, and must not only be concentrated on the advantages associated with its use. A clear understanding of the challenges associated with its use must be laid out, so that the process of bringing in the new technology is a conscious decision that the organization takes. The use of this new technology also impacts organizational priorities and brings in new means of operations and business priorities, to sustain industry competition but also progress with the changing technological landscape.

3. Theoretical Framework

In this section, the different academic theories are discussed that will be used to analyze this research comprehensively. First is the Technology Acceptance Model (TAM) will be discussed, which aims to understand the factors that affect the adoption of technology in an organization.

Later, the Resource Based View (RBV) is discussed to understand the ways in which organizations build sustained competitive advantage by building unique competencies and resource capabilities within themselves. This is followed by a discussion on Sociological Institutionalism that aims to understand the impact of socio-cultural factors in influencing business operations.

This section lays an introduction to the theoretical approach of this thesis. It briefly discusses the different theories that were explored while developing a theoretical framework for this research. A number of theories were studied to be potentially used in this research, however the ones that closely resonated to be answering the research question are discussed in this section. While all the theories discussed as part of this section were not finally used for the research, this section helps to develop the reasoning for using/ not using a particular theory.

Ecological Modernization theory - This theory emerged in the late 20th century, as a response to the growing concerns over environmental degradation, with the rapid economic growth. The theory presents an optimistic view on the value of using technology to optimize processes, reduce waste, and thus help in bringing environmental sustainability (Andersen & Massa, 2000). At its core, The Ecological Modernization theory suggests that societies can ensure environmental sustainability without compromising economic prosperity. 'Efficiency revolution' is being adopted by organizations to allow economic growth, while improving the environmental impact by, improving the efficient use of materials, increasing resource productivity, etc (Huber, 2000). While this theory could bring two of the most important aspects of this research together, i.e. technology and sustainability, its use would limit the understanding of the research question. An important aspect of this study deals with the idea of 'adoption' of technology (here, AI). While the Ecological Modernization Theory could help understand the impact and relationship of technological growth on the environment, it would not have helped explore the adoption of technology and its associated challenges in the wind energy sector. This theory was thus removed from further consideration.

Diffusion of Innovation - Diffusion of innovation simply refers to the idea of how, why, and at what rate, a new technology, product or practice is adopted in a social system (Rogers et al., 2014). For the purpose of this theory, 'innovation' is understood as an idea, procedure or system that is new for the adopter (Rogers, 2010). It may not necessarily have been recently developed, but it is considered to be new for the person or organization adopting it. This adoption could vary across the social system- with early adopters, late adopters, or laggards spread across the system in terms of their readiness for innovation adoption. While some groups can be willing and accepting of change, others may have skepticism or reluctance to bring change, and hence the spectrum of adoption exists (Lundblad, 2003). While the Diffusion of Innovation addresses the aspect of 'adoption' which is an important aspect of this study, it still remains broad to discuss the adoption of 'innovation', at large. For this study, the core idea lies in the idea of 'adoption of technology (AI)'. Hence, a more robust theoretical understanding is required to explore the idea of adoption of AI by the wind energy companies. This was resolved by utilizing the Technology Acceptance Model (TAM). The TAM very comprehensively discusses the different factors that influence the adoption of technology by an organization. Using TAM also helped overcome the shortcomings that were evident with the theories discussed above. The TAM is discussed in detail in the following section.

Next, the Core Competency Theory was explored to understand its fit with the research. Organizations today are faced with dynamic market situations and external factors that may disrupt their traditional ways of operations. A growing competitive environment, global market disruptions, changing customer preferences, technological growth or reengineering necessitate managers to build strategies to navigate these changes. The Core Competency Theory proposes that organizations nurture their unique value propositions in order to sustain competition and ensure long-term success (Prahalad & Hamel, 1994). Top executives are increasingly required to identify, cultivate and exploit core competencies within the organization, in order to make growth possible (Prahalad & Hamel, 1990). These core competencies are the unique knowledge and skills that exist within an organization that bring it competitive advantage. However, when exploring this theory further, its understanding of 'core competencies' did not resonate with the idea of using 'AI' in the wind energy sector. By core competence, the theory refers that it should be competitively unique, must be difficult for competitors to imitate, and should provide potential access to a wide variety of markets (Prahalad & Hamel, 1994). However, the discussion for this research does not involve a product or technology that essentially is difficult to imitate by its competitors. Rather, the research focuses on how organizations are using existing technologies to build skills and gain competitive advantage. The Resource Based View (RBV) discusses this aspect much better, in the context of this study. RBV explores the ways in which organizations can build sustained competitive advantage by the effective utilization of valuable, rare, inimitable, and non-substitutable resources (Barney, 1991). This is discussed in greater detail in the following sections.

Lastly, the Actor Network Theory (ANT) was studied to understand its fit with the research. The ANT is an analytical tool used to investigate the creation and maintenance of coextensive networks of human and nonhuman elements (Callon, 1984). These elements are referred to as actants, meaning that they must interact between one another, with the goal of forming a heterogeneous network of aligned interests (Latour, 1996). ANT studies the interaction between both the human and non-human actors and focuses on the interactions between them. It captures the idea that the actions of one actor in a society, whether human or non-human, influence other actors to take action too (Bencherki, 2017). While the theory would have potentially helped to understand the various external factors that influence the adoption and use of AI in the wind energy sector, its understanding in this context would be quite broad. This is primarily with the broad range of external factors that can have an influence on the AI adoption for the wind energy organizations. Moreover, a major focus of this research is on organizational change with the adoption of AI, and hence emphasis is laid more on the internal factors to witness this change. Thus the external environment is not a major focus of the research.

With this consideration, and to narrow down the scope of external factors in understanding organizational change, Sociological Institutionalism was used. Sociological Institutionalism focuses on understanding the social and cultural aspects of institutions and their influence on individuals, organizations, and society. It examines the ways institutional change is shaped through social interactions, power dynamics, and cultural connotations. This becomes relevant as the production and use of wind energy is influenced by institutional factors, but also cultural and social norms. This is discussed in greater detail in the following sections.

3.1. Technology Acceptance Model (TAM)

Technology adoption is a major research focus in the information systems (IS) domain. It is a major element to be studied, with a rapidly changing technological landscape (Marangunić & Granić, 2015). There have been several definitions of technology adoption, one being that technology adoption is defined as the first use or acceptance of any new technology or new product" (Khasawneh, 2008). Technological adoption has been studied with an aim to understand, predict, and explain factors influencing adoption patterns and behaviors of individuals and organizations to use technical innovations (Gangwar et al., 2014). TAM can help study this well, as it has been found to be a valid, robust, and the most dominant model to explain technology adoption at an organizational level (King & He, 2006). The TAM, in such cases, is a widely accepted model to understand the factors affecting the acceptance of technology by different users and organizations.

TAM has been derived from two psychology-based theories: Theory of Reasonable Action (TRA), and the Theory of Planned Behaviour (TPB) (Marangunić & Granić, 2015). Further, TAM aims to study technological adoption via two factors: Perceived Usefulness (PU), and Perceived Ease of Use (PEOU) (Davis & Davis, 1989). PU is defined as "the degree to which a person believes that using a particular system would enhance his or her job performance," and PEOU refers to "the degree to which a person believes that using a particular system would be free of effort" (Davis & Davis, 1989, p.320). The model also suggests that PEOU can influence PU, as the technologies that are relatively easier to use by the user could in turn have high usefulness.

The initial studies in this domain showed that humans act as rational beings and make good use of the information available to them (Ajzen, 1985). This was called the TRA, which viewed a person's actual behavior to be determined by their prior intentions, coupled with the prior belief the person would have for a given behavior (Davis, 1985). The TPB was later added as an extension to the TRA, to accommodate for the limitations that existed with the use of only TRA. The TPB was used to bridge the gap that existed with TRA over decisions that lay outside of an individual's control (Ajzen, 1985). The TPB lays that an individual's specific behavior is a result of their intent to perform that behavior (Marangunić & Granić, 2015). The aspects of TRA and TPB were then brought into the TAM to understand the attitude of an individual or user towards a system. Thus the origin of the TRA and TRB came from psychological contexts, but has now evolved as a key model to help understand the determinants of human behavior towards the potential acceptance or rejection of a technology (Marangunić & Granić, 2015).

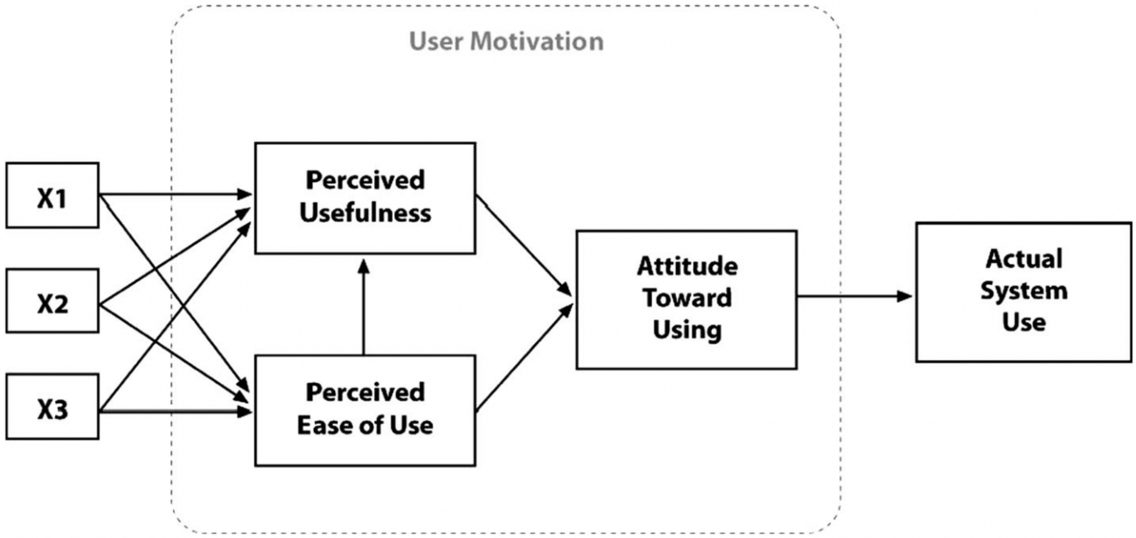

Figure 1. Technology Acceptance Model (Marangunić & Granić, 2015)

The TAM has been widely used in the IS field, and continues to provide a strong backing for understanding technological adoption. For the purpose of this study, TAM provides the right theoretical understanding to study the incoming AI technology in the wind energy sector. The adoption of AI systems in this sector brings changes to the ways in which operational and maintenance activities are conducted, while also changing the kind of skills that are required to be able to make sense of the vast amount of data being generated. The data is fed into training sophisticated models that can help derive meaningful insights in assessing turbine health, predictive maintenance, routine operational checks, among many others (Hameed et al., 2009). Moreover, with the right upskilling initiatives, people could learn the technical know-hows of using such systems, easing the process of use of the new technology.

However, the adoption of the technology poses both opportunities and challenges. This aspect of the research will be studied with the use of TAM, more specifically understanding it with respect to its two elements of PU and PEOU. The PU aspect will be used to analyze the ways in which the use of AI enables lean models of working, enabling greater efficiency with limited resource requirements. This aspect will explore the degree of operational efficiency being brought by the AI systems, and also its impact on reducing the turnaround time in fault detection of the wind turbines. At the same time, ethical constraints with the use of AI systems will be studied, in order to understand inhibitions that organizations could have towards its adoption. Moreover, the element of Perceived Usefulness (PEOU) will be studied by investigating how people involved in the wind energy sector are able to learn, reskill/ upskill and adapt to the technical know-hows of using AI. This will be supported with discussion from technical experts, and also wind turbine technicians that face the use of AI systems in the wind energy sector, first hand.

3.2. Resource Based View

The Resource Based View (RBV) is a theoretical framework that aims to understand the ways in which unique resources and capabilities can give an organization sustained competitive advantage in the industry (Barney, 1991). Some key contributors of the RBV are its emphasis on the heterogeneity of resources, resource capabilities across the firm, firm-specific resources rather than industry-wide resources, the idea of core competencies, and dynamic capabilities ((Barney, 1991), (Prahalad & Hamel, 1990), (Teece et al., 1997)). These aspects have contributed to the RBV for building a better understanding of strategic management and competitive advantage for a firm.

Understanding the determinants of sustained competitive advantage has been an area of research in strategic management (Porter, 1985). There have been different ways to understand a firm's ways of gaining competitive advantage: an analysis of the firm's opportunities and threats (Porter, 1985), or its strengths and weaknesses (Hofer, 1978). Porter's “five forces model” is also an attempt in this regard, to understand the attributes of an attractive industry, implying that the opportunities will be greater than the threats for such cases (Porter, 1980). However, these theories have made some simplified assumptions across the industry in that they assume that the firms are identical in terms of their resources and capabilities (Porter, 1981), and that resource heterogeneity developed in the industry is short lived (Barney, 1991). The RBV builds on these shortcomings and lays stress on the uniqueness of resources within an organization, and also builds an understanding that the resource heterogeneity is sustained over a considerable period of time, rather than being short lived (Barney, 1991).

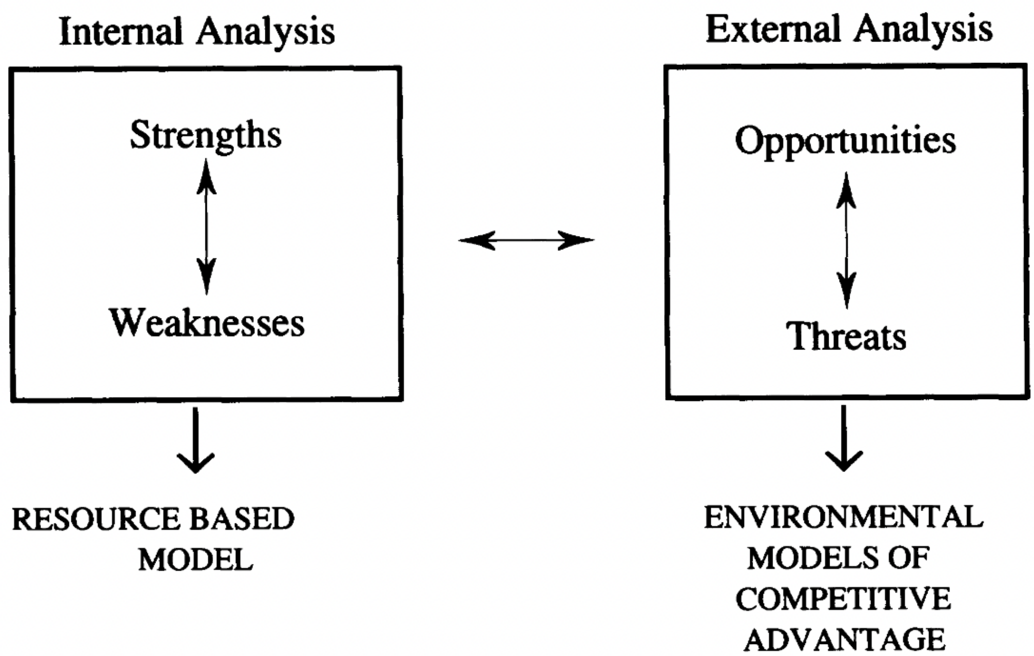

Figure 2. Relation between traditional "strength-weakness-opportunities-threats" analysis, resource based model, and models of industry attractiveness (Barney, 1991)

The RBV stresses on the idea of 'sustained competitive advantage'. A firm is said to have sustained competitive advantage when it is implementing a business/ value creation strategy that is not simultaneously being implemented by any current or potential competitors, and when these other firms are not able to duplicate the benefits of this strategy (Barney, 1991). In addition, a competitive advantage is sustained when efforts to duplicate its advantages have ceased (Lippman & Rumelt, 1982). More importantly, sustained competitive advantage does not mean that it would last forever, but rather it implies that it will not be competed away by efforts of its duplication by other firms. However, some resources that may have provided competitive advantage at a certain period of time, may not continue to do so with changes in firm structure, economic landscape and market changes. Unanticipated shocks to economic structures lead to "Schaumperian shocks" which in turn redefine the firm's resources that would now bring them value and competitive advantage in the changed environment (Barney, 1986a).

An organization's resources can thus be an important factor in determining its competitive advantages. It can help firms implement organizational strategies, and improve business efficiency (Porter, 1981). Some of these resources can include assets, capabilities, information, knowledge, and the like (Daft, 2010). These resources could be physical, human capital resources, or organizational capital resources. In the context of this research, human capital resources will be focused upon, which includes training, experiences, and insights of employees in the organization (Barney, 1991). This study will delve into the resources in terms of people skills, competencies, and technical expertise that can evaluate the changes to organizational structures when technology is introduced within the organization. Once the resources are set in place, organizations can then invest on building the right managerial groups and linkages amongst these resources to bring value to the organization (Barney, 1991). These managers can eventually become a valuable resource for the company in aligning its business strategies, and defining a clear vision for the future (Zucker, 1977).

There has been growing research in understanding the ways to build competitive advantage with information processing systems (O'Brien, 1983). Physical information processing systems like computers and laptops, are commonplace now and may not necessarily provide a competitive edge to an organization (Barney, 1986). However, the process of technology adoption, and connections between computers and managers, is something that brings uniqueness to an organization's operations, thus building potential for competitive advantage (Bruce, n.d.). Existence of good organizational culture and business practices can help build a good company reputation. This in turn helps bring a competitive advantage to a firm and brings value among customers and suppliers (Porter, 1980). Such values bring a unique component to organizations that may be difficult for other firms to replicate.

For the purpose of this research, the RBV will be used to understand the firm's resources, both human and non-human, and how it builds on them to bring sustained competitive advantage. The different aspects of the firm will be analyzed, in terms of human resource, skill availability, upskilling and reskilling activities, infrastructural capabilities and efforts of the organization in investing in unique internal resources. An understanding through the RBV lens will help identify the core competencies within the wind energy organizations, and the ways in which organizations develop and leverage these core competencies to bring sustained competitive advantage (Prahalad & Hamel, 1990). This will help understand the internal drivers and capabilities of organizations in order to build its competitive edge within the industry.

3.3. Sociological Institutionalism

Organizations work within the complex network of social, economic, and global market forces. These factors act as an external push to shape organizations and mold them in accordance with the socio-cultural reality of society. These factors are motivated by increasing the legitimacy of the organization, bringing stability, and ensuring long-term success, but eventually bringing increased complexity in the formal organizational structures (Meyer & Rowan, 1977). Sociological Institutionalism explores the ways in which organizations are influenced by external social and cultural factors and the ways in which they adapt to these external influences. Sociological institutionalism identifies 3 types of institutional pressures that can influence the behavior of an organization (DiMaggio & Powell, 1983). These are referred to as ways of institutional isomorphism and are discussed below, along with their contact for this research:

a. Coercive isomorphism: This arises from political, legal, or regulatory environments. For the context of this study, policy regulations by the governments on adhering to certain quality measures, standards, energy production, and legal requirements when setting up wind farms in foreign lands, can play a role in defining how an organization defines its business operations. These factors influence the operations and expansion of wind farms, and in turn their readiness for new technology adoption. Organizations need to abide by these measures to avoid penalties, loss of sanctions or the loss of legitimacy.

b. Normative isomorphism: This occurs when organizations conform to the social or cultural values to adopt certain organizational practices. For the context of this study, the social confirmation on setting up of wind farms needs acceptance by the wider public. Some sections of the public have reservations on the growing windmill installations, and believe that this disturbs the natural landscape. Such opinions need to be encouraged so greater community participation is reflected when acting upon certain decisions. Organizations tend to abide by these factors to bring legitimacy, but also social and cultural appropriateness in their operations.

c. Mimetic isomorphism: Mimetic behaviour is when an organisation imitates or mimics some other organization that has successfully brought change in its business practices. With growing technology adoption in the wind energy sector, there is an increasing competition within the industry for faster adoption of new technology and smoother business operations. For the context of this study, organizations may be willing to invest in AI adoption, when witnessing the growth and success that it is bringing to other organizations in the same industry. This leads to some organizations emerging as success stories for others to follow suit. Such mimetic behavior is often driven by a desire to reduce risks and uncertainty, while also evolving as per industry growth.

Sociological institutionalism thus offers a powerful lens to understand the influence of social, cultural, and regulatory factors on institutional behavior. The choice of using sociological institutionalism helps bring a comprehensive view to understand the influence of external factors in defining the operations of an organization.

3.4 Analytical Framework

The framework used for the purpose of the research is the Technology Organization Environment (TOE) framework developed by Tornatzky, Eveland, and Fleischer in the nineties. This framework has also been understood as a theory that is used in the field of information systems (Awa et al., 2017). For the purpose of this study, the TOE will be utilized as a framework that will be connected to different theories to bring a comprehensive understanding of the framework across all aspects of Technology, Organization and Environment.

The TOE framework is composed of different factors that are considered to be enablers of successful technological adoption, technological assimilation for innovation, and indicators of the likelihood of the adoption happening (Oliveira & Martins, 2011). The framework identifies three aspects that influence an organization in adopting and implementing technological innovation: technological context, organizational context, environmental context (Eveland & Tornatzky, 1990).

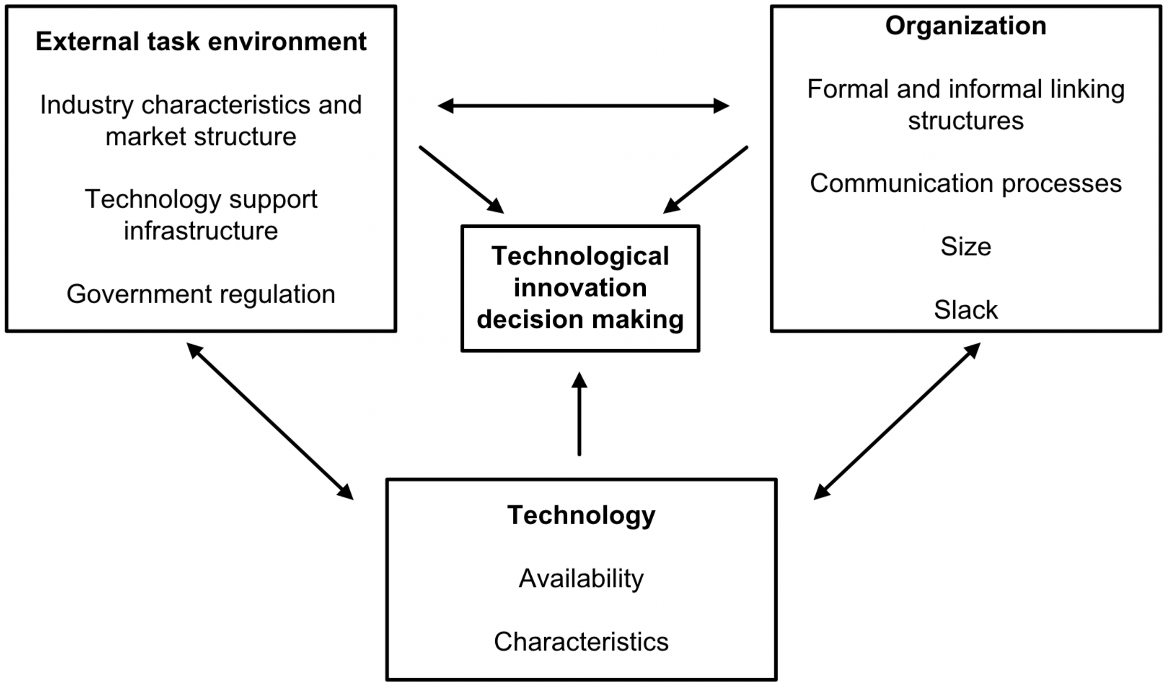

Figure 3. Technology Organization and Environment framework (Tornatzky et al., 1990)

Some researchers have argued that the usefulness of the TOE is further enhanced in conjunction with other theories (Awa et al., 2017). This has motivated this research to include theories of Technology Acceptance Model, Resource based View, and Sociological Institutionalism to complement the understanding built from the TOE framework. The foundation of the analytical framework is built on the TOE, as it has a strong theoretical basis, consistent empirical support, and its potential use in different aspects of Information System adoption (Oliveira & Martins, 2011). The use of the TOE for the purpose of this study will help build a comprehensive understanding of organizational change being brought about with the introduction of AI systems. It will also help evaluate this change from different perspectives, and help identify the internal drivers and challenges for bringing the change.

The TOE framework has provided a robust theoretical model akin to that of other adoption theories. It is found to be more strongly theoretically backed for technological acceptance, in comparison to other ones such as the Innovation Diffusion Theory (DOI) (Gangwar et al., 2014). Moreover, the TOE utilizes the environmental aspect (which is not included in the DOI), making it better to be able to explain intra-firm innovation adoption (Oliveira & Martins, 2011).

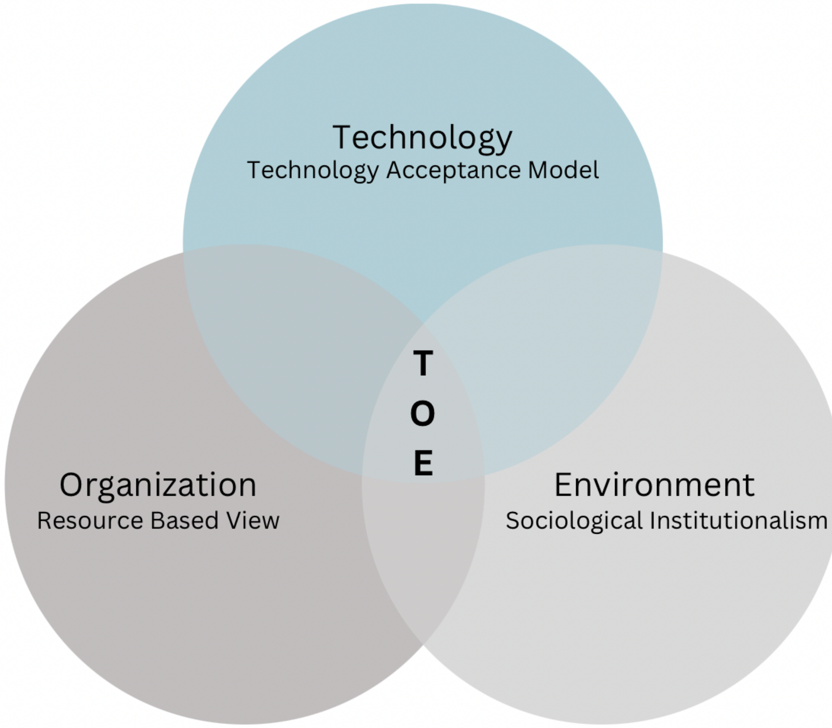

Figure 4. Analytical framework

The technological context of this framework focuses on the technologies that can be implemented or adopted by organizations. This would often be influenced by the existing technical expertise within the organization. This is further supplemented by the preparedness of an organization to bring in the technology, its existing infrastructural capabilities, and the resources at hand to seamlessly adopt the new technology. Therefore, in order to ensure that the adoption of technology positively impacts the organization, it is important to ensure a plan of technical implementation and clear benchmarking of parameters to reflect a successful adoption of technology, are put in place. This adoption can eventually help build processes for the adoption and implementation of new business processes (Eveland & Tornatzky, 1990). For example, the use of AI is now helping build systems that are trained in predictive maintenance of wind turbines, and enhancing operational efficiency. This not only helps in the early detection and possible mitigation of faults, but also helps reduce financial and human labor hours to rectify such faults (Hameed et al., 2009). Thus the right technical skills and infrastructural capabilities need to be built within an organization for it to successfully adopt technology and bring sustained competitive advantage.

The organizational context in the framework focuses on the kind of people skills and managerial structures that exist within the firm, the degree of formalization and centralization, the organization's size, the different kinds of resources it owns, and the ways in which employees are linked within the organization. It also tries to understand the ways in which communication happens within the organization, and the role of the leadership team to facilitate these conversations. Understanding an organization and its structure plays a key role in enabling or constraining its ability to be technologically innovative (Eveland & Tornatzky, 1990). For this research, the organizational aspect will help understand the ways in which wind energy companies invest in reskilling/ upskilling its employees, R&D initiatives, to better adopt AI capabilities within the organization.

The environmental context of the TOE framework focuses on the surrounding regulatory requirements imposed by the government, but also the competitive pressures that force certain organizations to adopt ICTs (Govindarajulu et al., 2006). This context also helps to understand the external support required by organizations, for example, in case of small businesses where vendors and contractors can push towards specific technology adoption (Awa et al., 2017). For the purpose of this study, the socio-cultural context of technology adoption is studied with the help of sociological institutionalism. The discussion on the environmental aspect will however be limited here, since this study focuses on the internal drivers of change when adopting a new technology.

4. Methodology

4.1. Literature Review Process

The literature review process was broken down into three main steps; planning, conducting, and reporting, adapted from the systematic literature review method.

An initial review of wind energy organizations using AI technology was conducted to identify potential research areas. Based on this review a research question was formulated to aid the initial planning of the review:

RQ (V1) - How are AI-enabled robots supporting environmental sustainability, with their use for fault detection in windmills?

The next step was searching for academic papers, journal and conference articles, book chapters, and reports that matched the areas identified in the initial research question. The search was conducted primarily via the Google Scholar database with keywords listed in Table 1. Results were scanned and the abstracts were reviewed to gauge their relevance, and 26 papers were selected from this search.

Keyword	**Selected Entries**
AI in wind energy	6
Technology adoption in wind energy	5
Challenges of AI adoption in wind energy	5
SCADA data in wind energy	6
AI for environmental sustainability	4

Table 1. List of keywords

The results were then studied for an in-depth review. During this review, further themes were identified in the papers that were then grouped together to form the main themes for the research. These themes were: wind energy and AI, motivations for AI adoption in wind energy, challenges with AI in wind energy, and SCADA data analysis.

Based on this review the research focus was then altered to formulate a new research question:

RQ (V2) - What are the motivations of the wind energy companies to adopt AI-based systems for fault detection in windmills?

Based on the further literature review and the revised research focus, it was realized that the idea of 'motivations' could lend a philosophical angle to the study, which was not intended. Further literature sources helped add additional keywords to the search: ethical implications of AI in wind energy, future of AI in wind energy. 8 further literature sources were added to help in building an understanding of these themes. The research question was then formulated as:

RQ (V3) - How does the use of AI drive change within the wind energy organizations to achieve environmental sustainability?

As the themes and the literature sources better matched this research question, the reporting of the literature review was then conducted based on the themes, and the in-depth review of the 34 initial sources. During this process, the references cited in the papers were used to further enrich the literature sources.

Two sub-questions were added, to comprehensively analyze the main research question. These questions were:

1. What are the driving forces and barriers to the adoption of AI-enabled systems in the wind energy sector?
2. How are wind energy organizations (re)aligning themselves with the advent of AI-enabled systems?

The key learnings from the literature review process can be found in Section 2.1.

4.2. Scientific Method

Utilizing the research onion (Saunders et al., 2019), a deductive approach was followed, starting from acquiring an in-depth theoretical background. Through a literature review about the research topic, focus was laid on the adoption and use of artificial intelligence in the wind energy sector, the related opportunities and challenges, and the future prospects. Following this, a number of academic theories to study these aspects were explored. The Technology Acceptance Model (Davis, 1985), Resource Based View (Barney, 1991), and Sociological Institutionalism (Meyer & Rowan, 1977) were used to understand the research topic from different perspectives, and provide answers to the research question. The theories and literature review helped guide the methodological approach. As the approach moved from building a theoretical understanding, to the data gathering and analysis, it went from something general to something more specific (deductive). The deductive approach enables one to see the causal relationship between a series of variables. By following the principles of reductionism one can simplify the patterns and relationships found in the interviews (Saunders et al., 2019).

For this study, qualitative interviews (Gubrium & Holstein, 2002) were conducted because the research aims to understand the driving forces and barriers in the adoption of technology by the industry, which suggests qualitative answers. Qualitative interviews, in this case, also provide an avenue to do exploratory research and give an opportunity to the interviewees to express their ideas and thoughts based on their experience in the industry. Two sets of interview questionnaires were prepared, to delve into the technological (TAM) and organizational (RBV) aspects of technology adoption in the wind energy sector.

The following table (see Table 2.) shows the details of each of the interviews that were conducted, including the time duration and the mode of the interviews.

Sr. No	Date	Duration	Setup
1	15.06.2023	46 mins	Online interview
2	18.06.2022	45 mins	Online interview
3	22.06.2023	40 mins	Online interview
4	24.06.2023	47 mins	Online interview
5	27.06.2023	50 mins	Online interview
6	30.06.2023	70 mins	Online interview

7	01.07.2023	42 mins	Online interview
8	02.07.2023	50 mins	Online interview

Table 2. Interview details

4.2.1. Methodological Approach

The choice of this methodological approach was such since it enabled a qualitative understanding of the driving forces and barriers of technology adoption, which are qualitative aspects. Taking a quantitative approach would not have given an objective insight into the views of experts in the industry. Interviewing the participants resulted in the collection of primary data for the research.

4.2.2. Methods of Participant Selection and Data Collection

To be able to better analyze the research question, semi-structured interviews were conducted to structurally guide the discussion, while also allowing the interviewee to share additional thoughts on topics that were not included in the interview draft. The process of participant selection and data collection is discussed below.

4.2.2.1. Participant Selection

After a thorough search online on wind energy organizations using AI systems, and using a combination of keywords such as “Wind energy”, “Artificial Intelligence”, “Environmental sustainability” a list of companies was prepared that fit the research criteria. 28 organizations were reached out to, which resulted in the final sampling being generated through self-selection from the organizations that agreed to collaborate.

4.2.2.2. Data Collection

A total of 8 interviews were conducted, these ranged across interviewees from the technology and organizational (technology-managerial) positions. Semi-structured interviews were conducted since they gave the possibility to ask additional questions and come up with newer themes that might not have been thought of otherwise. The interviews started with a structured set of questions, which was then followed by additional non-preplanned questions. The interviews conducted were between forty minutes to seventy minutes. All the interviews were performed online and were recorded via an audio recording application. All note-taking and recordings were performed with consent by explicitly asking the participants if they were comfortable with it.

To start the interview, the interviewer gave a short introduction of the topic, the motivation of the research, requested the consent to record the interview and stated when the recording started. To conclude the interview, the interviewer announced when the recording was stopped.

The interviewees were allowed to suggest the option of having the interview in person or online. In order to ensure the best audio quality in the recordings, the interviewers asked for a room with few people and if possible only for the interview. The suggested time slot for each interview was about an hour.

4.2.2.3. Data Analysis

Two sets of questionnaires were developed, to explore the technology and organizational aspects of bringing AI in the wind energy industry. The interview questionnaires were mapped against the theories used for the research. Interview transcription was conducted post each of the interviews. Once the interview transcripts were finished, individual quotes were extracted as part of the thematic analysis.

The Technology Acceptance Model was used to understand the factors affecting the adoption of technology (here, AI) by the wind energy organizations. Questions were designed to understand the opportunities and challenges that are witnessed with this technology adoption. Another perspective in the data analysis was bought by the Resource Based View. This helped identify the ways in which organizations (re)align themselves when a new technological model is introduced within the firm. Further, a third lens of Sociological Institutionalism was added to explore the impact of socio-cultural factors in the adoption and use of technology by an organization. This helped understand the ways in which governments, regulatory bodies, and also the general public at large can affect the adoption and use of AI by the wind energy organizations.

After the interviews were conducted and transcribed, a theoretical thematic analysis was performed on the transcripts. This approach was chosen since it enables one to look for patterns within the interview data (Braun & Clarke, 2006). During the literature review, some initial themes were identified to answer the research question. The thematic analysis further helped understand more about the interviewee's perceptions and views. The transcribed interview notes were coded with the help of a computer-assisted qualitative data analysis tool and, and 15 themes were shortlisted. These themes were then utilized to gain an understanding of each interviewee's perceptions. Additionally, the process of transcription also helped identify themes that were complementary to the ones found in the initial literature. After each interview, the transcription was performed with the use of a third party application, followed with quality control by the interviewer.

A thematic analysis was found to be the best option to analyze the data from the interviews. To find the relevant topics, the themes identified within the data were used as a benchmark. The theories and frameworks from the theoretical framework of this report were used as complementary sources to support the analysis.

4.3. Ethical Considerations

In order to ensure that this study was conducted ethically, the researcher took all necessary measures. During the initial discussion, interviewees were provided with all necessary information about the project. If participation in the project was confirmed, consent to record the interview was asked for beforehand. The participants were also free to share any questions, concerns or opt out at any point during the process. If requested by the participants, the interview questionnaire was shared beforehand. After the interview, a third party software was used for an initial transcription and the data was then removed from the cloud storage. The transcripts of the interview were anonymized and any personal identifying information was removed.

5. Results

In this section the demographics of the research participants in this study are shared, in order to set the background. This is followed by a discussion on the key findings. The thematic analysis is used to discuss and analyze the findings based on the literature review and analytical framework. Finally, this section concludes with a discussion on the overlapping ideas in the themes.

5.1. Demographics

For this study, two sets of interviews were conducted to explore the technical and organizational aspects of AI adoption in wind energy companies. These interviews discussed the driving forces for the organizations to adopt the technology, challenges faced, ethical considerations, as well as its future potential in the wind energy sector. Table 3. describes in more detail the characteristics of the interviewees.

#	**Interviewee Specialization**	**Years of experience with AI**	**Interview Type**	**Specific use of AI in interviewee's job role**	**Organization size**
1	Wind turbine bearing and hardware	10 years	Technological	Using AI to understand the patterns of vibration in the turbine bearing for early fault detection	>25000 employees
2	Product and portfolio management	7 years	Organizational	Providing technical expertise on the use of AI for predictive maintenance, Agile ways of business operations	>25000 employees
3	Wind prognostics engineer	5 years	Technological	Ensuring quality training data for AI systems	>80 employees
4	Wind turbine blades and neural networks	8 years	Technological	Use of AI for predictive maintenance in wind farms	>30000 employees

5	Wind turbine technician	10 years	Technological	Use of AI enabled robots for fault detection and diagnosis	>100 employees
6	Technical Manager	7 years	Technological/ Organizational	Technical outsourcing and insourcing for the use of AI	>150 employees
7	Technical expert	12 years	Organizational	Building AI capabilities for wind farm operations	Dedicated team of 5 experts within a larger organization
8	Technical director for offshore wind farms	10 years	Organizational	Responsible for the use of digital technology in offshore wind, technical upskilling activities	Dedicated team of 7 experts within a larger organization

Table 3. Overview of respondents

5.2. Findings

15 codes were identified (see Appendix 5), which were applied in 197 codings. Further, 6 themes were identified which were assigned to different codes in the codebook (see Table 4.).

#	Theme	Codes
1	State of the Industry	State of Industry
2	Driving Forces	Operational Efficiency Predictive Maintenance Competitive Advantage
3	Organizational Change	Upskilling/ Reskilling activities Technical Competence Research and Development
4	Ethical Concerns	Reliability in Decision Making Impact on Human Employment Environmental Sustainability in AI Systems
5	Challenges	Data Quality Cyber Security Financial Investment
6	Way Forward	Impact of External Factors Future prospects

Table 4. Themes assigned to codes

5.2.1. State of the Industry

The theme *State of Industry* is based on the code *State of Industry* consisting of 21 quotes. The theme was used to describe the current developments in the wind energy sector. Data analysis capabilities have existed long before, but discussions with industry experts have highlighted the ways in which AI capabilities have enhanced decision making with shorter turnaround time for fault detection and diagnosis.

> *"So let's say if you have some measure of detecting vibrations. And from that data that you can kind of analyze that something is going on is perceived as a failure and so on. And that's how traditionally we've been detecting these faults, using the existing systems. [...] Where you are finding the normal behavior and every time the behavior goes off, then that tool that you can kind of send out a message to you alerting you also, you know, abnormal behavior. And this is how things have been working all this while. So even without AI or machine learning, you know, there has been a system in place and another system and that so that's kind of the status quo when it comes to it."* - Interviewee 1

> *"And so our industry has been in that state actually, but in at least the last couple of years, I see the talk is happening about this area and. I mean, there are a whole lot of digital parts in terms of monitoring and diagnostics and for taking a next step like AI is now there. It is using 50% capacity [operational capacity] or something like that."* - Interviewee 5

> *"And we started making them [wind turbines] more precise and more complicated systems that were not that good. So the more complicated your models will get, the more difficult it will be for you to kind of get a quick answer from. [...] But as I said, if you have a big complex market which takes hours and days to solve just one loading situation, then how do you get to kind of another situation where you're supposed to solve its immediate offloading situation. You use a tool or model [digital technology and AI] to be able to have such a quick turnaround time or response time. So as I said earlier, like in the last few years, because of the advances in technology, this has become very possible."* - Interviewee 1

However, there are also challenges that exist with the adoption and use of AI. Discussion with industry experts highlighted financial constraints and funding opportunities as some of the challenges. Moreover, while there is an overall industry-wide AI adoption, some orgnizations continue to be conservative in adopting new technology, and instead opt for outsourcing technological capabilities.

"The data collection is quite scattered in the wind industry, and almost every component is critical in terms of either the safety or the operation point of view. Most of them have sensors and they get connected. Yeah, I think maybe after the year or some of them are. A fast log or data like event happened and then last 30 seconds. Very high frequency data is collected. And of course, that will be over rewritten because you cannot afford to store such high frequency, massive data." - Interviewee 5

"From a wind energy background, let's say that earlier, the wind turbine technologies had a vibration analyzer, which didn't have much AI embedded in those systems. Even now, a lot of companies don't use too much of AI. Now, when we speak with OEMs, like all manufacturers still buying technologies, they realize that. Yes, because it's not some of the companies that are the OEMs, they have their own in-house data and it seems some of the technologies are outsourced outside the company because they have to have a healthy competition between suppliers." - Interviewee 6

Moreover, AI is enabling the use of innovative technologies to be used in the wind energy sector. It has helped with the use of robots, self-learning in fault detection and diagnosis, and has also brought in advanced data analytics capabilities to derive meaning from large volumes of data within relatively shorter periods of time.

"So I mentioned drones already. That's quite widely used in [wind] industry. So drones loads large volumes of image data. And then on top of that, there's a whole bunch of stuff that people are developing. So we have one site called [Site name] that is about measuring how blades pitch, so how they spin around. Those are the things that have different strain gauges on foundations or in the blades. There's lots of different inventions out there doing other kinds of instrumentation." - Interviewee 3

"You could have let's say you have a whole wind farm and you have one turbine running at a much higher temperature than all the other ones. And probably, you know, there's some component causing friction, you know, and putting it into the system. So you can say in that way, relative to other ones, it's an outlier. But you can also say relative to itself, over time it's an outlier. And I would imagine all of those methods are used in one

way or another. You know how much real AI is in the sense of self-learning systems and is actually used." - Interviewee 4

The theme *State of Industry* thus aims to understand the current level of technological adoption in the wind energy industry, with respect to AI capabilities. Further, it also explores the existing challenges and opportunities that currently exist within the industry.

5.2.2. Driving Forces

The theme *Driving Forces* is based on the codes *Operational Efficiency* consisting of 21 quotes, *Predictive Maintenance* consisting of 8 quotes, and *Competitive Advantage* consisting of 6 quotes. The theme broadly consists of all aspects that push wind energy organizations to invest in and adopt AI technology for their business operations.

Wind energy organizations have been driven to use AI capabilities given its advantage in bringing operational efficiency over traditional humanforce involvement. AI systems help in streamlining operations, and also bring in advanced capabilities in understanding and analyzing the vast data being captured at the wind turbines.

> *"[When] it comes to, let's say, the human side of things, then we also need data for a certain period to kind of make sense of it. So minor deviations might not trigger your, you know, interest to say. And then when you look at what an enhanced or what an extended data and that might make sense to you. [...] Whereas, you know, having an AI system can definitely, you know, speed things up quite a lot."* - Interviewee 1

Moreover, with AI capabilities robots help take over the need for humans to scale heights and collect data at the wind turbines. This in turn helps with data availability that can eventually with faster data processing to realize any potential threats or challenges.

