Challenges for product development of wind turbines from the current market situation in Germany

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Abstract. The qualitative results of this empirical thesis are the four superior challenges “reduced time for development”, “integration of the value chain”, “reduction of complexity” and “digital transformation”, which apply to the product development of wind turbines. It is assumed that these superior challenges apply to a variety of business areas rather than only for the product development. Recommendations for actions to reduce the time for development are “customized integration of agile approaches”, “break down silo mentality” and “optimization of the innovation culture”. For the integration of the value chain in the product development process, an “establishment of a common basis of trust”, “establishment of multi-company development networks” and an “increase of compatibility of different tools and process automation” are recommended. A reduction of complexity can be achieved with an “expansion of the available capacities in predevelopment” and “development of long-term multi-platform strategies”. The challenges and possible solution approaches for “digital transformation” need further investigation, but it is clear to advise to “ensure access to operational data through digital business models or service contracts”.

1. Introduction
The transition from the previous fixed feed-in tariffs to so-called tender systems for subsidies of electricity generated from wind turbines led to a significant reduction in profit margins in the wind industry in Germany, with the intended outcome of increasing competition between companies. This competitive pressure results in decreasing Levelized Cost of Electricity (LCoE) for wind energy and increasing cost pressure on all participants in the wind industry. The objective of this study is to investigate the resulting challenges and potentials from the current market conditions for product development of wind turbines in Germany. The aim is to develop recommendations for actions to approach the identified challenges and potentials for manufacturers of wind turbines.

For this purpose, an analysis of the current market conditions are presented first, and the challenges are identified and quantified in two rounds of interviews with seven different manufacturers of wind turbines. After the first round of interview, solution approaches to address the identified challenges are developed, which are evaluated and discussed in the second round of interviews.

2. Current market conditions
The latest changes in the Renewable Energies Law 2017 in Germany has led to a cost-based competition between the various manufacturers of wind turbines and the different windfarm planner due to the introduced auction system combined with a withdraw of subsidies. This reduction in LCoE is not only limited to Germany. The global forecast predicts a decrease of 26% onshore and of 35% offshore of LCoE for wind energy till 2025[1].
This cost-based competition is facing a declining market volume in Germany too. The given permissions to constructed onshore wind turbines dropped to 40% from 2017 to 2018 and 55% less turbines were commissioned[2]. Through lawsuits against the high number of already approved wind turbines before the latest changes in the Renewable Energies Law 2017 came into action explains the declining commissioned turbines[3]. Reasons in declining permissions are various: the available areas for wind turbines are more restricted through federal regulations, regulations for species conservation and air traffic control[4].

As a reaction to this market conditions, the direct customers of the manufacturers, the wind farm developers and planners, pass down the resulting pressure to the manufacturers by only purchasing wind turbines with the lowest