> *"[It is] really hard work to go to a site and drive around to climb up turbines and look at things and take and scope measurements, it really takes a long time. So you try to build out analytics that you can use instead of that. Or they can give you some indication of which [turbines] you should prioritize [for inspection]."* - Interviewee 3

> *"We would just carry a suitcase, a small suitcase like 20 years ago. And then have to go in the center of a wind turbine, come back and then transform that data onto the software on the computer, and then do a fast fourier transformation. [...] And then they will do all these time series and then change it to fast fourier and everything was done manually. Well, okay. 20 years ago. And still some of the companies are doing that. Still, all of these very old technology companies will give this job to Internet companies and they have AI based systems."* - Interviewee 6

Wind energy companies are also witnessing the benefits of AI with it making it faster and easier to predict potential faults. Predictive maintenance with AI has transformed the ways in which data was studied earlier.

> *"So now we are slowly coming to a point wherein [the] integration of AI and machine learning is becoming more and more interesting to us. Let's say the models were so big and there were no alternatives as such. Computation power was limited and therefore there was only so much that could be done. But now with the period of the last, let's say 5 to 6 years, because of the tremendous growth that you've seen in terms of computation capability, now things are kind of getting into our reach and therefore this problem [of fault detection at the wind farms] becomes more and more predictable."* - Interviewee 1

Enhanced predictive maintenance capabilities not only reduce the turnaround time for fault detection and diagnosis, but also helps reduce unforeseen financial losses. It helps better manage human and financial resources, and be prepared in times of risks.

> *"So definitely you can reduce the maintenance cost significantly by better predictability and a high confidence level that utilizing those fleets actually takes this. You don't have only one term anywhere down the line. I foresee that AI will have a very, very big role. Yeah, more or less I see the data. The rate of growth is high. What matters is how you use this data."* - Interviewee 5

Moreover, the push towards green and cleaner sources of energy are pushing organizations to adopt advanced technical capabilities in order to have a strong position amongst its competitors.

"And there's definitely growing competition that is growing. There's quite a lot of companies who are now being acquired by big investment firms. [...] So this is in sort of like ten years or so and this is a small timeline. But at the moment it feels like it's ramping up and there's lots of bigger players pushing it [green energy]. And you can see it also in the energy companies this time to do this green transition. And they're going to build as many gigawatts. So. It's quite a bit of a race, definitely." - Interviewee 3

However, some organizations have also been conservative in AI adoption. This could be due to apprehensions in financial investment, skilled labourforce, or the associated investments in organizational change to bring in new technology.

> *"Some companies are more conservative than others. [...] But like in general, digitalization is a thing. And you could say digitalization is like the bottom is some of the working that you need, like good digitalization is what you need in order to get these data feeds established. And then you need to have a processing layer that kind of unifies the data set so that you don't end up with like 50 different tables, allow you to train 50 small models on something, but rather have a unified table that allows you to train a big model that can get like more generalized insights."* - Interviewee 4
>
> *"So it is hard for us to sell anything as a technology solutions company [to sell digital solutions to the wind energy companies]. They may just or could take our software, maybe use it for a couple of years and then they will build up their own software. [...] So it's very hard to pivot the other way as a solutions company, we have to see what the customer is trying to do."* - Interviewee 6

These results reflect the drive of the wind energy companies towards the adoption and use of AI in their businesses. This drive is fueled with AI capabilities bringing in greater operational efficiency, enhanced predictive maintenance capabilities, and lending a competitive edge to the organizations. However, technology adoption is accompanied by its set of challenges, including financial investment, technical expertise, etc, which will be discussed in greater detail in the following sections.

5.2.3. Organizational Change

The theme *Organizational Change* is based on the codes *Upskilling/ Reskilling* consisting of 12 quotes, *Technical Expertise* consisting of 22 quotes, and *Research and Development* consisting of 7 quotes. This theme aims to encompass organizational changes that are brought with the incoming AI technology in the wind energy sector. This includes business re-engineering processes, changes to upskilling activities, and skill development initiatives by the organizations.

5.2.3.1. Upskilling/ Reskilling activities

The code *Upskilling/ Reskilling activities* aims to identify initiatives by the organizations to invest in skill development of their employees. Such initiatives help organizations build internal capabilities and gain a competitive advantage over others in the industry.

Discussions with industry experts highlighted that the focus on reskilling and upskilling activities has grown over the recent years. Organizations are investing in skill building initiatives, particularly the ones that people gain knowledge and expertise of newer technologies.

> *"I think the last couple of years this has picked up even more as a corporate strategy [...]. But since last year [post COVID-19 pandemic], I would say a 2 to 3 year strategy is being executed and is getting focus actually. And I can only speak for my company, but there are many others also. I can see at least in our side that we do recognize the value. And the question is always like how fast you can move and how much opportunity you can see it."* - Interviewee 5

However, such upskilling activities require financial investments. This is also coupled with the fact that upskilling activities take time to execute, and it may require a considerable amount of time after which the right technical capabilities are built among the people. In some cases, these factors may deter organizations from investing in newer technologies.

> *"When it comes to training people and the fact that it sort of takes time. So you have a certain set of people that you kind of use. Once you put that [training modules] into practice and it takes some time for you to kind of realize, okay, this is how the future setup will look like and this is where I can make use of the people who can increase the efficiency."* - Interviewee 1

"So there's a lot more upskilling of the people and then they [the wind energy companies] need to get someone from outside, new organizations. But that also comes with a lot of financial investment, right? I mean, it's not going to be as easy to develop and implement new technology in the organization. [...] But it is in this profession that I've seen usually upskilling as being more of a preference" - Interviewee 2

Nonetheless, skill development was greatly stressed upon, be it an organizational or individual initiative, to help stay competitive in the industry.

"If we, if we don't upgrade ourselves, we would be losing easily. [...] The only thing is if you don't upgrade your skills everything, you cannot find a space in the wind industry. Like a lot of engineers, we are seeing that they are trying to build something out of the graph. That's what is happening." - Interviewee 6

An interesting aspect regarding business operations was that of outsourcing technical capabilities. Since upskilling and reskilling activities can be an resourcefully intensive process that stretches over a period of time, organizations prefer outsourcing their technical requirements to third party organizations.

"Typically what I see is that they [wind energy companies] bring in people from outside, but that's probably biased because I only work with people who bring people in from outside. I say typically you bring people from outside to do it because to build out, to build that kind of a full suite, to do these analytics, that's going to take you a team for like a year or two building from scratch. So it's a lot cheaper to buy something that somebody else has done." - Interviewee 4

"Another example would be Google and how they're intervening. [...] And then Amazon is the last company with Amazon Web services, cloud computing, etc. to support a lot of the industry as well as it could have on the Internet. And we have been working for the first time with their data engineers. We are getting new projects with them now, full of hands-on research. " - Interviewee 8

5.2.3.2. Technical Competence

The code *Technical Competence* is used to identify the changes in skill requirements with incoming technology. It aims to understand the ways in which talent acquisition by organizations is witnessing a shift.

Industry experts also highlighted that the skill requirements keep changing frequently as the technological landscape changes. This brings changes to the skill requirements that the organizations look for during hiring and them taking additional efforts in acquiring technically-competent staff from their competitors.

> *"The technical expertise to do the job is quite a niche in this field and not too many people in it. So that's definitely tricky. There tends to be a lot of poaching between the same sort of companies. Yeah, that's quite common"* - Interviewee 3

> *"For example, these days most of the companies are asking if you are a wind engineer that you should also have a knowledge of Java or Python programming. That was not the case earlier. So libraries and engineers are like they need to look, for example, in [Company 5] itself, you know, we have a data analytics engineer like, you know, who's sitting with us. But yeah, he's, he doesn't have any background about wind turbines, but then he knows the knowledge about how to use data analytics to know what else to look for. [...] And then they say, okay, can we get better results out of prediction from ML methods"* - Interviewee 6

There was also an emphasis on the technical skills complementing the domain expertise required in the sector. A need for greater opportunities of collaboration was highlighted among the technology experts and the domain experts to ensure that technology adoption happens in accordance with the needs and requirements of the industry.

"And then in the research area, they spend a lot of time on AI. [...] I mean, because in the computer you see the blade looks like three inches long right, but in reality when you think of changing anything we literally need the on ground knowledge to make changes. [...] So there is a huge difference between the people who analyze the data and then people who actually make the decisions. So somehow the domain knowledge and the analytical capabilities come together that could be a win-win and could be accelerating." - Interviewee 5

Moreover, academic institutions have realized the value of upskilling, and have begun the skill revolution from the academic front. Academic programs tailored to industry requirements are being designed to bridge the gap between academic knowledge and practical industry applications.

> *“But for us and for educators as universities, we are certainly realigning ourselves. So that's something we're really happy about. The other day we actually got very good news that we are now going to introduce another master's program as a special sort of a special track. So it's going to be digital skills, digital upskilling. So it's going to be an additional program for the Masters. And we will also introduce a lifelong learning program. As we were saying again, for these upskilling and this is going to be tailored for industry..*” - Interviewee 8

5.2.3.3. Research and Development

The code *Reserach and Development* aims to explore the willingness of organizations to invest in R&D initiatives. This code also helps bridge the understanding of R&D initiatives across industry and academia, to understand how academic research can aid industry operations.

The broader consensus was that research and development in the field is growing, with organizations wanting to push for research in developing innovative use of technology. This has been even more with the data analytics firms that act as third party resources for the energy companies to bring in new technology.

> *“And we sit in a kind of a wider production kind of engineering team. And so what we really do is lots of kinds of R&D methods, development, analytics, development and work a lot with different operators around the globe who kind of need help working with their data analytics.”* - Interviewee 3

At the same time, long-term investments are favorable over short-term investments. This is because bringing in a new technology is a financially and resourcefully intensive prospect, and so funding agencies want to release funds for organizations willing to commit to using technology long-term and bringing change.

“But in the short and medium term, like with the five year look ahead, it's you know, there is I think the message they're [funding agencies] not willing to bet on because soon the technology can get outdated. [...] And that's, that's the nature of it.” - Interviewee 2

An interesting insight that evolved from industry and academic discussions was that the wind energy industries are not often willing to share their data with academia. This happens because the industry considers the data of high economic value, and thus prefers to guard it. However, this results in the lesser avenues of collaboration between industry and academia, and thus limited research with real-life data thus compromising with the quality of research.

“So because we [academicians] are not necessarily the ones operating the wind farms, we cannot actually provide solutions, sometimes it can be hard to find the data that you can sort of play with and see what kind of value you can get out of it. Access to the data is the number one issue. And I think also one of the underlying reasons for that is there's a lot of hype around the data itself. So the value of the data because we don't know what that actually is, I think it gets a little overprotective. [...]So we would need a little bit more collaboration between the base owners also to sort of relax those requirements a little bit and maybe to have sort of third bodies like natural organizations, like academia, to have a little closer look and sort of all of us can get actually really benefit from this.” - Interviewee 8

The theme *Organizational Change* thus helps to understand the ways in which organizations evolve with the advent of new technological capabilities. It also helps understand ways in which the organizations can build capabilities to ensure a smooth transition to the new technology.

5.2.4. Ethical Concerns

The theme *Ethical Concerns* is based on the codes *Reliability in Decision Making* consisting of 12 quotes, *Impact on Human Employment* consisting of 20 quotes, and *Environmental Sustainability in AI Systems* consisting of 5 quotes. The theme discusses the issues concerning the ethical use of the AI systems in the wind energy sector. This discussion explored the ways in which the AI systems can be accounted for in their decision making, and also the impact that their use has on traditional business operations, including their impact on the human labourforce.

One of the major roadblocks to the adoption of AI systems in the wind energy sector has been concerns regarding the reliability of the systems. The decisions made by these systems are high stakes, and need to be considered with due diligence in order to ensure adequate allocation of financial and human resources. This was also highlighted during the interviews with industry experts.

> *"I would say the one thing is they [AI systems] might be very reliable, but it's very hard to prove that they are. And, it depends on how well your AI training data is and that the AI system is based on is covering rare events. And it just requires a bunch of knowledge on, it requires you to have a lot of turbines and it requires you to be good at pulling the data from all of those turbines into a single set and make a convincing case that you are covering rare events."* - Interviewee 4

> *"It's very hard to understand the numbers [the output from AI systems], actually. It is just a black box. And in products like ours, in the industry, you cannot use a black box. And it has to be part of it. And that something AI has the tag of a black box. And somehow that is the bottleneck also [for AI adoption by the wind energy industry].*" - Interviewee 5

Moreover, there were interesting insights on the impact of the AI systems on the human labourforce involved. The discussion explored that the impact will, most likely, follow a trend, where the initial negative impact on the human technicians will eventually be witnessed with changes to roles and skill sets, with a continued involvement of the human labourforce.

> *"So the first effect in my head, as I see you would affect negatively, you will see with the advent of AI, thereby leading to job reductions most likely, and then will come a period where things will stabilize in the companies, [companies will] figure out, okay, how will the setup work keep going.*" - Interviewee 1

> *"So if you think in a very short term that tomorrow I build AI models, it automates what I'm going to do with these 500 people. Yeah, that could be a tough question to ask. But if you are looking at how society will evolve in 20 years. It will be going to help in a positive way. Yeah, because then people will start thinking [to invest in alternate skills].*"
> - Interviewee 5

The discussions also highlighted that the wind energy industry, even with the advent of AI capabilities, cannot function fully autonomously and will continue to employ humans as part of its business operations. The experts highlighted that humans will continue to work along the AI systems, to maintain regular checks and also contribute to more creative tasks, while passing on the redundant ones to the machines.

> *"There is a continuous need for skilled labor for this industry to grow and mature and still find a lot of untapped potential. There are, of course, activities in the overall product lifecycle that have to be managed and done by skilled labor. But in general, the innovation culture and the need for more creative solutions in the industry being at least from the demand part of it, kind of translates to the need for skilled labor not going down.*" - Interviewee 2

> *"But I don't think we are trusting the computers to do it [decision making] for us yet or robots. And so it will still be a human in the loop if you follow the decision making part. So the way I see it, it is basically three points. And in a lot of those processes there will be domain scientists, meaning more physics based people also in the loop as well as more digital skills."* - Interviewee 8

The discussion also emphasized that the growth in the industry will be sustainable when the advancement in technology is coupled with the involvement of human labourforce, to deliver efficient and creative solutions.

> *"There are drones. They are able to [...] make the drone also repair the blades. [...] But, the person still has to either bring the blade down, make a small makeshift shelter, and then repair the blade and then take it back to the turbine. So that part [of human involvement] will never change."* - Interviewee 6

> *"They [AI capabilities] make not just products safer, but also more efficient and more effective. This is in combination with this technology of, in my opinion, not to replace human labor, because that's simply not sustainable. There is definitely a need for skilled labor and organizations that realize this and are the ones that can, you know, sustain and this can grow."* - Interviewee 2

There were also discussions regarding the ethics of the AI systems, concerning their energy consumption and environmental sustainability. The industry discussions, here, showed a larger agreement on making the tradeoff in using better technology to produce green energy, than the significantly lower amount of energy consumed by the AI systems to produce this energy.

> *"I really do wonder if, like of course, when you have such big enterprise capabilities, then it has a carbon footprint. But once again, I would see the end goal is what needs to be kept in mind. So let's say this carbon footprint is being offset by an enhanced wind farm performance, for example."* - Interviewee 1

> *"If you're controlling a let's say a ten megawatt wind turbine, even if you run like a whole tower of GPUs to control it, it's still no energy compared to what the wind turbine could potentially generate extra. [...] Yeah, of course the GPU is going to pull more power. But you will only do that if you generate more energy. Get the turbines to generate significantly more power or have a significantly longer lifetime, or in other ways, just be a better energy generating asset."* - Interviewee 4

This theme, *Ethical Concerns*, thus covers the various aspects of the ethical considerations that must be checked when bringing in AI capabilities within the wind energy industry. These aspects also influence the rate of technological adoption as it may raise questions regarding the impact that the technological adoption could have on the organization and the environment, at large.

5.2.5. Challenges

The theme *Challenges to AI Adoption in Wind Energy* is based on the codes *Data Quality* consisting of 17 quotes, *Cyber Security* consisting of 9 quotes, and *Financial Investments* consisting of 8 quotes. The theme addresses the challenges and roadblocks that wind energy organizations face when adopting AI capabilities in their business operations.

5.2.5.1. Data Quality

The code *Data Quality* aims to identify the challenges with the availability and accessibility of quality data. This becomes particularly important since it is fed into training the AI models for high-stake decision making.

Data quality was highlighted as a major concern when adopting AI in the wind energy industry. The quality of data, its storage, and security were concerns raised by the industry experts. There was an emphasis on the training data to be made comprehensive, in the sense that it includes rare case events, so that the AI systems consider such scenarios while taking decisions.

> *"The next one that's a big challenge is having structured organized data and a clear record of how one records this data. So for example you can't bring in some big AI technology unless you have data to train it on and the current state of the data to train it on is not necessarily good with every wind operator. So that's a challenge."* - Interviewee 3

> *"But then the worse thing was it [the company AI models] could mislead the data. That sort of can happen. [...] So that way, that interference is a cause of concern. Like, the worst case consequence of all of this for everyone is okay, but the turbine shuts down.*" - Interviewee 6

> *"You know, the standards there aren't like a very good wind energy data storage standard yet, and so people are trying to do it. And then it depends who you work with. Like some people have really good secure data kind of control methods and some people are more immature in their processes."* - Interviewee 3

Moreover, the changing technological landscape changes the quality and standardization in the data generation and collection process, which could pose challenges in data analysis. Further, wind farms are located across different landscapes, offshore, onshore, on mountain ridges, plains, etc. This further necessitates the need for different data sets for training the models across different geographic locations.

> *"And the challenge in the next step is like most products change so fast. Like every two years, three years, there are new products. So that's another challenge too. Because your focus goes on the new product, right? Better technology and designs. And they are the old fleet. [...]Unfortunately, when you keep changing the product, the nature of data also keeps changing actually*" - Interviewee 5

"But, you know, and in turbines you have slightly different cases like, you know, the one turbine that stands on a ridge of a mountain.[...] So they seem to have very high wind speeds on the bottom of the tower. Whereas on other turbines, they see high wind speeds, the higher you go up. So they have really odd, you know, conditions. And then you can say, well, what kind of things happened in their SACA data feeds that are different. [...] So you always need to be cognizant of whether you actually have a large dataset." - Interviewee 4

5.2.5.2. Cyber Security

The code *Cyber Security* is used to identify concerns with the safety and security of data collected at the wind farms. It aims to understand the degree of cyber threats in the wind energy industry, particularly with the use of AI systems.

Cyber security was highlighted as a major concern by the experts. The use of AI systems relies on collecting huge quantities of data at the wind turbines. This data is of high financial value, as it can be used to understand the energy production by a particular wind farm. Thus when bringing in new technology, organizations need to be cognizant of the potential risk that its use could lead to.

"So data security definitely becomes a big challenge. Yeah, because if you have so much data floating out there then the anti-social elements in the society can get a hold of that data that you know, and use it. You know hackers have kind of tried to gain control of the different systems on the windmills out there. And they've been trying to kind of influence the performance of the windmills. So in that sense, I would say that, of course, the more you are relying on the data from the windmills, the more important it gets to ensure that the data is not getting compromised. Security is definitely very, very important." - Interviewee 1

"So you have to be really careful that you don't compromise the data that is gathered at the wind farms. Or, like a lot of the data could be used then to work out how much the wind farm is generating, and then how much could equate to how much it's worth. So it's quite sensitive. [...] In terms of other ethical things, you obviously make sure security is

super tight, like the same. You wouldn't want someone coming in and being able to take the data that you have and." - Interviewee 3

The risk of data leak or breach from the wind farms can have huge financial implications, not just for the wind energy organization, but this effect could further trickle down to manipulating the energy market.

"And so it's important to know which boundaries the data crosses. And how sensitive are these systems to hackers. I would say it is like national security, because if you have a lot of renewable energy on the grid, then it can be taken over by external parties or the data can be siphoned off or, you know. I would say that there's a bunch of work to be done [regarding data security]." - Interviewee 4

"Definitely the risk is very high if data is compromised in the real time because then somebody can use it for the stock market manipulations and stuff like that actually. But cybersecurity plays quite a big role because if you know exactly how this farm is behaving and then you can speculate on the stock market, of the next quarter result would be I mean, imagine someone posted all the operational data, then they will know how the next order is to be in. And so the cybersecurity is quite critical." - Interviewee 5

"Hackers call you and say we have control over your wind farms. Unless you pay me $10 million now, we won't give charge of the wind farm and it happens a couple of times a month because cyber security is a very different avenue. Everybody is talking about AI and this technology is really, I would say vulnerable to attack." - Interviewee 7

5.2.5.3. Financial Investment

The code *Financial Investment* aims to explore the constraints with funding opportunities, and its impact on AI adoption in the wind energy industry.

Financial investments and funding opportunities were highlighted as a major roadblock when adopting AI capabilities. These are not only required for the technical software and hardware capabilities, but also to upskill and reskill employees, get third party technical assistance, ensure regulations and compliances are met, and account for any unforeseen circumstances.

"So there's a lot more upskilling of the people than they [wind energy companies] need to get someone from outside. But that also comes with a lot of financial investment, right? I mean, it's not going to be as easy to develop and implement in the organization compared to getting experts from outside. But it is the profession that I've seen usually upskilling being more of a preference." - Interviewee 2

Incentives by governments like subsidies and tax benefits can also push organizations to adopt advanced technologies, without being heavily constrained by financial requirements.

"Definitely funding. And I know in the UK they are doing that. So if you're a crossover between renewables and tech, there's quite a lot of funding polls open. They also have some sort of price levy that the government will top up on wind farms. [...] There's some sort of government subsidy for wind farms in some countries." - Interviewee 3

The theme *Challenges to AI Adoption in Wind Energy*, thus discussed challenges and issues that wind energy organizations face when adopting AI systems. These are also useful to be looked into when an organization plans to make a switch to a new technology, or adopt a new technology into its existing business operations.

5.2.5. Way Forward

The theme *Way Forward* is based on the codes *External Factors* consisting of 14 quotes, and *Future Prospects* consisting of 9 quotes. This theme aims to understand the future prospects of the incoming AI technologies in the wind energy sector. The theme is also explored with the impact of external factors like policy, regulations, as well as the social structures in guiding technology adoption.

"You cannot count on these companies [private wind energy companies] to work in public interest even though they are you know making improvements. You cannot leave it to these companies to fully act on public interest. Is it is that there is a big role for these parties [government bodies] and they have to be able to upskill themselves." - Interviewee 2

Further, the interviews with industry experts highlighted the future prospects of the incoming technology, and the ways in which it could change the technological landscape for the wind energy organizations. There were discussions of the increasing level of autonomy in the AI systems, coupled with a growing environmental and ethical consciousness that needs to be built into these systems as the use of technology in the industry grows.

> *"So in the next 5 to 10 years, I think we will have increasing levels of autonomy. So what you might see now is that there's a bunch of different analytics that someone may have written and how so they've outsourced and they have loads of different trends all at the same time. And then people would sit there and look through all the ones that are flagged as an alarm and try to work out what's going on. Yeah, I think as time progresses, those systems will become more intelligent. These trends are all grouped together and that kind of rationality might make recommendations or do things a bit more joined up. But I can't see it yet. Sending people automatically to climb a turbine without somebody having some oversight. It might be faster than I think."* - Interviewee 3

The discussions also highlighted the need for a strong foundation of data collection and analysis to be required to drive the use of technology and innovation in the industry. The use of technology will then extend beyond only operational needs, but will be used to design and manufacture better hardware and software components that can eventually aid the changing operational needs of the businesses.

> *"If you want to become a company, you have to realize that, okay, this data is going to factor into our evaluation in five years or ten years, and therefore we need to have a just the whole company needs to be made so that data streams into our systems and then we build our software on top of it later. Yeah."* - Interviewee 4

> *"How to use air to make a lighter and cheaper design. Yeah. Of course, one can argue about the materials and all this stuff, but I am talking more about AI based design and environmental conditions. So you are not designing something like everything is standard deviation. That's what happened in all this. You cannot handle so much data."* - Interviewee 5

Moreover, technology adoption and use becomes complex when cross-border wind farm installation is done. This could impact energy production given changes to the geo-political scenarios, but also with changing government policies and regulations.

"One of the ethical considerations I've heard about recently is what happens if you have a government based manufacturer and operator and then they build wind turbines in another country and they have the power to shut down or alter wind production in another country. Like if it's a government backed organization, will other countries all be happy for those?" - Interviewee 3

Setting up wind farms also raises questions in the social context where the general public may be divided over the setting up of wind farms and the related change to natural landscape.

"So by 2030, we are hoping to double or maybe even triple our onshore wind farms. That's the big challenge. And to convince people to have them in their backyards and also to properly address the issue of it is becoming a little bit more centralized from top to bottom in the communities, choosing what they want for themselves." - Interviewee 8

The theme *Way Forward* thus discusses the future of AI in the wind energy sector. It does so by discussing the level of autonomous operations expected in the future, the related carbon footprint, and also the need of building robust foundations for data collection and analysis.

6. Discussion

The themes previously identified helped comprehensively address the research question, and identify major driving forces and barriers to AI adoption in the wind energy sector. The observations from the industry discussions, as well as learnings from the literature review, are discussed below.

6.1. State of the Industry

The drive towards a sustainable and green energy-driven world, prompts for an investment in cleaner sources of energy. This drive has been further pushed by growing environmental consciousness, increasing carbon footprint, and increasing consciousness toward biodiversity protection (Tchakoua et al., 2014). This brings organizations to invest in cleaner sources of energy, the production and consumption of which do not adversely affect the environment.

Wind energy is a prominent source of energy that plays an important role in reducing the carbon footprint (Wang et al., 2018). Moreover, with growing developments in digital technology, the data being generated and captured at the wind turbines is increasing. A large number of sensors are now being installed on wind turbines, which along with the advent of IoT has enhanced data availability and accessibility (M. Lee & He, 2021). It has thus become important to study this data within shorter spans of time, to derive meaning from and ensure adequate functioning of the wind turbines. The literature delves into different aspects that AI is currently being used in the wind energy sector, with the use of artificial neural networks being used in fault diagnosis (Bose, 2017), to the use of deep learning for fault predictions.

Discussions with industry experts highlighted the importance of AI adoption in the wind energy sector. They focussed on the need for faster turnaround time for fault detections and maintenance of the wind turbines. For this, AI has been helping wind energy organizations with more accurate and reliable predictions, and thus efficient operations of wind farms. This is in line with the literature review that discussed the role of ICTs in streamlining operational activities (García Márquez & Peinado Gonzalo, 2022), bringing predictive maintenance capabilities (Ren & Bao, 2010), and ensuring timely fault detection and diagnosis (Colak et al., 2012). These factors lead to a great emphasis on the perceived ease of usefulness of AI systems, which prompts organizations to invest in the technology adoption. Moreover, with the increase in data collection and availability, it has become tougher for human technicians to continuously interpret data and quickly act upon it. The use of AI has brought in operational efficiency for wind energy organizations and has helped these organizations adapt to the changing technological landscape. The literature has focused on this too, with considerable literature on the use of AI systems for turbine control (Colak et al., 2012), real-time data analysis (Ahmad et al., 2021), and anomaly detection in turbine health (Helbing & Ritter, 2018). In this way, AI capabilities have been helping wind energy organizations with advanced technological capabilities, ensuring sustained growth over a period of time.

6.2. Driving Forces

Advancements in digital technologies have given a boost to the renewable energy sector. AI-based systems enable better operational and maintenance activities, and efficient energy management systems, and lend a competitive advantage to an organization (*Digitalization and Energy*, 2017). AI systems also help bring meaning to the vast amount of data that is collected at the wind turbines, which in turn helps in streamlining operations and ensuring timely decision-making.

Discussions with industry experts focussed heavily on the ways in which AI has brought operational efficiency within the wind energy sector. Minor deviations in data analysis may go unnoticed by humans, but AI systems ensure faster and more accurate data analysis, highlighting aspects that could have otherwise been omitted by manual inspections otherwise. Moreover, there is an increase in wind farm installations, increasing the number of sensors being installed, and eventually the amount of data being collected at the windfarms. In such a scenario, it becomes important to efficiently train the AI models to derive meaning from large datasets within shorter periods of time. The literature supports the use of AI systems for improving operational efficiency, by enabling analysis of large volumes of conditon-based data, making fault detection and diagnosis easier (Ahmad et al., 2021). These aspects can help organizations to closely monitor the wind turbines on a real-time basis and have a quick turnaround time in case an issue is reported. Studying data real-time becomes even more important for offshore turbines that are installed deep into the sea, and are exposed to extreme weather conditions. A regular check on them ensures the safety and operations of the wind farms. Thus adopting AI capabilities helps the wind energy organizations to capture the usefulness of the technology by improving operational efficiency in their business processes.

There were also discussions on AI enabled robots that help paint the blades of the wind turbines, with the help of advanced image processing capabilities. OEMs have also now been using AI capabilities to introduce reliable turbine designs. In general, AI has helped to streamline the process of data collection and analysis for the wind energy sector, but have also opened doors for innovation. Traditionally, data collection at the wind turbines happened with human technicians climbing up the turbines and conducting manual inspections to check the health of the turbine. Moreover, manual data collection exposed risks to human safety in scaling large heights of the windturbines (Bernardini et al., 2020). The overall time for data collection has now greatly reduced, with robots that can easily scale the heights of the turbine and carry out the maintenance activities. This way, the process of data collection becomes relatively easier, safer, quicker and more reliable.

The renewable energy sector, at large, is dependent on the assets of energy production, the efficiency of which can be greatly enhanced by artificial intelligence (Kow et al., 2016). For the wind energy sector, AI capabilities help in optimizing operational and maintenance activities, bring in predictive maintenance capabilities, along with real-time communication capabilities with the wind farms (Ahmad et al., 2021). Well trained AI models can effectively help in notifying potential faults in the WTs (Merizalde et al., 2019). This helps organizations in planning their resources well in advance and reduce the risk of any unforeseen financial losses.

Discussions with industry experts emphasized the important role of digital technology and AI in predictive maintenance of the wind farms. Manual analysis of data sheets to study potential faults is not only cumbersome, but also a time and resource intensive process. AI models help here with ensuring accuracy in fault detection, compared to manual data analysis processes. This way the faults can be detected with greater accuracy and well in advance, reducing the risk of any catastrophic losses. Moreover, manual data collection has also been highlighted as a risk for the human technicians that have to scale the heights of the wind turbines for data collection (Bernardini et al., 2020). This way, AI models help the wind energy sector considerably by optimizing predictive maintenance across its windfarms, with better predictability of potential faults and a higher confidence level for its results. Thus, the usefulness with predictive maintenance capabilities drive organizations in investing in and adopting AI-based systems.

The use of AI has thus eased the overall process of conducting operational and maintenance activities of the wind energy organizations. This helps organizations gain a competitive advantage over others that continue to operate on traditional means (Tchakoua et al., 2014). AI is helping the wind energy organizations to transform their business operations with the use of advanced digital capabilities, an increased investment in upskilling people, and a growing focus on research and development. The industry discussions confirm the insights from the literature review, in that technology adoption lends a competitive advantage to organizations. This is in accordance with the Resource Based View discussed earlier, that suggests the building of internal technical capabilities and investment in R&D to help organizations bring sustained competitive advantage over others in the industry.

6.3. Organizational Change

With the dynamic nature of technology, and a growing willingness for organizations to adopt technology, there is an organizational-level change that is driven by the adoption of ICTs. This adoption of ICTs has the potential to eventually influence the skill requirements of organizations (Arvanitis & Loukis, 2009). The internal drivers of enhancing organizational success push organizations to invest in upskilling and reskilling activities of its employees. Management processes including adequate technical training, teamwork and upskilling initiatives play a huge role in assessing the rate of technology adoption by an organization (Murphy, 2002).

However, insights from the industry emphasize that reskilling activities are not only financially intensive, but are also time intensive. In that sense, organizations need to invest in the technology adoption considering a long-term frame of operations. This may also prevent some organizations from investing in the technology adoption, given an initial reluctance to the success that the new technology will bring to their organization. Building skills within the organizations help them improve their technical know-how, reduce dependence on third-party vendors, and also gain a competitive edge in the market. Industry discussion also showed that some companies continue to outsource their technical capabilities, given that technology adoption within organizations is a time and resource-intensive process. This has however shown to create some friction between the organizations and the third-party organizations because there is a lack of transparency in how the insights from the data, for example, may be generated or how accurate the results from the analysis are. In conclusion, the overall industry discussions have highlighted the need for constant upskilling and reskilling, more when a new technology is adopted within the organization. The importance of this has also been reflected in organizations taking this as part of their organizational strategy and making efforts in upskilling their employees. Moreover, building internal capabilities helps organizations bring a competitive advantage over others in the industry.

Building the right technical competence serves as a strong foundation for technological adoption in any organization. With greater digitization, the possibilities of risk also increase, with the potential for data leaks, data mismanagement, etc. The right technical competence in the organization can not only protect the organizations against such events, but also help them adopt the new technology at a faster pace. This is important since the readiness of adoption of technology becomes a defining factor in differentiating an organization from another, within the same industry. Industry discussions stressed the need for technical expertise, especially when bringing AI capabilities within the wind energy sector. The literature also emphasizes that the right skill development practices help increase productivity at work, and also builds technical competence within the staff (Black & Lynch, 1996). Moreover, there were also discussions on the specific skill requirements, with data science and Java/ Python programming gaining prominence. Many companies also prefer to outsource the technical expertise, rather than building it in-house, given the costs and resource investment required to do the same. However, this opinion is divided within the industry, since there have also been organizations that prefer to invest in their own employees since they are reluctant to share their data with third-party vendors.

As organizations begin investing in technology adoption, their willingness to invest in related R&D impacts the pace of technology adoption. The industry discussions revealed that organizations are not very eager to invest in technology and related R&D if it serves a short term agenda in their business plan. This is usually because of the financial risk, and also the investment needed in terms of upskilling the people to be able to make use of this technology. There is a greater enthusiasm for the adoption of technology when it serves a long term purpose. Organizations have been witnessing a greater availability of funds for research and development, in the long term, when it involves the adoption of any digital technology. This has been partly due to 'digital technologies' being a buzzword that helps organizations raise funds and eventually invest in the technology adoption.

6.4. Ethical Concerns

The use and adoption of technology comes with an inherent concern over its ethical use. An important aspect when discussing the ethical implications of AI systems is the aspect of accountability in their decision making. AI systems are perceived as a black box, essentially implying that there is a lack of clear reasoning in understanding why a particular decision was taken by the system (Jobin et al., 2019). The literature on this topic discusses the ways to reduce the ambiguity in decision making by these systems, by pushing for more interpretable and explainable tools in order to ensure ethical decision making (Machlev et al., 2022). An attempt to ensure this can also be done by bringing in human technicians while acting upon the decisions made by the AI systems. This would help to ensure regular checks, and maintain the reliability in decision making (Berscheid & Roewer-Despres, 2019). This aspect of human involvement is strongly in line with the discussions with industry experts. While the industry experts are aware and concerned of AI systems potentially taking decisions autonomously, they have emphasized the need to engage humans in the process of acting upon the decisions. Some issues highlighted during the discussion were the lack of appropriate training data, and difficulty in including rare case events, in order for the AI systems to take the most appropriate decision. Thus human involvement was stressed upon, in order to ensure a check on the decision making by the AI systems. However, including humans in the decision making process also prolongs the time of decision making, thus impacting the pace of technology adoption by some companies. Organizations may not always be willing to invest in the appropriate technological resources, while also investing in human resources since it can be a resourceful and financially intensive process. This may in turn slow down the process of technology adoption, even if it was perceived as being useful initially.

Another ethical consideration with the use of AI in the wind energy sector, is its impact on the employment of the human labourforce involved. AI enabled robots help with faster and more efficient turbine inspections, assist in predictive maintenance, and also carry out the redundant operational activities, much seamlessly than humans doing so. This impacts the employment of the human labourforce and technicians that carried these tasks otherwise. As the literature suggests, this impact of incoming technology on the human labourforce can be studied across different aspects: human employment being moved away with the advent of technological advancements (Frey & Osborne, 2017), the demand for more skilled labor increasing with the growing use of technology (Mykhailychenko, 2019), or the possibility of humans and machines working collaboratively to ensure the best results (Wilson & Daugherty, 2018). Discussions with industry experts led to interesting observations and insights that they had on this topic. A general starting thought indicated that the use of AI in the wind energy sector will negatively impact the human labourforce involved. But the discussions further led to understanding that this initial negative impact will gradually fade and that different forms of human involvement in the industry will eventually be witnessed. This could be in the form of a growing demand for skilled labourforce, required for the necessary human checks on AI decision making. Moreover, there were discussions on the idea that an overall skill transformation will take place in the wind energy industry, where people would adapt to this incoming technology and take up other related tasks that may arise with this new technology. This may include the possibilities of hiring people skilled in data analytics, or people with the knowledge of the working of AI systems at large. Thus upskilling and reskilling initiatives become of importance to the organizations, as they help with the ease of use of the technology for the people who will be involved with it first-hand. This also helps employees gain relevant skills so that their participation in the organizational processes is not heavily impacted. Overall, the industry discussions suggested that the adoption of AI in the wind energy sector is relatively slow, given that there continues to be human dependence to support the use of technology and ensure best results.

Further, the use of any technology should be checked to ensure that the operations of the technology itself is not compromising with ensuring environmental sustainability. More specifically, for the case of AI systems, their use may contribute to rising emissions or increased energy usage, in turn compromising with the quality of the environment (S. Zhao et al., 2022). With the use of AI in the wind energy sector, higher computational power for predictive maintenance, coupled with the use of hardware equipment like sensors can pollute the environment if not rightly accounted for. The literature on this aspect focuses on the need to bring attention to this, and duly consider the environmental implications of the use of technology. Findings from the industry, however, reflect a positive outlook in the tradeoff from the emissions from the AI systems, over the clean energy production that they enable through their use in the wind farms. There was a general consensus in realizing that the energy required and consumed by the AI systems is only a small fraction of the amount of clean energy being produced by them eventually. In this sense the energy produced by the wind farms, thanks to enhanced efficiency with AI capabilities, offsets the energy consumption by these systems. Thus, the perceived usefulness of the AI technology in the future, pushes organizations to adopt it, despite it initially consuming some amount of energy itself. From an industry perspective, organizations willing to take this tradeoff and use AI capabilities to improve operational efficiency and reduce the overall carbon footprint over a period of time (Moyer & Hughes, 2012).

6.5. Challenges

Data quality has been highlighted as a major concern when using AI models in the wind energy sector. Since AI models are trained on large training data, it is important to ensure good quality data is being fed into the systems, in order to ensure the most accurate results. The literature highlighted that the data quality may at times be compromised due to network congestion and sensor failures (Li et al., 2019). The discussion with industry experts further highlighted the gravity of the situation when quality data is not provided to the AI systems. The industry discussions shared that given the relatively fewer number of windfarms installed yet, the amount of data collected to train the wind turbines is still not adequate to account for rare case events. Also, considering that wind farms are located across very different geographic locations, from offshore windfarms in the oceans, to mountain ridges, the AI models need very different training datasets to be able to accurately work across the different geographic locations. According to industry experts, the wind energy sector lacks a comprehensive training dataset to be able to accurately train the AI models for their use in this sector. This in turn exposes the risk of safety breeches.

Poor quality data also compromises with the ease of use of the technology, since it restricts the quality of operations that can be performed on it. To overcome this, data standardization processes emerged as a strong element from the industry discussions, to ensure quality of data can be maintained. With rapidly changing products and technologies, experts believe that having industry standards for the wind energy sector can greatly enhance the quality of data collection, processing and analysis. Moreover, AI systems make decisions based on the huge amounts of data that they have been trained upon. This exposes them to the risks of data breach and data leak, since this data is of high economic value. Large amounts of data gets collected via sensors on the wind turbines. With this, and other data across the SCADA system, intruders can potentially hack or impact the operational efficiency of the wind farms (Jha et al., 2017). The data thus needs to be protected in order to ensure adequate functioning of the wind farms, and prevent any potential economic losses (Ahmad et al., 2021).

Studying these aspects in accordance with the TAM, this poses a challenge to the level of technological adoption by the wind energy industry. The additional resources required to invest in cyber security may pose a roadblock for organizations to be willing to bring new technology into their existing business operations. Discussions with industry experts highlighted that cyber crime is an important element of discussion when assessing the adoption and use of AI in the wind energy sector. Experts also highlighted that the wind energy industry is reactive, than proactive when addressing concerns over cybersecurity of the windfarms. There was an emphasis on the high value of the data being collected through the wind turbine sensors, and the growing need to ensure that the data is safe and does not reach malicious attackers. Additionally, the impact of data leak was highlighted by the fact that any such event can potentially be used to manipulate the stock markets. Thus, the perceived usefulness of the technology needs to be supplemented with the requisite safety standards for its operations, to be able to ensure an overall positive impact with its use.

The use of digital technologies, and their adoption across organizations is a dynamic process. The adoption of AI in the wind energy sector calls for financial investment, for the technology to be of considerable business value. For the purpose of using AI models, financial investment in terms of greater computational power, data storage capabilities, and the need of specialized experts to be managing the technological side of business, is required. Moreover, this financial investment is needed throughout the process of change, through software design, configuration, management and maintenance (Ahmad et al., 2021). Funding is also required for Research and Development (R&D), and ensuring compliance to set standards. The industry experts shared the need for adequate financial investments to ensure that AI adoption across the wind energy sector happens in a seamless and sustainable manner. Moreover, with AI capabilities, a large number of sensors are installed on the wind turbines, incurring additional costs with maintenance of the hardware systems. This adds to the financial investment in bringing AI capabilities in the wind energy sector. Additionally, there were discussions on the need of adequate funding to ensure upskilling of the labor force, particularly when a new technology is adopted in an organization. This ensures that upskilling activities take place parallelly with the technological adoption. It also helps organizations build capabilities within themselves, and ensure they bring a competitive advantage to their products and services. This is in accordance with the Resource Based View, which emphasizes the need of building resources within an organization that lend it a sustained competitive edge over others in the industry.

During the industry discussions, public funding came about as a major source of funding for organizations wanting to adopt technology in their businesses. The discussion also highlighted that public authorities across some countries give subsidies to wind energy companies for technology adoption. This can boost the pace with which these organizations bring in technology and build their technical capabilities. Such opportunities can further help the economically weaker countries to invest in technology adoption, and generate a source of clean and green energy at the fraction of the original cost. This discussion is also tied to sociological institutionalism to reaffirm the role of external bodies, governments and policy makers in shaping the adoption and use of technology. According to industry experts, the relatively more concrete regulatory bodies and funding opportunities in Europe and the US have helped these regions witness greater technological adoption compared to its APAC counterparts.

6.6. Way Forward

An important aspect highlighted as part of the industry discussion was the ways in which public authorities can push for the production and use of renewable sources of energy. Some governments give subsidies for startups to operate in this sector, which has influenced the ways in which the production of wind energy is be enhanced, in turn affecting its growth. Thus public authorities need to set regulations and incentives in place that could possibly encourage private entities to make investments in technology adoption. In the case of wind energy, an important consideration is also that of society's perception of the growth of wind farms. The installation of wind farms alters the natural landscape, which may not be appreciated by all. Thus the social context needs to be evaluated as well, by facilitating discussions with the public, to understand their apprehensions about the installation of wind farms. Participatory discussions and dialogues can help understand the concerns people might have and bring a consensus among the different stakeholders (Lange & Hehl-Lange, 2005).

Moreover, organizations work within the social context. Government policies and regulations impact organizations to operate in ways that may not have been their primary concern. This was an important aspect that did not find much discussion in the literature but was heavily focused on during the interviews. There were discussions with the policy makers themselves to get upskilled with the latest technological developments, in order for them to understand the implications of technology. Moreover, the inputs suggested that governments and policymakers have an important role in shaping how organizations adopt technology. This technology adoption could be influenced by certain standards that policymakers could place, in terms of energy production and consumption.

Experts also suggested that private organizations may not always have environmental sustainability as their primary objective and that they could be driven more by profits and market shares. Here, government and regulators can play an important role in keeping a check to ensure that organizations are evolving in a way that is sustainable for society at large. An important case discussed was that of the growing windmill installations that happen within a country, that are operated by wind energy companies in another country. In such a scenario, social and political changes could influence how a country operates to increase or decrease energy production and distribution for another country. Thus the geo-political aspects also play an important role in influencing the energy sector. These factors lay outside the scope of the organization itself but play a role in impacting the ways organizations witness growth and thrive in the long run. Thus, a number of factors impact the adoption of AI capabilities in wind energy companies, including the role of public authorities, regulatory bodies, and society's perception of the growth of this industry. This highlights the implications of external factors, as laid out by sociological institutionalism, in impacting an organization's business processes.

When wind energy companies adopt AI in their business operations, the future implications of this technological adoption need to be thought of. AI algorithms currently being used for fault detection and predictive maintenance of wind farms, are costly and expensive(Ahmad et al., 2021). Moreover, complex algorithms need higher computational power to process data thus consuming higher amounts of energy. Industry discussions have also highlighted the need to be mindful of the energy being consumed to power the AI models. From industry discussions, there is an optimistic growth of the wind energy sector and its technological adoption in the near future. There will be increasing autonomy in the operations and maintenance of wind farms, and more intelligent systems will be placed to ensure adequate maintenance of the wind farms. This increases the need for building energy-efficient systems, so the output may be a sustainable solution. There has also been research on more efficient AI-based designs of windmills that can help streamline operations. Thus the perceived usefulness of AI capabilities is extending much beyond the purpose they were initially intended for, and expanding the business prospects.

6.7. Summary

The previous discussion of the findings reflect the ways in which the adoption and use of AI can bring a shift in an organization’s traditional business operations. This was explored through discussions on the driving forces to adopt the new technology, introduction of upskilling/reskilling initiatives, investments in research and development initiatives, ethical concerns regarding the use of technology, the role of policymakers, etc. Each of these factors brings a unique perspective to understand the ways in which an organization undergoes change with the introduction of AI systems.

The findings suggest that the impact of using AI systems needs to be considered holistically in order to ensure a positive influence with its adoption. AI capabilities help with bringing operational efficiency, and predictive maintenance capabilities, helping organizations gain a competitive advantage over others in the industry. Industry experts shared insights on how robots now help paint wind blades, collect data from the wind turbines, and conduct repairs, all while being remotely operated. This not only helps improve operational efficiency and save time but also reduces the risks of accidents for humans conducting such operations otherwise. Moreover, such activities ensure regular data collection, and faster data analysis to ensure timely fault detection and diagnosis. It also helps to better engage the human labor force with more creative tasks while moving the redundant activities to be taken over by machines.

With the adoption of AI capabilities, organizations have witnessed a positive change in their willingness to invest in upskilling and reskilling initiatives for their employees. Upskilling activities make sure the employees are sufficiently skilled to be able to best use the new technology, and alsoensure that the technology adoption happens in a much faster and safer way. However, industry experts have raised concerns over upskilling activities being time and financially intensive, thus leading to some organizations instead investing in outsourcing technical capabilities. Moreover, the kinds of skill requirements are also evolving, with an increasing focus on data analytics, python, and other programming languages. These skills are required to better train and gain insights from the AI models, compared to traditional skill requirements for such activities.

While the advantages of the use of AI are evident, it is important to ensure due consideration to the negative implications of its use. The environmental impact of the use of AI systems is a point of concern. Following industry discussions, organizations are increasing awareness on this front but they continue to take the trade-off of the emissions from such systems, over the larger prospect of them helping generate clean and green energy. Moreover, the decision-making by the

AI systems remains questionable, with AI being tagged as a ‘black box’. Since the decision-making for the wind energy sector can be high stakes, it is important to ensure that humans are involved in the decision-making of such activities. This aspect further delves into the discussions on the engagement of humans when AI systems are introduced. The industry seems very optimistic that the initial reduction in human labor will eventually be filled in with newer skill requirements to engage the human labor force. Moreover, there was an industry-level consensus on humans to work alongside machines in order to ensure accountability of decision-making and sustained growth of the industry at large.

Industry experts also highlighted the increasing risks of data breaches and data leaks, thanks to the growing data availability and accessibility to feed into the AI models. It has been a frequent occurrence for hackers to take over wind farms, and manipulate energy production. Since wind energy data is of high economic value, there needs to be a focus on cyber security to ensure that the data does not reach malicious hands. However, despite the high sensitivity of this data, experts shared that the wind energy sector largely remains reactive than proactive, in conserning issues of cyber security.

Further, the role of external factors like governments, policy regulators, incentive schemes and the general public was emphasized upon, in shaping organizations. The discussions explored how subsidy schemes and tax relaxations have helped some organization adopt technology at a much faster pace than others. Similarly, policy and regulatory support help certain countries to flourish their energy sector and the related technological developments more than others. Lastly, for the case of establishing wind farms, a need for public discussions was emphasized. The establishment of windfarms disturb the natural landscape, and thus there must be active discussions with the general public in understanding their ideas and apprehensions associated with the growth of the wind energy industry at large.

7. Limitations

For the evaluation of the quality and limitations of this research, the framework proposed by Guba (1981) was used. The framework proposes four criteria to gauge the trustworthiness of qualitative analysis, namely- credibility, transferability, dependability, and confirmability. Credibility means that there is an accurate representation of what a researcher is evaluating by utilizing multiple perspectives, transferability, on the other hand, looks into the extent to which the findings of a study are applicable in other situations, and dependability explains what steps were taken to ensure a study can be replicated, lastly, confirmability looks into what steps a researcher took to ensure their own bias does not influence the outcome of the study. The next paragraphs explain how these elements were implemented for this study.

The credibility of this study was established through an in-depth review of over 120 research papers and triangulation. Specifically, the theory triangulation (Guion, 2002) was performed. Theory triangulation happens when someone uses different theories or perspectives of other researchers in the field to analyze the data. For this research, theory triangulation was accomplished by involving three different theoretical standpoints — Technology Acceptance Model (TAM), Resource Based View (RBV), and Sociological Institutionalism —to give a holistic understanding of the organizational change with the adoption of AI systems. In addition, frequent faculty debriefing and discussions with the primary and secondary supervisors provided the study with valuable feedback on the ways to better improve the research.

To support the transferability of this study, anonymized yet descriptive information about the background and expertise of the interviewees has been provided. The codebook was developed with definitions for each of the codes to understand the scope and use of the code for the purpose of this study. The coding was performed twice, to re-evaluate the codes assigned initially, and better understand the reasoning behind any inconsistencies that arose. Some of these practices are in line with recommended practices of previous studies in refinding codebooks(MacQueen et al., 1998).

To ensure the dependability of the research a list of documents were provided, including an audit trail of the interview questions guide, and the codebook, alongside other useful information to make the process of replicating this research in the future easier. All this information has been added to the appendix of this document. The audit trails and triangulation specified previously also help with supporting the confirmability of this study by ensuring the avoidance of the researcher's personal bias in swaying the outcome of the study. Some degree of conformability was also achieved by recording experts' interviews and providing them back with the interview interpretation and findings. This was done to ensure that the researchers' personal opinions are not reflected in the discussion and that the interviews are the sole representation of the experts' opinions.

While this study includes a variety of discussions with experts, a replication of the study on a larger sample might be necessary to ensure saturation. Furthermore, as discussed in the research, technology adoption can be greatly influenced by governments and policymakers, and thus a regional study may be useful to study a particular geographic/ country-wide area. The current study aims to gather a general understanding of organizational change in wind energy companies and is not representative of specific geographic locations. Furthermore, qualitative research is typically used for exploratory studies of this type, and generalizability might require future work to validate the findings through a method such as a quantitative survey or archival research.

8. Conclusion

Sustainable development has become an active part of mainstream industry discussions, more with the acceptance of the Sustainable Development Goals (SDGs) by the United Nations in 2015 (B. X. Lee et al., 2016). Information and Communication Technologies (ICTs) are a part of the targets to achieve these SDGs, with their potential to foster innovation and development (Wu et al., 2018). The advantages of the use of ICTs have led firms to bring these into their formal business processes, in an attempt to accelerate their organizational goals. An industry-wide acceptance of the advancing technologies also leads to greater competition amongst organizations in terms of ICT adoption, their use, and integration into organizational structures (Murphy, 2002). Thus, the adoption of new technology brings a fundamental shift in the ways businesses are structured, and how they define organizational priorities and future business prospects.

Energy improvement and efficiency have become a worldwide priority to ensure adequate energy supply, and address challenges related to global warming, carbon emission, biodiversity protection, and developments in renewable energy (Tchakoua et al., 2014). Wind energy is gaining prominence with it being a clean and renewable source of energy, serving as an alternative to traditional fuel-based energy systems (Sun et al., 2020). Operational and Maintenance (O&M) activities can account for about 10%-20% of the total cost of energy (COE) of a wind project, and this number can reach up to 35% over the end of life of the wind turbine (Tchakoua et al., 2014). ICTs can help here with their support in streamlining operational activities (García Márquez & Peinado Gonzalo, 2022), bringing predictive maintenance capabilities (Ren & Bao, 2010), and ensuring timely fault detection and diagnosis (Colak et al., 2012). This research aims to study the organizational change in wind energy companies with the use of AI systems for operational and maintenance (O&M) activities.

To address the research question, eight interviews were conducted with experts who have worked extensively with AI in the wind energy sector. The interviews aimed to study the technological and organizational-level changes to companies adopting AI systems. The interviews included discussions on the drivers for AI adoption, but also the related challenges, ethical concerns, and the impact of their use on the human laborforce. From a theoretical perspective, the Technology

Organization Environment (TOE) framework was used to comprehensively understand organizational change from different perspectives. Further, the Technology Acceptance Model (TAM), Resource Based View (RBV), and Sociological Institutionalism were used to supplement the analysis with the TOE.

The findings emphasized the need to holistically understand the impact of the use of AI systems. The discussions emphasized the advantages of the use of these systems with advanced technical capabilities but also explored the negative implications of their use, and the need for conscious decision-making when introducing such systems. Nonetheless, participants both implicitly and explicitly emphasized the power of AI capabilities to bring a fundamental shift in existing business operations in the wind energy sector. Some of the findings from the research are listed below:

- *Upskilling and reskilling initiatives* are major changes observed within organizations that adopt AI systems. The literature laid focus on bringing in-house upskilling and reskilling activities in order to build internal capabilities and gain sustained competitive advantage in the industry. However, industry experts have emphasized that such activities are financially and resourcefully intensive. This constraints some organizations to invest in such activities for their employees, and resort to outsourcing technological capabilities to third-party organizations. Moreover, industry experts emphasized the need for upskilling activities for policymakers, so technical advancement goes hand-in-hand with policy and regulatory changes.
- Organizations increasingly focus on considering the *environmental impact of AI systems*. While the consciousness of the industry is growing in this aspect, experts have largely agreed that the industry is willing to take the tradeoff of the emissions with the use of the AI systems, over the larger prospect of these systems helping to contribute towards environmental sustainability with efficient green energy production.
- An overall *skill and competence change* is being witnessed in the industry. AI capabilities have ensured faster and more efficient means of data collection and analysis, which was restricted with the engagement of the human laborforce earlier. This has led organizations to value the knowledge of data science, data analytics, and cybersecurity, shifting focus from the need for manual data collection and analysis. However, there has been a

consensus that human laborforce is needed to work jointly with technological capabilities, in order to ensure sustained growth of the industry. Humans are now being tasked with more innovative and creative tasks, while the redundant tasks are being moved over to machines.

- *Cyber security* has emerged as an important aspect with the vast amounts of data available in the wind energy sector. Given that this data is of high economic value, the literature stresses the need to build robust data management systems to guard it against being used maliciously. However, industry discussions have reflected that the wind energy sector largely remains reactive, than proactive when dealing with issues concerning cyber security. Cases of hackers getting access to wind farms and manipulating energy production and distribution remain a frequent occurrence.
- *Collaboration between industry and academia* has emerged as a challenge with the vast amount of high-value data available in the wind energy sector. Organizations tend to guard their data and refrain from sharing it further with academia. However, academic research relies heavily on industry data for latest research and development purposes. This eventually compromises innovation in the industry at large. There is thus a need to bring greater collaboration and avenues of data sharing between the industry and academia so that academic research can benefit industry operations, and vice versa.

These findings suggest some of the ways in which wind energy organizations have witnessed changes in their business processes, priorities, and operations with the advent of AI in their operational and maintenance activities. These findings have been synthesized together with the insights from the literature review to bring together inputs for potential future research in this area.

9. References

Adekanbi, M. L. (2021). Optimization and digitization of wind farms using internet of things: A review. *International Journal of Energy Research*, *45*(11), 15832–15838. https://doi.org/10.1002/er.6942

Agrawal, A., Gans, J., & Goldfarb, A. (2018). *Prediction Machines: The Simple Economics of Artificial Intelligence*. Harvard Business Press.

Ahmad, T., Zhang, D., Huang, C., Zhang, H., Dai, N., Song, Y., & Chen, H. (2021). Artificial intelligence in sustainable energy industry: Status Quo, challenges and opportunities. *Journal of Cleaner Production*, *289*, 125834. https://doi.org/10.1016/j.jclepro.2021.125834

Ajzen, I. (1985). From Intentions to Actions: A Theory of Planned Behavior. In J. Kuhl & J. Beckmann (Eds.), *Action Control: From Cognition to Behavior* (pp. 11–39). Springer. https://doi.org/10.1007/978-3-642-69746-3_2

Andersen, M. S., & Massa, I. (2000). Ecological modernization ? Origins, dilemmas and future directions. *Journal of Environmental Policy and Planning*, *2*(4), 337–345. https://doi.org/10.1002/1522-7200(200010/12)2:4<337::AID-JEPP62>3.0.CO;2-G

Artificial Intelligence and Big Data – Innovation Landscape Brief. (2019).

Arvanitis, S., & Loukis, E. N. (2009). Information and communication technologies, human capital, workplace organization and labour productivity: A comparative study based on firm-level data for Greece and Switzerland. *Information Economics and Policy*, *21*(1), 43–61. https://doi.org/10.1016/j.infoecopol.2008.09.002

Awa, H. O., Ukoha, O., & Igwe, S. (2017). Revisiting technology-organization-environment (T-O-E) theory for enriched applicability. *The Bottom Line*, *30*. https://doi.org/10.1108/BL-12-2016-0044

Barney, J. (1991). Firm Resources and Sustained Competitive Advantage. *Journal of Management*, *17*(1), 99–120. https://doi.org/10.1177/014920639101700108

Barney, J. B. (1986). Strategic factor markets: Expectations, luck, and business strategy. *Management science*, *32*(10), 1231-1241.

Barney, J. B. (1986a). Types of competition and the theory of strategy: Toward an integrative framework. *Academy of management review*, *11*(4), 791-800.

Belkhir, L., & Elmeligi, A. (2018). Assessing ICT global emissions footprint: Trends to 2040 & recommendations. *Journal of Cleaner Production*, *177*, 448–463. https://doi.org/10.1016/j.jclepro.2017.12.239

Bencherki, N. (2017). *Actor–Network Theory*. https://doi.org/10.1002/9781118955567.wbieoc002

Bernardini, S., Jovan, F., Jiang, Z., Watson, S., Weightman, A., Moradi, P., Richardson, T., Sadeghian, R., & Sareh, S. (2020). A multi-robot platform for the autonomous operation and maintenance of offshore wind farms. In *Autonomous Agents and Multi-Agent Systems (AAMAS) 2020* (pp. 1696–1700). International Foundation for Autonomous Agents and Multiagent Systems. https://dl.acm.org/doi/abs/10.5555/3398761.3398956

Berscheid, J., & Roewer-Despres, F. (2019). Beyond transparency: A proposed framework for accountability in decision-making AI systems. *AI Matters*, *5*(2), 13–22. https://doi.org/10.1145/3340470.3340476

Black, S. E., & Lynch, L. M. (1996). Human-Capital Investments and Productivity. *The American Economic Review*, *86*(2), 263–267.

Bose, B. K. (2017). Artificial Intelligence Techniques in Smart Grid and Renewable Energy Systems—Some Example Applications. *Proceedings of the IEEE*, *105*(11), 2262–2273. https://doi.org/10.1109/JPROC.2017.2756596

Bovens, M., Goodin, R. E., & Schillemans, T. (2014). *The Oxford Handbook of Public Accountability*. OUP Oxford.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*(2), 77–101. https://doi.org/10.1191/1478088706qp063oa

Brousseau, E., & Rallet, A. (1998). *Beyond Technological or Organisational Determinism: A Framework to Understand the Link Between Information Technologies and Organisational Changes*.

Bruce, C. (n.d.). *Human factors of information technology in the office | Titel*. Retrieved March 18, 2023, from https://library.wur.nl/WebQuery/titel/411858

Burnes, B. (2009). *Managing Change: A Strategic Approach to Organisational Dynamics*. Prentice Hall/Financial Times.

Callon, M. (1984). Some Elements of a Sociology of Translation: Domestication of the Scallops and the Fishermen of St Brieuc Bay. *The Sociological Review*, *32*(1_suppl), 196–233.

https://doi.org/10.1111/j.1467-954X.1984.tb00113.x

Carolin Mabel, M., & Fernandez, E. (2008). Analysis of wind power generation and prediction using ANN: A case study. *Renewable Energy*, *33*(5), 986–992. https://doi.org/10.1016/j.renene.2007.06.013

Colak, I., Sagiroglu, S., & Yesilbudak, M. (2012). Data mining and wind power prediction: A literature review. *Renewable Energy*, *46*, 241–247. https://doi.org/10.1016/j.renene.2012.02.015

Daft, R. L. (2010). *Organization theory and design* (10th ed). South-Western Cengage Learning.

Daneels, A., & Salter, W. (1999). *What is SCADA*. https://www.semanticscholar.org/paper/What-is-SCADA-Daneels-Salter/5f5925da3e9ce547c04cb580abc28d27475a5d9b

Davis, F. (1985). *A Technology Acceptance Model for Empirically Testing New End-User Information Systems*.

Davis, F., & Davis, F. (1989). Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology. *MIS Quarterly*, *13*, 319. https://doi.org/10.2307/249008

Digitalization and Energy. (2017).

DiMaggio, P. J., & Powell, W. W. (1983). The Iron Cage Revisited: Institutional Isomorphism and Collective Rationality in Organizational Fields. *American Sociological Review*, *48*(2), 147–160. https://doi.org/10.2307/2095101

Engels, Prof. Dr. A., Kunkis, M., & Altstaedt, S. (2020). A new energy world in the making: Imaginary business futures in a dramatically changing world of decarbonized energy production. *Energy Research & Social Science*, *60*, 101321. https://doi.org/10.1016/j.erss.2019.101321

Eveland, J., & Tornatzky, L. G. (1990). *Technological Innovation as a Process* (pp. 27–50).

Frey, C. B., & Osborne, M. A. (2017). The future of employment: How susceptible are jobs to computerisation? *Technological Forecasting and Social Change*, *114*, 254–280. https://doi.org/10.1016/j.techfore.2016.08.019

Fujii, H., & Managi, S. (2018). Trends and priority shifts in artificial intelligence technology invention: A global patent analysis. *Economic Analysis and Policy*, *58*, 60–69. https://doi.org/10.1016/j.eap.2017.12.006

Gangwar, H., Date, H., & Raoot, A. D. (2014). Review on IT adoption: Insights from recent technologies. *Journal of Enterprise Information Management*, *27*, 488–502. https://doi.org/10.1108/JEIM-08-2012-0047

García Márquez, F. P., & Peinado Gonzalo, A. (2022). A Comprehensive Review of Artificial Intelligence and Wind Energy. *Archives of Computational Methods in Engineering*, *29*(5), 2935–2958. https://doi.org/10.1007/s11831-021-09678-4

Govindarajulu, L., Lippert, S., & Govindarajulu, C. (2006). Technological, Organizational, and Environmental Antecedents to Web Services Adoption. *Communications of the IIMA*, *6*. https://doi.org/10.58729/1941-6687.1303

Guba, E. G. (1981). Criteria for assessing the trustworthiness of naturalistic inquiries. *ECTJ*, *29*(2), 75. https://doi.org/10.1007/BF02766777

Gubrium, P. of S. and C. J. F., & Holstein, P. J. A. (2002). *Handbook of Interview Research: Context and Method*. SAGE.

Guion, L. A. (2002). *Triangulation: Establishing the Validity of Qualitative Studies*.

Guo, Y., Wang, J., Chen, H., Li, G., Huang, R., Yuan, Y., Ahmad, T., & Sun, S. (2019). An expert rule-based fault diagnosis strategy for variable refrigerant flow air conditioning systems. *Applied Thermal Engineering*, *149*, 1223–1235. https://doi.org/10.1016/j.applthermaleng.2018.12.132

Hagendorff, T. (2020). The Ethics of AI Ethics: An Evaluation of Guidelines. *Minds and Machines*, *30*(1), 99–120. https://doi.org/10.1007/s11023-020-09517-8

Hameed, Z., Hong, Y. S., Cho, Y. M., Ahn, S. H., & Song, C. K. (2009). Condition monitoring and fault detection of wind turbines and related algorithms: A review. *Renewable and Sustainable Energy Reviews*, *13*(1), 1–39. https://doi.org/10.1016/j.rser.2007.05.008

Hariem Brundtland, G. (1985). World Commission on environment and development. *Environmental Policy and Law*, *14*(1), 26–30. https://doi.org/10.1016/S0378-777X(85)80040-8

Helbing, G., & Ritter, M. (2018). Deep Learning for fault detection in wind turbines. *Renewable and Sustainable Energy Reviews*, *98*, 189–198. https://doi.org/10.1016/j.rser.2018.09.012 Henzelmann, T., Hammermeister, F., Wurm, B., Nonnenmacher, L., Preiss, S., & Schroer, K. (2018). Artificial intelligence: a smart move for utilities. *Roland Berger: Munich, Germany*.

Hilty, L., Lohmann, W., & Huang, E. M. (2011). Sustainability and ICT - An overview of the field. *Notizie Di Politeia*, *27*(104), Article 104. https://doi.org/10.5167/uzh-55640

Hofer, C. W., & Schendel, D. (1978). Strategy formulation: Analytical concepts. *(No Title)*.

Hu, Y., Qiao, Y., Liu, J., & Zhu, H. (2019). Adaptive Confidence Boundary Modeling of Wind Turbine Power Curve Using SCADA Data and Its Application. *IEEE Transactions on Sustainable Energy*, *10*(3), 1330–1341. https://doi.org/10.1109/TSTE.2018.2866543

Huber, J. (2000). Towards industrial ecology: Sustainable development as a concept of ecological modernization. *Journal of Environmental Policy & Planning*, *2*(4), 269–285. https://doi.org/10.1080/714038561

Jha, S. Kr., Bilalovic, J., Jha, A., Patel, N., & Zhang, H. (2017). Renewable energy: Present research and future scope of Artificial Intelligence. *Renewable and Sustainable Energy Reviews*, *77*, 297–317. https://doi.org/10.1016/j.rser.2017.04.018

Jobin, A., Lenca, M., & Vayena, E. (2019). *The global landscape of AI ethics guidelines | Nature Machine Intelligence*. https://www.nature.com/articles/s42256-019-0088-2

Khalid, O., Hao, G., Desmond, C., Macdonald, H., McAuliffe, F. D., Dooly, G., & Hu, W. (2022). Applications of robotics in floating offshore wind farm operations and maintenance: Literature review and trends. *Wind Energy*, *25*(11), 1880–1899. https://doi.org/10.1002/we.2773

Khasawneh, A. (2008). Concepts and measurements of innovativeness: The case of information and communication technologies. *International Journal of Arab Culture, Management and Sustainable Development - Int J Arab Cult Manag Sustain Dev*, *1*. https://doi.org/10.1504/IJACMSD.2008.020487

King, W., & He, J. (2006). A meta-analysis of the Technology Acceptance Model. *Information & Management*, *43*, 740–755. https://doi.org/10.1016/j.im.2006.05.003

Kling, J. (1995). High Performance Work Systems and Firm Performance Workplace Practices. *Monthly Labor Review*, *118*(5), 29–36.

Kow, K. W., Wong, Y. W., Rajkumar, R. K., & Rajkumar, R. K. (2016). A review on performance of artificial intelligence and conventional method in mitigating PV grid-tied related power quality events. *Renewable and Sustainable Energy Reviews*, *56*, 334–346. https://doi.org/10.1016/j.rser.2015.11.064

Lange, E., & Hehl-Lange, S. (2005). Combining a participatory planning approach with a virtual landscape model for the siting of wind turbines. *Journal of Environmental Planning and Management*, *48*(6), 833–852. https://doi.org/10.1080/09640560500294277

Latour, B. (1996). On actor-network theory: A few clarifications. *Soziale Welt*, *47*(4), 369–381.

Lee, B. X., Kjaerulf, F., Turner, S., Cohen, L., Donnelly, P. D., Muggah, R., Davis, R., Realini, A., Kieselbach, B., MacGregor, L. S., Waller, I., Gordon, R., Moloney-Kitts, M., Lee, G., & Gilligan, J. (2016). Transforming Our World: Implementing the 2030 Agenda Through Sustainable Development Goal Indicators. *Journal of Public Health Policy*, *37*(S1), 13–31. https://doi.org/10.1057/s41271-016-0002-7

Lee, M., & He, G. (2021). An empirical analysis of applications of artificial intelligence algorithms in wind power technology innovation during 1980–2017. *Journal of Cleaner Production*, *297*, 126536. https://doi.org/10.1016/j.jclepro.2021.126536

Li, Q., Cheng, L., Gao, W., & Gao, D. W. (2020). Fully Distributed State Estimation for Power System with Information Propagation Algorithm. *Journal of Modern Power Systems and Clean Energy*, *8*(4), 627–635. https://doi.org/10.35833/MPCE.2019.000159

Li, Y., Peng, S., Li, Y., & Jiang, W. (2020). A review of condition-based maintenance: Its prognostic and operational aspects. *Frontiers of Engineering Management*, *7*(3), 323-334.

Li, Z. L., Xia, J., Liu, A., & Li, P. (2019). States prediction for solar power and wind speed using BBA‐SVM. *IET Renewable Power Generation*, *13*(7), 1115-1122.

Liao, W., Bak-Jensen, B., Radhakrishna Pillai, J., Yang, D., & Wang, Y. (2022). Data-driven Missing Data Imputation for Wind Farms Using Context Encoder. *Journal of Modern Power Systems and Clean Energy*, *10*(4), 964–976. https://doi.org/10.35833/MPCE.2020.000894

Lin, Q., & Wang, J. (2014). Vertically Correlated Echelon Model for the Interpolation of Missing Wind Speed Data. *IEEE Transactions on Sustainable Energy*, *5*(3), 804–812. https://doi.org/10.1109/TSTE.2014.2304971

Lin, Z., & Liu, X. (2020). Wind power forecasting of an offshore wind turbine based on high-frequency SCADA data and deep learning neural network. *Energy*, *201*, 117693. https://doi.org/10.1016/j.energy.2020.117693

Lippman, S. A., & Rumelt, R. P. (1982). Uncertain Imitability: An Analysis of Interfirm Differences in Efficiency under Competition. *The Bell Journal of Economics*, *13*(2), 418–438. https://doi.org/10.2307/3003464

Lundblad, J. P. (2003). A Review and Critique of Rogers' Diffusion of Innovation Theory as it Applies to Organizations. *Organization Development Journal*, *21*(4), 50–64.

Machlev, R., Heistrene, L., & Perl, M. (2022). *Explainable Artificial Intelligence (XAI) techniques for energy and power systems: Review, challenges and opportunities | Elsevier Enhanced Reader*. https://doi.org/10.1016/j.egyai.2022.100169

MacQueen, K. M., McLellan, E., Kay, K., & Milstein, B. (1998). Codebook Development for Team-Based Qualitative Analysis. *CAM Journal*, *10*(2), 31–36. https://doi.org/10.1177/1525822X980100020301

Manwell, J. F., McGowan, J. G., & Rogers, A. L. (2010). *Wind Energy Explained: Theory, Design and Application*. John Wiley & Sons.

Marangunić, N., & Granić, A. (2015). Technology acceptance model: A literature review from 1986 to 2013. *Universal Access in the Information Society*, *14*(1), 81–95. https://doi.org/10.1007/s10209-014-0348-1

McDaniel, P., & McLaughlin, S. (2009). Security and Privacy Challenges in the Smart Grid. *IEEE Security & Privacy*, *7*(3), 75–77. https://doi.org/10.1109/MSP.2009.76

Merizalde, Y., Hernández-Callejo, L., Duque-Perez, O., & Alonso-Gómez, V. (2019). Maintenance Models Applied to Wind Turbines. A Comprehensive Overview. *Energies*, *12*(2), Article 2. https://doi.org/10.3390/en12020225

Meyer, J. W., & Rowan, B. (1977). Institutionalized Organizations: Formal Structure as Myth and Ceremony. *American Journal of Sociology*, *83*(2), 340–363. https://doi.org/10.1086/226550

Monostori, L. (2014). Artificial Intelligence. In L. Laperrière & G. Reinhart (Eds.), *CIRP Encyclopedia of Production Engineering* (pp. 47–50). Springer. https://doi.org/10.1007/978-3-642-20617-7_16703

Moyer, J. D., & Hughes, B. B. (2012). ICTs: Do they contribute to increased carbon emissions? *Technological Forecasting and Social Change*, *79*(5), 919–931. https://doi.org/10.1016/j.techfore.2011.12.005

Murphy, M. (2002). *Organisational Change and Firm Performance* (OECD Science, Technology and Industry Working Papers No. 2002/14; OECD Science, Technology and Industry Working Papers, Vol. 2002/14). https://doi.org/10.1787/615168153531

Mykhailychenko, R. (2019). The 4th industrial revolution: Responding to the impact of artificial intelligence on business. *Foresight*, *21*(2), 318–319. https://doi.org/10.1108/FS-04-2019-109

O'Brien, J. A. 1936-. (1983). *Computers and information processing in business*. R.D. Irwin.

OECD. (2001). *The New Economy: Beyond the Hype: The OECD Growth Project*. OECD. https://doi.org/10.1787/9789264033856-en

OECD. (2017). *World Energy Outlook 2017*. Organisation for Economic Co-operation and Development. https://www.oecd-ilibrary.org/energy/world-energy-outlook-2017_weo-2017-en

Oliveira, T., & Martins, M. R. (2011). Literature Review of Information Technology Adoption Models at Firm Level. *1566-6379*, *14*.

Ozcanli, A. K., Yaprakdal, F., & Baysal, M. (2020). Deep learning methods and applications for electrical power systems: A comprehensive review. *International Journal of Energy Research*, *44*(9), 7136–7157. https://doi.org/10.1002/er.5331

Porté-Agel, F., Bastankhah, M., & Shamsoddin, S. (2020). Wind-Turbine and Wind-Farm Flows: A Review. *Boundary-Layer Meteorology*, *174*(1), 1–59. https://doi.org/10.1007/s10546-019-00473-0

Porter, M. E. (1980). Industry Structure and Competitive Strategy: Keys to Profitability. *Financial Analysts Journal*, *36*(4), 30–41.

Porter, M. E. (1981). The Contributions of Industrial Organization to Strategic Management. *The Academy of Management Review*, *6*(4), 609–620. https://doi.org/10.2307/257639

Porter, M. E. (1985). *Competitive advantage: Creating and sustaining superior performance*. Free Press ; Collier Macmillan.

Prahalad, C. K., & Hamel, G. (1990). The Core Competence of the Corporation. *Harvard Business Review*.

Prahalad, C. K., & Hamel, G. (1994). Strategy as a field of study: Why search for a new paradigm? *Strategic Management Journal*, *15*(S2), 5–16. https://doi.org/10.1002/smj.4250151002

Puri, V., Jha, S., Kumar, R., Priyadarshini, I., Hoang Son, L., Abdel-Basset, M., Elhoseny, M., & Viet Long, H. (2019). A Hybrid Artificial Intelligence and Internet of Things Model for Generation of Renewable Resource of Energy. *IEEE Access*, *7*, 111181–111191. https://doi.org/10.1109/ACCESS.2019.2934228

Qian, P., Zhang, D., Tian, X., Si, Y., & Li, L. (2019). A novel wind turbine condition monitoring method based on cloud computing. *Renewable Energy*, *135*, 390–398. https://doi.org/10.1016/j.renene.2018.12.045

Ren, Y. F., & Bao, G. Q. (2010). Control Strategy of Maximum Wind Energy Capture of Direct-Drive Wind Turbine Generator Based on Neural-Network. *2010 Asia-Pacific Power and Energy Engineering Conference*, 1–4. https://doi.org/10.1109/APPEEC.2010.5448343

Rogers, E. M. (2010). *Diffusion of Innovations, 4th Edition*. Simon and Schuster.

Rogers, E. M., Singhal, A., & Quinlan, M. M. (2014). Diffusion of innovations. In *An integrated approach to communication theory and research* (pp. 432-448). Routledge.

Salahuddin, M., Alam, K., & Ozturk, I. (2016). The effects of Internet usage and economic growth on CO2 emissions in OECD countries: A panel investigation. *Renewable and Sustainable Energy Reviews*, *62*, 1226–1235. https://doi.org/10.1016/j.rser.2016.04.018

Sani, A. S., Yuan, D., Jin, J., Gao, L., Yu, S., & Dong, Z. Y. (2019). Cyber security framework for Internet of Things-based Energy Internet. *Future Generation Computer Systems*, *93*, 849–859. https://doi.org/10.1016/j.future.2018.01.029

Saunders, M., Lewis, P., Thornhill, A., & Bristow, A. (2019). *"Research Methods for Business Students" Chapter 4: Understanding research philosophy and approaches to theory development* (pp. 128–171).

Schlechtingen, M., & Ferreira Santos, I. (2011). Comparative analysis of neural network and regression based condition monitoring approaches for wind turbine fault detection. *Mechanical Systems and Signal Processing*, *25*(5), 1849–1875. https://doi.org/10.1016/j.ymssp.2010.12.007

Sodhro, A. H., Pirbhulal, S., & de Albuquerque, V. H. C. (2019). Artificial Intelligence-Driven Mechanism for Edge Computing-Based Industrial Applications. *IEEE Transactions on Industrial Informatics*, *15*(7), 4235–4243. https://doi.org/10.1109/TII.2019.2902878

Stetco, A., Dinmohammadi, F., Zhao, X., Robu, V., Flynn, D., Barnes, M., Keane, J., & Nenadic, G. (2019). Machine learning methods for wind turbine condition monitoring: A review. *Renewable Energy*, *133*, 620–635. https://doi.org/10.1016/j.renene.2018.10.047

Sullivan, G. P., Pugh, R., Melendez, A. P., & Hunt, W. D. (2010). Operations & maintenance. *Best practices. A guide to achieving operational efficiency, sl: Pacific Northwest*

National Laboratory for the Federal Energy Management Program, US Department of Energy.

Sun, H., Gao, X., & Yang, H. (2020). A review of full-scale wind-field measurements of the wind-turbine wake effect and a measurement of the wake-interaction effect. *Renewable and Sustainable Energy Reviews*, *132*, 110042. https://doi.org/10.1016/j.rser.2020.110042

Tchakoua, P., Wamkeue, R., Ouhrouche, M., Slaoui-Hasnaoui, F., Tameghe, T. A., & Ekemb, G. (2014). Wind Turbine Condition Monitoring: State-of-the-Art Review, New Trends, and Future Challenges. *Energies*, *7*(4), Article 4. https://doi.org/10.3390/en7042595

Teece, D. J., Pisano, G., & Shuen, A. (1997). Dynamic capabilities and strategic management. *Strategic Management Journal*, *18*(7), 509–533. https://doi.org/10.1002/(SICI)1097-0266(199708)18:7<509::AID-SMJ882>3.0.CO;2-Z

Tong, K. C. (1998). Technical and economic aspects of a floating offshore wind farm. *Journal of Wind Engineering and Industrial Aerodynamics*, *74–76*, 399–410. https://doi.org/10.1016/S0167-6105(98)00036-1

Tornatzky, L. G., Fleischer, M., & Chakrabarti, A. K. (1990). *The Processes of Technological Innovation*. Lexington Books.

Tra. (2019, March 19). Global Wind Report 2019. *Global Wind Energy Council*. https://gwec.net/global-wind-report-2019/

Turing, A. M. (2009). Computing Machinery and Intelligence. In R. Epstein, G. Roberts, & G. Beber (Eds.), *Parsing the Turing Test: Philosophical and Methodological Issues in the Quest for the Thinking Computer* (pp. 23–65). Springer Netherlands. https://doi.org/10.1007/978-1-4020-6710-5_3

Wang, X., Zeng, X., Yang, X., & Li, J. (2018). Feasibility study of offshore wind turbines with hybrid monopile foundation based on centrifuge modeling. *Applied Energy*, *209*, 127–139. https://doi.org/10.1016/j.apenergy.2017.10.107

Wang, Y., Sun, Y., Wei, Z., & Sun, G. (2018). Parameters estimation of electromechanical oscillation with incomplete measurement information. *IEEE Transactions on Power Systems*, *33*(5), 5016-5028.

Wilson, H. J., & Daugherty, P. R. (2018). *Collaborative Intelligence: Humans and AI Are Joining Forces*.

World Meteorological Organization (Ed.). (2010). *Guide to the global observing system* (2010 ed). World Meteorological Organization.

Wu, J., Guo, S., Huang, H., Liu, W., & Xiang, Y. (2018). *Information and Communications Technologies for Sustainable Development Goals: State-of-the-Art, Needs and Perspectives* (arXiv:1802.09345). arXiv. http://arxiv.org/abs/1802.09345

Yoon, J., Zame, W. R., & van der Schaar, M. (2019). Estimating Missing Data in Temporal Data Streams Using Multi-Directional Recurrent Neural Networks. *IEEE Transactions on Biomedical Engineering*, *66*(5), 1477–1490. https://doi.org/10.1109/TBME.2018.2874712

Zaher, A., McArthur, S. d. j., Infield, D. g., & Patel, Y. (2009). Online wind turbine fault detection through automated SCADA data analysis. *Wind Energy*, *12*(6), 574–593. https://doi.org/10.1002/we.319

Zhang, W., Yang, D., & Wang, H. (2019). Data-Driven Methods for Predictive Maintenance of Industrial Equipment: A Survey. *IEEE Systems Journal*, *13*(3), 2213–2227. https://doi.org/10.1109/JSYST.2019.2905565

Zhang, X., & Wei, C. (2022). The economic and environmental impacts of information and communication technology: A state-of-the-art review and prospects. *Resources, Conservation and Recycling*, *185*, 106477. https://doi.org/10.1016/j.resconrec.2022.106477

Zhang, Y., Xiang, Y., & Wang, L. (2017). Power System Reliability Assessment Incorporating Cyber Attacks Against Wind Farm Energy Management Systems. *IEEE Transactions on Smart Grid*, *8*(5), 2343–2357. https://doi.org/10.1109/TSG.2016.2523515

Zhao, S., Hafeez, M., & Faisal, C. M. N. (2022). Does ICT diffusion lead to energy efficiency and environmental sustainability in emerging Asian economies? *Environmental Science and Pollution Research*, *29*(8), 12198–12207. https://doi.org/10.1007/s11356-021-16560-0

Zhao, Y., Xiao, F., & Wang, S. (2013). An intelligent chiller fault detection and diagnosis methodology using Bayesian belief network. *Energy and Buildings*, *57*, 278–288. https://doi.org/10.1016/j.enbuild.2012.11.007

Zucker, L. G. (1977). The Role of Institutionalization in Cultural Persistence. *American Sociological Review*, *42*(5), 726–743. https://doi.org/10.2307/2094862

10. Appendices

10.1. Appendix 1 Interview Questions

10.1.1. Interview - Technological Aspect

PEOU- Perceived Ease of Usefulness (part of TAM)

PU- Perceived Usefulness (part of TAM)

RBV- Resource Based View

TAM- Technology Acceptance Model

THEME	QUESTION	THEORY
Status Quo	How is the adoption of AI based systems, in the wind energy sector, accelerating the drive towards an environmentally sustainable future?	TAM (PU)
	Do you witness a reduction in the turnaround time when AI systems are involved in the fault detection and analysis of windmills? Is this a significant reduction as compared to traditional fault detection mechanisms when it was completely human labourforce dependent?	TAM (PU)
	How are organizations (re)aligning themselves with the advent of AI-based systems to take over traditional (human) employment? Ex. upskilling/ reskilling of employees, redesigning employee roles, etc?	RBV
	Do you see the shift to AI systems as a constructive change, as it helps reduce the risks of human labor getting involved in tasks that might compromise with their safety?	TAM (PU)
	Do you think the adoption of AI in the wind energy sector is motivated by organizations wanting to gain a competitive edge in the market?	RBV
	Is there a consideration of the amount of energy that the AI systems themselves consume in order to support environmental sustainability?	TAM (PU)

Data analysis	Do you think that the wind industry has sufficient quality data to be able to use AI systems effectively? Is there an industry-wide data standardization process?	RBV/ TAM (PEOU)
	From an implementation point of view, does the use of AI need specific skills/ technical expertise to be brought into the company for the systems to be put in place? Or these competencies are present in-house and no additional significant cost is incurred?	RBV/ TAM (PEOU)
	What kind of human skills and expertise are required to derive meaningful insights from the SCADA data, and then to train the model with AI capabilities? Ex. investment in skills related to data analytics, software programming and development, cybersecurity, etc?	RBV/ TAM (PEOU)
	How is the SCADA/ other data sets analyzed for fault detections, or predictive maintenance in the windmills?	TAM (PEOU)
	What kind of data is usually collected at the wind turbines for analysis, like wind speed, wind direction? Are these the parameters that are used by the AI systems for fault detection? And how is this data generated and gathered?	TAM (PEOU)
Future perspectives	Do you see a growing competitiveness in the industry towards the adoption of AI systems for the wind energy sector? Are there any other emerging technologies in this sector? Ex. advanced material science study, digital twin technology, installation of floating offshore wind turbines?	RBV
	Does your organization invest in R&D in the use of AI for fault detection in windmills? Ex. Are the machine learning models developed in-house, or is it something acquired from other third party organizations?	RBV
	Do you think government regulations and policy measures can play a role to ensure that the use of AI in the wind energy sector does not negatively impact the environment? Ex. setting energy efficient standards, increasing funding for R&D in this field?	SI (Sociological Institutionalism)
	What is the future potential of AI for its use in fault detections in windmills? Ex. decreasing the prediction times of notifying the faults, or assisting repair and maintenance completely without human support?	TAM (PU)

Ethics	What kind of ethical considerations does one take when using AI in the wind energy sector? For example, issues related to privacy and protection of data, data bias, safety?	TAM
	Are AI systems reliable when it comes to fault detections in windmills? Are there any major safety concerns or risks of accidents, and is the decision making considered trustworthy?	TAM (PU)
Challenges	What are some challenges that you face when using AI for fault detection in windmills? Ex. high installation costs? need for professional expertise? etc.	TAM (PU)
	What do you do as an organization to help mitigate the negative effects of AI on your employee? Ex. upskilling/ reskilling of employees, redesigning employee roles, etc?	RBV

10.1.2. Interview - Organizational Aspect

THEME	QUESTION	THEORY
Organizational Change	Do you think the advent of technology is bringing a fundamental change to how the industry is organized? Ex. the demand for skilled labor is increasing as compared to unskilled labour force?	RBV
	How are organizations re aligning themselves with the advent of digital technology to take over traditional (human) employment? Ex. upskilling/ reskilling of employees, redesigning employee roles, etc?	RBV/ TAM (PEOU)
	Does the incorporation of technology in the wind energy sector give significant competitive advantage to an organization? Do you think the level of technology adoption plays a role when customers sign up for associating themselves with a wing energy company?	RBV
	Does the coming in of digital technology change how teams are organized in a company/ does it lead to new teams being formed now? Ex. Maybe there is now a need for a dedicated team working on Artificial Intelligence and Machine Learning models to train for predictive maintenance of windmills, which was not	RBV/ TAM (PEOU)

	needed earlier?	
	How are organizations upgrading themselves to the latest technology? Is it purely by hiring technically competent staff, or are they also training their employees for such skills/ hiring external consultants on short term projects?	RBV
	Do you see the shift to AI systems as a positive change, as it helps reduce the risks of human labor getting involved in tasks that might compromise with their safety?	TAM (PEOU)
Status Quo	Do you think the wind industry has reached sufficient reliability in terms of the decisions made by the AI systems? Is the decision making trustworthy?	TAM (PU)
	Is there a consideration of the amount of energy that the AI systems themselves consume in order to support environmental sustainability?	TAM (PU)
	Do you think that the wind industry has sufficient quality data to be able to use AI systems effectively? Is there an industry-wide data standardization process?	RBV/ TAM (PEOU)
	Do you think that the use of AI systems in the wind industry helps eventually bring down the cost of energy?	TAM (PU)
Challenges	What do you do as an organization to help mitigate the negative effects of AI on your employee? Ex. upskilling/ reskilling of employees, redesigning employee roles, etc?	RBV/ TAM (PEOU)
	Do you think the advent of technology in this sector will translate to growing income disparities and a social imbalance?	RBV
	Is there a tradeoff that we make when we install advanced digital technology in the wind energy industry? So the higher operational efficiency with the use of such technology is traded with lowering human employment , thus creating social imbalances?	RBV

	Do you see a growing competitiveness in the industry towards the adoption of technology, like Artificial Intelligence and Machine Learning, for the wind energy sector? Are there any other emerging technologies in this sector? Ex. advanced material science study, digital twin technology, installation of floating offshore wind turbines?	RBV
	Do you think wind energy organizations are investing in R&D for the use of technology in this sector? Is this done in-house, or is there a dependence on academic and research institutions to do this?	RBV
	Do you think government regulations and policy measures can play a role to ensure that the technology is incorporated in organizations in a way that it does not impact ways of doing business. Ex. ensuring the human labourforce is engaged in companies, not moving everything autonomous, etc?	SI (Sociological Institutionalism)
Future perspective	What skills and competencies must be built to help people find jobs in wind farms with AI taking over their jobs? Ex. investment in skills related to software programming and development, cybersecurity, etc?	RBV/ TAM (PEOU)

10.2. Appendix 2 Interview 1 Transcript

Speaker 1: [00:00:01] Yeah. So I will just give a little bit of background about myself. My name is [Interviewee 1] and I am currently working for [Company 1]. And prior to this I spent a little bit of time in the UK and spent time in Bangalore and at my masters in the US. I originally come from the state of [State name]. My background is in structural mechanics, so I have been involved in the design of different construction components of windmills. Like of course, as you are aware of, windmill components are subject to different kinds of losses and whether those components will withstand that loading over its entire lifetime, basically that becomes an important part of the structural design. And that's basically what I've been doing all this while and my background is in this specialization also. So to start, I started working on the gearbox to which all the plates are connected and the plate bearings, out of which the plate basically is attached, so as to make the plate have an optimum angle so that it can generate more tork. And then later on, I've been working on the main bearings and then basically looking at structural design that are derived from the turbine.. So yeah, that's basically my background chart. It's as, as you can kind of feel like it's more it's pretty technical. Yeah. So I'm, the kind of person who has a very, very narrow and technical focus. So, yes. Hopefully this is what it is, and the discussion is worth the time you're spending we're spending here. [00:02:57][176.1]

Speaker 2: [00:02:57] Yeah, thanks. I'll keep asking the questions in and you can answer as much you can share is perfectly fine for me. [00:03:17][19.7]

Speaker 1: [00:03:19] All right. [00:03:19][0.2]

Speaker 2: [00:03:48] I'll start maybe with the first question. Please feel free to skip any question or yeah, however you feel best. Um, so. Okay, first question. Like I had said to you, it was just about how AI and other technologies or um, yeah, information communication technology are basically helping the wind energy sector in its drive towards environmental sustainability. Any thoughts you would want to share on this? [00:04:22][34.2]

Speaker 1: [00:04:27] Yeah, I'd like to. What I would say is generally, you know, I'll be jumping back and forth when it comes to the different sections that you've provided here. And as you look at it and of course, then, if I let it comes to that, to the work that I'm doing, yeah, this has become an area of interest, let's say, in the last few years. Especially in the world of wind energy. I mean, how can the, you know, kind of connect with the world directly. And when it comes to calculations and calculations are, of course, typically complex because what you're trying to do is to simulate the real world. And the windmills are, as you know, subjected to a lot of different loading situations. So in real time, of course, the output keeps changing as the loading keeps changing. And then the problem is and the big simulations of the turbine, that the model gets pretty big because you have all these huge components which have dimensions and meters plus you have bearings which perform, but. Yeah. So you have components ranging from five meters going all the way down to tens of millimeters. An even smaller one presents a lot of challenges when it comes to, you know, separating such a reality. And of course what you can do is you make some simplifications, you make some assumptions, you because it's, it becomes way too complicated, not be feasible to kind of lower one, one modeling of what's out there. So you definitely make some simplifying assumptions and then you display options to kind of see whether they are representative of the outcome. After having done that and the problems, we then have millions of different loading situations. Yeah. And you have a model which is kind of pretty big. And every time you have the one loading situation, and, due to the complexity of the problem, basically, it takes a lot of time to solve. And then. Yeah, but you have a big complex windmill, and if you are to kind of subject to one loading situation at a time, then it'll take you forever basically to kind of come to any conclusions, especially if you are asked to do real time data. So now we are slowly coming to a point wherein this integration of AI and machine learning is becoming more and more interesting to us. Let's say the models were so big and there were no alternatives as such. Computation power was limited and therefore there was only so much that could be done. But now with the period of the last, let's say 5 to 6 years, because of the tremendous growth that you've seen in terms of computation capability, now things are kind of getting into our reach and therefore this problem becomes more and more predictable. [00:08:26][238.3]

Speaker 2: [00:08:27] Understandable, yeah. [00:08:27][0.2]

Speaker 1: [00:08:28] So now and then if we look away from that area that I'm working for.. And what to focus a bit on, let's say the service part of my organization, because then turbines traditionally are extremely rich in data because, of course, the data keeps coming all the time. And then you have a tremendous pool of data getting generated in real time from all the different lines that are operating out there. So this is you know, this since the last few decades. You know that when we started putting up the first point, there was some means of getting some data back, you know. And at that time, the data collected was pretty primitive, the means of trying to assess what's going on. And then lately, of course, the advent of the Internet and all that, things have changed a lot. So. When it comes to, let's say, other parts of my organization, they have. They're pretty good at looking at data, handling big amounts of data and kind of drawing conclusions using that data. So I think that comes naturally. It kind of nicely complements what they're already doing. So let's see if you are able to fetch data from a turbine out there and you have some different examples we call the KLN systems. You can kind of continuously monitor the performance of the turbine. So let's say you have a certain component that benchmarking kind of generates a certain load. Yeah. And how do you measure that? That's basically through the different sensors. So you put sensors on the player, you put up different sensors on a different level. So all the time then you put up sensor integrity and then you put up the turbine. Then of course, you do the calibration and then you kind of get a feel for what the output from the sensors is on normal working conditions. So that gives you an idea, okay, this is how normal looks like. And if something goes off, then of course, you can immediately tell that this doesn't look normal, you know. So let's say once again that parts of my organization, especially service, have been dealing with this data and the processing of this data for quite some time, for at least as long as I've been here in this company, you know. So there you have definitely find noise detection systems. We have different vibration detection systems. Yeah. So let's let's say, like, because they're in the turbines, there are different external disturbances, right? So if you have a bearing, then that has a limited life. That's the nature of the conflict, basically, because in a bearing, I mean, you have two metal parts bumping against each other over a period of time or in there. And there comes a time that I think they can, as will be various defects so they can be manufactured, let it be a kind of defect and so on, which might cause it to behave abnormally. So let's say if you have some, some measure of detecting vibrations. Note this insight inside you can directly face that data. And from that data that you can kind of analyze that something is going on is perceived as a failure and so on. And that's how traditionally we've been detecting these faults, using the existing systems. Yeah. And that and you include that it's such you can do a lot of automation. So let's say if you are receiving data with regards to vibration, then you can do some particular scripting which looks for the normal behavior. Where you are finding the normal behavior and every time the behavior goes off, then that tool that you can kind of send out a message to you alerting you also, you know, abnormal behavior. And this is how things have been working all this while. So even without the AI or machine learning, you know, there has been a system in place and another system and that so that's kind of the status quo when it comes to it. [00:14:08][340.0]

Speaker 2: [00:14:09] Got it. Right like very interesting insights but like you were saying that you tag it as normal and not normal and then you detect if there's an anomaly. But you have been doing this much before AI or any machine learning came into picture. But do you think that with the advent of this technology, the turnaround time for predictive maintenance decreases so that, you know, you can invest more resources in something else and you already know at least two, three months maybe in advance over traditional methods that there is a potential for it in the windmills. Or do you think in terms of things it's helping even though. [00:14:51][36.3]

Speaker 1: [00:14:52] Absolutely. So, I mean, of course, if you have a system like this, then you can create it, you know, to kind of support the problems. Well in advance, because then it comes to, let's say, the human side of things, then we also need data for a certain period to kind of make sense of it. Yeah. So minor deviations might not trigger your, you know, interest to say. And then when you look at what an enhanced or what an extended data and that might make sense to you. Okay. That it started like this and then over a period of time it has been growing so now I can come to this conclusion or conclusion. Okay, now I think about it. Whereas, you know, having an AI system can help definitely, you know, speed things up quite a lot. My organization has been pretty advanced when it comes to processing of data and service optimization. [00:16:28][96.1]

Speaker 2: [00:16:28] Yes. [00:16:28][0.0]

Speaker 1: [00:16:29] So I think manufacturing, whether it be business, Company X or any other manufacturer, typically is the service organization that's handling a lot of what they would be. So it comes into my head when it comes to, you know, looking at data, considering the possibilities in the community, AI and machine learning in the business. [00:16:50][21.0]

Speaker 2: [00:16:51] Okay. Got it. So. But interesting. Oh, okay. And then there's one other aspect that I wanted to get your insights on. And this is more generally with the advent of how technology coming into organizations disrupts the traditional structure of the organization, like with I suppose we have more automation, so it leads to more people leaving that sort of traditional data analysis jobs. So maybe some people are moved out of the organization or maybe it's that the organization invests in reskilling those people, maybe in data analytics or stuff like that. So how do you think the human labor force is being affected with the advent of this kind of technology and organization that's working in wind energy and is greatly affected by technology? [00:17:38][47.5]

Speaker 1: [00:17:41] I think the first effect will definitely be negative. Yeah, because when it comes to training people and the fact that it sort of takes time. Right. So you have a certain set of people that you kind of use. Okay, That's what I'm doing right now. Yeah. Once you put that into practice and it takes some time for you to kind of realize, okay, this is how the future setup will look like and this is where I can make use of the people who can increase the efficiency. A lot of it. Yeah. And all of that. That's kind of not a short term process. So that in itself takes time. So the first effect in my head, as I see you would affect negatively, you will see the advent of AI, thereby leading to job reductions most likely, and then will come a period where things will stabilize their companies, figure out, okay, how will the setup work keep going. [00:19:06][85.1]

Speaker 2: [00:19:07] Yeah, Sounds fair. Yeah. This is just because I was trying to understand what kind of skills people can develop to, you know, keep their involvement or engagement with organizations. So maybe things like big data analytics or stuff like this. But yeah, as you said, this is a long term investment because it can probably have a dip and then will grow back again. The human labor force and more. [00:19:30][23.4]

Speaker 1: [00:19:30] Just because at any given time, at any given point in time, you can only see so far ahead, right? Yeah. So, you need to kind of learn along the way. But you have a new system. Then you kind of realize, okay, first you are just curious and then you are trying it out on an experimental basis and then come back and be a part of it. This is going to have extremely impactful and have consequences. Yeah. And then that happens. And then comes the next stage. Right? You kind of get used to working with the system and then are in a better place to predict where you will go from here. But every technological change is kind of associated with this kind of uncertainty in the beginning, of course. [00:20:28][58.2]

Speaker 2: [00:20:29] Definitely. Yeah, that makes complete sense. Okay. Next thing, i'm trying to understand how this is coming, how like you said, for your organization. But do you think there are other organizations also who are adopting this new technology into their organizations at the same pace? So do you think the market is growing at a similar pace and which is in turn leading to competition within organizations, or is it just a few organizations are picking pace and disrupting the market? [00:21:00][31.5]

Speaker 1: [00:21:04] Well, I would say actually, because as I said, I mean, I listen to the content here, but it when it comes to my industry, you know, the capability of data processing, data handling has been around for a while. Yeah. So it's in that sense, it's from the traditional industries, you know. So like when you put up a turbine, then you obviously need to be able to ensure that it performs to the level that you've promised to the customer. Right. And how would you do that? And that's only possible when you figured out a way to get something out of the turbine.Yeah. And in that sense, like I wouldn't say that [Company 1] has been the only one out there that has an interest in getting it. The same applies to all the other wind companies. So in that sense, I would say that it's not like, you know, I would be surprised to hear that one company is, you know, is ahead of the other. Because everyone has the data. Yeah, sufficient data. So it all comes to you making use of a system like this here. Yeah. To kind of go to that standard. Yeah. But yes, this is definitely going forward. Yeah, there's no doubt about it. I mean, now, slowly but steadily, you can hear the different, you know, people in management talking about it. So then you can have a gauge. Yeah. [00:22:49][105.1]

Speaker 2: [00:22:54] Cool. Yeah. Okay. And since you were talking about simulation earlier, I was reading about digital twins and how the idea of digital twins is basically used to simulate what would happen on the field. So is it something new that is being used now, or are there any such emerging technologies that you see a big increase in this sector? [00:23:23][28.3]

Speaker 1: [00:23:25] And this has certainly been a big topic of interest in the last 4 to 5 years. Yeah, but as I said, like if you have a big complex market which takes hours and days to solve just one loading situation, yeah, then how do you get to kind of another situation where you're supposed to solve its immediate offloading situation. You use a tool you're not equipped to correct and model to be able to have such a quick turnaround time or response time. So as I said earlier, like in the last few years, because of the advances in technology, this has become very, very possible. So what we're trying to do is kind of.. Look, they're not representative of what's happening out there and using those as the basis for arriving at an infrastructure. So kind of coming up that let's say, and an appropriate level model. That in a general sense provides you the same response as that big, complex model. Yeah, and of course, the advantage of using such an abstract model is that it takes milliseconds. So instead of this big, complex model of yours, that could take days to solve. And decide. You do some simplifications to come up to this level of abstraction. But this is on the all important data scenario of the spokes, actually you know the data and that's what you basically use to our advantage. If you have such a model that can and has such a very, very short response time, then what you can do is you can start and look at this model real time data. So what's happening out there and then get a quick response of what influence it will have on the structure and so on. And once you are at that stage, then of course you are in a position to kind of integrate this fit into the timeline, right? That kind of accounts for the loading situation, the situation and so on. Then this can directly be fed into this. If I had a model of yours for you to do to kind of come up with a response. And by doing so, you can basically alter the behavior of the campaign. You can regulate the loading situation that we are now seeing basically. So that's why I said that. Now when I started and it was, you know. These and because it was rather limited at that time. So we used to be rather stingy with a lot more maintenance because we knew that there's only so much that we could do. So we have to take a lot and the windmill size needs to be small. And no one's also in a limited amount of time. Then we realize that you cannot always make simple models because it becomes too simplified. It cannot actually capture the response of the system. And then we started making them more precise and more complicated. Yeah. Systems were not that good. So the more complicated your models will get, the more difficult it will be for you to kind of get a quick answer from. And then slowly things have progressed. And now we are at a stage where we can, you know, yeah, come up with this level of abstraction that can then be used. [00:28:00][275.5]

Speaker 2: [00:28:03] Well, yeah, so but yeah, interesting. And I like how you moved from, like low complexity to high complexity. But even high complexity has its own drawbacks and finding answers. But I want to understand, like this shift from, you know, to more advanced technology, the kind of research and development that an organization needs to be investing in to training new models. Does this research and development happen within organizations or is the technology part outsourced? And then like organizations just use that product for their windmill? [00:28:48][45.3]

Speaker 1: [00:28:49] The problem is that this will almost always be applicable when you have a certain component and standard out there, right, Let's say a bearing. Now, bearing is not a revolutionary concept. It's used all over the place and you'll find it in automobiles and bicycles and you name it, it's all over the place. The problem is that when you put it on that one application of that same company, which is so widely used out there, it's very, let's say, product specific so that it seems confident that it gets used elsewhere and has been designed or indicates that it is subjected to this new kind of application. Then you need to think again. Like, how are you using this openness that has been out there for many, many years. So it's not always that you can take a product from a shelf, let's say, and outsource things or just buy something from out there. And from one day to the other, you can simply start using it. Then the problem is that the organizations will need to kind of slowly start building this expertise and knowledge because the organizations like, let's say a wind turbine manufacturer, has people that know the wind turbine very well. Right. Like how the turbine moves and what kind of loading situations are subjected and what are the challenges. So these are the people who are best equipped or the most experienced to kind of make use of this technology that is out there or let's say even if it's a shell product to you, that they are able to understand this product and then they are trying to link it to this application here so that they can make the best or they can get the best out of it, basically. So it's not like, you know, you pick something and then yeah, off you go. Yeah. [00:31:11][142.4]

Speaker 2: [00:31:12] Yeah. And more specifically that the wind energy sector is also, like you said, very specific kind compared by standards to wind energy, like the buildings of it. Okay. Another aspect that I wanted to understand from you was regarding government regulations and how policy and government measures can play a role in this idea of technology coming into the wind energy sector. And I'm asking this specifically because, you know, if suppose technology comes in, it also comes in with its own carbon footprint or bringing energy efficiency or at all. Yeah, things like that. With the generating more carbon footprint with the incoming of new technology. So do you think policy measures or government support can in any way help to regulate how much technology or what technology standards should be used in organizations? So yeah, can the government play a role in keeping a check? [00:32:11][59.2]

Speaker 1: [00:32:15] That's a tough one. Especially when it comes to the implementation. I really do wonder if, you know, like of course, when you have such big enterprise capabilities, then it has a carbon footprint. But. Once again, I would. Once the end goal is what needs to be kept in mind. So let's say this carbon footprint is being offset by an enhanced wind farm performance, for example. Yeah, so that's the only thing. I mean, that's basically kind of helping in increasing the production of clean energy in that sense. So let's say in a general sense, let's say you were talking to another part of my organization that deals with windmill optimization. You are doing wind farm studies. Unless there was some way possible to kind of gauge. You might, you know, So let's say it in a wind farm, you will kind of arrange windmills in a little ways in a row. So that'll be the first row that sits up front. Then there'll be rows behind it. And then one of the first rules will be different from what subsequent roles will see you. And then there can't be this kind of a communication between the individual windmills. So it kind of helps binds at the back of reactivity, the kind of thing that is. And this is something that can only happen when you have all of this data and you have the capability to process this data in real time. So the use of AI in such a context would only help in making the wind farm more efficient, so to say. [00:35:02][166.9]

Speaker 2: [00:35:07] Yeah. [00:35:07][0.0]

Speaker 1: [00:35:08] So obviously it'll have a carbon footprint and no doubt about it. But then, uh, better. How is that used, you know? Yeah. Would be sufficient because when you make a turbine that it, when you make it that way, then it's not completely clean. You know, you need steel and then you produce a lot of carbon dioxide, Right? But it's really that. That's right. Yeah. So there's no way there's no other alternative that's the cleanest. And if you look in the future, there is energy being used by these steel plants is also the sort of thing that happens. I mean, it'll always be this challenge. Yeah. [00:35:56][48.3]

Speaker 2: [00:35:57] Yeah, that sounds fair. Okay, I'm just tying back to the earlier discussion we were having, and like you said, Oh, like these windmills and wind farms are basically they aggregate is in some sense they are just full of data. So now wanting to understand, especially in the context of the EU, we have GDPR and all these regulations when it comes to data collection. So do you think with technology coming in, since we need to train the model, do you need to feed a lot of data? The ethical considerations when a technology starts coming into these kinds of fields. So it's not just technology, but also starts extending beyond some ethical considerations. [00:36:38][40.8]

Speaker 1: [00:36:38] So data security definitely becomes a big challenge. Yeah, because if you have so much data floating out there. Yeah. Then if the provide, let's say, the anti-social elements in the society to kind of, uh, yeah, hold on to that data, get a hold of that data that you know, use it use it the there but take and you of course are probably already aware that such things have happened to big, big companies. Like, you know hackers have kind of uh, to try to gain control of the different systems on the windmills out there. And they've been trying to kind of influence the performance of the windmills. So in that sense, I would say that, of course, the more you are relying on the data from the windmills, the more important it gets to ensure that the data is not getting compromised. So, I mean, you have sufficient levels of data security. Security is definitely very, very important. You know, pretty good security. [00:38:07][88.3]

Speaker 2: [00:38:07] You know, data security, the keyword, which really helps me. And I can just go back and look more about it. But I think I get your point with this. Okay. I now want to understand your views on how technology coming into this wind energy sector, AI and machine learning or these technologies is a challenge like right now. You said, of course, data security, but do you see any potential challenge that this can bring to the sector, especially because now that we are pushing so much on wind energy with SDGs and stuff like that, this sector is only going to increase. But are there any challenges that you see with the growth of the wind energy sector? [00:38:54][46.7]

Speaker 1: [00:39:02] Yeah. The challenges are, as you mentioned yourself, like the challenges as I see it because like the data footprint of such a system. So the carbon footprint of such a system, you know, the use of such a system and that the other one is obviously the effect it'll have on the job situation. So those are the two primary challenges that I see, at least, facing us. [00:39:32][30.3]

Speaker 2: [00:39:34] Yeah. Okay. Yeah. And just a very last quick question. We're almost at the end. Yeah. And just trying to understand, like we were talking about the effect of technology on the human labor force, but do you think this will translate to social disparities, income disparities, and eventually lead to a balance in how societies are arranged? I know it's a very small, not very small, but a small effect, but maybe it would trickle down to bringing social changes in our society. [00:40:13][39.4]

Speaker 1: [00:40:20] Oh, that's so. Yeah, of course. I mean, disparity seems like what political aspects have on the job situation. That is something that. That. That's a question that I in general, that's a challenge that age general poses a part of the society. So that's not so let's say that's not affected when it comes to the wind industry. And generally, when you look out there, like, how is society going to adapt to this use of machine learning and AI. That's a very big question in itself. Are we probably ready for it as a society? Yeah. That's the bigger question. [00:41:23][63.8]

Speaker 2: [00:41:24] Yeah, that's right. Okay. Got it. And. Okay. What kind of parameters are collected in this data analysis? I read somewhere it was wind speed, wind direction. But, uh, yeah. What kind of data is being collected? I always know there's a lot of data being managed? What kind is it? [00:41:51][25.2]

Speaker 1: [00:41:52] Yeah, it's mostly like, as I said, as I briefly mentioned to you earlier, like you are putting up a lot of different sensors. On the different components. So starting from the, from the blades for example. Now the blades are supposed to be oriented in an optimal direction so as to produce the most torque here. Yeah. So obviously you need to kind of understand that gauge. This direction is different coming from where you can be, by the way. And of course then how much of the speed and then you need to kind of pitch to play to orient position and once you've done that then you are looking at, let's say the load sensors on the blade which help you figure out, okay, what is the load level of the plate? And then you will put up a different kind of sensor of the different components that will tell you, okay, how much is the strain. That means how much information is happening in each corporate, you know, and there'll be other kind of sensors like sensors that when you kind of try to gauge your turbines are getting overheated or whatever, you know, know that they're going to be kind of like trying to figure out whether there's too much vibration, you know, and there could be some collision sensors. There can also be, you know, some of those sensors and so on and so forth. So, yeah, the data, how to say that there are a wide variety of sensors that are trying to collect different kinds of data. So let's say you are supposed to be in a gap between two parts and because of something deforming relating to the other that might introduce. And then you just started to sort of the way in real time what that gap is, you know, so that the device can react to that gap or something that you are trying because of the heating that's happening and you're trying to use cooling systems to carry the heat away and send it away, and then you will need different kind of measurements, temperature measurements all over the place. And depending upon what you measure that, you can take a cooling system to blue or air or less air or whatever the case may be. [00:44:27][142.4]

Speaker 2: [00:44:28] Got it. [00:44:28][0.2]

Speaker 1: [00:44:28] So, yeah, there is that. There are a bunch of sensors trying to collect different kinds of data, basically. [00:44:35][7.1]

Speaker 2: [00:44:36] Yeah. Got it. Yeah. Like, the more I started getting into this field, it's all the more interesting. Like, at least with my interaction or the work that I do with listed, it's mostly project management and just trying to understand how different teams interact. But getting these kinds of inputs really helps me understand that. It's fascinating actually how this sector is growing, especially because I didn't have prior exposure into it. But yeah, super helpful to have these interactions. Yeah, I think that was it with my questions. Thank you so much again for taking the time. This has been really helpful to me. [00:45:28][52.1]

Speaker 1: [00:45:30] I'm happy to hear that. I really hope it was worth your while because I was again burnt out. Let me know if you’d like me to connect you with more people in the industry. [00:45:59][61.6]

Speaker 2: [00:46:05] If you have anyone in mind, it can be really helpful for me to get in touch with them and possibly have a conversation. Thankyou [00:46:50][17.4]

10.3. Appendix 3 Interview 2 Transcript

Speaker 1 [00:00:00] So I did find your email, and I had a chance to look at the questions. And I'm going to give answers based on my experience. And I will. But before we get into the questions, what did you say your master's was in.

Speaker 2 [00:00:29] In digital communications. So it's called Masters in Digital Communications and Leadership. So it's a leadership based masters revolving around technical bits, social aspects of the technology, and also policy, and some leadership. It's like a mix of a couple of things.

Speaker 1 [00:00:44] Okay. Okay. Your profile in that direction is actually young. Great

Speaker 2 [00:00:50] So. Yeah. So the thing is, like my past experience has mostly been core technical, like I did my bachelor's in computer science. And then later I was working mostly with the policy side of things. So I got an inclination towards policy. So I'm trying to align my role in policy and sustainability in Orsted.

Speaker 1 [00:01:32] Yeah thanks. Yeah. If you like, I can. I can give a very I don't know if you got the status of my profile from LinkedIn already. If you like, I can give it to you a really quickly.

Speaker 2 [00:01:54] Yeah. It would be nice, actually. Yeah.

Speaker 1 [00:02:00] My name is [Interviewee 2] from [Country 2]. If you know it, you know. Yeah. And have lived all my life in [Country 2]. I Have a bachelor's and master's in mechanical engineering. And then in 2010 I was part of the renewables industry for seven years back home in [Country 2] and then in 2017, I made a move to Denmark. Okay. In [Company 2] Yeah, Yeah. Product, Product and portfolio management profile from Engineering Profile, which I was doing my postgraduate So yeah, I'm primarily, as you may kind of and or get some product placement for them responsible for essentially portfolio management or mandate for an external point of view. How is industry moving and how should companies be interested in those market needs? And then of course working within the organization to get those realized. Yeah.

Speaker 2 [00:03:20] This profile fits very well into my category to get inputs from is what I realized from this. But yeah, thanks for sharing your brief introduction. So perfect. Maybe I can just start with the first question that I have and then we can build the conversation from there.

Speaker 1 [00:03:41] Yep.

Speaker 2 [00:03:42] Okay. So the first question is, do you think that the use of digital technology could be AI and machine learning, helping the wind energy sector in accelerating its growth towards sustainable development?

Speaker 1 [00:04:02] And yeah, I think it is but there is a lot to look for and it is a technology industry like wind which is relatively newer, for example in Australian aviation which are several decades almost a century old. Or in some cases, considering wind being relatively new on the block. Yeah. I would have liked to have more digital technologies both go to the industry. There is already there's already some technologies in the wind industry that are making it more sustainable, making it grow as well and making it early is quite a great thing. It's more useful for that and not just for the industry but also for the customer. Yeah, there's, there's potential for more. I mean, we do have, you know, a lot of data getting created and recorded every minute of every day and events are operating. Yeah. So two aspects of using these technologies in the industry, everyone is in the stage of designing the turbine or making it ready for the market or yeah, and making it better for the customers, etc.. So that part is to do with having, you know, smart people to simulate and to. They make an agile outlook made possible by a lot of this size. You know, size plays a huge role. And those digital twins, yes, they have been growing naturally and making sure that they get it right. Yeah, that's part of it. And it's pretty cool. I mean, there has to be an evolution of the models we use. Statistical models are going to work in a state of the product life cycle, but they haven't been, you know, evolving. And for me the reference is just here in the wind industry. And for example, the motive is if I take that as a reference, it hasn't been as fast as it could. But yes, there are improvements in use in these tools and technologies of the day. And the other part of the product life cycle that operates from the field before and in that space there is like an enormous amount of data getting gathered. Yeah, I think that the industry in general has to be a little better in trying to use the data to run the domains more smartly to not necessarily to produce more value for customers, but also to deal with failures to be able to use, to be able to give careful values. So there is a more learning quality learning curve being better in that part of the I think that in the design space.

Speaker 2 [00:07:46] Got it. Got it. Okay, perfect. The next thing is about how, like when this shift happens from maybe the use of human labor force to wind technology to do any task related to maintaining. And for stuff like that, how do organizations evolve? Like do organizations invest in people for reskilling them or they just hire more people from outside? Like, how is the skill? How does skill development happen here?

Speaker 1 [00:08:18] So. It's going to be very, you know, organization specific. Yeah. In my experience, the impact of organizations in the industry, both of which are quite big in scale. Yeah, and also quite multinational compared to some of our countries. For example, Chinese organizations are very in China, of course, you know, of Soviet operations. So thinking, listening to them and trying to invest in big retailers like Vestas, Siemens, and other wind energy companies is and Energy, you know, these are a little more long term oriented than short term needs. Because they have the, you know, the luxury, but not so much of a luxury these days because everyone is, you know, posting losses. Yeah, but they have a lot of cash. Too much. Okay. So that helps them make a little more. So there's a lot more upskilling of the people than they need to get someone from outside. New organizations. But that also comes with. It comes with a lot of financial investment, right? I mean, it's not going to be as easy to develop and implement in the organization compared to getting experts from outside. Yeah. And just in terms of adopting this construct and additional means. So they're keys to industry needs in general as well. So that's the trade off. But it is the profession that I've seen usually upskilling. Okay. Being more of a preference. Yeah. Okay.

Speaker 2 [00:10:26] Got it. Perfect. Yeah. And also the next question is somewhat related to this, I was just wondering if the demand for. What do you think if the demand for skilled labor is increasing right now or unskilled labor? And I'm just trying to understand this with respect to technology coming in. Is it impacting the human labor force in terms of employment, especially in the wind industry, or you would think otherwise?

Speaker 1 [00:10:57] That's actually a good question. I mean. Again, I mean, for an industry that is as old as wind. This is not really all that is not in the future. There is a continuous need for skilled labor for this industry to grow and mature and still find a lot of untapped potential. Yeah. There are, of course, activities in the overall product lifecycle that have to be managed and done by skilled labor. Hmm. But in general, the innovation culture and the need for more creative solutions in the industry being at least from the demand part of it, is being a which kind of translates to the need for skilled labor not going down.

Speaker 2 [00:12:04] Got it. Got it. Yeah. And like you were saying, there's some reliance still on unskilled labor. So I think that part, I think some will still continue to be that way. And it's not that technology is going to completely overtake people or something like that because this is also, I think, a very complex industry to work in?

Speaker 1 [00:12:29] Right. Yeah, yeah, that's true. That's true. I mean, but I have to also say, I mean, me being part of certain engineering automation as well. In my early years, I have seen big organizations, especially having these long term plans to slowly make these activities more machine based and people like to create those tools and processes. Yeah, I live in [City 2], so yeah. And so and then they move on to those that skilled labor doesn't disappear from the industry, they just move on to something else. Yeah. So to your question about whether the unskilled labor is going to be or if there are any trends in having the labor replaced by. Yeah, you can be very uh, but that's the normal trend that you see any of it. You know, you need to. Yeah.

Speaker 2 [00:13:37] That's true. Yeah. Got it. Okay. The next question is, if you think the incorporation of technology in industries like wind gives certain organizations a big competitive advantage, and if you think organizations are going at a similar pace in terms of adoption to technology is like the entire industry moving at the same pace, or is it like just few organizations having a very competitive advantage over others? So it's like a very balanced growth in the industry. How do you think it's going?

Speaker 1 [00:14:19] The growth is not necessarily balanced growth in the industry, but that is not because of lack of access to technology trends. Okay. Again, in this industry, there are no I mean, there are, of course, a lot of patent wars that you see. Yeah. So that's that I guess that's a symbol of one organization having a slight technology advantage over another. But there are other technologies. So it's never, you know, one organization having a unilateral technology advantage if there is something one organization is better at and then there is another organization that is catching up on something else. So I wouldn't really I wouldn't really see any organization having a huge gap in terms of technology compared to the rest of the players in the single market. But it is again, also to do with everyone growing together by their industry growing and not necessarily it's willingly. Yeah, but it's just having the industry growth in mind. And the technologies are usually linear like the telecom industry growth. The clear question about whether there is any gap. Yeah. Between the companies. I wouldn't say the gap is coming from technology, but the gap is coming from the markets. A company's goal is to care, for example, that companies are able to do business in some markets and not so much in global markets. Okay. So growth will have to be looked at across the markets. You know how big you are versus how profitable you are in this process. Right. Yeah. So there are some companies that are not necessarily aiming for bigger markets, but aiming for a bigger profit. There are some organizations that need a bigger market share for them to be able to survive because they've grown so big. And, you know, many of their capital expenditures that they had to make that's part of this growth is sustainable only by having a global presence. Okay. So they have to work with global market share. Even though it comes with, you know, not necessarily the best guarantees, but they will have a scale of economy. Yeah. So that's usually how it is. I mean classic examples. I usually was impressed early on. And some of the European wind companies say they are not really focused on the entire world but let's focus only on Germany for example. Yeah, some parts of North Europe that you guys, that, that, that is one of the main factors that are and. Kind of resulting in a difference in the growth. Yeah.

Speaker 2 [00:18:05] Okay. And that's you know, that's interesting because I thought otherwise, but this makes complete sense. Okay. The next thing is, how do you think this coming in of technology is changing how organizations are fundamentally structured? And I'm asking this if, like in terms of building new teams, suppose like with the coming in of you need more specialized a team or machine learning team. So it changes how teams interact with each other because new people are coming in. Redundant operations get stalled, so those teams are removed. So do you think the information team communication also changes once a new technology comes in to make business operations?

Speaker 1 [00:18:59] Well, I think the organizational structures are actually not not very rigid, at least in the wind industry. They are agile. And again, maybe this is not completely true because I'm coming only from the experience of [Company 2], which is not exclusive between companies. Right. Maybe other companies would have a different position or any sort of different positions being small or big companies that they are. There is a constant need for restructuring and reorganizing organizations in line with the organization needs at that time. This has more to do with organizational layers. And if there are any pivotal connections in the pivotal changes in the organization, the foundation, for example. Okay, Now we just you know, we don't just make money in this market. So that's kind of directional. There is another direction. Okay. We have to grow even at the cost of losing some money. But there is a budgeting process. Has to be, right? I mean, do you sense busy machines, native capitalism as good as any to, let's say, make a footprint in the world? They have a strategic interest to bring richness in at the cost of not making a lot. But just as an organization presents it is in a strategic interest to be there because it is more or less nuclear and there is a larger organization's interest in looking at it. Okay. That me just, you know, make it work for an industry so that the kind of strategic directions that got you to organizational structures in these big companies' legacy is going to nurture our growth. To be honest, I'm not sure how it works in an exclusive company. I would imagine something similar plays a role is necessarily, you know, is other businesses in the same operation. But yeah, in general it always is a review of the organization's roadmap. And unless there is a big change, the leadership usually remains the same.There are such external factors bracketing the need for augmentation to change the direction. Yeah, I would imagine. Yeah. Not difficult. Even small restructures and you know the organization is based on the technologies that are available in the organization based on the new needs of the organization is common.

Speaker 2 [00:22:26] Yeah, that's true. Yeah. I mean, also with the Agile based, I'm actually working with the Agile and leadership team currently at work. So, you know, I keep seeing a lot of things like agile and sprints and stuff like that happening so. Yeah, that's very true.

Speaker 1 [00:22:40] Yeah.

Speaker 2 [00:22:41] Okay. So next thing is, uh. Yeah. How do I think you've kind of answered this before, but just touching on it again. The question is, how do you think organizations are upgrading themselves? Is it purely by hiring them technically compete and stuff from outside or having training from them or hiring external, um, consultants? Is that a pattern that you see that organizations have, especially when they bring in new technology?

Speaker 1 [00:23:17] I get it. I'm guessing there is a difference in how they can. Yeah. Spirits. With this. Again, seeing how big an organization's agency means commercial work. Yeah. They do tend to invest more in terms of for leadership positions with those being more technical and pull at the key experts in the organization and really a lot of attention paid to protect them and retain them against approaching the measures taken to avoid that successful things like competition, things to take care of, things that are pretty common. Right. But yeah, so yeah, I mean, I think that is. There is a lot more focus in it and using them to grow more technical than trying to get talent from outside.

Speaker 2 [00:24:36] Yeah, makes sense. Perfect. Yes. So this completes one section of the questions. And the other section is basically on ethics. So the first part of this is what kind of ethical considerations do you think wind organizations take when using new technologies in its operations? This could be more focused on privacy and protection of data. Now that we're talking about Europe, maybe or maybe they have different themes on cybercrime protection against cybercrime or data bias, the privacy protection. So yeah, is there a lot of focus on these topics?

Speaker 1 [00:25:21] Yeah. Of course, obviously the company is the acquisition leader, the one that I'm working on, the one that they were right. But I do think that they are more reactive than proactive. Yeah, I feel that doing so has limitations. Yeah. So yeah, the emphasis is more on foreign policy makers to be to make the private interests protected. Yeah. I mean through the regulations. And I have not seen them in my experience. This company has been given more time for investing in protecting private interests as part of product development. Yeah.

Speaker 2 [00:26:21] Yeah. I mean, that's very true. I see that, too and I do realize it's mainly reactive than proactive. I mean, there's a lot of discussion happening about these things, but on ground doesn't really translate to. Yeah. Giving too much focus on these things like privacy protection of data. So that makes complete sense. The next thing is if there are concerns in the use of digital technology in the wind energy sector, and if in your experience you've come across any such incident where there was a safety concern, risk of accident just because technology was used.

Speaker 1 [00:27:08] First of all, the digital technologies are very much needed in the industry. They make not just products safer, but also more efficient and more effective. This is in combination with this technology of, in my opinion, not to replace human labor, because that's simply not sustainable. There is definitely a need for skilled labor and organizations that realize this and are the ones that can, you know, sustain and this can grow. And you have to change organizations and organizations and not be, you know, this will have a risk of becoming obsolete. Let's try to get that to answer your first question. But to your second question about whether technologies have made our lives and industry unsafe in general, and I don’t think so, but I wouldn't be surprised if there are any. Right. I mean, just to go with the context in which we are using technologies. If we are using technologies to alter the energy production or the profit making, then making domains more efficient, there is a chance that the technologies are not foolproof, too, right? Yeah. So there are enough measures envisioned in the technologies. It's a possibility, a technology that was, you know, implemented in the product just to replace an example is to avoid one main down cycle. Yeah. We're getting some technologies that are not completely, you know, foolproof to avoid that rendering. And that is if it is, can in many other kinds. Yeah.

Speaker 2 [00:29:30] Got it. Yeah, I was reading about, like, trying to find examples if there was, like, some serious accident with some windmills or something like that. I haven't come across any yet, so maybe not as much of a risky thing right now, Which is good?

Speaker 1 [00:29:48] Yeah. Yeah, I'm in the middle. Once in a while we keep hearing about fires and the turbine turbines falling down. Yeah. Yeah. But it's difficult to correlate them. Exactly.

Speaker 2 [00:30:02] That's true. There could be a lot of factors. Okay, got it. The next section is on challenges. And the first question as part of this team is what do you think are some of the challenges to bring technology into the wind energy sector. Why do you think the wind energy sector is a little late in catching up on technology? Do you think it's because there aren't enough skilled people available or there's lack of funding or lack of research and development that's happening in this industry?

Speaker 1 [00:30:45] Well, I think the industry has in general caught up on not necessarily the technology, but in general the technologies. And it seems to me I wouldn't say it's lagging because, I mean, just look at the speed at which the various things are progressing. So by the size of the windmills. Yeah. I mean, I do see this as a raised level of actually. Okay. Yeah, but I mean, maybe it's sort of the same with digital technologies specifically. Yeah, we could do better with digital technologies. And I'm saying I'm not sure why. Just reflecting on that for a moment. Yeah. I don't know what maybe it is to do with the industry not attracting legitimate thinkers enough. Yeah. To, to, you know, make this make this an interesting industry to work with economically, because this is. This is true.

Speaker 2 [00:32:32] Yeah. I was just wondering, is it like lack of funding in this sector? But I think sustainability is like a big deal. So I'm sure there must be enough funding and research and development. So maybe there are other factors to be explored.

Speaker 1 [00:32:46] Yeah.

Speaker 2 [00:32:49] Uh, this we have taken. You've answered this. Uh, okay. There is one question, although I think this is very tangential to the conversation, but I think, you know, I was wondering if the advent of technology and I think this is not only specific to wind but very general, but do you think if the advent of technology will translate to growing income disparities among people just because, yeah, there's less requirement for manual labor and more for skilled labor. So it creates an imbalance in income and leads to social inequalities etc.

Speaker 1 [00:33:34] Yeah. But there is always a certain widening gap with any industry that is more technology driven and has more skilled labor than labor. Yeah. What I wouldn't mean, is still this unskilled labor is required in many office activities. Okay. And, but I mean, to be honest, there isn't enough income inequality right now. There's a little problem there. Yeah. Yeah.

Speaker 2 [00:34:27] Okay, so we're here and the last section and this is on the future perspective. Okay, so this is on future perspectives. And, um, do you think organizations are willing to invest in R&D when it comes to technology adoption? So are the internal teams working on research and development, or is this sourced out? Is this technology outsourced? Usually How does the technology adoption process happen within wind energy organizations?

Speaker 1 [00:35:28] I think it's a mix. It is a very big operation of technology and growth in the organization, at least in the short, medium term and short to medium term in a look ahead. Yeah, there is a mix of corporations. For example, do you see research institutes or team organizations for more longer term technology innovations? Yeah. So I would say it is both. But in the short and medium term, like with the five year look ahead, it's you know, there is I think the message they're not willing to bet on because as soon as you get into accounting. There is always a probability of a trade. Yeah. And that's, that's the nature of. Yeah. Is that research? Hmm. Or to be counted on making sure and including a technology talent pool that we can do.

Speaker 2 [00:36:51] And we talked about, I mean, you mentioned digital twins earlier, so I was wondering, like, if in the future you see any emerging technology coming in. We already see AI and machine learning and also digital twins coming in. Do you? Yeah. What do you think of the future? Is there something new coming up?

Speaker 1 [00:37:12] Because it is already quiet, uh. Quiet. I mean, to be very honest, digitalization is kind of broad, right? I mean, everyone wants to use digital for. For what they're doing. Yeah. So everything becomes digital. Nothing is truly an internet. Yeah. Yeah. So from that point of view, you can I can create accordingly when I am asking for, for example, funding from my top management and if digital is a new buzzword, I think of course connection to start doing the rest of them working on. Yeah, I'll put it in a buzzword and put that right to it so that it happened a lot in the last decade across the work in order to integrate across the industry. Of course, you know, because what it is, and I think that these companies have been using the profits in innovation to bring in physical and also digital and connections. I'm not really doing that because they're not digital and not yeah, I mean, they're not really in print and hence it is. I mean, the revenues and profits are great, so that is totally preventable, I think. So it is the way it used to be a much, much bigger buzzword and yeah that's true. Yeah it's about I mean so they're organized to spend more on digital innovations. Mm hmm. They are truly digital innovations. I mean, it's just a little more cost to make a business case and to demonstrate how really digital is important. But this.

Speaker 2 [00:39:18] Sounds good. Perfect. Probably. This is the last question. Let's see. But I was wondering, do you think there's a role of government and regulatory bodies in deciding how much of technologies to incorporate in the wind energy organization? Or is it just open? Whoever wants to use can use however much to hope it will expand it wants to use? Or are there some gaps by governments? Or how can governments do what they think can facilitate this technology adoption by wind organizations?

Speaker 1 [00:39:57] Right. I mean, I think there is a huge problem in any industry that has. I think, in fact, there's a huge push by governments, right? Everything that I mean, to be very honest, against the documents they took. And the policymakers need to educate themselves and ask good questions. And across the world, it hasn't been the case. And just taking an example of the US, I think unless you remember the Senate questioning of I took a look, okay, last year on the part of the Senate members who are asking how Facebook is compromising privacy? That's how Facebook was monetizing people's privacy. And the kind of questions that those were asking for, like in the seventies and had no clue about what it is. Yeah. Yeah. So it was fun to watch. And I think it was tenfold answering this question because people completely get away with stupid answers. Yeah, I think something is not right and there wasn't enough in the party that is supposed to be negative interest rates. So I could have a very strong assumption in our industry approach that there'll be enough in and a technology talent pool. Yeah. That necessarily the talent pool was you know sort of thing and needs some kind of research talent pool in the policymakers. Yeah. Bodies that because it is a business that works in public interest Yeah and you cannot count on these companies to work in public of companies even though they are you know making improvements, not you know minting what you think about it is doing good things and doing. So yeah, you cannot leave it to these companies to fully act on public interest. Is it is that there is a big role for these parties and they have to be able to upskill themselves. Yeah, but we need to combine that.

Speaker 2 [00:44:30] Got itI think. Yes, I think we left with 2 minutes. Thank you so much. Amazing. That is. I have so much food for thought. Also, if it interested, I can when I finally I'm done with my thesis writing and if you want to see an academic perspective on this, I'm more than happy to share it with you if you want to just read it in.

Speaker 1 [00:45:35] Yeah, I actually very much like to. So please, if you don't mind, I would be really interested to know how things look from here, from you around.

Speaker 2 [00:45:45] Okay, perfect. That's. Yeah, that's super interesting. So I'll. I'll be done with this in July, most probably, if everything goes well. And after that, I've shared my work with you. I have actually been very interested in this topic ever since I started writing on it. So looking forward to sharing my work with you.

10.4. Appendix 4 Interview 3 Transcript

Speaker 1 [00:00:00] And we sit in a kind of a wider production kind of engineering team. And so what we really do is lots of kinds of R&D methods, development, analytics, development and work a lot with different operators around the globe who kind of need help working with their data analytics. Two years earlier I started as a data scientist and before that I was at another data science company doing something else. Okay. And then previous to that, as a Ph.D., which was civil engineering, kind of like modeling and coding based. So kind of like something along a similar route.

Speaker 2 [00:00:46] So I think if you're fine with the questions I have shared with you or if you have any other questions that we think it's good to skip or anything, you can just let me know and we can just take it that way.

Speaker 1 [00:01:06] Okay.

Speaker 2 [00:01:10] Okay. So the first question is, do you think wind based technologies in the energy sector and accelerating the drive towards environmental sustainability? And I ask this question just because like the U.N. SDGs and everything. So there's a lot of focus on sustainable development goals. I was just wondering how technology plays a part here.

Speaker 1 [00:01:35] Okay. So technology towards sustainability. So do you mean specifically like AI technologies or just in general?

Speaker 2 [00:01:43] Mostly insights on AI would be nice.

Speaker 1 [00:01:51] Yeah, sure. So definitely, yes, like turbines are getting bigger and more complicated. Especially if you look at some of the bigger kinds of offshore, you know, turbines that are being developed. That's huge. That then gives rise to a whole bunch of other things. So for example, if this turbine is out and into the sea, how are you going to make sure whether that's working well or not? So then you start to get more technology coming in around how we monitor things and figure out if something's going to break or not or when it might break. Which is the kind of area that I'm in. Yeah. And then on top of that, there's a whole bunch of other kinds of new technological advances coming in. For example, using drones. Yeah. Blades, I've seen some things about different robots that go up and clean blades and things like that. So I'm not sure if it's that the technology is driving the expansion. I think it's a bit cyclic. So the need is that technology is being built to fill that gap. And the more complex technology you build, more of the technology you need to support it.

Speaker 2 [00:03:09] Yeah. It's interesting thinking of it cyclically. Good. So you work in the predictive maintenance department, right?

Speaker 1 [00:03:25] Oh, yeah. Some of our projects are looking at predictive maintenance, so we're doing a big piece at the moment. How long would you expect the component to last after you see a problem. Like remaining useful life. What we do a lot is identify where there might be an issue, and then you should go do the maintenance. Like one builds on the other.

Speaker 2 [00:03:46] Yeah. Yeah. Okay. Because this is where my next question was heading towards. And like understanding if there's a reduction in turnaround time when we're talking about predictive maintenance with AI and how long do you think AI systems can predict well in advance if there's a potential fault.

Speaker 1 [00:04:09] Yeah. Okay. So turnaround time. Yes. So if you were to just look at all the data yourself, you probably wouldn't even see it. Okay. So say you're using an accelerometer and you put it on and you track vibration trends on the component. And if you just had a whole bunch of trends, you wouldn't see anything. You'd just see like a bunch of data jumping around. So once you've written an algorithm to work out and track that and have that pretty much automated search around time is really fast. Yeah. And then on top, you can say, you know, this thing looks bad. Scheduling for maintenance and the downtime that you have to maintain if you know it's before it completely fails is much easier to get the parts. The damage might not be so catastrophic. You can plan it in. So that's the other one. In terms of how far could you predict? At the moment, it's very hard to say this thing will last like 30 days. Exactly, or whatever. But you could start to see a progression trend like in the order of years out. So a year, I think two years out. Okay.

Speaker 2 [00:05:26] That's interesting.

Speaker 1 [00:05:29] Yeah. So you do get quite good heads up, like if you don't have some conditional on. Yeah. Something in that space. You just know if it starts like someone climbs a tower that sounds really bad or Yeah, looks bad and all catastrophically fails. So. Yeah, yeah.

Speaker 2 [00:05:46] Yeah, that's true. Because I think I did not have too much of an insight into how this was happening, like with the manual labor and everything. But when I started reading about it, I was like, Whoa, this is super interesting. Like how this kind of change is coming in from maybe humans to robots or like you said, drones and stuff. So yeah, it's pretty interesting.

Speaker 1 [00:06:07] Yeah. So unless we would look at reducing our claims because it's really hard work to go to a site and drive around to climb up turbines and look at things and take and scope measurements, it really takes a long time. Yeah. So you try to build out analytics that you can use instead of that. Yeah. Or they can give you some indication of which ones you should prioritize. Yeah.

Speaker 2 [00:06:30] Okay. Yeah. This is interesting because this is where I was headed to with my next question. In trying to understand how organizations would be aligning themselves with this move from human labor force to maybe software or technology taking over, is there something that organizations are doing within themselves? Maybe it could be that a new data analytics team is being set up, or maybe people are being trained in data analytics or coding or stuff, But do you think that internal motivations of organizations to do something about it?

Speaker 1 [00:07:04] Yes, in some so some larger ones, they're building out of kind of data warehouses based on data and internal teams with that expertise in lots of other operators that, you know, people are actually doing the they own the farm and they're doing the day to day stuff less so in which case they would usually bring in someone like [Company 3] or another player in the same space to come and help do that for them. Yeah, definitely. The manufacturers you've asked us, they've been doing this in-house for a long time too. You know, they have their own monitoring and tech.

Speaker 2 [00:07:42] Okay, interesting. Okay. This completes with one section of the conversation and the next one is towards data analysis. This is what kind of data is usually collected by these sensors and the windmills. I read about wind speed, wind direction, but if you could just shed your ideas on how this data is collected and gathered.

Speaker 1 [00:08:12] Sure. So you have this kind of SCADA system, then. It is an acronym for Supervisory Control and Data Acquisition, that has a bunch of stuff in it and it sits on the turbine and it controls what the turbine does at different times. So whether it's yaws in a different direction, so turn it around to point in different directions or blades pitch to control how much, how fast it turns, basically on how fast the blades move. So that system will have a bunch of stuff inside it, like temperature sensors on loads of different components inside the turbine, pressure sensors on the components in the turbine, wind speed, wind direction, power rotor speed, like it was the hub. Sometimes they have things that monitor sway in the tower. It really depends on the system. What that system will do is if something goes above a threshold, then it will shut the turbine down. So if something gets really hot, like the main bearing gets really hard to shut down. But you can also pull all that data off and build out analytics based on the whole history of the data. So you might find a component. The temperature starts to trend up over time, which might be an indication that there's more friction in it because you've lost material and you've got some things like grinding around. Okay. That's one aspect. The other thing you can do, which is like its main thing, is vibration based sensing. So when things rotate, they make a vibration signature. And if you get some fault in that, that vibration signature will change. So they would go up accelerometers on it and. You use things that measure this kind of vibration, and then you analyze that to see if something is going to fail. That's another one. Then you get extra stuff. So I mentioned drones already. That's like, quite widely used in industry. So loads of image data. And then on top of that, there's a whole bunch of stuff that people are developing. So we have one message site called [Site name] that is about measuring how blades pitch, so how they spin around. Those are the things that have different strain gauges on foundations or in the blades. Yeah, yeah. There's lots of different inventions out there doing other kinds of instrumentation. That's new.

Speaker 2 [00:10:55] Okay, Perfect. Yeah. Gives me an idea, I think. Yeah, I get the sense.

Speaker 1 [00:11:10] So, you know, this kind of data's useful. You can see quite a lot in it. Yeah. Quite good. Yeah.

Speaker 2 [00:11:19] Okay. And. Next question is on the analysis of SCADA data. Basically, I'm just trying to understand if the specific human skills that are required to make sense of this data or is this made sense of just fit and machine learning capabilities? And if there are human skills involved and what kind of skills do people need?

Speaker 1 [00:11:41] Yeah, it's a mix. So you might see some things that show up pretty well, like statistical analysis. So if something is higher than the next or turbine, you might say one turbine is reading a higher wind speed than its neighbor. We got a problem with the wind speed sensor example. Okay, some methods you might use are a machine learning approach. So say you want to look how, but I mean bearing temperature again, it would increase over time, but in winter the temperature would be lower because it's cold or outside or in low wind, it would be lower because it's rotating less fast. So in that case, you can use this deep learning model to get rid of that kind of variability and get a more smooth progression. So it's another example you might find methods that need to be more complicated. So if you're looking at a more complicated system, like if it's. We've done one that's like multiple brushes in an accumulator. That's if you have a hydraulic pitch system on the blade that you need a more complex model to do an analysis, more of the data is more complicated, so you need something more complicated to deal with it. And then in terms of skills. Yeah, we don't as I said, we see a few companies in-house have people with the skills in-house to do it. Lots of people are outsourcing to companies who have expertise in that area of.

Speaker 2 [00:13:27] Yeah. Got it. This discussion on having resources in-house at outsourcing. I had this question on understanding if implementing a new technology, it could be around any digital technology. I do think usually it's a lot of financially invested projects or usually an organization just uses the skills within the organization, within the people. But are they more willing and ready to invest in resources and have people from outside and bring in more people?

Speaker 1 [00:14:04] Typically what I see is that they bring in people from outside, but that's probably biased because I only work with people who bring people in from outside. Yeah. I say typically you bring people from outside to do it because to build out, to build that kind of a full suite, to do these analytics, that's going to take you a team for like a year or two building from scratch. So it's a lot cheaper to buy something that somebody else has done.

Speaker 2 [00:14:35] That's true. Yeah, and just for the time being, maybe outsource it, but maybe over a period of time the skills are built within the people in the organization. So.

Speaker 1 [00:14:45] Yeah, we see that, too. Here.

Speaker 2 [00:14:47] Okay, perfect. Uh, the next is a quick section on ethics. And, of course, there's always a discussion of digital technology and ethics in general, but just trying to understand what kind of ethical considerations are there when we use A.I. in wind energy. Especially because there's a lot of data here and data privacy, maybe data protection and security is a concern

Speaker 1 [00:15:11] Yeah, for sure. So you have to be really careful that you don't compromise the data that is gathered at the windfarms. Or, like a lot of the data could be used then to work out how much the wind farm is generating, and then how much could equate to how much it's worth. So it's quite sensitive. So it obviously be really careful that data doesn't make it into the public domain. In terms of other ethical things, you obviously make sure security is super tight, like the same. You wouldn't want someone coming in and being able to take the data that you have and. But I don't think we have the same sort of ethics as, say, for example, autonomous vehicles when they have to choose what we're going to like in a crash hit kind of thing. We don't really have that same. Ethical dilemma.

Speaker 2 [00:16:06] Yeah. Yeah, that's true. Because I think I was also going through some literature and maybe, I don't know, to some extent the data security part is being implemented for this kind of data in 2019. Maybe we're not completely there where the data is very secure and compliant with standards. Yeah, at least that's what I could gather.

Speaker 1 [00:16:31] You know, the standards there aren't like a very good wind energy data storage standard yet, and so people are trying to do it. And then it depends who you work with. Like some people have really good secure data kind of control methods and some people are more immature in their processes.

Speaker 2 [00:16:51] Yeah, got it. Yeah. I think maybe, like, the industry is like and different levels, like, different organizations are operating at different levels. Yeah, for sure. Same threshold that everyone is operating.

Speaker 1 [00:17:04] Yes, I agree. And that would be probably because. And wind hasn't been like a massive target for people to come in and shut down a wind farm. It doesn't really have that much. That's true, although there are some. One of the ethical considerations I've heard about recently is what happens if you have a government based manufacturer and operator and then they build wind turbines in another country and they have the power to shut down or shut down wind production in another country. So. Oh, well, yeah, that's one that should be considered. Like if it's a government backed organization, will other countries all be happy for those?

Speaker 2 [00:17:53] Oh yeah. And then that would be super interesting here if it goes into the political ballgame. And it's interesting how these things just snowball affect so many other aspects of society also.

Speaker 1 [00:18:06] Yeah, it's true. So if you have a country whose wind power is predominantly controlled by a company that's based in another country, well, stable is your kind of power grid. Yeah, it's an interesting one. Yeah. I mean, the same as what's happening in Russia now.

Speaker 2 [00:18:24] Exactly. That's what came to my mind also. Yeah, But yeah, I think this is a really interesting perspective. The next section is on challenges, and the first one is yeah, it's just very open ended. What are the kinds of challenges that you see with the coming of technology? Maybe it's the high installation costs or the need for professional technical expertise. So where do companies usually struggle to bring in?

Speaker 1 [00:18:58] There are a couple of things. The first is hiring. The technical expertise to do the job is quite a niche like field and not too many people in it. So that's definitely tricky. There tends to be a lot of poaching between the same sort of companies. Yeah, that's quite common. And then the next one that's a big challenge is having structured organized data and a clear record of what how and one. So for example you can't bring in some big AI technology unless you have data to train it on and the current state of the data to train it on is not necessarily good in every wind. Operator. So that's a challenge. And those were laws that I thought of. I remember.

Speaker 2 [00:20:11] Yeah. Okay. The next question I think you kind of have answered, so maybe we can skip this. Oh, okay. This one, I was wondering if this incoming technology impacts the employment of the human labor force and then in turn leads to social disparities or income disparities because people are out of their jobs, they don't have to do the manual work anymore. This is true for technology in general, but I just wanted to know in wind energy, how do you see this?

Speaker 1 [00:20:47] I don't think so. Okay. Mostly because. So normally the team is small anyway. So if you bring in technologies to help them make decisions, they'll just have more time to make better decisions from then. So it's more like you would reduce the cost, but you would have amazing people. You just do things quickly. Also, there is not just in this kind of energy sector, but in the wind industry in general, there's a shortage of people to do the job and it's growing super fast. And so I don't think it's likely that if you're a wind tech, you would lose your job in the next ten years. It's more like, how are you going to get more wind into the coast? Yeah.

Speaker 2 [00:21:39] Yeah. I think this is very important to understand when you are investing in the wind energy sector that it's only growing, at least for now. So there's only more and more people required in this industry.

Speaker 1 [00:21:52] Yes, I think because we're not talking about it's a bit different. So say you've got a factory and people used to sit and make things and actually nice robots in the factory. We don't have that. So it's not like we're sending a robot to climb the tower and check the turbine and do everything or. You know, when they say you're doing a major corrective, you've got this like, using a crane and someone's got to drive it and pull the thing out and fix it. They're doing all that work. Still would be done by humans. Yeah, it would just be done at a time that was more optimal rather than being done when the things exploded. So.

Speaker 2 [00:22:34] That's true. Yeah. And also, like you were saying, maybe not all companies have the full effect training datasets already, so there will always be a human involvement for the worst case scenario. So there'll always be a need for people to be on ground to cover up for those outlier cases.

Speaker 1 [00:22:53] Yeah, exactly. And yeah, if you had, it would be a different situation. If all the wind operators had, as you know, 30 analysts just manually looking through data and then you replace them with the tech. Yeah, but that doesn't really exist. Like they've never had that. There might be like a few people, but they've got more data than they could possibly look at. Yeah. So I think mostly no or very minimal.

Speaker 2 [00:23:23] Oh, thank you. That's great. Okay, so the next section, this is the last section. This is mostly on future perspectives of how AI technology is going. So the first one is, do you see a growing competitiveness in the industry towards the adoption of AI? Or is it just like a few big players moving towards A.I. and technology and other players not doing anything at all? Or do you think there's quite some competition?

Speaker 1 [00:23:50] And there's definitely growing competition that is growing. You can look. There's quite a lot of companies who are now being acquired by big investment firms. So look at a company called Goldman Sachs. Goldman Sachs recently acquired another company called Sky Specks. So there's quite a lot of like. Yeah. So that I sort of like ten years or so of this small thing. But at the moment it feels like it's ramping up and there's lots of bigger players pushing it. And you can see it also in the energy companies this time to do this green transition. And they're going to build as many gigawatts. Yeah, renewable as they were nonrenewable. So. It's quite a bit of a race. Yeah, definitely.

Speaker 2 [00:24:49] The next thing is, are there any emerging technologies that you see in the sector? Mostly from a future perspective. I was reading about digital twins and installation of floating wind turbines. I'm not sure if this is already into practice or it's still going, but.

Speaker 1 [00:25:05] If you take this both, as I said, we have digital twins. I'm not sure whether it's ever going to work or not. One of the floating offshore is definitely a big topic and there are a lot of projects that are planned for that and nobody really knows what they're doing until they know what they're doing, but they're not done. It says floating offshore will be a big one, and general offshore expansion will also be quite big in a lot of countries outside of your team. Actually wind offshore and onshore. Yeah. There's also a lot of buzz around. I should like green hydrogen. Yeah. And talk about combining solar, wind and hydrogen all into one place. And then sometimes you would sell electricity into the grid sometimes and produce green hydrogen all the time.

Speaker 2 [00:26:07] Oh, okay, I should read about this. Okay. The next thing is. Yeah. Do you think organizations themselves are investing in research and development in these areas for, like the future kind of AI, or are they mostly like are organizations mostly relying on some other third party organization to build and develop and then just outsource and source the stuff?

Speaker 1 [00:26:37] Oh, good question, because it really depends. So like a big kind of oil major, they might be developing their own in-house stuff. And that is kind of like a green transition route. Some people are more investment based, so they would see it as like, I'll come in, I'll buy a wind farm, I'll put it on a full service agreement with whoever manufactured the turbines, and then it would just run. And then in ten years they'll sell it and a real mix. I just remember my other challenge is that the people who manufacture the turbines and who operate the turbines don't necessarily always communicate well with each other. And you might have the operator on a cell service agreement with the manufacturer. So they had everything off to the manufacturer to run the operational side. But it's sometimes difficult, like. It is not always the most transparent between the two.

Speaker 2 [00:27:43] Yeah. Okay. That's interesting though. But do you think do you have any ideas what can be done to, like, build in more conversational transparency around this?

Speaker 1 [00:27:57] Um. Yeah, I'm not really sure. It's just like there's some, like, friction, like who owns the data and gives the other person insight. So you might own the turbines, but you don't own that data.

Speaker 2 [00:28:16] Okay. Yeah. And I was also wondering, usually if there's a customer, do they just get the data from a company and then provide it to some other organization for the analysis? Or there's just one team doing everything.

Speaker 1 [00:28:38] Some people would do it in-house themselves. And so usually I say, just an example. They manufacture a turbine. Yeah, and they sell it to an engineer. Someone shall or somebody, I don't know. And they're building wind farms. Yeah. Then they have their own internal team of analytic analysts who will be looking at a turbine, especially if they've put it in the warranty period or it's on something called a full service agreement, which means the manufacturer looks after the turbine. So they will analyze it, send people out to look after it, etc. And then the person who bought it set it up, they might also have a team in-house looking at some data like performance team or reliability. And then they might also contract somebody like [Company 3] to come in and. To give them a second opinion, and then you end up with this kind of back and forth. So they might say, Oh, it's this site that found this issue, and we thought you fixed it, but you haven't fixed it, so you have to fix this again. So it can be quite backwards and forwards. It's not very, not always very collaborative sometimes.

Speaker 2 [00:29:48] Yeah. Also makes me think that how many people are involved and how many organizations bring meaning to that data that we have.

Speaker 1 [00:29:57] Yeah, yeah.

Speaker 2 [00:30:00] Yeah. At least for me, initially, I just thought maybe it's just two organizations working together. But no, the more and more I started delving into this and a couple of people coming in and. Yeah, yeah, it's. Perfect. Cool. Almost at the end. Okay. So do you think government regulations and policy measures can play a role in how AI is brought into the wind energy industry? And I was just thinking about maybe setting energy efficiency standards or increasing funding in this area, but any other way you'd think government support could be helpful.

Speaker 1 [00:30:38] Definitely funding. And I know in the UK they are doing that. So if you're a crossover between renewables and tech, there's quite a lot of funding polls open. And there's also I can't remember exactly what they called it, but some sort of price levy that the government will top up on wind farms. Yeah. I can't remember exactly what it's called. Find it online. But, like. There's some sort of government subsidy for wind farms in some countries.There's a big one in the U.S. code. It's like. Yeah. There's some sort of like. I can't remember exactly what it was. I think it's like a tax credit or something similar to wind farms that they've implemented in the US too. But yeah, to kind of help people invest in wind so they can make certain policy decisions to make it more likely for people to move into renewables.

Speaker 2 [00:31:58] Yeah, because I think, like most, this technology has a very dynamic nature. I think technology moves much faster than policy can catch up.

Speaker 1 [00:32:18] Yeah, exactly. Telling people to focus on that anyway. Getting. Yeah, I can't remember. All right, we'll pass on that.

Speaker 2 [00:32:40] Yeah, no worries. Okay, so the next one is on. What do you think is the future potential of A.I. in for detection or predictive maintenance? Do you think it'll go completely, completely autonomous or. Yeah. Or the. There's still a scope of decreasing the time that you are notified of the faults. Do you think this time will reduce significantly?

Speaker 1 [00:33:13] Yes. So. Completely autonomous? I don't think so. Yes. So in the next 5 to 10 years, I think we will have increasing levels of autonomy. So what you might see now is that there's a bunch of different analytics that someone may have written and how so they've outsourced and they have loads of different trends all at the same time. And then people would sit there and look through all the ones that are flagged as an alarm and try to work out what's going on. Yeah, I think as time progresses, those systems will become more intelligent. So you might have. You know, these trends are all grouped together and that kind of rationality might make recommendations or do things a bit more joined up. But I can't see it yet. Sending people automatically to climb a turbine without somebody having some oversight. Yeah, well, see, I might. It might be faster than I think.

Speaker 2 [00:34:24] Okay. And this is just the last question from my side, But I was wondering, because the more I talk to people about this, I've just been wondering if there's, like, a geographical distribution of how the industry is currently. Do you think all parts of the world are growing at an equal pace? Because at least in Denmark, I see a lot of emphasis on sustainability in general, but also wind energy because there's a lot of wind here. But like, how do you think the world is moving towards technology?

Speaker 1 [00:34:54] Yeah. I'm sure we can find statistics and good ones, but yeah, just off gut feel. We have quite a lot in Europe and are especially focused on offshore in the UK. America is going to start ramping up quite fast, mostly onshore. Then you've got India and China. They're doing massive growth into renewables both. And then other countries stand up too. So for example, in Asia, there's quite a few countries that are just starting to build out wind farms as well. And not so much in Africa yet. I think there's one or two projects ongoing.

Speaker 2 [00:35:40] Okay. Hmm. Well, that's quite a stark difference.

Speaker 1 [00:35:44] Yeah. And in the north, like in Canada, they have loads of hydro loads of hydropower.

Speaker 2 [00:35:57] Yeah. Okay. Yeah, it's interesting to me, especially with the wind energy here at the time. If you're taking a plane to Copenhagen, you just start seeing these offshore wind turbines. And it's a nice sight to look at. But yeah, it's also interesting how different parts of the world are growing at a very different pace.

Speaker 1 [00:36:19] Yeah, definitely. In Europe and in the UK, there's less appetite for onshore, from the governments. There's a lot of push into offshore, but other countries like for example, the states, they are really going to push onshore.

Speaker 2 [00:36:36] Okay. But actually just this discussion got me thinking but I never realized why there would be a push for offshore rather than onshore. Is there a reason for this?

Speaker 1 [00:36:46] Yes the government we have here thinks that wind farms are not pretty. Even though people here generally believe that it's fine, it's kind of a strange thing. Um, but some countries like, yeah, America is an example, but they have loads of space and they certainly went out to the U.S. in recent days, massive amounts of land turbines everywhere. They also got like these pumpjacks going to pull the oil out and the farming on top as well. And it's just a huge amount of space. No one can see their houses nearby. Yes, it depends, I think, on how densely populated and with public opinion or government. Yeah. Okay.

Speaker 2 [00:37:38] That's. That's interesting. I think I have covered everything that I had to ask you, but do you have anything that you feel I should look into or maybe I shouldn't cover? And it would be interesting for me to. Yeah. Have in my research.

Speaker 1 [00:37:56] I don't know. And I think it's good. What's your kind of main angle field thesis?

Speaker 2 [00:38:04] My main angle basically is organizational change. So it's this attempt to understand how organizations build resilience also against like a lot of technologies coming in and also how they're preparing themselves better for this incoming technology. So like. Investment on resources, investment on people skills. And if more teams are being built like more data analytics teams that are being built or become organizations, basically changing. So it's basically an efficiency change with technology.

Speaker 1 [00:39:02] Sounds really good.

Speaker 2 [00:39:15] Yeah, I think it kind of built over time. Kind of built, but I'm super interested in this. The more I start talking to people about it, the more curious I'm getting about a lot of stuff that's happening.

Speaker 1 [00:39:47] And you're specifically looking at wind or. Yes, that is much more interesting. Yeah, it was pretty cool.

Speaker 2 [00:40:02] Perfect. So, yes. Thank you so much again for that. I am like, really, really I very much appreciate all these insights and I'll be done with my thesis mostly by June or July. If you want to give it a read or see what's the academic side of this.

10.5. Appendix 5 Interview 4 Transcript

Speaker 1 [00:00:00] So you have seen my LinkedIn page. So you know a little bit about what I do. Yeah. So I'm actually a mechanical engineer from my background. I always worked with composites and blades. And then a couple of years ago, actually quite a long time already in early 2000, I worked. I had a project in the university where I started to use neural networks for optimizing airplane structures. And then afterwards, I always kind of kept it, kept an eye on it. And a couple of years ago, I started a company called [Company 4] with a colleague of mine to make. If these tools break small, pragmatic tools for all kinds of things in the wind industry, because, you know, wind wasn't used all that much for many tasks. So we made tools for, you know, parsing image data streams from manufacturing and from whatever manufacturing processes were manual processes. But also tools that could use classifiers, for example, figuring out what is going on inside images that are made by drones of the plates. I made some tools that parsed data from SCADA data systems to figure out whether, you know, turbines after modifications have started performing better or worse. Yeah. And so actually, yeah, that. There's a, there's a nice open field there, I would say, because there's not that much adoption of it.

Speaker 2 [00:01:42] Exactly. Yeah. Because when I started, when I was in the middle of, you know, searching for a topic for my thesis, I was looking at different things. But when I started narrowing down to this, I realized it's so much interesting and there's so much stuff going on in this area, especially now that it's evolving and developing and evolving right now. So I thought it's a good idea to go with this.Yeah, perfect. I was wondering if we could just do like a Q&A and I can just start with the questions. Of course, like I said, we can also skip any question, if you feel that doesn't fit into the context or doesn't isn't in the area of your expertise. But if you are fine, maybe I can start with the first question now.

Speaker 1 [00:02:28] Mm hmm.

Speaker 2 [00:02:29] Okay. So perfect. So my first question basically was to understand from you how these technologies and accelerating this drive towards environmental sustainability more so because we have this focus, focus on sustainable development goals and the 2030 agenda. So how is it helping basically achieve this goal of ours?

Speaker 1 [00:02:53] Um, yeah. So I actually read the question. I mean, when I read the question, I kind of thought, like, do I think that on on aggregate level? Or, you know, basically if it's, contributing more energy than if it's than it's using.

Speaker 2 [00:03:11] Okay. I even that's a good idea to start with so we can go ahead with it.

Speaker 1 [00:03:17] But I mean, the other way is fine. I would say, of course, if you mean, you can. So you could swap wind into many parts of an existing business. Right. And optimize, you know, manufacturing, optimize operation and maintenance for protection. You can use much cheaper sensors by, you know, because you can now parse image streams that are from cameras that are very cheap audio streams, etc.. So in that sense, it allows you to. Yeah. I mean, in that way it will make your hand. The difficulty, I guess, is then, okay, let's say you have added a whole bunch of microphones and cameras to your turbine. Let's say it's a turbine, so. So how do you translate all of this knowledge that you now have into some kind of business value? That's kind of tricky, right? Because, um, but at least the simplest way is that you can probably, you know, remove some people that are monitoring it because you can make smarter, you know, you can, you can make it. Flag up in a smarter way so that you only really get issues. Instead of that, you just have a person detecting the issue. So you can save a little bit of man hours. But I would say that's another super interesting revolutionary, you know, thing to do. Yeah, Yeah. But it's usually the first start where you're like, okay, that is like a contribution.

Speaker 2 [00:04:57] Perfect. This actually builds to the next question that I was looking at and was on. How do you think this coming up of AI is changing how wind organizations are operating? If AI is taking over the traditional human labor force and basically how organizations realigning themselves in terms of upskilling their employees, reskilling them, etc..

Speaker 1 [00:05:22] Yeah. So I mean. From what I know about drone image campaigns like drone inspections of wind turbines. They're of course, you have lots and lots of image data where usually people have to weed through it and flag issues, damages, cracks and whatever. And you can pre screen using A.I. and get an initial bid on where the cracks and the issues are to look at. And then you can get people to classify. So in that way you could first move to a hybrid and then you at some point will move to some fully automatic system. I mean, there's usually a bunch of hurdles because if you make a fully automatic system and then, you know, practice overlooks, then it was to blame for it and where. So there's all these kinds of issues. So in that sense that the move is slower than it could technically be. Always. But it's happening. Yeah. And I would say it makes these jobs more interesting because, you know, they become less or less repetitive, but you need fewer people for them also. But you can also just cover more because there's like a huge backlog before, you know, you're not doing all the drone campaigns that you might ultimately want to do. Um, so, so I would say to get it closer to where you can monitor the way you want to. Yeah. Rather than that, it just eliminates people. Yeah. Yeah.

Speaker 2 [00:07:05] That's true. Yeah. And maybe there's always some sort of human dependance always. Like you said, if there's a lag. And who's to be blamed for that? And just having accountability. So maybe it is. Yeah, there's a human dependance on this as much as automation or it comes into the picture.

Speaker 1 [00:07:21] Yeah. Yeah, that's right.

Speaker 2 [00:07:24] Oh, the next thing was to understand what kind of data is usually collected at the windmills. I was going through some research papers, and they talked about wind energy, wind direction. But if you could just help me understand how this data is gathered and collected, basically.

Speaker 1 [00:07:43] Yeah. So I would say feeds that I know are like you have. It's a system in the turbine and that, you know, usually turbines have some kind of remote control system. And any kind of actuators and. Now, systems in the turbine give some feedback. Okay. So, you know, you know, the opposition's pitch actuation system, the temperature of the oil and the gearbox and all these kinds of things. Then you have it with a certain time resolution. Then you have the electricity company that has some production data. Then once in a while you do drone inspections, maybe. Which, if you were a snapshot of image data, then you might have meteorological measurements close by like net mass that give you wind detail when data from a spot not too far away from the turbine. And then you might have, like, general weather predictions and general weather measurement data. And then, of course, you might have. All kinds of additional sensors that you use. Have their own logging system that sends data back or they or they are connected through this K2 data system and feeds the discredited system so that that's more or less the data coming out.

Speaker 2 [00:09:14] Yeah, that's a lot of data. Yeah.

Speaker 1 [00:09:18] Well, I don't know. It is a lot of data, but it's also like if you compare samples, let's say you take Tesla as an example that has, like, I don't know, 20 cameras per car. Running solely for high resolution video all the time. Hundreds of thousands of cars, right, in that sense or millions of cars. And I would say there actually is fairly little data you have. You don't have that many turbines. You don't have, you know, high resolution video feeds or anything. So in that sense, you know, you have sometimes timelines with floating point numbers, very, very big machines, you know? Yes. So in that sense. I would argue it's fairly little data.

Speaker 2 [00:10:08] Okay. That's interesting. That's very counterintuitive to what I thought. But yeah, I get your point.

Speaker 1 [00:10:14] Yeah.

Speaker 2 [00:10:15] Interesting to think about this.

Speaker 1 [00:10:17] I guess. I mean, yeah, I would say yeah, it's a lot of data if you're like, you know, logging into your workstation and you're looking at this data table or whatever, then it's a lot of data. But if you're looking at it like, okay, what are the big applications like, for example, G.P.S. or, you know, automatic self-driving, those people, they have like a database that either like the whole Internet body of text. Yeah. Or, or like continuous high resolution video from hundreds of millions of cars all around the world. Yeah, you're nowhere near that level of data. Yeah. So that's that.

Speaker 2 [00:10:54] Yeah, that's actually a super cool example. I didn't think about it that way. So yeah, that makes sense. But for now, the next thing. Yeah, now that we have a lot of or not a lot of data, but just trying to understand what kind of human skills are required to make sense of this data are skills like data analytics programing are going to be big now that is coming into this picture and how do you see this skill evolvement with basically AI coming in wind energy?

Speaker 1 [00:11:26] Yeah. So I like the skills that I wrote down as data analytics programing. I mean, of course, programming itself is undergoing a major revolution. So, you know, it's I don't know if you were the copilot or computer programmer, but, um, so in that sense, I think what that means is that it actually becomes easier for domain level experts to write code. That is good. So it actually, which I think is a good development. So in that sense, I think engineering and physics are probably engineering. Math and physics are probably going to be more important again because, yeah, you know, writing code, writing good code, it becomes easier. Because you have AI help there. Yeah.

Speaker 2 [00:12:24] Sounds good. Um, the next part is how is SACA and other data sets basically analyzed for predictive maintenance? If you have an idea of this for fault detection or predictive maintenance.

Speaker 1 [00:12:40] Yeah. So I've seen some fault detections. I've looked at it a couple of years ago. I mean. Basically, you could say AI is like advanced interpolation, right? So you're just fitting basically, it's curve fitting or as you want to call it. So if you can make a good predictor of what is normal behavior, then you can also figure out whether you have it you know, whether you have a delta to the normal behavior, like if the behavior is abnormal. And then. And then you can set alarms. And of course, initially you start with some static alarms saying, oh, well, you know, if this sensor is if this temperature is too high, then give me an alarm or whatever. Right. And then you make it a little smarter and you say, well, if the turbine is already running at Max Power, then I expect the temperature to be higher, the gearbox oil temperature, because, you know, you're running a lot of power through the gearbox. So in that sense, then, you know, I want a dynamic limit saying that, you know, I want it to be relatively high compared to normally in this circumstance. Yeah. So you make all of these boundaries smarter and smarter. And at some point, you could say, well, I now make these boundaries no longer manually set. Even though they're very smart, I make them actually automatic or set or adaptive or whatever. And then at some point, you can call it AI.

Speaker 2 [00:14:21] Okay.

Speaker 1 [00:14:22] It just moves in that direction and it gets smarter and smarter and more and more adaptive and self-learning. At some point you just call it a learning system, and it's some kind of A.I.. But that doesn't mean it's like a doesn't mean it has to be a neural network, right? I mean, for smaller datasets, one that works, maybe not so perform that well. Yeah.

Speaker 2 [00:14:46] Okay. Yeah. I'm just wondering, when you were talking about, like, categorizing something as an error and not and then seeing the data, is it like supervised learning where you categorized different kinds of files and labeled them?

Speaker 1 [00:15:02] Yeah. Like, I would imagine that. You know. I mean, you can go different ways there. You could have let's say you have a whole wind farm and you have one turbine running at a much higher temperature than all the other ones. And probably, you know, there's some component causing friction, you know, and putting it into the system. So you can say in that way, relative to other ones, it's an outlier. Yeah. But you can also say relative to itself, over time it's an outlier. And I would imagine all of those methods are used in one way or another. Yeah. You know how much real AI is in the sense of self-learning systems and is actually used. Yeah. Yeah.

Speaker 2 [00:16:01] Yeah. That's the thing. When we talk about AI, it's so big. Also, just to narrow it to, like, a specific, is it machine learning or neural networks or deep learning becomes tough. That’s what I’m looking into right now. So just scoping out AI is kind of tricky, I think.

Speaker 1 [00:16:26] Hmm. Yeah. Right. I mean, also like. I would say because the data sets are small Right. It's kind of hard to talk about. I still in this like you don't, you're not going to quickly see a self-driving type of smartness coming out because you, um, I mean you only have a couple of hundred turbines worldwide so there's not that many turbines and you know that means like the outlier events for example turbine burning down. You may have maybe I don't know how many the total world SCADA data set, how many of those include events where the turbine burns down. Right. Yeah. That's like a fault you want to prevent. But there's very few of them. Yeah. And I would say any one company would be lucky to have like one or two burned down. So I think the company is unlucky but the data scientist would be, right? To have this outlier event in their data set and I guess they're trying to nurture this outlier event and try to expand it so that, you know, you can learn from different variants of it. Yeah, but you have very few of them. Where it was, you could see. I mean, you can see in the news whenever Tesla has it with their autopilot, right, they have like, oh well you know, the car crashed into a truck that had completely damaged the side panels. So it actually wasn't seeing the truck, but was seeing the reflection of itself. This is like a super rare outlier.Yeah. Now, you now have one of those in the set. Yeah. But yeah, that's kind of a difficult issue as is, you know. If you are, how do you deal with these rare events? Yeah.

Speaker 2 [00:18:25] And that makes sense because these rare events could be very unique, like you said, with this mirror thing. So possibilities that you might not think of earlier. So it's only when in reality you can categorize it as a fault.

Speaker 1 [00:18:41] Yeah. And then, of course, you need to quickly reinforce, learn and make sure that this case is now covered and whatever. But, you know, and in turbines you have like slightly different cases like you have like, you know, the one turbine that stands on a ridge of, you know, a mountain ridge. It sees very weird wind conditions. Right. So that, for example, like mountain ridge turbines, they can have let's say the turbine is damaged by the air, ironically, but the air. So they seem to have very high wind speeds on the bottom of the tower. Whereas on other turbines, they see high wind speeds, the higher you go up. Right. So they have really odd, you know, conditions. And then you can say, well, what kind of things happened in their SACA data feeds that are different. And, and of course the mountain ridge is only relevant when the wind comes from a certain direction. Yeah. Maybe there's no ridge there. Yeah. So, uh. You always need to be cognizant of whether you actually have a large dataset. Like, even if there are not just many rows in your table, but like, is it actually covering a significant number of the events that you want your detector to cover? Yeah.

Speaker 2 [00:20:05] Okay. Thanks. I see you have put down a comment for the next question, so I think that suffices. We can move to the next one. And this one basically covers the idea of ethics and to get your ideas on what kind of ethical considerations one need to take when using AI in wind energy? And this can include issues of privacy, protection of data, data bias, safety. But yeah. Your thoughts?

Speaker 1 [00:20:33] Yeah. Um, I would say that the place where we, um, where I encountered it most is when you're monitoring two manufacturing facilities where there's people. And then you have to and actually then you can use A.I. to, to anonymize the people, like make sure that they become, you know, figures rather than persons. And in that way. But I would say. Like if you're parsing time series from SCADA data. Yeah, I don't quite see um, yeah, I don't see privacy or ethics as a big problem. Of course you can get it. I mean, I don't know if you could get like. You know it. A request in terms of due diligence. When you want to buy a wind farm, you know, this kind of data transfer has become interesting if you're like, okay, I want to have this whole data set actually for myself, calculate how reliable this thing is running. But I don't think so because then as an owner, you would have to first build up the technical expertise to deal with it and so on. Yeah, but, but normally, I mean, you make a good product, I think you're going to be able to. Your difficulty is not so much with ethics, but with sophistication, I think. Okay. Like, you know, okay, you made an AI system. Let's say you made an AI wind controller. You know what happens if a typhoon comes that always does it. And even if you demonstrated, it reacts well to the typhoon and it's in its initial state after it does some reinforcement learning, does it still react well? So it's like, I don't know, like you could use you can't it becomes a non deterministic. Yeah. So this kind of a thing. Yeah. Yeah.

Speaker 2 [00:22:43] Got it. And I was just wondering, like with all of this data coming in, however big or not it is, but just threats to cybersecurity, because I was reading about a couple of incidents where there were hacking attempts to get a lot of data and how hackers wanted to compromise with the data security. But do you have an idea about this?

Speaker 1 [00:23:04] Um, yeah, I mean, I would say. It's not so much an AI issue. I would say that's more of a cybersecurity issue related to the control systems, you know, because the control systems are in some way on the Internet and that means you can. But because of and there you can say the link to a I might be because, you know, you want to connect everything with the Internet of Things. So you have like data feeds and that means that the connection is there and there's connections there and then somebody can break into it. Or can try to break it. Yeah.

Speaker 2 [00:23:40] Okay. Yeah.

Speaker 1 [00:23:42] Yeah.

Speaker 2 [00:23:42] Got it. The next I had written was on systems reliability when it comes to fault detection and any major concerns or risks of accident. I think we've kind of covered this but any, any more.

Speaker 1 [00:23:56] Yeah. Yeah. I would say the one thing is they might be very reliable, but it's very hard to prove that they are. And, and it depends on how well your AI training data is and that the AI system is based on is covering rare events. Yeah. And it just requires a bunch of. Knowledge on, you know, I guess requires you to have a lot of turbines and it requires you to be good at pulling the data from all of those turbines into a single set and make a convincing case that you are covering rare events.

Speaker 2 [00:24:35] Yeah, that's true. So I think it's all about, I think training, training the data set, but would always have possibilities of rare events. So probably cannot have a comprehensive data set training dataset, but maybe you can reach a good level of accuracy.

Speaker 1 [00:24:52] Yeah. And there you could say if you're a Europe wide operator with thousands of different turbines and different types of climates, and you have you presumably you have way more rare events than if you only have three turbines. And you know, first you then.

Speaker 2 [00:25:07] That's true.

Speaker 1 [00:25:09] Yeah.

Speaker 2 [00:25:10] I've got it. This covers ethics. Now we have the section with challenges. Yeah. The first one is if you see any major challenges coming with the use of AI in wind energy, I just wrote down high installation cost and need for profession and expertise, basically people skills. But if you have any other thoughts of major challenges.

Speaker 1 [00:25:35] Yeah. So I said, Oh , right. Like I would imagine installation costs for AI is not really a factor because usually software as a service. I would say you could say start costs might be high in the sense that you're gonna have to, you know, set up all your systems to first feed data into your company and then to where, how is it in a way that allows you to kind of deposit all into a single table and then, and then. But I think your other challenges are convincing underwriters and certifiers that you're like that you're actually reducing risk and that you're covering rare events better than you would with a, you know, human monitoring system. So I think that's where your challenges are.

Speaker 2 [00:26:33] Okay, so like what I hear from you, it's mostly challenges and people adapting to it rather than the technical challenges because maybe technically we are quite advanced. So implementation isn't a problem, but just people coming on board with this idea probably is a bigger issue.

Speaker 1 [00:26:51] Oh yeah. Not just with the idea, but also that. Yeah. If you just have a yeah, if you see it as having a small data set, then you're probably like, you know, like we were saying, these burned down turbines, you have very few of them. In the current system, so. Let's. If I was sitting, let's say for example I'm Allianz or some big insurance company that wants to own a lot of wind farms and somebody's trying to sell me a system to monitor. Right. So then. Then you can ask, okay, how many burnt down turbines do you have the SCADA data feed from leading up to the burning event? And are they in your training data and like how would you know? Can you augment your training data with, for example, simulation data? That would make it more robust. I think you would have to. Shall we, like, be transparent to these people that own all these assets? Because. Because if you have these big assets, it's actually not that expensive to hire a bunch of people to look at the technology. Yeah, right. So. They would have to prove that it's better than the people, not just cheaper. Yeah, that makes sense, right? Yeah.

Speaker 2 [00:28:12] It's perfect. Next I see a very interesting answer. At least that's very interesting to me. So I'll take this question and it says, Are there any challenges that deter organizations from investing in AI for wind energy? And you write your response as having young and technical leadership. Very interesting to me, actually, because I feel this would also bring kind of an organizational change in how managerial positions are held within companies or, you know, do you want to share what you thought about this?

Speaker 1 [00:28:50] And like. Yeah, I guess it is required to some extent. So, like, there's. There's the two sides, Right. So the, the one side people that don't know about it, I think it can do everything. And then you on the other hand, you've got people that think it's, you know, not even when it can do a lot of things that it's still, you know, still you just feel more secure when there's people there. Yeah. Right. So there's two sides where you can fall into a ditch of not having the right level of adoption or. Right. And I think it also requires you to be strategic about. Okay, you know, you're, you're setting up your whole day to day to slow or setting up your whole company around data flow. Like, for example, you know, like Tesla's a good, good one, right? So they, they sold. They sold cars full of cameras. Feeding data back to them before those cameras gave any features to the user. Right. So they their years and years, they just are like, no, you get the full camera packs regardless of whether you want automatic self-driving, right? Because they were like, Yeah, they're like, Yeah, we just want that data. We want to be ahead in the data dataset. And so like by the time it would be one to five years to be better than anybody else's. Yeah. So any other, any traditional company was like, well, I'm not going to pay for somebody's cameras. Yeah. And they realized, no, they're not somebody's cameras, they're our cameras doing our work, improving our AI, making our value higher. And that kind of thought process you would have to have. MM Yeah. I mean now you can say well. Yes. Wind turbines have an astonishingly low number of sensors in them. Given how big of a machine it is yet has like a blade has almost no sensors in it. Oh, right. Because they break and, you know, they get shaken around and they cause all kinds of problems and it costs money. And you can't rely on them anyway to to run the turbines. So just keep them out. So I would say if you wanted to become a company. Then you would have to turn. Sorry, I'm just going to the other part of that. Yeah. Yes. If you. If you want to become a company, you have to realize that, okay, this data is going to factor into our evaluation in five years or ten years, and therefore we need to have a just the whole company needs to be made so that data streams into our systems and then we build our software on top of it later. Yeah.

Speaker 2 [00:31:44] Yeah. I think this kind of insight or foresight is very important, like you said, even with Tesla. So maybe there's something with wind energy also, like maybe having more sense of just this kind of foresight I think is very important and probably will be a game changer in the coming five, ten years or something like that.

Speaker 1 [00:32:04] Yeah, and you could say, see for example, as examples like Envision is a good example, is a decent example, They, you know, they would have this mindset. Yeah, yeah.

Speaker 2 [00:32:16] Yeah. Because this also leads to what kind of training data you'll have then and then train your monitors and have advanced AI systems and everything.

Speaker 1 [00:32:25] So yeah. Because you know, a system like unless you're Google or OpenAI, you're not actually developing the model, right? You're only developing what you train it on, you're developing your training sequence and maybe you're picking different models or doing some different reinforcement learning. But really the model architecture, you know, there's very few players that actually make models from scratch and train them. Yeah, that is so, so and I would say. Yeah. For me, also, like I would never consider, you know, starting a new project on a blank sheet of paper and just starting to develop a neural network from scratch.

Speaker 2 [00:33:19] Got it. And coming close to this question. The first one was, Do you see a growing competitiveness in the industry towards adoption of any emerging technologies that you know about? I was reading about digital twins and how it hopes to stimulate, make a digital copy of a physical asset. But do you know anything else that's coming up, new technologies that can help you in this industry?

Speaker 1 [00:34:02] Yeah, I would say digital twins are, you know, a buzz word in the sense that, I mean, they're just engineering models of things. And you can and and you could say that given that is just interpolated models or data based models, then you could make digital twins using neural networks. Yeah. So, I mean. And also digital twins like many of those. And you've got, of course, all kinds of developments and floating turbines. You've got gradual developments in materials. And I think this as you see it now and I've said normally, like these transformer models that make texts and make images and make designs. And so I think that for some of the design departments it might seem. Like more advanced.

Speaker 2 [00:35:03] That's true. Yeah. That's, Oh that's actually super interesting.

Speaker 1 [00:35:07] Yeah. Um, and. Like proper operation maintenance for a time like this. Now you have technicians going out there and, you know, they do a whole bunch of work. Then they take out a camera and take a picture of one thing. Then they do a whole bunch more work and then make another picture. I would imagine that, you know, these people are going to have video feeds, video cameras that just picture everything and, you know, might give them live feedback or whatever. Yeah. You know, figure out whether the repairs are compliant with the process that you're prescribing. I'll just you know, for example, if you have a blade and you have a crack in it, you have some kind of general manual of how to repair cracks and place. Yeah, I would imagine that there's going to be pictures of this crack and there going to be a specific manual on how to repair that crack that might be formulated by a transformer model, right? Yeah, that's true. And the image is made up in parts and the depth of this crack might have been evaluated by a and it might have been the criticality might have been just based on, you know, based on the large data set of loss of cracks. Yeah. Using AI. I mean, similarly, I think like what you have to, you know, in Tesla, Tesla's a good example. You can always look at Tesla and be like, Oh, what are they doing? Well. Yeah, probably. Probably. Given that we are also making machines. Yeah. Going to be doing the same thing in ten years. Yeah. So like they have neural networks that directly drive. Right. So they take video camera feeds in and then they steer to the left or the right or brake. Yeah. I would imagine wind turbines are going to take, um, sensors in and, and, and, you know, raise or lower to torque, change the pitch and change the direction. Yeah. So I would imagine the field of control theory is going to be modified and disrupted.

Speaker 2 [00:37:28] Yeah. This is super interesting. You've given me so much food for thought. Like, every time I have this kind of conversation, you know, I just want to go back and research more because this is something I had no idea about. And it's just interesting as I start going into it. So, yeah, I think these are great. Also, do you think with these technologies, digital twin and whatever, whatever, do you think companies are ready to adopt this so that the industry is moving altogether? Or is it just some organizations that are investing so maybe some organizations are going ahead, others, or is there an industry wide advancement towards adoption for these technologies?

Speaker 1 [00:38:16] Yeah. Yeah, I would say some. Some companies are more conservative than others. But I would say everywhere you have, I mean, like digital twins. I don't know. I mean, digital twins, I consider more of a buzzword. But like in general, digitalization is a thing. And you could say digitalization is like the bottom is some of the plumbing that you need, like good digitalization is what you need in order to get these data feeds established. And then you need to have a processing layer that kind of unifies the data set so that you don't end up with like 50 different tables, allow you to train 50 small models on something, but rather have a unified table that allows you to train a big model that can get like more, more generalized insights. Yeah, yeah. So I'm not sure that's a useful answer, but. Yeah. Yeah.

Speaker 2 [00:39:12] Um, I think I can skip the next question, but maybe we can take up this one if you think government regulations and policy measures can play a role in ensuring how AI is used in the wind energy industry. Yeah, just having a perspective on how external factors can influence the adoption. So like I mentioned, increasing funding in this area or setting energy efficiency standards and basically any sort of external pressure from the government that can help in this, you know, adoption of AI. And yeah, maybe that could be a possibility.

Speaker 1 [00:39:56] Well, yeah, I know. Like, for example, energy efficiency standards or any kinds of setting standards. So it's kind of difficult. I mean, it's just fine to like, set a standard at some point, but I would say it's going to be difficult to make it adapt at the pace where it's useful. Right? Because if you look at the GPU's, you know, compute capacity for both for what our and for it just grows very rapidly. So something is energy efficient. Yeah. And I would imagine that law making is not operating at a speed where, you know, you can kind of say, oh, well, let's go and keep track of that. Also, if you're controlling a let's say a ten megawatt wind turbine, even if you run like a whole tower of GPUs to control it, it's still no energy compared to what the wind turbine could potentially generate extra.So and, you know, anybody that would make that set up and say, okay, now from now on, we're no longer gonna use this little old controller to control it, but we're going to use this stack of chips used to control it. Yeah, of course the GPU is going to pull more power. But you will only do that if you generate more energy. Get the turbines to generate significantly more power or have a significantly longer lifetime, or in other ways, just be a better energy generating asset. So I would say that that would take you know, that is a fairly, uh, yeah, simple that basically the market, you know, the person owning the turbine will have to pay for the power of the so, so it's in their incentive to get as much extra power generation out of it as possible. Yeah. Yeah.

Speaker 2 [00:41:51] But yeah, I also think I agree with your point of maybe policy or regulations not moving at the same pace as that of technology, maybe technologies at a very fast pace. And it's so dynamic. So that probably makes it tougher for policy makers to catch that speed. Just because this is the technology side is so dynamic and moving so fast.

Speaker 1 [00:42:15] Yeah. Yeah. I think if you want to see where there are like, you know, roles for regulators, I would think more in terms of security like, and in terms of laws about where you can move data and place data. Because they're all going to be powered through cloud computing. And so it's whether, you know, which boundaries the data crosses. And how sensitive are these systems to hackers. And, you know, that's more of a concern, I would say is like national security, because if you have a lot of renewable energy on the grid, then it can be taken over by external parties or the data can be siphoned off or, you know. Yeah, I would say that there's a bunch of work to be done. Yeah.

Speaker 2 [00:43:05] Okay. I would just make a note. Sounds good. And I think we're on to the last question. Really. If you just have two more minutes, I realized it's 9:45.

Speaker 1 [00:43:17] Yeah. Yeah, sure. Okay.

Speaker 2 [00:43:19] The last question, which is basically on the future potential of A.I., how do you think this will impact the industry?

Speaker 1 [00:43:36] I would say try to decouple a little bit from that and think, you know, how is this, how is default this action going to cause additional energy production or a lower rate of failure of assets or something like that? Right. So, that's where the gain is going to be. I would imagine. It's not a huge step game. Like I, I mean, wind turbines are really pretty reliable and pretty performing. Um, of course, if you can use a couple of GPUs and squeeze out 2% extra power, for example. Right. That, that's fairly reasonable thought that that is possible. Yeah. And there is of course an extremely efficient use of a bunch of that you can use. However, 2% more power is. Yeah, it's not like, okay, now we can suddenly extract power from Siberia or and where before it was useless land or whatever. It's not that kind of revolution. But you can definitely make us more make a company that, you know, adds a bunch of almost free extra improvements on the top of the the assets using AI. Yeah. Yeah. So. I mean, the thing is, the problem with false detection is like. Yeah. So proving it's actually better than human beings realizing that human beings are already pretty cheap at this, given that the assets are so big. Yeah. And that there are so few of them. Yeah. And that your data set is small. So in that sense it's I would say it's not an attractive problem of detection to me. Unless we can generalize over machines, let's say you're not talking wind turbines, but you're talking just machines. Hmm. I think. I think that would be, you know, because there's lots of machines and factories and cars are machines, wind turbines and machines. If you make a general fault detection, that does not care what kind of machine you're looking at, then maybe. And I would imagine a company will come from that perspective, because if you manage to unify a dataset across machine types, then you suddenly can have more and more rare cases and then your is going to be better. So I would imagine that your fault detection A.I. is going to come from some company that has a more generalized perspective on machines rather than specific ones.

Speaker 2 [00:47:03] Yeah. That sounds fair. Yeah. I think we just made it to the mark, and I would want to thank you again. Thank you so much for taking out your time.

Speaker 1 [00:47:17] Good with your thesis.

Speaker 2 [00:47:21] I think you've given me a lot of food for thought. I think my biggest takeaway, I think, from this would be just my idea that I had vetted earlier, that there's a lot of data out of date. A lot of data. But just you giving me that perspective of Tesla and this I think, brought a shift in my thinking because I always came from the idea that, oh, there's a lot of data and what do we do with that data? But just having this conversation with you, I will go back and think about really how much data is there, because, yeah, I think that really helped me put things in perspective. So thank you so much. This was very fresh perspectives for me and a lot of things for me to go back and look at.

10.6. Appendix 6 Interview 5 Transcript

Speaker 1 [00:00:00] I'm glad that you seem like you have made your mood to stay in wind energy. So that's good. Yeah.

Speaker 2 [00:00:11] Yeah. I did.

Speaker 1 [00:00:14] Yeah, I think it's a good decision. I made the decision almost 11 year ago. I was working with gas turbines. Generators, nuclear generators. And then I thought. This is not sustainable. I needed to look something different and then thought of it. And then when I thought of wind, then any place better than Denmark I could not think of. Yeah, of course. You have different challenges and your languages and all that stuff. Yeah, I think. Thanks for reaching out. It's always a pleasure to support someone. Yeah, especially those who want to build a career high. I only. I have a couple of friends in teaching professions, and then I do take the opportunity to talk to the students also. So recently, I think a week ago, I gave it up online to. And I it and just the goal is to tell about the bend and also the complexities and those who are interested to take the challenge to take it. Yeah. And yeah so four years. Yeah. Yeah.

Speaker 2 [00:01:53] Thank you so much. Here again for taking out your time. I already know you're very busy with a lot of things.

Speaker 1 [00:01:58] So that's fine. Yeah. Yeah.

Speaker 2 [00:02:00] Very quick and okay, I will start with the questions. The first is just like to open the discussion and to understand your thoughts on how digital technology is helping the wind energy accelerate towards sustainable development. Like we're always talking about SDGs and everything. So do you think technology has a big role to play in achieving sustainable environmental development in general?

Speaker 1 [00:02:30] I think you can put an end to part and just interrupt me if you are going out of sight. One is “doing something” and the second one is “can do something”. And maybe I'll say, is it doing something? I don't think it is doing anything. What it could do, actually. And the reason is very simple that if you really look at the industry in the last ten, 11 years, the growth has been so strong in development that somehow I mean, imagine like 10-11 years back we were talking a size and now we are talking ten times bigger products actually. And that all brings a lot of challenges because somehow they are distorted, i.e. people are pulling something and then someone is trying to solve a wheel and say, okay, I don't have time for it actually. And so our industry has been in that state actually, but in at least the last couple of years, I see the talk is happening about this area and. It is also not fair to say that there is no digital part, actually. I mean, there are a whole lot of digital parts in terms of monitoring and diagnostics and for taking a next step like A.I. is now there. It is using 50% capacity or something like that. That's the answer, of course. And I guess I don't know if just you can have a follow up because actually so. Yeah.

Speaker 2 [00:04:29] Yeah.

Speaker 1 [00:04:29] And then also trying to be limited because I know two years ago we developed a lot of digital strategies for ourselves. So I can Yeah. And it depends on the follow up question.

Speaker 2 [00:04:42] Yeah.

Speaker 1 [00:04:43] But just feel free to ask.

Speaker 2 [00:04:47] Thanks. Okay. So the next question is how, with this coming in of technology, like especially with and is predictive maintenance and reduction and doing it on time for detection, do you think it's really helping or like boosting the turnaround time for detection? Time has increased over the past few years, so maybe companies are able to know well in advance what kind of failures they should be expecting, and does this help them to manage resources and finances better?

Speaker 1 [00:05:25] Yeah, I can. I can give you a little broader picture. So since you're also working in wind energy or maybe you have a limited view on the server side. But if you look at opportunity, I mean, opportunity starts with. So maybe you just take a step back. Any B2B business, right? Business to business products. Start the business of consumer products. So, basically, I hope you know already. Yeah. Just excuse me if I sound like a teacher. Uh, and so there are the two types of product I need to see that I sell toothpaste the consumer is using directly. There's a lot of emotions and all kinds of things that are involved. And the second part is B2B business, where a business is selling a product to a business. So. So our products are B2B products. So we are selling and someone will make money from it. Actually, it's not consuming. Basically they will make money, they will operate. And in those products there are many factors. One is the capital cost. So you develop something that someone can invest the money and say. I can get the money back. It's some kind of recovery. So, for example, if you want to buy a wind turbine to do business, you can borrow money and buy it. So it needs to make sense that it can and you can return back that money, actually. And then in the second part, you can make a profit so you can draw on it. So OpEx comes with operating costs. Generally, you have a cash flow during that time because it's already producing. You are selling electricity. So both are quite critical and finding the balance between both. So maybe the first part. The second part, I think digital took quite a big role or doubt about it, and I'll give you a simple example. They're not allowing you to go. I mean, one of the problems with the wind is. An important product in an uncontrolled environment. Actually, most of the products you design, you know that environment, right? The gas turbine, you know, the big cell and you can control things, but when products are put in an uncontrolled environment. So there are so many operating conditions which you do not have control of, actually. And there I give you just a small example, like ten or

11 years ago. And when in the afternoon, let's suppose you are not in Denmark, but you are in Thailand or in the US, Texas, and suddenly afternoon turbines, they start tripping actually, and then someone will take two or three hours to drive and then reset it. And then they started actually. So those learnings has been automated because I need a temperature limit because that's like a defect. But suddenly in the afternoon you have a lot of solar radiation and the ambient temperature went high and it dropped. That's not a defect, actually. That's just like it's happened. And you can accept one or two or three automated resets. Actually, you don't need to send somebody. So those kind of experience based learning implemented in a logic form actually, like if ambient temperature is going high and it tripped and you saw there is a trend, you make some small models and you say, okay, fine to reset it automatically and then you put a counter the two, three time it happened, then of course you need to send somebody in, but they are they are progress. And that kind of progress, diagnostics happen a lot and it saves a lot of time for everything and maybe on. So it is quite easy that you can drive, you can reach in. Ofcourse It's quite difficult and and especially the weather is better than turbine can stand for many days actually. So in that sense it's quite critical and also the progress. It is quite commendable, actually. I mean, last year, based on experience, learnings, a lot of things happened. But now we are. Now the question is what is the next step, actually. And the challenge in the next step is we like mostly none of the products to be products changed so fast the way the wind turbines are changing. Like every two years, three years, new product and new product. So that's another challenge too. Because your focus goes on the new product, right? Better technology and designs. And they are the old fleet. I'm sure enough data will be there. But then maybe some time could be spent to see what they could bring on that because of time, what we do, what we do, what we know. Right. But there could be an opportunity where something is obviously not seen and the old fleet could be an opportunity. Unfortunately, when you keep changing the product, the nature of data also keeps changing actually. And I don't know how to summarize this part, but I could say that it is a huge opportunity. But somehow the race to make new and new turbines, this opportunity is less utilized in the wind industry for knowledge. And then the second part is the design part. But since you make sense, you put the turbine in a completely uncontrolled environment, then you have to follow all the standards, which covers all extreme scenarios and everything because investors are putting money not for AI, right? I mean they, they just want the turbines were designed for 25 years and it's a safe really don't care I mean what

technology is behind it and they are the standards and then you are third parties that all the design is according to the standards means it with sustaining to live like you have a probabilistic in 50 year. What kind of storm can come, what kind of wave can come in the regular scenarios, what kind of people can come. And so there are a lot of standards and you have to comply. And when you comply, then your product is going to be expensive. And if you want this to be a solution which is affordable everywhere, especially the countries which are not so rich. I mean, it is quite okay to spend the money, but if you want to go there again, I will have a bigger role to play. And I would say we are doing a lot of things. There's no doubt about it. But in quite early stages, because it's the when you put a rule, the rules are said to be a strike. I mean, you can think everything can happen. Same time, actually, a great big example. They are this morning's discussion. Let me think about this one. So you say, okay, if I fear that your normal operation is consuming the life and then there could be a 50 year extreme event that can happen. That happens in 50 years. But we need to design that. I mean, you design the players and everything for that. Those things, in fact, they are, I think, designed for 200 year extreme events to extreme event can happen and what is the probability in last 50 year? But that can happen any time like you put it in the next state. And so you design based on the rules and standards and then it becomes bulky and expensive, actually. But if all these standards started using the AI to say, okay, what realistic I mean. I mean, they all are. When I then the. Yeah. And then you cannot afford it. Like, I mean the perfect storm doesn't exist. It's just a myth, actually. So what is the acceptable limit? Because all the standards you put also, then you put a safety margin on everything.And then like, suppose I, I say, okay, here is the load. And then I, I say, okay, but I'm not certain about it. So safe to put a 35% safety margin, then someone will take that load to, to develop a component. And that component needs to have the capacity to match that load. Right. And then design the component and say, okay, there is a lot of uncertainty because of applying light of air bubbles in the steel and blah, blah, blah. Then I will also put in 35% and then I say it's fine. But those uncertainties which you are just assuming and of course designing, they all have an opportunity for air actually. So it means that the supply and production, if something is there and then how you cascade it together to make it, it's quite complex. It's not something you can see in the near future, but definitely in the far future. I see those things playing a role to make the wind more affordable, cheaper, and lighter. I hope so. I gave you that sense.

Speaker 2 [00:16:40] Yes. Yes. This was a super interesting possibility to me. Honestly, that was it. Everything. Thank you so much for that. Okay. So the next question is, if you think organizations are investing within themselves to bring this kind of change. So this could be in terms of upskilling their own employees, upskilling, reskilling their own employees, or are organizations completely dependent on third party organizations to get experts and building in-house capabilities for your technology to come in on How do organizations prepare themselves for this transition?

Speaker 1 [00:17:18] I think the last couple of years this has picked up even more as a corporate strategy that it is something like maybe five years ago it was a bunch of old foreign hardware kind of companies like us where we play with so much hardware and fiber. But last year, I would say a 2 to 3 year strategy is being executed and is getting focus actually. And I can only speak for so many companies, but there are not many also. Yeah, but I can see at least in our side that we do recognize the value. Yeah. And the question is always like how fast you can move and how much opportunity you can see it.

Speaker 2 [00:18:16] Yeah, that's true. Okay. Okay. So there's some questions on data analysis that I have. I was reading about that. A lot of data is collected through sensors and the SCADA data and everything. But do you have any idea on what kind of data is collected? Is it like wind speed, wind direction? Yeah. How is this data really collected and understood?

Speaker 1 [00:18:46] Yeah. I mean. So there are two parts, right? One is very basic data like you have in sensors. So when a sensor is measuring the temperature outside of the turbine, speed and turbine is operating, but that's very basic. I think it is typical and I don't want to put a number because I don't know if it is too internal, but I can give you a range. Think 300 to 500 census data. Many like temperatures, accelerations, and speed. So I think the data is quite huge. It's quite rich data and. It's a little bit funny because sometimes you take it as and then sometimes you start looking at how we are spending a lot of money to collect the data. What are we doing about it? Yeah, because then you need to justify it, right? Because how long you want it is stored and stuff like that. Yeah. And time. That's one thing I always opposed internally. Like. It's a very general nature. When you get a pressure on the cost reduction, then people start looking for low hanging fruit. And sometimes you say, Ah, this sensor may not be needed because we have seen we always designed for our full capacity, blah, blah, blah, and we got desensitized. And I always oppose it because this is something like it cannot compromise the data. And of course then somebody argues that what we have done in the last three years is data. So yeah, those I think will answer it. The data collection is quite scattered in the wind industry, and almost every component is critical in terms of either the safety or the operation point of view. Most of them have sensors and they get connected. Yeah, I think maybe after the year or some of them are. A fast log or data like event happened and then last 30 seconds. Very high frequency data is collected. And of course, that will be over rewritten because you cannot afford to store such high frequency, massive data. But if an event happened, like a trip or something happened, then there is a high frequency data is you there? And diagnostics and prognostic teams use that data. If something is not obvious, then those high frequency data and typically like in the design, also some time we use for root cause analysis and stuff like that. So yeah, and I think we are much richer from a data point of view than any industry at any event talking about energy based industry.

Speaker 2 [00:22:10] Okay. Yeah, perfect. And now that we're talking and there's a lot of data. So like, what kind of skills and human skills are needed for making sense of this data? Like, I'm just trying to understand what kind of skills do people need to have to enter into the wind energy industry, since that is a lot of data. Is there data analytics as a theme going to grow or, you know, machine learning? Yeah, the kind of skills people should be having for this.

Speaker 1 [00:22:46] Yeah, I can. I don't know what would be the specific answer, but one of the challenges I can tell in this area and I started my career as a prognostic control engineer, actually where I used to play with a lot of data and analog data, to be honest. Yeah, And one of the challenges with the data and black box models is if you want someone to make a decision based on that, it's really hard for some of the area guys. Now I'm in there to cross my forte to trust that actually and say, Oh, and then slowly what I learn if I take that phase where I had a hard time to, to convince anyone to change the control algorithm. Yeah. Based on some of the analysis I did, it was hard to convince anyone like, I mean in an offline diagnostic is fine, right? I mean you can so a lot of plots and followed up and and this all ten nine is kind of signature but do you want to implement in real time to do something it's always hard and over time what I learned that if you have a profile where you have a domain knowledge and the capacity to to analyze it, and that's quite rare, either you know, to analyze the structure or, you know, to play with the data. And that's where I see some of the guys I remember. They were like mechanical engineers. And then in the research area, they spend a lot of time in AI. And they were quite successful, at least when I was mentoring actually, because then it's easy to explain the one sided challenge, right? I mean, because I'm and in the computer you see the blade looks like a three inch long right And but in reality we when you make when we think of changing anything we we literally many times it takes up the consequences of so big. So when we sit down making very small decisions I mean many times six and many days is just it. It's the mind. I made the decision. Hope so. So there is a huge difference between the people who analyze the data and then people who actually make the decisions actually. So somehow the domain knowledge and the analytical capabilities come together that could be a win win and could be accelerating.

Speaker 2 [00:25:53] Yeah, yeah. That's really interesting. I actually just, I don't think.

Speaker 1 [00:26:00] A simple example is if you talk about structure I will say okay I mean a lot except to such extreme conditions and if you are going to hire a guy for him too. It just is, is a number. Right. And the view on that to me is quite different.

Speaker 2 [00:26:22] Very true. That's very true. Yeah. I think that's a nice answer. Okay. Okay. And then since we're talking about a lot of data here now that we have placed in Denmark but also otherwise also I was wondering what are the ethical implications of having such huge amounts of data like in Europe, it's in GDPR, so there's a lot with privacy and protection of data. So yeah. Do you think that in any ethical considerations and if organizations are doing something about it actively?

Speaker 1 [00:27:04] I think it's not someone personally that it's turbine operates and it definitely the risk is very high if data is compromised in the real time because then somebody can use it for the stock market manipulations and stuff like that actually. But cybersecurity plays quite a big role because if you know exactly how this farm is behaving and then you can speculate on the stock market, although the next quarter result would be I mean, imagine someone posted all the operational data, then they will know how the next order is to be in. And so the cybersecurity is quite critical. The past data I mean, it's really not personal data, it's machine data. Of course it's intellectual knowledge and stuff.

Speaker 2 [00:28:04] I get it. Yeah, I was just reading some of it and I'm not sure, but it said that this data also can help to understand how much energy is consumed by different households. So that's why it could be personal data. But I'm not sure if it actually happens in business.

Speaker 1 [00:28:21] No, I mean, that's more the grid data like the not the turbine data, because the turbine is producing and sending to the grid. But when you look for a more smart grid where you want to know which house has produced, consumed, how much, what time, yeah, they, they could be a little bit different. Yeah. Because then you can balance the greater how you want. There's far more for those guys actually.

Speaker 2 [00:28:48] Got it. Okay. That's for the grid side then. Now. We were talking about how you should many people could not trust systems to take decisions but do you think it's in generally happens they did a lot of manual checks also happening in certain machines or decisions So for example, if one machine sees that this one turbine needs maintenance and operation, so you just go on the decision of the machine or are they still human beings involved in re taking this or. Yeah. Is this based on machines?

Speaker 1 [00:29:33] This is quite complex right now, but I'll give you one example. Maybe. Let's say the main building of a wind turbine, you made a great algorithm and it can detect the part. Now you need to replace it, but then you need to know when to replace it. What is the lead time of buying those components and. It is quite manual because yeah, once you detect a failure, then of course basically you are triggering the risk for the shutdown. And then after that it's quite more or less quite manual. To someone to look. Borrow scope and specs and stuff like that. How big the risk is. What exactly? And that is the one of areas like one could think of, at least I think of a strategic point of view that the approach should be. Knowing what is the lead time. And then you put your requirement that how far ahead in the future you predict should be. No, it's still it will never be 100% because so it depends who brought it. So I don't think you can take out human interest and of course you can minimize it. Yeah, but that will always not matter.

Speaker 2 [00:31:21] Oh okay. Yeah. Now that we were talking about this, it takes data and everything, I was wondering what are the kinds of challenges that wind energy organizations face with the coming in of A.I.? Maybe this could be like the need for more technical expertise or funding or high installation costs. Are they major challenges or like roadblocks that are witnessed when new technologies come? Or is it like a smooth transition?

Speaker 1 [00:32:01] From a resource point of view, it would be a challenge and it is a challenge. I mean, you can see it solved in Denmark. Yeah. Though the teams are becoming more and more global, there are a lot of resources in India actually. I mean, so there is no quality to people like you who have a talent and a step up. But the challenge is the experience, actually. And I think I repeated before that without experience. It's very hard to understand the numbers, actually. Otherwise, it is just a black box. And in products like ours, in the industry, you cannot use a black box. And it has to be part of it. And that something AI has the tag of a black box. Yeah. And somehow that is the bottleneck also. And that bottleneck could be only broken. If experts have domain knowledge about the product, Then they will find a way to make it a gray box rather than a black box, which. It was never going to be a white box, but. I remember when I was working and some of the to finish say we really don't care, we want results and now I understand what results means something you can you can fundamentally trust. And there I see. Like I'm saying, resources in my domain. In B2B business especially, it's always you. You can take your credit card debt. You can analyze. You can. And out of a thousand, maybe 10% fails. It really doesn't matter. Like in the insurance business, that's how they work, right? I mean, they collect €200 and you are working on such a big product. Every one individual product matters.

Speaker 2 [00:34:32] Yeah.

Speaker 1 [00:34:33] And and they are the confidence level in two sense. One is what we predict and second one is. How do we believe what could predict is right this to our. Yeah. Quite critical.

Speaker 2 [00:34:49] Yeah, that's true. Yeah. I've been reading a lot about like and black box and how, like you said, it's so important to have the domain context when you're using it. So, yeah, that's exactly what I was. Okay, The next thing is, you know, you based upon it briefly, but I was trying to understand, like whenever we talk about new technologies coming into any sector, we say that they start impacting human employment. Yeah, human labor force. But yeah. Do you see this happening or do you see machines taking over a lot of human work in the wind energy industry, or do you think it's still a transition so humans will continue to be involved in this industry and just supplement the knowledge of the machines?

Speaker 1 [00:35:38] I don't have any black and white opinions about this. But what I believe, and especially when I look at India and the West, especially Denmark and Denmark, I mean, if someone will come to cut the grass, they will come with the machine. Yeah. In India, we will have 500 people coming there. So if you keep 500 and then you buy the machine, then you would have to think about 499. But what I see naturally, what happened. You. You prosper, you automate and slowly your population also gets to be creative. And because then people are really busy, they really think about it. I would argue that this goes in a completely another direction. So I really don't have any opinion, though I believe the automation is also a sign of prosperity and respect and being actually like you can have 100 people tightening the bolt that are. And those 100 people do something different. More valuable things. Yeah. And I think society figured out itself, on what would be the most valuable things.

Speaker 2 [00:36:59] Yeah. Actually, I was also reading about this in one of the research papers we were talking about. It's not that humans will be out of jobs completely, but maybe, like, the redundant part will be taken over by machines, and humans can invest more in the creative aspects or like the design aspects. So maybe there's like a shift in how skills are approached, the reskilling, but not completely wiping out of humans.

Speaker 1 [00:37:23] Yeah, exactly. I mean, I know this topic comes up and I give only one example. Yeah. That when we were like hunters and gatherers, we all were busy finding food. But all we did was find food, actually. Yeah. And then we figured out how to do farming. Yeah. And then we got extra resources, actually. And then we started thinking, Then we've got time to get free. And then we figured it out. So if you think in a very short term that tomorrow I build AI models, it automates what I'm going to do with these 500 people. Yeah. Yeah, that could be a question to ask. But if you are looking at how society will evolve in 20 years. It will be going to help in a positive way. Yeah, because then people will start thinking.

Speaker 2 [00:38:20] That's such a great analogy. Actually, I never thought about it this way. I think I'll always keep this example in my mind. So this is. Very interesting. Okay. The next is more on the future side of where this industry is going. So do you think there's a growing competitiveness among different organizations, even though they are not a whole lot in the wind energy industry? But do you think there's a growing competition in the terms of adoption of technology or the use of new technology? Maybe we're talking about digital twins now or floating offshore wind turbines. So you do see a competition amongst organizations for approaching these technologies.

Speaker 1 [00:39:13] There's always a bit there, right? I think the good thing about the wind is that the wind is a non-traditional business. This has started where people believed in something and then they started of course, it's a commercial, so. You need to have a balance, because when you want to ask everyone to build offshore, there is money and then the cost of the money depends on the risk on the business. The cheaper the money you get, the more you can do and more you can do. If somebody will put their money cheaper because higher risk is higher gain, you want to know what that's like? You cannot make offshore farms so big. Money means it is safe. And that challenge comes when you introduce a new technology that always takes time, but it never is a bottleneck. If there is a need, then it comes automatically. So and then there is not for the wind. Also, I have seen more or less I mean, in aviation business, if you want to change something some time, it takes 20 years to change because safety is a concern here. It's more the risk is concern because you are putting something in an uncontrolled environment and. But I mean, I don't see it, to be very frank, that if something is really useful or makes sense that has any kind of competition to enter and just felt like it started. How much? I mean, I have never seen any industry which has grown in changes with the different technologies, new technologies in the last 11 years.

Speaker 2 [00:41:23] Okay.

Speaker 1 [00:41:24] And I'm not talking about mobile devices and stuff. Yeah, of course. I mean, the risk profile is too low to change it. Yeah. Yeah.

Speaker 2 [00:41:30] Yeah, that's true. Do you think organizations themselves also invest in research and development for these new technologies, or are they just. Yeah. So is that in-house research and development also that takes place like maybe machine learning models are developed in-house, or is it a technology that's mostly acquired from outside?

Speaker 1 [00:42:04] Let's put it this way. I think all the wind industry for talking, they are highly experienced in the design. And I think everyone has some form of technology development for research and development because you need to be mature enough before you put in a product, actually. So a lot of pre-work and a process happened, and the use of digital technologies research is also part of it. Only the question is the applicability. Like something is obvious. There are obvious values there. There I think it is a part of such a thing. There are no obvious values. Or maybe you can say it's not related to the product. Like maybe that activity. Then of course you want to buy from Microsoft that you want to outsource things to because it's just a matter of productivity actually that automates something in this conflict. So the non-critical non-product related automation is stuff they outsource, but IT product related end in domain really need the domain knowledge. And again, I already said it's not a black box. And that's our ramping up, of course, is the new. But they are picking up.

Speaker 2 [00:43:32] Okay. Perfect. We're just approaching the end of this, last two questions. The first one is, do you think government regulations and policy measures can play a big role in how technology is brought into the wind energy sector? And maybe this is in terms of safety standards or energy efficiency standards, or maybe governments can push for more research and development funds. So all together, do you think policymakers have a role in, you know, in the technology adoption by wind energy industries?

Speaker 1 [00:44:15] I think there is always a role. But, you know, I mean, the policy has more of a role for these startups. The start of this like when they really started and subsidy was a yeah. A big role to build a supply chain and stuff and now capitalism is picking up. So when you start something is not mature or the commercialization is not mature because you have many suppliers, everybody has to build and the government has a big role, no doubt about it. And. I think. I have seen less in Europe. You see? I can see a little bit and. It could be like the next phase of this. Then your growth is like a ramp up, right? I mean, 10, 11 years ago, you start to make quite big, big numbers. And some time the funding comes, I'm sure. Yes. I don't know, specifically or maybe I cannot park a specific actionable figure.

Speaker 2 [00:45:41] Okay. Yeah. And last question is, what do you think Is the future of technology or in the wind energy industry? Maybe it's in terms of detection, making the time increase for organizations and being able to better predict faults. Maybe maintenance happens completely autonomously without human support. But yeah what kind of future potential do you see?

Speaker 1 [00:46:11] Yeah. How to use air to make a lighter and cheaper design. Yeah. Of course, one can argue about the materials and all this stuff, but I am talking more about AI based design and environmental conditions. So you are not designing something like everything is standard deviation. That's what happened in all this. You cannot handle so much data. So you said and here the average confidence interval and I need to design for this 99% confidence interval. But now you have computers. You don't need to think about everything. And 99%, you can take all the time to the data and make it something that looks. And that's where we call the file and then relook those standards. Does it make sense to design for a confidence interval or something different? The new requirement will come. So basically, the defining the requirement for the standards is standard requirements. It should be driven by actually the second part of how to utilize the best turbine performance during operation. I'm not talking about maintenance, I'm talking about performance. Right. And it could have many parts like. You are producing when it is needed, and because you're designing something 25 years of your lifetime. Every enterprise at this point. But when you have enough wind, I can give you a simple example. Like in the countries where there is no subsidy, like the Netherlands, which are subsidy free. If you look at the electricity price in it now, it is more or less not in its early morning. When wind is too high, then basically everybody is producing a lot, so there is no electricity price. So I had to produce quite a design for that actually, so they could play a bigger role on their side than how to utilize the turbine in the best way. Actually this commercial. And the third part comes of course are the maintenance part actually and maintenance when you say the wind turbine has. A huge opportunity for AI compared to the gas turbine industry. A steam turbine industry because you have one steam turbine that's producing 400 megawatt. But here you have, like, hundreds of turbines. Yeah. And they said that you have quite enough data to make a confident decision, actually. Then if you compare with the gas turbine I this time to go to 1 to 1. So definitely you can reduce the maintenance cost significantly by better predictability and a high confidence level that utilizing those fleets actually takes this. You don't have only one term anywhere down the line. I foresee that AI will have a very, very big role. Yeah, more or less I see the data. Yeah. The rate of growth is high. What matters is how you use this data.

Speaker 2 [00:50:32] Yeah. Okay. Perfect. I think these were all of my questions for now. Thank you so much.

10.7. Appendix 7 Interview 6 Transcript

Speaker 1 [00:00:00] I'm making a recording of the discussion here.

Speaker 2 [00:00:04] Yeah.

Speaker 1 [00:00:05] Okay, perfect. So, okay, let's begin with the first one. I want to get an understanding on if you think AI and digital technology in general is accelerating our drive towards environmental sustainability with the wind energy industry. So like,your thoughts on that.

Speaker 2 [00:00:27] Mm hmm. So there are various ways in which this technology has evolved. From a wind energy background, let's say that earlier, the wind turbine technologies had a vibration analyzer vibration condition, which didn't have much AI embedded in those systems. Even now, a lot of companies don't use too much of thi.. Now, when we speak with OEMs, like all manufacturers still buying technologies, they realize that. Yes, because it's not some of the companies that are the OEMs, they have their own in-house data and it seems some of the technologies are outsourced outside the company because they have to have a healthy competition between suppliers.

Speaker 1 [00:01:18] Makes sense. Yeah.

Speaker 2 [00:01:20] So one of the myths, as best as I heard, happened to go in the month of January this year to meet the conditions monitoring team of [Company 5]. Okay. So they are doing around the clock global monitoring of 30,000 turbines. Well, okay. So that's probably one of our software that is also being used for them to monitor just a fraction of their turbines. So. Okay, I can give a background in that whole technology before and after this like the system when it came into use. So previously, when in vibration analysis, what used to happen was they would not even in turbines in general in space, like in industrial space or any space, they used to carry a, you know, a box on a foot. We would just like carry a suitcase, a small suitcase like 20 years ago. And they have to go in the center of a wind turbine, come back and then transform that data onto the software on the computer, and then do a fast fourier transformation. So, you know, fast fourier and those kinds of technologies are very similar to fast forward transformation, also just in vibration space. Okay. So they do at times in data collection of the program and then transform, especially if you see a point from Rotary, they would typically collect all the main building data, gearbox data and generator data. And then they will do all these time series and then change it to fast fourier and everything was done manually. Well, okay. 20 years ago. And still some of the companies are doing that. Still, all of their very old technology companies will give this technology to Internet companies and they are not molded or AI based. So and they are getting now what is it by the market? Because obviously I know what's happening. Yeah. So I can tell this transition what is happening in the case of this OEM, which is employing 30,000 turbines, having this technology. So these vibration based companies now, they started realizing, okay, it's not organic, it is giving now, you know, from the manual based now they started doing more sophisticated software based where it is reducing the time for an analyst as an engineer to do the analysis or perform less time on the computer to know the decision making process. That's what has been there in the last ten years. But then this was even before machine learning was implemented. So it was based on 80% efficiency. Right now, that 20% efficiency starts kicking in because of the scale AI based. So, so what has happened is like, for example, now let's test this case. They have 30 engineers for 30,000 turbines. Okay. So they are trained with four different software. Looking at all these 30,000 documents. That's what we came to know. How these guys are monitoring and working, because we were also looking at what future road mapping is like, how these OEM companies want to move. So there are companies like Microsoft Azure, all these things. They also started using energy based technology to harness data. Okay. Yeah. So there are multiple things. I'm only now focusing on the vibration side. Yeah. So [Company 5] is also one of the companies which implemented machine learning and AI within vibration based monitoring. So there is a big difference if there is no way. And that is. So without the AI for all these years, you are able to detect a windmill failure maybe six months or 12 months and or don't even based on the sensor technology, it is even going to be big for them. But what a model is doing is collecting the data in order to solve it all at the back of the software. It is also trying to see which are those turbines, which tells us even more, but it is also having similar kinds of things. For example, bearing manufacturers themselves are using AI in this format like they are trying to know globally where they are bearing sort of the same make or have income that's coming from the same batch. So they are using this technology to improve the design. Well, okay. So that is really helping. The other way is, for example, OEMs. Okay. They are now using AI technology to see, okay, how to improve the turbine design reliability. So that's where they are going. But then it started. The end user needs to have an AI knowledge. That's the guy who created and put that software behind. He's the one who's actually driving it. Like, for example, [Company 5] doesn't need it in the order. In this case, you know, people who are coming from data background and part code or engineering background to have any upskilling. Okay. For example, these days most of the companies are asking if you are a wind engineer that you should also have a knowledge of Java or Python programming. That was not the case earlier. So libraries and engineers are like they need to look, for example, in [Company 5] itself, you know, we have a data analytics engineer like, you know, who's sitting with us. But yeah, he's, he doesn't have any background about wind turbines, but then he knows the knowledge about how to use data analytics to know what else to look for. Uh, okay, so they're saying where to say yes. For example, our principal consultant in their core engineers, they know in a note of the behavior pattern, the only thing additionally with AI is that okay, they try to know the prediction models and what exactly this a science behavior model ought to be. And then they say, okay, can we get better results out of prediction from ML methods

Speaker 1 [00:08:16] Got it. Got it.

Speaker 2 [00:08:18] That's the difference. Okay. It's not like it is giving something out of the box, something new that people don't know. The only thing is decision making capability across different locations for the same component, you will have a better, bigger picture with AI. Yes. So if a person is like, let's say I'm not a data analytics fellow at all. You can do a bit of a prediction in the Excel sheet as well. Yeah. If using an advanced Excel sheet, if there are people who are doing cool things as well, then they can go to setting regression models which is being spoken about in the cases. Those things don't exist in what is an actual Excel sheet based stuff. Yeah, so that displaces the person's competency over time. What happens all being 5 to 10 years time they would expect in SCADA engineers to also have this programming knowledge. So there is a technology solution. Companies like [Company 5] are bringing in this expertise and at the same time we are seeing Oracle hiring data analytics people only without even any knowledge and they are paying a very high premium price to them. So we are seeing for example, we have our generation company which has got hydropower, wind power, nuclear power, you name it, like there are companies like EDF. Yeah. Or there's a company in Australia which is known as [Company X], which is a private based company. Okay. Now what we saw, they were owning thermal coal assets. They are owning hydro assets and their only alternative in IT and also solar methods. So what these guys started doing this has been ongoing on it. We are building an open source platform within the company so they're already there and its engineers can map all the sources of power. Okay. So they are doing the analytics in what they don't want specifically and. Mm. Just for wind turbines.

Speaker 1 [00:10:29] Oh that's interesting.

Speaker 2 [00:10:31] So they were building that and so it is hard for us to sell anything as a technology solutions company. They may just or could take our software, maybe use it for a couple of years and then they will build up their own software. Okay. And this can map them like that. So it's very hard to pivot the other way to as a solutions company, we have to see whether what the customer is trying to do. Yeah. So yeah. So if I could say a company like that kind of power generation company, yes, it is increasing its footprint of data analytics to know how to reduce this operational cost and all the stuff in the long run. Yes, it is becoming that our customers are realizing this data is important. Okay. Okay. So I gave a long answer.

Speaker 1 [00:11:21] That is alright, but I think you also cover different aspects of the domain. And so this was like a very nice start to it. So just picking up from it, you said, like you said, at least traditionally you could predict the fault, you could predict for six or 12 months in advance. But do you think there is a significant reduction when AI is introduced and how much like what kind of an estimate before? You know, of course with AI systems is there now.

Speaker 2 [00:11:51] For the go directly. And so it is hard to only inquire, with the person who has first hand experience on this can give that and so because I have not personally used this. Say, okay, that is what is the difference between this and that.

Speaker 1 [00:12:03] Okay, so for now we can just say maybe it gets reduced, but.

Speaker 2 [00:12:07] Okay, yeah, it gets reduced. Yes, definitely. For sure.

Speaker 1 [00:12:09] Okay, Got it.

Speaker 2 [00:12:11] And oh, okay. So then it's only vibration space. This is like that case in terms of detection of only things. For example, if you put a what's it called, blade damages stuff or even those stuff. So, I think earlier I explained to you that the meta analysis was not so important. No, image analysis has become so important. Yeah. So you could see that pretty soon. But they're told they're using it. They used to go and one person used to go in, take a picture on a good bright day at the ground. Yeah. And then try to imagine what is there trying to find something. What happened on the blade even before the drones were there. So now the drones have drones. Camera has become so special that it is detecting. Okay, what's my size of the crack length and width thickness? Okay. It has gotten to that level. So it also has a detailed heat sensing capability as well. Okay. Okay. So this difference of a normal cameraperson taking from the ground, trying to find something out of the room to the normal condition, everyone, it's a this one was a rapid change or, you know, but still it's not like it. Companies at what is a shift because they haven't seen the business case for the management. That's what it is they're thinking, okay, one person is losing a job. Yeah because a drone can do eight turbines a day and an average in a day. But for a person it will take at least three days, maybe three turbines is the maximum. That's what they can do. So because he has to drive through the wind farm and then properly take it, all the three blades are not in the same position as he is trying to do that, correct? So there's a big difference in the way in which they are processing. It's much like an Excel sheet method to convert to advanced data analysis. What is a supercomputer? That's a radical shift that the drone is making a change. Yeah.

Speaker 1 [00:14:26] But like you said, the drones are coming in, so maybe, like, there's a cut down on human labor employment when it comes to these things. So what do you think?

Speaker 2 [00:14:35] Is it affecting definitely. How, for example, let's say, let's say that our state is that you own the company which you had her working for and if it is having just hired labor just for taking cameras to convert to maybe for drones doing the whole job and I'd. So there's a difference. Right. They will not try to say that. Okay, we are getting bigger and the people are okay. They have got to take it into the other kind of work activities they trade. For example, let's say that in a year of what they say, the operation and maintenance budget for, let's say, 50 people was this much there are now all this time everything is taken there. And what you said, the reporting, then someone has to review all these things. Is that right? They say that budget, let's say how 1 million gets reduced or something like directly that 1 million is going to be thrown. He's doing a much more efficient job. Yeah. With this number of people. That's true. Like if we see a big win for the team, which has got thousand plus turbines and you can't expect like 50 odd people to just go there and you don't know when the blade of the blade is going to crack. Definitely, yeah. By the time you cover the whole full scope of maintenance, right? Yeah. Yeah. So that part has to be taken in because when comparing where it is good and bad, it is bad, right? Yes, definitely. It doesn't mean that you are fatal. But drones cannot create that. There are drones. It is able to create that due to finding or finding this technology how to make the drone also repair the blades, that is it's still in the initial lot and if there are some companies doing that but it's not sold in very advanced and, well, mechanized. Right. The person still has to either bring the blade down, make a small makeshift shelter, and then repair the blade and then take it back to the turbine. So that part will never change.

Speaker 1 [00:16:39] So even though technology is coming in, there is still some sort of dependance on human labor.

Speaker 2 [00:16:44] Definitely. Yeah. So in terms of data analysis of such a large, let's say 100 turbine, 100 means 3000 blades.. So 3000 leads if I ask to be analyzed. So it'll take three, enabling me to be by a drawing. It's agreed to take 1 to 2 months. Okay, well, if you have to see, let's say you just put a number, it takes eight, 7 to 8 terabytes of data. Eight turbines per day, right. So if you see them, how much time does it take for 100 turbines? Uh. It happens per day. 200 turbines. How much time does it take?

Speaker 1 [00:17:36] Yeah, that's a lot.

Speaker 2 [00:17:38] Well, right. So there's a time because I don't see whether all these things are correct. Yeah. It doesn't mean the drawing is all automatic. As a person in, there is a person of a skill who is on scene in order to know how to operate a drone or even a drone has become so automated there is only a switch on a button and then get it back to the base. Hmm. So those skills are not like with all these like technicians or site managers today. Yeah. All they want is okay, where my criticality of the brain determines how many go into entering high danger of complete crack. That's what they want to do. End of the day, they're using the technology to make additions. The cluster.

Speaker 1 [00:18:27] Definitely. So, like you said, there must be someone who is operating the drone itself. So maybe we can see that the kind of skills that are required is changing. Like earlier. Maybe that wasn't a need for someone to operate. Could it nowadays be needed for people with skill to operate these?

Speaker 2 [00:18:50] Yeah. So even just generating employment as a young adult, investing in this kind of company saying, okay, let's take the drone, I'll be an entrepreneur, entrepreneur and then maybe hire a couple of people or might be skilled. Not only do they look at only one third of an industry, they also look at entity inspections of other industrial aspects where they can't reach those safety locations. Right. So that's how shifting technology has become a major radical shift.

Speaker 1 [00:19:22] Okay. And the other thing was about SCADA data. So I was just trying to understand how the SCADA, the data is analyzed or like what kind of basically human skills are needed for interpreting results from SCADA data. Just to understand how people can build their skills.

Speaker 2 [00:19:44] It's like actual operational data that any machine downloads based on how much the settings are typically in the wind industry, there's a lot of regulations or guidelines, and data is a must. Okay. As a veteran, I mean, you want to prove your certificate or buy a certificate. But then people are increasing that resolution based on the component or reliability. So typical scholar engineers who just Google scholar engineers. I'm just trying to see what are the role opportunities in what they do right. So in terms of people that are asking in the wind industry, what has got into Google, is that they do troubleshooting a lot of troubleshooting. So their troubleshooting is mostly electrical electronics and also operational point of view. So their background can come from being an electrical engineer who just can look at the data and analyze the trend and see what is the actual potential. That's how they do this part of business. So there are, of course, that have been written on a very nominal basis, like Oracle, all these software, big software companies have written the coding for [Company X] and it is their point of view. So for example, Vestas or GE or anything, they will give it to the factory, implement their guard system for the turbine, all the turbines. Every turbine will download the technical data, put it to the site server, and then from the site a vertical go to a maybe. I hope it should be sitting there within the country or outside the country. Right. And then there is see? How's the progress on that particular wind farm? How is the performance? Every aspect is looked at. Maybe I'll bring up a typical one because I only saw in his column. This is from his point of view, how different you and we were generating a report for the customer. There's a sample report. And what are the things that are typically looked at. So maybe I can bring that up. So that would be good for you to understand. The same thing is done. What's happening? The difference between technology bound companies to just our company. Like, for example, Vestas is having advanced algorithms as it is normal, so they are just selling it as a base and then medium and thing, something like that to understand it. So they also split the way in which they tried to sell a solution to the customer. Like I said, a package deal for the customer. So it doesn't mean that, okay, because somebody is doing everything there. There are two ways in which this has been dealt. One is what is a detail, the raw data which is coming at the source. OEMs have their own software and can pick it up and then perform. So the customer base for that maintenance as well. Okay. That is one option. The other option, like big companies like BP and all, all these companies, they said we are not in distributed oil, the activity of this performance. You give us the raw data, we will have a third party data software and we will analyze with that and we will, what you said, dictate all the performance of data by country. Oh, okay. So that's how the companies are moving. Okay. That's interesting. So in most of Europe and as well as in the U.S., the companies are like that. They don't depend on the OEM to tell them about the performance of the wind turbine.

Speaker 1 [00:23:51] Oh, okay. That's very interesting.

Speaker 2 [00:23:53] So that's what I came to note from my. There is a company here, Those customers in Australia. In Australia, what's happening is there are energy companies or independent power producers, but they don't do any of their own work to actually buy them. So they just give it back to OEM saying that, okay, you give me tell me what how the companies performances. So what they do as a contract agreement is every month we have asked us to or anyone they have to give a monthly report on decommissioning of how the performance of the report to the right. So customers may have a little bit of understanding or they have an expert, maybe one or two. But then it's not like in Australia, people don't have such a background where they have worked with an OEM. But they have been very specialized design, tired or extremely scarred. It is hard to judge. Okay, your performance is wrong. Cross questioned. They just taken a low risk model. Okay. Give me the performance. Like a report already said, they signed a deal before they're going to start operating, say, or get a letter or anyone will say, Are you willing to put in 90% over this? Hmm in a year? So that 90% availability better by but in the we will look at everything is yes it's going to put a turbine can be switched off one turbine in a whole wind farm can be switched off for a whole one years till the whole wind farm performance is negative. Okay. A turbine 90%. They become 90%. Let's say three turbines are still not performing. The 90% is still guaranteed. Yeah. Right. The cost of that, you wouldn't any. Would you say that a lot doesn't affect the wind in any way. Yeah, that's true. And even the developer who is what you say, if three turbines are down, one megawatt is lost. So three megawatt is lost for the whole year. No, three megawatt per hour is lost for the whole year. Right. All right, so there are eight. So how will you know that the calculation eight doesn't own 60 hours in a year? If you take that into the three megawatt hour so that this amount of energy is lost as compared to customers point of view. So that loss is what you say compared to the rest of the 97 turbines. They're still making a good amount of profit to the customer. So then they don't bother about this. So there's. It's fine with that. Yeah. Yeah. All right. This is also a lost hundred turbines. Yeah. This is. There are more turbines. Exactly. And then. Then the problem is. So this is what i said earlier.5 to 10 years ago, there was a difference in which this energy was assessed from the start up. There's something called time based energy availability and energy based availability. Okay. So time based availability was a constant in the income stack. How much time the turbines were present to how much time they were absent? This was the scale of the ratio they were judging based on time. Based on a record. All right. No overtime. What was happening was it was not favoring the OEMs. It was favoring the customer because based on the time when their strategy lost customers was pretty close to OEMs and that OEMs will struggle a lot to pay the more they have to put up because they started it or if it comes, it is already covered by OEM and IP owners. So what happens is that order to their OEM and the customers are dealt with for this amount of money time which has been off. So they put a penalty clause against you. Right. So even though there was sufficient wind there were a big number of cases where the turbine was switched off or all those things. Everything, even like a wind turbine is virtual for a minute. It will get captured in Scotland. So at that level they were able to track down. So what happened was we didn't realize that this is not a good business model. Let's shift from a time based to energy based model. Okay, So the energy based model was much like, okay, the wind has got to limit the amount of energy my turbine has got. It can generate energy very well. So I'm giving it an implicit guarantee. Okay. So they shifted from time to energy basis. So yeah. So most of the like still have not got away from the time when there are still companies contracts still there. Maybe in the next 10, 15 years it is still growing but all the companies have realized they should be shifting to energy based availability. Yeah. Which just only gives an energy boost of a little bit. They've got away from time-based analysis basically.

Speaker 1 [00:28:55] Yeah. So I think different companies are at different stages right now.

Speaker 2 [00:28:59] Correct. Correct. So that's one side of it. Oh I was telling something about how the current data report looks like. Mm. So I'm just pulling up. Yeah. I think sometimes when I speak a lot, it will be hard for you to capture technology. So do tell me.

Speaker 1 [00:29:45] No, no, no. If there's anything I will ask you. But for now, it's going very well. I also have done my background study, so I'm clear with all the data.

Speaker 2 [00:29:56] Yeah. Thank you. Right. Okay. Okay. That's all it is and this is what's happening. I was mentioning to our test engineer that they have their own software which is supplied by [Company X]. They have their own team as well. So they were maybe having it and they may not have any, but I don't even know the case is going to happen. So we were assessing and actually a is our independent service provider company who was using the OEMs software to do this kind of analysis. But what we found was that it was not so robust. So there are some OEM templates that cut out the software, but then the AI or ML was not integrated in that they were doing a typical layman shop, but in the compact order in terms of prediction that was not available at all. So if it was limited, what could have been is a different case. So our report or our software, what [Company 5] is doing, there are so many other components which are doing a similar job. So just put everything on the screen. Are you able to see the screen?

Speaker 1 [00:31:28] It shows that it's presenting. Yes, I can see it.

Speaker 2 [00:31:30] Okay. So when you see this table of contents, this is a recorder sample report generated. All information is connected to revenue. It's just a complete list of what is recorded and just for the sake of customers. So what we generated. So let's say we take our turbine survey, and on day one, we think that it will take at least 3 to 4 weeks to completely turn the data and get out this kind of a report. Right. This is a millennia based, embedded like, connected to an auditor which is sitting at the console. If it is diverted to a software like AI, then it will do something like this. Is there a difference in which the systems engineer would look from the software to what it is you are looking at compared to what you will look at this report definitely here and on the Google end of the day, orange would look like an orange. Maybe the taste of that orange is different. Yeah, that's a difference. So most of those emails and elements, they would say. What I'm saying is, as a layman, I don't know anything about them. And I have only been looking at a video by our wonderful presenters. Yeah, it's like they tried to put different kinds of regression models, prediction models to see which ought to be compelling. What you see predictions compile for that particular component. Right. And what you say, then come to a conclusion. Okay, this is my career. So that part is not any typical normal SCADA software. So typically they have not downloaded most of them. So what's happening just in the general business case, what does it say? That you have hired a data analytics engineer over this time to upgrade this machine learning? So they have to obviously judge that. And the customers, like, you know, are just like, okay, hiring, you know, you can't get a revenue. That's all they practice with the software is what? About what is normal of what they're going to put. Let me say that if I do a poor performance review. So all this is an automated one. So this is not like manually put in and execute or MATLAB, then compile it and throw it out. Right. So for a customer to sort that it already said I don't age in terms of looking at this gray area, what you see is a three sigma effect of the whole event. And then this particular gladiator to show down this red line turned underperforming third base. Okay. So this is against events. It was an escalation of power. What did you do? So typical. Apparently she can pick it up from them. So think of this system and what it is going to do. Okay. Yeah, that's true. So the decision making is a bit faster. But the thing is that it's also a shift. Whether the engineer is there and altering this or he needs to be updated, we have those opinions which we are doing. So for example, BP, they have interest in the reliability engineers or performance engineers, but it is not necessarily that they are also acquainted with this kind of technology. So we compared them one when we were giving the software to them. Okay. And then keep updating them once every two years there's a forum like that. What's new and all that stuff? Yeah. Okay. That's what is happening. So, for example, let's say this is a kind of a heat check. So this kind of thing is not typically something you can produce as often. You have to download compiled something, then you get this correct? Yeah. Yeah. You can do that in an Excel sheet also. But the thing with time, how much it takes to think of the rewards of anything. Right. So a person making this data automated becomes a sort of challenging thing. Making it automated is important, especially to the engineers. So what happened in this case is this customer said instead of me downloading the data every three months. It's like the data is not only for the last segment, it's a date of the last of 1 to 2 years of admitted data. So you can take 10 minutes every day and the data download is generating data. How much terabytes of data is sitting there? Yeah. Then you are copying the data. Get your right inputs and outputs. So this stuff, a normal engineer will take a look to find. No. So that's the difference that the AI agencies are creating. So this heat map will directly tell me what to look for if there is something red shift later. These are the ones which can see horizontally is what you're starting.

Speaker 1 [00:37:11] Okay. Here.

Speaker 2 [00:37:13] So if you see this is the base and this is a timeline. So what has happened from October 2018 all the way to June 2021. So zero to eight turbines are all good since it is the real residual. The residual is high. It is a red color. It is high. So you will see it. Okay, There is one more anomaly. Okay. So what's happening is that we are only not taking any data, but we are also comparing our role of conversion or loss, yaw misalignment and what sort of loss pitch. All we see is combined in the background to see what all the changes it is impacting. Like if you see our normal tradition, there will only take one component of that and the one and then you have some kind of expectation, okay, this should have been like this. Yeah, okay, you can do that. It's traditional, no problem. But the thermal technology, the trend cross-reference. Okay. No anemometer. All of the turbines have one turbo and see its own system. And then compared with hundreds of systems, result at the same time. Right. This is the beauty of the technologies. Yeah. So that's where the shift is happening. That's what I'm after. Like being in Nordics and seeing how they're molecular structure is looked at when they say deep dive or what's it called in terms of AI, deep learning. So it's like we're using thousands of data plus intensive data plus it's all called deep learning. So that's what my understanding was.

Speaker 1 [00:38:50] Now, this is super interesting, but I thank you so much, especially with this report and studying the heat map and everything.

Speaker 2 [00:38:57] And like this one I definitely want to share. That's no big deal. So this is a typical report which we are creating for our customers. So this is even I'm not sure what the actual report total looks like because they said it looks something like this and then they try to change the report like every maybe once in a quarter or every six months. Because once you have an issue like this, for example, if you see this kind of misalignment chart, what's happening is that you see some blue dots here. So there is something that's underperformance by a particular company. Out of just so much of the data that has been gathered. Okay. So we try to see these blue dots disappear all the time. It's not that. Okay? If we can, instead, we generate the same report again and again. The customer would be delighted. Yeah, Yeah. We have to tell that. Okay. You repaired your misalignment. Take your time and that or end of activity and see what's happening after the next day. Then they say, this is it for the year, they will be doing the same thing again. Yeah.

Speaker 1 [00:40:03] That's true.

Speaker 2 [00:40:06] And here's a case of a West Coast wind farm which isn't reporting. They're doing a monthly report on the theme in a Japanese location. This is because I got it in particular, sort of shared with me how it looks like. So it's a concrete build. That's what they call it. And this is a kind of data generating thing, 90% of it. This is what they have to prove. And that's the job done. So I've compared what we have generated. Let's see. You have to go on to turbine component delivery. This is all wind speed. It's all been conditional. Let me see if the content of this is a content report. Content. So what they're saying is, quote, greater than one prediction of your content time and between conditions, production, availability. So they are not going to. But what is a component? Yeah. So that's it. Yeah. So let's say one of the cleaner inputs, what they're trying to see. If you want to go to any alternative and independently, this is a must. So smaller turbines only have up to nine tables to have you do this in any capacity factor. I was calling because I think that I see it as, um, what you're saying, too typical to what our report is telling. But then you could see that I would see how many hours of working that are or whatever happened to, you know. So that is what the main difference is. If they haven't had one system, if they are signed up with the contract, then it should be possible that they should be in good shape. But then investors are very particular about how they deal with the customer's whole knowledge as it goes.

Speaker 1 [00:42:49] Exactly. So I think the customer also needs to have their own awareness.

Speaker 2 [00:42:55] Yeah. For example, we helped the other customer who was actually evaluating for this customer on a six megawatt platform because he was trying to choose the Vestas versus Siemens. No, he said that I am not happy with their response. One system, which was just by default, gives for. All right. What they said investors came back and for that is if you are saying that they are not happy with our condition monitoring system then we will increase it 90 from 90 to 95. Okay. No, the customer will be surprised because he has technical knowledge. Yeah. A condition on a big system which is just like a wiper on their car reduces performance of their car. That's true. Right? It's like a condition monitoring system is like a wiper. Yeah. It's a little super data and tells you what's happening nowadays. Some customers, what you say they went out and what you say is a closed loop system in the sense that if it senses something wrong or defect there's a detection anomaly in the behavior of the carbon of the individual turbine. They have their sophisticated condition monitors also they actually write. So in that case, maybe research is correct? Yes, it is trying to say that it will decrease turbine performance, but then we will be surprised when we say no, you cannot just be like that. Data is if the data you are not monitoring do not hamper your performance. That's true. So here to turn the tail for the moment, it is on sort of a little bit more and then it is so that you can put that turbine monitoring data out in a tender and you can get a company like [Company X] or any U.S. company and then you can do a better data analysis. Definitely, yeah. Okay, So there was a case here. And again, this was like in Las Vegas numerous times, one, one, two, and also in Thailand or somewhere in Southeast Asia. Okay. This happened to be one of our customers. So what happened was that this just gave them our own warranty. So they have an obligation for it. Right. So you said what is a power cord warranty?

Speaker 1 [00:45:13] Power of warranty. Maybe you could tell me. That would be nice.

Speaker 2 [00:45:19] Right. Okay, so let me pull up. So something like this power cord, which is in the name of the company.

Speaker 1 [00:45:26] Oh, okay. Yes, Yes, I have seen this.

Speaker 2 [00:45:29] Something you have selling your brochure, thereby really interested in your brochure. They will tell you what their power is cut off depending on their income. Yeah. Yeah. So this is a power cord of a wind farm cover that has been this. All this data, what you're seeing is 100 turbines ought to be able to. Yes. Okay. So what does it tell the green badge, what you're seeing or the yellow dot badge? This is an actual I.D. about this phone call. Okay. The dot that you're seeing this green is what has actually happened, actually, in good case. Okay. A normal case. But in some of the cases, what you've seen is that the turbine was not able to go up to the green here, but it had to saturate and the power wasn't going to work because not giving a guarantee who doesn't get caught for the same things in that location. Yeah, right. So based on the location at the same wind farm, same regional location, this power was not generating good power compared to the rest of the damage. Typically, in the oldest turbines, the laws shouldn't be identical. Okay. Here. All this part of what you're seeing is not a good power production. So what happened was that in the case of this, let's just everybody, just about two one half years ago. It was produced as per the screen. There is no blue and all these things. Right. But then what this problem was, what was happening is this threat, what you're seeing? It goes underneath this look all the time for all the campaigns. So you think that there is a marginal loss across all the domains? Right. That 1 to 2% difference was unclear. When going to look, you have 100, 100 square meters of land bought and then you have 4.1% in all aspects. So legally you are not actually getting the area energy. Yeah. Yeah. So there is water and that amount of money is also lost from customers. But the perspective definitely. So the customer didn't know that. So you think you're so blind to data saying that, okay, validate this data and tell me whether this energy loss is understood by non embedded components, which just didn't. So we had to put a case against customers instead of energy loss. They didn't tell us anything. And you said that this energy loss and so on and the customer went and bought a case against them in a court saying that this is not right, a turbine is not a thing. I have been to our customers or you missed giving me a guarantee.

Speaker 1 [00:48:15] Oh, yeah.

Speaker 2 [00:48:17] So there are loopholes in that if you don't know a person unless he's collecting or general money, it is not proactive. Then the old law of customer law, Lord of the Rings in this world will be like.

Speaker 1 [00:48:28] Wow, I never knew something like that existed, but this is so surprising.

Speaker 2 [00:48:34] Do you see I'm not pinpointing any customer. There is a product and there's a power of that sort of oil it should be doing. But then, for example, the [Company 5] can also reveal the design date of the turbine, the reverse engineering to know words about how the turbine was designed. Okay. If I take a screenshot out of this and do kind of a break up of this into a CO2, I can go through it, put it into an excel sheet and get to know that at night how much load the board each wind speeds up, how much the pitch angle changes behavior of the turbine in terms of its pitch because there's nothing I can go to that limit. Yeah. If you want an advanced understanding of having a turbine is. So my boss told me, I can say this data is not right or there is something that is being misleading. So that is in terms of design type pertaining operations, say this is where customers can get caught up. Yeah. Yeah.

Speaker 1 [00:49:53] Yeah. I think that it's very important to be aware of these things and not completely rely on OEMs.

Speaker 2 [00:50:01] Yeah. Yeah, there's a certification company. So they are also our, our competitor again in this place. They also generate this kind of data. So the main thing that I've seen, there are so many companies like that when you pull that out. I'm going to pull up a report of our competitors.

Speaker 1 [00:51:51] Yeah, that would be interesting, actually. That is what I was also wondering if this technology's also bringing competition in the wind energy sector.

Speaker 2 [00:52:01] So many of your competitors. But. Yeah. So if you see Siemens, you would agree and you will be in the spotlight because these are all on a hard list of competitors. Yeah. Again, Toronto on the left, there are small, small companies as well. In this solution they like especially something they can do, something to make out of temperature some little space. So there are some bits and pieces of pockets of their old recipes, right? So it's more cluttered like hundreds of plus companies that have invented their own way of data analysis. And they can see why people are saying, okay, I can do this best I can do even if this is one of the best, of course. So it has become a competition. But in so many places, the problem is they're just only doing the best. No one looks. Yeah, that's true. It's much like using the same technique with ten different chips.

Speaker 1 [00:53:34] Yeah, there's too much competition.

Speaker 2 [00:53:36] Yeah. So. Yeah. So there is certainly all the same data that is looked at by all the people in, in different. Yeah. That's the same thing that I'm seeing with what you say. The drawing based image analysis companies. So everybody having their own data analytics data engineers just put in place their image analysis alone. They're doing multiple other things apart from their portfolio. But the group company is okay, saying, okay, we have invested heavily on this. That's how they're doing. Maybe I have literally an access to this. You. I get it. So this is a dashboard of a razor blade difference, which is that this particular software is not on its own software. We have partnered with a company which specializes in tools, but only does. Okay. So what has happened is like putting energy is one of our customers, a big base customer to us. He's got four gigawatt plus turbines. Okay. And so what's happening is this particular thing is all on any Excel sheet. No big deal there. No big deal with this. The work we are doing is that, for example, there are, I would say, loopholes for this software. And let's say that this particular wind farm project rate has got to be €85 you had before 66, right?. Yeah, it's just from blade damage. So this is a typical blade damage category. Okay. So that 66 is a number of, I would say, different categories of disorder for so many statements. Okay. In that particular way, some high technology. So what a software business starts doing is. For example, let's say that there's got a particular security flaw, correct? The other configuration of security for us goes. What is my security for it? So you can. What do you say? Right or no? See, here, you're just choosing the trailing edge section type of maybe two different types of visitors. These for any number of different countries. Many things are happening in those 3 to 4 seconds. Now, if this is happening this year, it will be compared to the previous RNC, based only according to data, two previous years. Historically, they don't really know what is happening in the current quarter. The difference. So you have to make a correlation. It's not there is no point in having a data analytics engine or any melody. Yeah. Yeah. So that is what the differences are. So there are so many hundreds of companies which if they can do their own data analytics, they would think they are not becoming smarter. Yes, that's what the differences are.

Speaker 1 [00:57:25] It is super interesting.

Speaker 2 [00:57:28] Yeah. But at the end of the day, our goal for any big corporation is the decision making process. And reducing their own cost. That is what the ultimate goal is. The goal is like a lot of those people are saying what to do as he was leaving, but still trying to get a grasp of that. The last 17 years, I didn't have much time to look at what exactly and how it's impacting. The interim is a major term that has been used and judged by most of the customers. In addition, making managers at the top level to the senior management. I would have a conference on performance as well. Okay. Based on the budgets that are already cited.

Speaker 1 [00:58:13] Oh okay. I didn't know about this. Okay. I will also read more about it then.

Speaker 2 [00:58:17] Yeah. So look at it because any customer I could be like even or anyone is directly looking at the carbon it in terms of purchasing first look at what sells and is one of the key parameters when they are trying to roll in terms of financial modeling. Anything else. Always looking for the key stuff. Okay, cool.

Speaker 1 [00:58:38] Yeah, I would.

Speaker 2 [00:58:40] Assume and a lot of energy production is pretty common. Okay. Yeah. So they also use not only what they say, but the levelized cost of energy use not only for what they say, in particular for the entire industry. It can be for all other industries as well. Okay, so maybe I have one chart where slide on that can show that currently. Great. And yet. So what's happening? So this is a screenshot of [Company X]. They said the government, you know. Australian Reserve Bank. Reserve Bank of Australia. They had this kind of scenario. What's happening? So when stand alone housing prices are from 2010, $800 per megawatt orders become normal as $55 per megawatt. Well this is the price of selling the energy into the market. So the customer or trying to see if my turbine or the whole wind farm was to sell or make the switch about energy. How much in terms of dollar values, what that was.

Speaker 1 [01:01:03] Right.

Speaker 2 [01:01:04] Right. So that's important for them. So they receive a holiday in theory from the wind farmers and compared to the technology. So they'll try to decide whether they should go with the combined winds or something like that. That's how they try to see if they even make a loss of wind. They will be able to make the profits from solar batteries. Right. So that's how it is. Okay. Yeah.

Speaker 1 [01:01:30] Okay. I think this looks like a very important concept that I should have read about.

Speaker 2 [01:01:37] Yeah.

Speaker 1 [01:01:41] And, um. Okay. I think you've covered up quite a bit of what I wanted to ask. Just, I think about the last two questions. If you have time, we can cover up very quickly. Um, one is, what do you think is the future potential of A.I.? Like, already there's predictive maintenance and everything, but anything that you see that can bring a big change in the industry.

Speaker 2 [01:02:09] I think one of your questions is about the issues related to privacy protection. Yeah. Yeah. So that part we're not playing those years ago from the U.S. we're seeing in U.S.. Some of them in France are affected because of the cybersecurity. Yeah. So a lot of turbines are made to switch off from here. It goes. And that's happening outside the country. Like they say from outside the U.SThere are countries who produce the energy, the generation of the wind farm or be golden, and then they make a loss to the company. They were doing due audit. Our data was not so convincingly secure because it could be okay. It was more controlling. Our system wasn't that way. It was good. But then the worse thing was it could mislead the data. That sort of can happen. But missing the reader who's interpreting the results of it. Okay, So that way, that interference was a cause of concern. Like, the worst case consequence of all of this for everyone is okay. The turbine shutting down. Or making a carbon copy of your goals or make a change in the control system in such a way that they are not able to run to save the turbine, those kinds of structures. What is happening is that they are simply too late. You would have also even heard Vestas had a big outage. Yeah. Last year. Yeah. Major outage. Yeah. So that kind of stuff, you think? How much? Millions of dollars every minute they are making. Yeah. Data can have an impact on them.

Speaker 1 [01:04:21] Yeah, definitely. I was reading about wind companies that invest a lot of money or are investing a lot of money in cybersecurity. And also, like you said, even some of the data compliances, of course, did not meet their cybersecurity safety standards. So now they're investing a lot in making and making it compliant with, you know, their data security.

Speaker 1 [01:05:20] And yeah of course like thank you for the discussion but I. I was just amazed by your knowledge and experience all through. Like I really admire that and also your enthusiasm for like, all the topics you and I really admired and all this. But I was just thinking that I also want to build up my knowledge and experience like that. So it really helped.

Speaker 2 [01:06:00] Yeah, it's like what I'm saying is like cool engineers like us and like even before me that are my managers and all the ones doing all the coding stuff, all these analyzes. If we, if we don't upgrade ourselves, we would be losing easily. Like there are hundreds of people who can say good things about their reality. The only thing is if you don't upgrade our skills everything. You cannot find a space in the wind industry. Like a lot of engineers, we are seeing that they are becoming, even though we're talking actual knowledge, to try to build something out of the graph. That's what is happening. And companies rely on their thinking, okay, they're doing me the right stuff, right? Yeah, this is a big kind of a shift. We are not sure how that part is actually evaluated. Like to accompany people depending on data analytics. Gonna tell you about having a background of turbine knowledge. Yeah. Also in the industry. Even with investors also. So there's a they're doing this because of saving the cost.

Speaker 1 [01:07:13] Yeah.

Speaker 2 [01:07:15] Yeah. I'm not sure if you are, and I'm working with them in and out. Okay, so not like ten years or something. But even within two years, I was able to make out how their business model was. We were working here and I was part of their simulation team of mimicking the turbines in the UK. Okay. In actual physical lessons, science based physical modeling, like what you have installed. We would mimic that same thing on an actual incoming air simulation, even into the operational level. Okay. They are also suppliers to us. Right. They have a data analytics engine. And they are writing codes for us.

Speaker 1 [01:09:09] Okay.

Speaker 2 [01:09:11] So this is something people coming from a data analytics background are on the forefront of shaping their data point of view. Well, so that's the difference. This is like I'm telling 2016 when I looked at it. Yeah. Okay.

Speaker 1 [01:09:30] Nice. So you have experience across, like, major energy players.

Speaker 2 [01:09:34] That's very nice. Yeah. Yeah. Okay.

Speaker 1 [01:09:37] That's amazing. Okay. Thank you so much. Again, once I'm done with my study, I can also share the results with you if it is of interest to you. I will finish my study in a few months from now. But still, I think I'll still keep in touch and send it to you. Of course, if you want to read it.

Speaker 2 [01:10:00] Yeah, definitely. Okay. Sure.

Speaker 1 [01:08:58] Thank you so much again. I really I'm very thankful for your time and you have a nice evening ahead.

10.8. Appendix 8 Interview 7 Transcript

Speaker 1 [00:00:00] I'll start by giving a brief introduction about myself again. So I'm from India currently. I'm pursuing my Masters in Digital Communications. So I previously hold a bachelor's in computer sciences, and then I wanted to move more into tech policy. And I also got a working opportunity with a wind energy company in Copenhagen, so I thought it's a good idea for me to also support my thesis and start working in that direction of writing. So for now, what I'm trying to understand with my thesis is how is bringing a change in the wind energy sector and basically how organizations are realigning themselves? And how are organizations preparing themselves better with this technology coming in to sustainability. So yeah, I as part of my thesis work, I'm also required to have discussions with people so I can also supplement my academic knowledge with exactly what's happening practically. So there's a balance to really see if academia and practical knowledge is going hand-in-hand. We could start with the questions I have, but like I said, it's mostly to guide the conversation. If you feel there's a question that falls outside of your area of expertise, we can move to another thing that you feel would be more interesting. So that's a quick brief introduction. I hope this puts you in a place where I'm coming from.

Speaker 2 [00:03:03] Okay. I definitely thank you for that. And it's quite interesting your study,e, if you want to record the interview is completely fine. It might be useful for you to remember later.

Speaker 1 [00:03:13] Yeah, that is true. I should do that. Yeah. I will do that now since I can't make notes too fast. Yeah. Okay, Perfect. Thank you so much. I will do that now. Perfect. Do you have anything that you want to ask before I jump into the questions? Or should we just go ahead?

Speaker 2 [00:03:36] I know maybe one question. Are you planning to interview anyone? Anybody else? Or is it just going to be the academics talking about it?

Speaker 1 [00:03:46] Yeah, I will be interviewing different organizations and people from academia.

Speaker 2 [00:04:07] Yeah, but we are coming from the research point of view, Right. So we might be looking maybe too far ahead. If you are more interested in what's going to happen in the next two or three years, it might also be helpful to talk to someone from industry. So if you're interested, I can also connect you with that last [Name of the person]. He was actually the first one to apply, AI then. So if you want to get to and maybe if he has time, he might also provide his input for all the questions. Yeah. Because he also has things. Of course, he also has seen how it was in the eighties and also the 2023 now. So he might give you a bit more of a, you know, even bigger perspective. The wind sector is quite digital enabled in that sense. So he might also give some input on that.

Speaker 1 [00:04:56] Perfect. That sounds very nice to me. Thank you.

Speaker 2 [00:05:00] All right.

Speaker 1 [00:05:02] Perfect. Then maybe we can start with. I'm not sure if you've had one chance to look at the questions that I shared.

Speaker 2 [00:05:12] I've seen through.

Speaker 1 [00:05:12] Them. Okay. So you know what, I had just categorized the questions into like four groups so that it can yeah, it can be thematic in some sense. So I'm just picking up the first theme now and which is to discuss what's happening currently. So the first question is, do you think AI is accelerating our mission towards environmental sustainability. Is it like a positive shift that is bringing in, you know, just your thoughts and thoughts on that?

Speaker 2 [00:05:46] Oh, of course. I mean, but I'm also working on a few, so as a grain of salt, my responses to many of your questions are inevitably biased, I guess because I am working a lot with an activist. I work on this because I believe in right. So I believe it has potential. So in that sense for sure. But we also have arguments that I just do, I believe, also have arguments why it can be extra useful for the sector in particular, especially in that market. So one of the things that I think is very interesting and perhaps specific to having that idea is that just a pure amount of data is actually quite a lot. So it is really terabytes and terabytes of data being collected every second as we speak coming from the turbines themselves. And on top of this, we also have a lot of interrelated measurements coming from technicians, and sometimes with drones. There are a lot of measurements happening around the turbines. With drones are a lot of other types of data that is coming from the turbines that could be high maintenance logs that could be yeah, so that could mainly be the maintenance logs, but also could be more static data about, you know, even the temperature and so on. So in that sense, just the sheer amount of data is sort of quite promising in terms of how much value we can extract from them. So that's one of the main drivers of and I think in wind energy, people are realizing the value of data in many, many fields as you know, using it, using wind without logging in the basis. Right. And so it is quite an important tool for us to figure out what to do with this data, and how to extract the best value of the data. And from everything that we have available and we have been collecting for decades. So that is the number one reason why I think AI can really be the enabler in accelerating a lot of our missions. In fact, I think we know that it's going to be really hard to do it simply because of the computational complexity of a lot of the phenomena that are quoted and things like planning, be it operations and the turbine connections, the electricity system, even local electricity systems. And of course it's even more complicated for the landscape. So how is happening in Europe and how it might help end global warming? So in that sense, it is quite crucial to get there. And we know from examples, you know, there are sectors of extreme cost. And so I think AI really has the greatest potential to achieve a green energy mission. It's not just a potential it might actually be a must have as fast as they're building together.

Speaker 1 [00:08:27] Yeah. So it's super interesting. Yeah. And like, I couldn't agree more. That's very true. With the amount of data scaling up and cases we are getting. Okay. The next question is do we already see a significant reduction in turnaround times when we see AI is being used for fault detection in windmills and this is compared to when there is no traditional means where there was no technology in the world and it was purely human labor force dependent. Do you think we have already come to a place where we see robust change?

Speaker 2 [00:09:07] Well, it's really hard for me to say that we'll be more informed, maybe it will be necessary to see this when they have more hands-on operation. But what I do know from talking with them so far is that it's maybe maybe in their broader sense of eye. So it doesn't have to be just the things, you know, breaks, etc.. But the broader sense of meaning, any kind of political decisions that is made so far to them, I'm sure it is already being used quite extensively and for field agitation, you said for almost analysis for the ongoing operations, because this data is coming in, is streaming constantly. And also perhaps to make the decisions based on operation based maintenance. But unfortunately, I'm not sure if it is true for the upcoming new finds. So there are still, you know, big challenges, big limitations regarding any kind of aid or sort of extrapolation of the data towards the future. So for the wind farms that don't exist yet, I think we are still not there in terms of tracking data to speed up the process. And most of the bottlenecks of that kind of speed are anyway not related to technicalities. It is more about regulations, it's more about wind turbine stations. And unfortunately I can not be helpful the way it is right now to speed up those processes.

Speaker 1 [00:10:22] Yeah, that's true. Yeah, I think it's a good point on regulation and also I'd also pick it up later when we talk about external factors. But yeah, thank you. For the next question, you could tell me if this falls in your expertise, but I was only wondering if you are aware of how organizations are realigning themselves with this coming in of technology. Are there any upskilling activities or reskilling activities for you? Designing theme structures, something like that, that's happening within an organization. But yeah, sort of. You would be aware.

Speaker 2 [00:10:59] Again for the industry. I mean, if you get to talk to [Person name], he can tell you more. But I know from these teams that they have already, ultimately some of the reporting process is purely business. So they have already used that process. And you know, there is a certification body. So I'm guessing it was a lot of the paperwork that was supposed to come back this year. He is the guy. I am quite happy about the turnover there. But for us and for educators as universities, we are certainly realigning ourselves. So that's something we're really happy about. The other day we actually got very good news that we are now going to introduce another master's program as a special sort of a special track, special check within the state. So it's going to be digital skills, digital upskilling. So it's going to be an additional program for the Masters. And we will also introduce a lifelong learning program. As we were saying again, for these upskilling and this is going to be tailored for industry. So we are educating a series of Masters students very much focusing on digital technologies as well as the industry, also upskilling them for the digital technology. So I guess you will have the chance to be one of the first ones to do that. And it's not just us, we are together with four other universities across Europe. So that's quite fun and exciting for us and we are hoping to initiate this master's program by September 2024. So that's my course.

Speaker 1 [00:12:25] Wow, that's super interesting to me.

Speaker 2 [00:12:28] Oh, it shows. Yeah.

Speaker 1 [00:12:29] Yeah, definitely quite interesting. Okay, so now onto the next thing, which is mostly concerning data analysis. And I was wondering if you could just shed some light on what kind of data is collected. Like you mentioned earlier, there's a lot of data collected every second, but would you be aware of certain barometers, maybe wind speed, wind direction? And how essentially just does this data gathering collection and making sense of this data, how does this process work?

Speaker 2 [00:13:02] Yeah. So I think it is still the main source of data. But again, I might be biased in that because I work with them a lot, but I would argue that the biggest source of data is from the SCADA systems. So if you're not familiar, that is the supervisory control analysis and data acquisition systems. So they're literally all the data coming from the turbines and they might look very different for older turbines compared to when you were turbines. So in order to use turbines we had a little less knowledge about that and we also had a bit of what might seem outdated communication systems for the data transfers and data acquisition in general. But of course with the new wind turbines, we're getting more and more channels, more and more sensors on the turbine itself and also much better communication systems, more cybersecurity also in that sense. So it is sort of a whole range of information that you get from the turbine. It is actually an idea to use turbines as sensors themselves. So I can tell you a lot about what's going on at the particular location onshore, offshore. So that is still, I would argue, the biggest source of data that we're having because we do have, I don't know, probably not millions, but certainly thousands. It's quite an important data source for us. And then we have the remote sensing or something on top of them. So that will be the lighthouse that is looking around, having fun and or sometimes within the mean time, we will also have, of course, additional sensors on the turbines. So that would give us something about how they're vibrating the blades, how much the power is vibrating. So something about the structural ones or mechanical loads. And so on top of that, we would also have, especially if it's onshore, we would also have some noise measurements because that's part of the regulations as well as some detection for the wildlife activities. So that would be bird detectors, detectors. And again, for many countries across Europe, this is part of regulations. It will be very tough to penetrate that. And you will also minimize their effects, both in terms of noise and also for wildlife. So these are the additional data that we have, especially for onshore. Okay. And most of the turbines, they will also have rain detectors. So that's a lot of lightning as well, I suppose. But maybe lightning is not for detecting, but more like lightning. But still, we would also have that. And of course, on top of that, we have lots of synthetic data, as we call it. So that is coming from big light scale models that we have. This is pretty much what you're seeing in your weather forecast every time you look. So it's not just the temperature that you have the forecasts for, but it's also the wind speed. You have forecasts for the fluctuations in August. So it's like phosphine coming very strong and leaving again and stronger, leaving again, very annoying for humans and also for turbines. What happens is for the economy. So we also do have different horizon forecasts for that up to a week or two weeks or down to a few minutes. So this is sort of additional data we have and that meeting referred to as in physics data. So that would come from simulations that have been developed decades ago and we developed and upgraded and continues to be actually improved. So yeah.

Speaker 1 [00:16:10] Yeah. Thank you. I think this was such a nice answer to you. To me, I could really understand how this gathering and understanding works. Yeah. What kind of human skills need to be focused on now that you mentioned there's a master's program being introduced. So this is essentially for reskilling people. But like, what kind of skills do you think will be important for people to acquire, maybe software programing or data analytics or cybersecurity? Maybe?

Speaker 2 [00:16:51] Yeah, all of the above, but maybe it might be helpful to put a little bit of taxonomy on those as well. So I would be the data steward. So these are the people who are helping with collection of data and make sure they actually make sense and the communication works. And that would include cybersecurity or at least solutions against potential cyberattacks, which is becoming very popular, by the way, unfortunately, especially with, you know, more in Europe and so on. But just to give you an example, there was what I heard, a crisis among several big farms in Germany fairly recently, and they lost communication with at least six wind farms over there belonging to one operator for a few days. They did not know if the turbines were still rotating, if they were producing anything. So it is becoming more and more revealed. Real challenge is it's just going to get worse over time with competitors like this is going to have to be about the work. So that is one thing. So data steward this and also making sure that, you know, this is being collected, right calibration. So the sensors work properly and also the communication of the data through cyberattacks is felt safe and sound. And the second one after data stewards. Actually acquiring the data would be the data analysts. And if you go further, you would call them big data analysts, and that would be more like an AI machine learning kind of technology. And these data analysts could actually come from very different applications, could be purely applied to people. It could also be more also domain scientists that are upskilled. So that would be the data analysts are, and they might work very closely with the decision makers. So that's probably the third one, the actual or the final end users, if you will. So in terms of that, because I by nature should also have a lot of decision making abilities because people are talking about intelligent beings and intelligence is about decision making. But I don't think we are trusting the computers to do it for us yet or robots. And so it will still be a human in the loop if you follow the decision making part. So the way I see it, it is basically three points. And in a lot of those processes there will be domain scientists, meaning more physics based people also in the loop as well as more digital skills. People are coming directly from digital fields, e.g. computer science or like mathematics, statistics, background people.

Speaker 1 [00:19:16] Okay, yeah, sounds that sounds good. And that also gives me hope so that my degree stays valid and my technical expertise within the market. Okay. Okay. The next section is on ethics and we will be talking about cybersecurity. So I think this is a good segue way into this theme, but I was wondering like, what are the kind of ethical considerations that are taken when we use AI in the wind energy sector and like you also mentioning about maybe data privacy and protection, data bias and what kind of safety measures are needed when using this kind of technology. Also, because it's a high value data financially also.

Speaker 2 [00:20:05] That's right. So one of the things on that ground that might really help your thesis in your study is the European Commission. The EU recently announced an act. It's quite an extensive report, but you can read a lot of the summaries per chapter that you might find helpful. And of course, it has a lot to do with ethics, both in terms of technical ethics, if you will, or security, but also in terms of more and you can see related issues. And the thing is, what I think will be coming from the engineering side tend to maybe oversee or on a look a little too much how it might affect and how informed themselves are for the people, but also sort of how they say that they are actually interacting with the people a lot and they will interact even more so now in Denmark in the next seven years ourselves. So by 2030, we are hoping to double or maybe even triple our onshore wind farms. That's the big challenge. And to convince people to have them in their backyards and also to properly address the issue of it is becoming a little bit more centralized from top to bottom in the communities, choosing what they want for themselves. So in that sense, there's a group of colleagues which is very unique to Europe that within our department that actually looks at such problems both in terms of social requirements, but also of course the economic implications of overall acceptability. So that would include the only things that would include making energy cheap. So maybe it's not too bad to have lower bills, but then all of this data, how the noise is perceived, how the visual impact of the wind turbines are perceived, and how the community is reacting to what's happening is very exciting, we think, to our colleague from that group. I'm conducting a lot of interviews that need to be protected. There are a lot of people who are mounting complaints or the commercial or developers of the wind farms or the operators of the big farms that is also disappearing or should be compensated if you want to use that kind of data also to help decision making, both for planning and operation, then you also need to be a lot more careful about how you approach that and make sure all donor organization practices are in place so that none of the data or immigration is to be traced back to individuals because nobody would like to do that and make sure you have standard consents in place when you're collecting the collection of such data. So these are the problems we're looking at for the wind space, especially for the socioeconomics and the ethics related to that.

Speaker 1 [00:22:41] Yeah, yeah. Super interesting. Always. Yeah. And I will actually look through the European act that you mentioned. I think that would be good for me to build an understanding. Well, I was.

Speaker 2 [00:22:52] Yeah.

Speaker 1 [00:22:54] And coming to the more technical aspect, I was wondering in terms of reliability on our technical. So I do think systems have achieved some kind of reliability in terms of the decision making right now or like there's still a long way to go.

Speaker 2 [00:23:09] No, I'm not sure if it's a long way to go. I hope not. But it certainly is not at the levels to be fully in charge yet. As I said, the hybrid solutions might be coming. That will be the same. We will get help. I mean, it's from the I want to say, just since coming out of studies of models, basically digital twins and other type of models, statistical analysis that is coming out of the computations, we will go and consult with them more and more, I believe, and with time, because it's just, as I mentioned, so much data for human minds to process at the same time. So we will rely more and more on our sort of buddies and colleagues, if you want to call them that. And then that's going to be hopefully a lot sooner than everything, becoming autonomous and writing their own or making their own decisions. If the turbines get there, if the turbines can actually be self-driving, like the cars, my might to be on there, then, then it would be quite nice. But I'm not sure it is going to happen within my career, to be honest. I think they have a long way to go. If you compare it with the car industry, this, by the way, later, right? So very much.

Speaker 1 [00:24:24] Yeah, maybe. Okay, perfect. And then we move on to the next page, which is on challenges. So there's this one question on what kind of challenges that you think organizations or even academia faces when thinking about bringing technology in the wind energy sector. Maybe we think about it academically and we have solutions, but on the practical side, maybe it meets challenges like high installation cost or a need for more professional expertise. So you do think there's a gap in terms of how academia is evolving on this topic and how on a professional side, how this is translating?

Speaker 2 [00:25:05] There is a lot of it. I don't think the gap is that serious, but there is a little bit of a gap in terms of limitations. The biggest limitation, I guess, for us in academia, especially maybe for more traditional universities, is that already universities of industry connections are a little bit weaker, perhaps because they have always been very strong in number one. But maybe for other universities you might be more of a challenge. That would be the access of the base itself. So because we are not necessarily the ones operating the wind farms, but we can actually provide solutions, sometimes it can be hard to find the data that you can sort of play with and see what kind of value you can get out of it. Access to the data is the number one issue. And I think also one of the underlying reasons for that is there's a lot of hype around the data itself. So the value of the data because we don't know what that actually is, I think it gets a little overprotective. So we're like, Oh, but what if I am convinced to get something out of that? And we can see that we don't share anything, so nobody can get anybody like that. So that is a little bit unfortunate, I'm thinking. So if you think about the higher purpose or the, you know, ulterior motive of making everything sustainable and reducing emissions, that's maybe not the way to go. So we will definitely need a little bit more cooperation between and also the sort of data owners. It could be so by manufacturers, it could be the farm owner operators. So we would need a little bit more collaboration between the base owners also to sort of relax those requirements a little bit and maybe to have sort of third bodies like natural organizations, like academia, to have a little closer look and sort of all of us can get actually really from this. One good example for that I think is not to see that it will be full of wind farms if everything goes well in about ten years from that and I think it will be sharing the same rent, more time connected to the same groups, sharing the same prices in the market. So and probably very likely they're not going to be having only one own operator. They will have competitors running. Those are the firms that are actually neighboring and sharing a lot of these common infrastructures. That means they will have to find a way to talk to each other. So in that sense, I'm hoping that we can be one of the interfaces to do that. Also, having access to the data set and help for a better sort of energy planning overall in the coming years, which I think would be more and more relevant the closer together.

Speaker 1 [00:27:36] Okay. Yeah, that sounds good. I think this is super interesting for me and maybe food for thought in writing everything down. Okay, the next question is rather very generic when it comes to air, but maybe there's something that you have an idea on. But I was wondering how AI in the wind energy sector might bring in some kind of disparity, maybe income disparity or social disparity amongst people, because maybe the people on the lower rung who are traditionally going on the windmills and collecting data are being replaced by air based reports. And I was even reading about how the main thing is also down, though the windmills are also being beamed in all by robots. So this is taking over some sort of employment from some people, right? It's also bringing in employment in the form of people who are more data influenced. But do you think this kind of gap will bridge with technology for the wind energy sector?

Speaker 2 [00:28:47] Yeah, I mean, that is true for many sectors. There will be shifting jobs. That is, I think for sure now and then. So I don't see it as a bad thing. But that is a personal opinion. And again, I'm working with AI so much, I never saw them as threats like many people tend to do. But I mean, will they come to take our jobs? But maybe some of those jobs wouldn't really exist for humans in the first place. Maybe they're not necessarily the most exciting jobs or interesting jobs. Anyway, so I'm. If anyone can actually help us, It's a cleaner and cheaper electricity that can only be good for everybody. And then people will look for other jobs or they will have other maybe more global economic solutions to how to approach the entire thing. But the more I use, the more I mean, that's something we should always say, although I'm very biased. Yeah, there is a very, very important sort of underlying problem that is coming. We say almost conflicting was energy, and that would be the consumption of using AI, storing the data and training models extremely closely. If you think about the cost of running the cryptocurrency's cost, if everyone switches full on energy, this consumption is going to skyrocket about the roof, which needs to be also powered by green electricity. So it becomes this cycle. The more I use the word energy you will need to produce and also hopefully green. And then they will also create more AI based needs and then it will go. So there will be a lot of new jobs created because of that shift. You know, I read it somewhere. Somebody was saying that for a lot of the jobs our children will have, we don't have a name for it yet. So I guess that will really be true for a lot of sectors. I mean, going is no exception. But from the beginning, when energy was not necessarily the most famous energy source in terms of job creation, it has never been higher.

Speaker 1 [00:30:48] Okay. Yeah. Makes sense. Thank you. Okay, We're coming close to the end. This is the last theme that is on the future perspectives. And you already talked about some sort of competition where organizations won't be willing to share their data amongst each other and stuff. But, yeah. Do you. Do you think there's a growing competitiveness in this industry in terms of green energy? Are there a lot of organizations coming up? Is that a lot of investment that you see happening in this sector, especially with AI also coming in here?

Speaker 2 [00:31:24] Yeah. Yes. I think for wind I am particular. It's some you have seen some of the actors that you have never seen before that are coming in. A good example too, that might be an equal aberration happening between Microsoft and the rest of us. So we have never seen Microsoft doing that before, but now they're extremely active. Another example would be Google and how they're intervening. And then another example would be I'm talking about like the big three. Right. Yeah. Of the tech giants. And then Amazon is the last company with Amazon Web services, cloud computing, etc. to support a lot of the industry as well as it could have on the Internet. So certainly they have already started, let's say, about five years ago, and this is only going to grow. And we have been working for the first time full of data engineers. We are getting new projects with them now, full of hands-on research. They don't know a thing about land domain wise, but we have a lot of things that we can still do together and, you know, teach each other. I'm changing a little. Is it a good thing? Is it a bad thing? I hope so. But that certainly is happening. And competition in that sense is still happening. I guess it's more because it's in and they just like they're just political inevitably. So then there is a competition between the U.S. and Europe and China, and then there is always also competition for it globally. If you think about it, wind versus gas versus solar, you know, but these are perhaps out of scope for you. Yeah.

Speaker 1 [00:33:10] Yeah. Sounds good. Okay. And I was wondering, you did mention briefly about digital twins, but I was also wondering what kind of other emerging technologies are coming in here. Of course, digital twins. And also I was reading about offshore floating winds that, um. And. But are you aware of anything else that I might not be aware of?

Speaker 2 [00:33:36] Let's see. So floating is certainly a big thing, but that's, again, not necessarily about A.I., it's really just about learning and how to power up the countries that don't necessarily have the luxury of shallow waters like we do here. So it is basically driven by the needs. And I think the US is actually one of the main drivers for that happening right now because of their coast. So apart from floating, which is not even a big thing or the next thing anymore, we already have two fully functional floating wind farms. So I think it is a factor, but we will have even more of them. That's that for sure. But I mean with floating comes certainly this because this motion and like all these degrees of freedom and health and allies and so on. So for us it's really exciting for sure. And floating wind farms, I'm you know, as I mentioned earlier, this idea is also fruitful and quite exciting for us to look at. Um, so that is definitely kind of a new thing. But I guess the next big thing is actually A.I. and how we're digitalizing the entire operation range that I think is still sort of an overarching theme for many hundreds of items, all the way from materials to the turbine itself and then to the operation of being farms or design of being farms to forecasting, to modeling the entire earth. Digital twin of the atmosphere. Yeah. Can you imagine how big that dataset will be? And then you know, so these are all very exciting things. We will have modeled every single energy creating bodies in the world very soon. So that's quite exciting. And so that is the next big thing. If you want, we will just have a simulation of everything and we will just play and create all these scenarios and say, Oh yeah, so this has been finalized, the only turbine I see from my window. But what actually happens if I shut it off and you can do it in the simulation and see how it affects the entire system. So I'm also talking about how it's going to be more accessible for everybody. We're not going to be just the privileged few, but it will actually be accessible for a lot of people to make it more acceptable. So I think these are going to be the most sort of exciting things that I do. Research has been traveling from the turbine technology to the wind farm operation and systems that will quite some years ago now. And I think that and so we will focus more and more on the system. And the challenges regarding the system is sort of just the turbine itself. So that will be better. And I think I can see the main sort of driver or solution. It's not going to be an easy thing to do, so it's not going to be just captivating to me, like to physics, because it will all have to be. Yeah. So, you know. People will have things to say. Yeah.

Speaker 1 [00:36:26] Yeah, that's very true. Okay. The next question is, do you think organizations and also funding bodies are actively investing in wind energy and investing in AI for wind energy? Do you think funding is a problem when we see academia to progress in investigating this field, or do you think there's sufficient funds and there is political motivation to get this area growing?

Speaker 2 [00:37:18] Yeah. It's almost impossible for researchers to say that there's enough funding. So that's a question I have a very obvious answer. Some definitely not. But there is funding. Yes, there's funding and there's almost no funding. If you don't include digitalization any more to your ideas, because it's really it's getting, as I said, quite a bit of a default thing to do, quite a bit of a very smart thing to do. So in that sense, yes. But I mean, I think what is more interesting also, again, as a university for us now is that the challenges that's coming with more use of AI are being discussed more. And I know you're trying to find solutions on how to, you know, avoid plagiarism that is coming up. Like how we actually do academic publishing or thesis or homeworks, you know, all the different levels. It's quite a challenge. And then they're also trying to figure out all these sorts of security issues and data access and cybersecurity, as I said. So in that sense, there's still so much to do because wind energy is so much in use now. So we are actually almost at that stage not developing AI only or trying to deal with the problems of having so much. I mean, you know, are they nice.

Speaker 1 [00:38:35] Yeah, that's true. The second last question and this is what do you think or if you think government regulation and policy measures play a big role in pushing into the wind sector? And maybe they could, by having appropriate policy measures and setting some sort of energy efficiency standards or technology standards, and just having a push from that on the political side can really, you think, boost the sector in terms of technological advancements?

Speaker 2 [00:39:13] Yeah, I think it certainly can. We saw very good examples of this also for data showing and their taxes unfortunately not in Denmark but in other European countries. So for example in the Netherlands and also in Belgium, in Belgium, if you own a wind farm, you have to share your data with the academia. And in the Netherlands, if you are building a big farm, you have to invest directly in education by hiring or co-funding a Ph.D. or two. So these are very good measures that are coming directly from the Minister of Education. So, so and these are very well applied practices by now, and they have been in place for several years now. And so there's something to be learned in Denmark on this. So that's something that we have been talking about for quite some time, but I'm not sure how successful we have been in communicating that to the Minister yet, but it would be nice if we actually can get some sort of preconditions Speaker 1 [00:40:16] Yeah, I think that's kind of my biggest takeaway from this conversation also. Yeah. Yeah. So I think we've kind of covered everything that I wanted to ask you. You think there's anything that I should be aware of or the topic is interesting and I should delve into could be helpful for me. Yeah.

Speaker 2 [00:40:39] Anyways, I said this already. I already mentioned the act, which I think is a very good read. So that's the digital twin, which is crazy to think about for me. And then on top of this, you can have a look at perhaps how did you compare in the works together? I think you had a few things about that too, but I think Europe also has a few, so you can have a look at both of them. And yeah, I think that's about it. And let me know if you would like to have a chat with [Person name] also and then I can connect you to.

Speaker 1 [00:41:21] Yeah. Perfect. That would be lovely. I really appreciate that. And I think this kind of the end of the conversation. But can I just say I really admire your knowledge and enthusiasm for this is so inspiring. Seriously? Yeah. I'm more than looking forward to it started working in the wind energy sector. But it's. Yeah, it's great to see you on the other side and you just have so much to share. It's wonderful.

Speaker 2 [00:41:49] Now, so it's my pleasure. One of my favorite topics to talk about, I was like, No, of course. It's so nice to see that you're also interested in this and, you know, having more and more younger people joining us for that, for that realm would be really nice. So thank you for being cool. We hope you stay and I do this.

Speaker 1 [00:42:17] Perfect. Thank you so much for sharing your insights and thank you once again for connecting me and yeah, just helping me with this thing.

Speaker 2 [00:42:27] I think we need more young women in the wind sector.

Speaker 1 [00:42:32] Yeah. It's so nice to have three three women in this discussion discussing a different culture. Exactly.

Speaker 2 [00:42:40] And also I think it's not an everyday meeting for me, Right? So it's.

Speaker 1 [00:42:48] Wonderful. It's okay then. Thank you so much and have a lovely day ahead.

10.9. Appendix 9 Interview 8 Transcript

Speaker 1 [00:00:00] We can start with the introduction.

Speaker 2 [00:00:02] I can give my name, [Interviewee 8]. As we discussed,the shorter version here in [Country name], it's a very difficult name. And working in an offshore center in the [University name]. So I'm quite keen on my work. My topic is they're preparing to even prepare some projects for the education of young people from the secondary school, for example, and for students. So now we are working together with the Digital Wind project. We received a very interesting, very big project for the digitization and building competence for the young people. So it's just my goal.

Speaker 1 [00:01:27] It's not all the progress. I recently was responsible for coordinating an agreement which was signed between an actor of good taste, [University name] and digital industry software. So we have received a license grant so that they have granted us licenses for the value of almost 5 million euros. And then they will be installed in the supercomputing center, which is brand new. When it was put in operation a few weeks ago. So now we are with [Interviewee 8] trying to, I would say, roll out the licenses themselves. So it's a huge toolbox with a lot of software, often very sophisticated and quite complex. So it is not just a question of installing it and using it like a wallet perhaps. But think about Excel. You are using like 5% of external capacity and then everything. What is behind requires a more in-depth attention. So this a third, although of course, [Interviewee 8] is working closely with a number of industrial stakeholders, and one of them or all of them are discussing digitalization. So basically it is because at the center we are dealing with an intersection between operation and maintenance. In [Country name], we don't have wind turbine manufacturers like it is in Denmark, but we have a lot of turbines which are also already installed and then soon to be installed and operated offshore. So we are now bringing this capacity mainly for the operation and maintenance because from the operation of the expenditure, you can see that almost 30% is an OEM cost. And then if you can, by applying digital tools around your wind farm, optimize managing the asset and it is quite an extensive area for and then the savings so we can do the same and have more money.

Speaker 3 [00:04:04] Yes. So basically the idea was just to start a conversation with you and for me to just lay out some questions that could guide our conversation. And we need not cover up all the questions or something like that, but it is just to have a floor to the conversation so we can proceed in a structured way.

Speaker 1 [00:04:32] So maybe we can follow your recommendation about the priorities.

Speaker 3 [00:05:38] Yeah.

Speaker 1 [00:05:41] So because they are in the sequence of appearance, but I don't know, the sequence of appearance is following the priority. So if you are about to pick the critical question the most, if we can also do the only one loop here, would that be good?

Speaker 3 [00:06:03] Yes. Yeah, that sounds good. We can take it in priority.

Speaker 3 [00:06:27] If you want to do it now, I can just go in priority and ask you questions.

Speaker 1 [00:06:33] That would be great. Yeah, but then at least you have something to work with, and then that's it.

Speaker 3 [00:06:40] So it's not that every question will take the same amount of time so it doesn't have to be too long.

Speaker 1 [00:07:22] Okay. So if it is. Yes, no answer. We have more than enough time. Yeah. Because those questions are with the thesis.

Speaker 3 [00:07:36] So first question. So do you think the advent of technology is bringing a fundamental change to how the industry is organized? The demand for skilled labor is increased and compared to unskilled labor force?

Speaker 1 [00:08:48] Of course, yes. It is. Yes. If you would like to elaborate. Yeah. We have a reply in form of the promo brochure mentioned to promote [Project name] for four years with the six universities who train around a thousand students in digital skills in gear. We know that. So it is a reply to the challenge, which is like if you are in mechanical engineering, you probably do not program. If you are excellent in programming or using machine learning algorithms, you probably have little comprehension regarding terminology. So it will be this interdisciplinary. We don't have anything because of the case and it is under the [Program name]. So this question is somehow provocative because Europe is putting 8 billion over the next few years under the Digital Europe program. And the Digital Europe program addresses a lot of what you are asking in here. And then they are providing billions of euros for education. So your question, a comment, please take a look at the digital europe program. Digital skills. If you type in Google, Digital Europe digital skills, you will have official documents from European Commission communications and entire policy. There is an entire policy at the level of the continents for all 27 member states.

Speaker 2 [00:09:36] Yeah, that sounds good.

Speaker 3 [00:09:38] Do you think wind energy organizations are re-aligning themselves with the advent of robotic intel technology?

Speaker 1 [00:10:41] Hundreds of [Company name] contracts which are running with the current employees. And then the added one line in the list of responsibilities is basic. I would say it has increased. They won the number of people who are involved in the organization in digitalization, because normally when they think of the organization as the digital transformation department whatsoever, maybe 50 people are working there. So it goes across the department. Okay, That's a must. And think of the job contracts. And a lot of people don't want the new responsibility added to everything in place as was left. So it was just a single line to get other things.

Speaker 3 [00:11:17] That's interesting. I should look into this.

Speaker 1 [00:11:23] Of course.

Speaker 3 [00:11:25] Does the incorporation of the technology in the wind energy sector give significant competitive advantage to an organization?

Speaker 1 [00:11:38]Yes.

Speaker 3 [00:11:40] Yeah, I was also wondering about this because I think I was reading some articles where they said that some organizations are still very conservative in terms of investing because cybersecurity issues and financial constraints or funding opportunities. But then you also see organizations that are heavily investing in it with the help of external funding opportunities.

Speaker 1 [00:12:05] And a third. If you would like to have a comment on this question as a quantification. What is your reference company without application of all those technologies? I look and then the same objectives which are reached with the use of the modern technology of digital technology, because otherwise it would not come to the value of the difference, whether it be in the percentage, let it be in error or in which is your operation certain by a 50% easier operation Shorten by or cheaper by 100 and or is it what it does? It required five people. Maybe think about data analysis. If it is done automatically by a machine, can you fire five people and or move them rather for a programming department to develop those algorithms? So it can be very tricky. Question. Hmm. And it can be, I would say, the sentence. It is doable from a technology perspective, but it has no economic justification that it can get that improvement. But the price of the improvement will consume all the benefits you will work out from that improvement.

Speaker 3 [00:13:45] Next question. Are organizations upgrading themselves to the latest technology.

Speaker 2 [00:14:19] It's a purely reinterpretation of conventions, of the training and practices, such skills and confidence. That's short term projects.

Speaker 1 [00:14:37] I would assume this licensing is a part of this plan, I think. Well.

Speaker 2 [00:14:42] Yes, we discussed what I just discussed. About that few minutes ago. So. I really. Yes. I really don't know what I should say now. But maybe [Interviewee 8b can elaborate]

Speaker 3 [00:15:13] Or maybe I can read about this project somewhere if you have it, if it's available online on your website and university website.

Speaker 1 [00:15:23] But I think that the first part of your question is an open one so people can come up with any type of reply. But the second part of the question is probably a bit more targeted means that it is put in terms of the alternative. Yeah, but it can be in conjunction, so it can be a mixture of all of those because it can be hiring technical but hiring from, well, from external market or internal recruitment because you can move people across to units within the company. So it would be nice to be more specific saying that maybe you will now be more involved in the digital aspects and then you are no longer in that design. Yeah, I do a lot of transfer from and design and you need to do the digital to under the same company. So it is also recruitment, but internal and training of course internal, external and hiring and external consultants. But for what? For the digital transformation program. For training in programming language skills. For training in what?. Yeah, we hired external consultants to help us apply getting funded for the training program, for example.

Speaker 3 [00:17:38] Got it.

Speaker 1 [00:17:39] What we do now, though, and this external consultant has nothing in common with any of the engineering or digitalization, is we're conscious of external consultants underwriting excellent proposals. We simply get funded within a competitive bid.

Speaker 3 [00:17:57] Yeah, that's true. Yeah, I think I can specifically mention which aspect I'm talking about. That's true.

Speaker 1 [00:18:03] No, but the question is, is it very good, is just a comment. Yeah. Assuming you can get a lot of different things.

Speaker 3 [00:18:15] Do you see, is it true that AI systems are bringing a positive change in the wind energy sector with advanced data analytics capabilities.

Speaker 2 [00:18:36] It depends at the moment. We've had a big discussion over IT and digital systems, how it could be a danger for human beings. It's for technology. Absolutely. It's my opinion. Absolutely. Yes.

Speaker 1 [00:19:01] Okay, so. It can be in between.

Speaker 2 [00:19:08] AI can reduce the risk of human labor getting involved. The task might be compromised. It could. Yes. I think it could be very good. Maybe not right towards cooperation aid, but we can. I. We can do something together. I think.

Speaker 1 [00:19:42] I would say it is a tool like a knife, and they can be used for many and I would say positive items and a nice thing that I would say. Very dramatic events as well.

Speaker 3 [00:19:55] Yeah, I think that's a great example, actually.

Speaker 1 [00:19:57] Here it is a tool and it is up to us. If you ask for my personal opinion, I said it would be strong. No. Yeah. Because they have no idea what we are doing. It is the algorithms and no one is. No, no one knows how do they what? We can program them, We put them in operation. They have some results, but people have no idea what happens inside. And I haven't seen any, I would say. Substance explanation on how it works. A lot of explanation of how it is being programmed. But once you put it into operation, no one knows how it works. Talk to the professors, talk to the specialist experts in this field and ask them how it works. They will provide you with a lot of explanation about how it is set up, but not if they understand the results of the work of the program. We can program them. We can design the program. But the outcome of the operation of the program, no idea. So my answer would be no, because we don't know what we are doing and we are playing with a kind of very powerful tool. And it can have two different outcomes: positive and negative. Status quo. It's.

Speaker 3 [00:21:44] But as yet, this kind of continues to the last question. So you said this is.

Speaker 1 [00:22:03] Tricky question. Yeah, that is a system that was consumed in order to support environmental sustainability. Why has it taken?

Speaker 3 [00:22:21] Yeah. Because then, like, the amount of energy being consumed by these systems should definitely be very much less than how much they're helping to produce. Only then. They can be positively used. They can be using more energy themselves and then producing less energy at the end of the day.

Speaker 1 [00:22:47] A microsoft representative at the conference, mentioned that computing power, the supercomputer to train and neural network to optimize the drinking water supply in the city has generated an equivalent of CO_2 emission for the entire life of the three passenger cars. So if you are using a car for 20 years and it is burning a fuel, producing this number of kilograms of CO_2, and then you multiply it by three tons, then you have a number of tons of CO_2. So training the algorithm to help optimize drinking water management in the city has produced this number of I don't know what was the saving in terms of applying the algorithm. And I know that it generated a lot of impact in terms of as it was like it is a large supercomputing center. So within a week it can use megawatts of power and the megawatts of power are corresponding to the emission of this or that number of tons of CO2. So is there a consideration you are thinking of here for some metrics, some uniform metrics? So how do you measure the one side? What is into the system, the amount of energy, and then what is the benefit, What is the outcome of the system? So in and out, you know, looking for a kind of a transfer function in between input and output, I think. And then you have a number. So if you can quantify what is your input, what is your output, and you can refer to both of them. Yes, I think I've seen some metrics.

Speaker 3 [00:24:56] Yeah, but I was just wondering like even from the academic perspective, when you talk about AI and its use in positively impacting the environment, do we consider or do we talk about how much energy that they are consuming or do we usually not consider that aspect, but we focus on the larger, larger part of AI helping in positively impacting the environment?

Speaker 1 [00:25:23] Okay.

Speaker 3 [00:25:25] Because maybe that discussion is a little later.

Speaker 1 [00:25:28] I know it was an excellent topic for discussion. Yeah, because like, if you think about Google, probably everybody knows Google in one sense. So if you are searching in Google, you're hit alone and then you are emitting a couple of grams of CO2. And then if you have a number of searches per second in the world, it means that this or that number of tons of CO2 are being used just for you searching for a road to go to your destination for whatever. And then Google stock prices started to decline dramatically due to the origin of that energy. And then they suddenly started to secure a number of contracts. So just to purchase entire production from entire offshore farms for five years in advance sounded like that. And then they said, okay, you can continue your service without a negative impact on the planet because we are powering your service with. We know that if you can ask for that in the US, if it is not as sensitive information as probably part of those contracts, they are made public. So if Microsoft is doing the same, Amazon, all of the huge IT operators are trying to secure and do not have to contest publicly contracts to explain to the public. So sometimes it is difficult to put that in. But in terms of numbers, it is rather a social aspect and the pressure made on the end user perspective.

Speaker 3 [00:27:27] Yeah, but I think this is a very interesting thing. I should look into this more. Yeah.

Speaker 1 [00:27:33] It was before, no one cared. Then suddenly it went viral. A few other researchers who have done today essentially three grams of CO2. So you produce half a kilogram of yourself today and then say, just a certain Google and it's. Is there an industry who won't understand the socialization process? Yes and no. It is that data. So there is a standard that is sufficient quality and there is a sufficient amount of good data to use a system effectively. What is missing is data sharing.

Speaker 3 [00:28:23] Okay.

Speaker 1 [00:28:24] So if our state has data, hmm, they are very reluctant to disclose that data to any set centers to use them. And I know that because we are now in a private proposal and honest, that is a part of that. And that is to send the data from 10000 to 2 bytes. Yeah, I know how difficult for them it is simply to at the end of a tender two years of our system, to lower the cost of energy.

Speaker 3 [00:29:00] Yes. We can take this as an answer.

Speaker 1 [00:29:14] But you face the perception. Installations for professionals. Well, it is a lot. Let's take it on the other corner. I mean, because it is an installation, because installation costs, of course, of installation are high. But then if you would like to maintain that for years, if you're designing a wind farm for 30 years, you're able to operate. And soon there will be a next generation every half a year. And so it's really a challenge on how to do that professional expertise. But the main program is a maintenance of that system. So the challenge is, yes, the installation for sure, but the professional experience to some extent. But keeping it up and running and delivering a meaningful table for two weeks when the install advanced. And so.

Speaker 3 [00:30:32] Got it. We can actually skip the next question.

Speaker 1 [00:30:56] Okay.

Speaker 3 [00:30:57] It's also maybe a longer discussion. That's fair. But here we can take the future perspectives. Do you see growing competition towards the adoption of the technology?

Speaker 1 [00:31:23] Of course. I don't think it should be a subject of the question because it is. It is. But the second point is, is there any interest in going in and other emerging technologies in this sector? Cybersecurity? Hmm. I'm excited and hackers are calling you and saying we have control over your wind farms. Unless you pay me $10 million now and it happens and it happens a couple of times a month because cyber security is a very different advent. Everybody is talking about A.I. and this technology is really, I would say vulnerable for the attack. For some hackers, and they can stop the operation of the fund. And they ask for money unless they are not paid. They can put the entire fund up. So cyber security is a technology which is, I would say. I would say more and more people are aware that it is not safe by default.

Speaker 3 [00:32:51] Yeah.

Speaker 1 [00:32:54] The thing that we know and I'm sure valuations are investing in R&D for two years.

Speaker 3 [00:33:09] Yeah.

Speaker 1 [00:33:10] And as for the numbers add ons that don't put a simple table in one column, it will be a year. And in the second column, there will be a number of employees working in R&D.

Speaker 3 [00:33:26] Yeah.

Speaker 1 [00:33:27] And you would see an exponential growth. Hmm. Previously, in the olden days, they were cooperating a lot with the academics, but they still want it under the hood. The truth is that they don't assign a topic corresponding to a competitive advantage. So if they analyze the problem and then there are some options, which would be nice to know. But it is outside their political path. Yeah. You don't have to have it. They simply offered it to the university. Just to play a bit with it and to learn a bit at the low cost. But nothing, as I would say, a fundamental knowhow which is making their business operational is to develop external. More and more items are being brought in-house, so we are facing the challenge that they are even now taking a teaching and education activity under their own roof.

Speaker 2 [00:34:42] Wow.

Speaker 3 [00:34:43] Okay.

Speaker 1 [00:34:43] Yeah. So it is. To some extent. For them it is a bit of a problem. Think about that. Yeah. Think about the support structure department. How many hundreds of people work there? Think about micro skill set students originating from India, from Texas, from Brazil, from Europe, whatever. Different continents. And think of a mechanical engineer from each continent and maybe different universities, even from a single country, and then they all end up in the somewhat structured department of a university. Their competencies are very much different. No one will be an expert in stress analysis. The other one will be excellent in the measurement, but without and I would say simulation skills and vice versa and so on. And then at the end you need to compose a uniform team who will work as a group of people delivering on the objective. So this is way more and more than grabbing teaching and education. So you should ask, do you think we need investing in R&D a lot? Yes.

Speaker 2 [00:36:10] Hmm.

Speaker 1 [00:36:11] Google for Siemens Gamesa, some European investment bank and that and we will end up with the information that they borrowed this amount of money for such a period so they have a half a million overall and they for an entity.

Speaker 2 [00:36:34] Well.

Speaker 1 [00:36:35] These are the numbers and you can Google for them and you can get them from the statement of the European Investment Bank, which is an official financial institution. And since Siemens Gamesa is on the stock assessment that they have to publish this. And then if you do your math right, you will end up with a half a million and a foot, which is a data response that does think we need energy organizations and investing in R&D.

Speaker 3 [00:37:08] Quite a lot.

Speaker 1 [00:37:10] But I can do it. Government policy isn't a straightforward way to make a change. Yeah. A policy can play a role to ensure. Of course, the Green Deal is a political thing and the Green Deal has a lot of positives. So this fits perfectly fine for the politics and it also has a budget. But if you look at how Europe is doing versus, for example, China, yeah, disaster and all the European leading organizations are in red numbers. So bear with the losses instead of income. And it is also, to some extent, indirect results on the policy of that policy issue as skills and competence.

Speaker 2 [00:38:33] And this is what is accompanied as a bit. People finding jobs in wind farms where they can go over wage jobs, investments in security related to cell phone programing and the world cybersecurity is saying that it's there. Yeah, we discuss a lot of it, but what kind of skills and competence must be out? Or do. To people finding their jobs in Poland. It's. Now we observe, but we need more technical staff than engineering. They should have said that in the University of Technology. I know I've to do. The phone calls and the future is when we meet more people and. Taking our staff. We've been taking our competence and bending engineering kit. At the moment in the wind farm we tried to. We tried to prepare some programs, some technical programs for the technical secondary school to prepare to finish off this back and forth class and to prepare the young people for the wind farm. Now with my core competence, for example, for the services, for the technical, for the electrical services, taking our services and. I'm trying to make some. I can go to workshops on them and show them how it could look for the future and how they have the pictures, what it could be depictions for them to start with the offering sector and with the new iPad as the editor skills. I think at the moment all the typical young people in employment are important, but yes, the demand. The programming, the softwares, the cybersecurity, the digital skills is absolutely the number one program. Take young people for taking stuff into the office like this might be okay. So I try to do my best. So did you bring project cleaning there?

Speaker 3 [00:42:23] Got it. Perfect. Thank you. Thank you for covering all of the questions, actually. Exactly the right amount of time. We are one minute over, but still, I think the discussion has jotted down a lot of points for me to go back and also look at your university website for relevant material and distill your program and a lot of a European Investment bank.

So I have a lot of things to learn, go back and read about. So I think this was really helpful for me and thank you so much for your time again.

Speaker 1 [00:42:58] Great. Because it was also very interesting what I learned. And then.

Speaker 2 [00:43:04] Just.

Speaker 1 [00:43:05] Congratulations for setting up a lot of questions. I would say it is a bit surprising to see how mature they are with regard to we are very, I would say at this stage of your career, you. But to be honest, from my experience it is like students at the stage where you are, they do not have such impressive comprehension of the topic because you are addressing from very different angles these problems. So of course some of the questions are not necessarily in a perfect shape. Yes, but it is all fine. It is just research. So 90% of the job depends a lot on the results and the 10% will give you a frame and.

Speaker 2 [00:43:59] Then.

Speaker 1 [00:44:01] They keep going. Congratulations. It is really a great effort and whenever you consider it very valid, please don't hesitate to contact us. And because we are pretty active in that field and it would be nice to level.

Speaker 3 [00:44:17] Yes. And when I'm done with my thesis, I would also like to share it with you because maybe it's of interest to you, because I will be talking to a lot of people during this process, both from academia but also from the industry side. So maybe it's interesting for you to read, but I will definitely share my results at the end of this with you. And so.

Speaker 2 [00:44:37] It.

Speaker 1 [00:44:38] Is probably because, you know, today you are a student, but the other day you will be somewhere where you will apply the knowledge you are now building. And then it will be quite interesting for us to continue just to keep this relationship active. This is mainly due to the fact that, my gosh, I am actively participating in what is called a green energy hub because it is a local regional area. So it's like you have it. Denmark, Zeeland, and all these two different districts or regions in. We are discussing this green energy hub because it's not only a window, also hydrogen, it is a photovoltaic, it is also. So all in all these different mixes of energy and then there is a lot of interaction with the regular policy. But because the policy is not only about support for infrastructure, there's not only job creation. Because from what you are addressing here, this is why I am saying that it has so much potential because it is addressing education, it is addressing education, it is addressing the job market. It is addressing the policy which is shaping the, I would say, the development for the future. So I wouldn't be surprised to see you in a year or two. It's pretty sure that will happen in an office which is straightforward to explain for a cooperation because Bulgaria is now addressing all the items too. You are thinking forward in your thesis. But I would say for you it might look like you are doing it for the purpose of the thesis. From my perspective, all the questions you are asking are excellent thoughts. Our policymakers, our partners, our role.

Speaker 2 [00:46:49] There are absolutely perfect questions, I agree.

Speaker 1 [00:46:53] That's okay, because it is How do we interact with companies? How do we interact with education? How do we interact with the automotive planning of infrastructure development? Because it is not only roads, it is not. And I was at the bottom, but you know, it was a person I cannot replace . Maybe a robot can do that task, but I would be just this is what I am saying. But it is already, I would say, very much interesting. Yeah. How do you build? So how do you I would say your knowledge, gaining skills and so on. So the only thing I can hope for is that you will not lose contact with us in your future role. We can cooperate because we are dealing in a very practical daily basis. Exactly with those questions at the university, interacting with the policymakers, with us, that as you can hear as well.

Speaker 3 [00:48:05] Yes. Okay. Yeah, definitely. Thank you so much. Yeah, this was a really nice conversation. And even for my thesis, that is why I wanted to do this topic, because I wanted to use this at some point of time and not just finish my thesis and get done with it. I want to use this knowledge in the practical sphere, so now that I have the right contact, I will definitely keep in touch and update you with my results whenever I'm done with this.

Speaker 2 [00:49:20] We had to come to [Country name]. Yeah.

Speaker 1 [00:49:23] My version is for hosting open lectures. Yeah, events from my center. Okay, so if you consider that I've discussed with your peers at the office, if you consider relevant, it is, I would say, to be considered. Maybe you can provide a kind of an overview of what you are doing and so on within a kind of an open lecture. It is not super highly attended. Think about that either. And there is a seminar with maybe up to 20 people or sometimes 60 people. Depends on the topic on the part of the year because students are sometimes busy with the social layer they drink beer over. To be honest, sometimes to gain some knowledge. But yeah, there are plenty of opportunities, so definitely. Good luck and thank you for your help.

Speaker 3 [00:50:28] Thank you so much. Have a wonderful day.

Speaker 1 [00:50:31] Thank you.

Speaker 2 [00:50:34] All the best.

10.10. Appendix 10 Codebook

Code	**Description**	**Entries**
Competitive Advantage	Building capabilities within the organization to stand at par and above similar organizations in the industry	6
Cyber Security	Issues related to data breach, data leak, malicious elements illegally gaining access to valuable information	9
Data Quality	Ensuring good quality data is generated, collected and processed to be able to derive meaningful insights	17
Environmental Sustainability in AI Systems	Assessing the energy consumption and GHG emissions of the AI systems	5
Financial Investment	Govt funding, other fundings, investments, subsidy etc to boost AI adoption	8
Future prospects	Future developments and progress that the industry is likely to witness	9

Impact of External Factors	Government support/regulations, along with the impact of socio-cultural factors	14
Impact on Human Employment	Impact of AI systems on the involvement of humans who performed those tasks earlier	20
Operational Efficiency	Improvements in business operations and streamlining operational activities	21
Predictive Maintenance	Ability to detect faults prior to when it actually occurs, helping better manage resources	8
Reliability in Decision Making	Trust in acting upon the decisions made by AI systems	12
Research and Development	Engagement in Research and Development activities for the use of AI capabilities in the wind energy sector	7
State of Industry	Current state of the industry, drivers and barriers to AI adoption	21
Technical Competence	Building technical skills, skill development initiatives	22
Upskilling/ Reskilling activities	Conducting trainings for employees to be able to better use new technologies	12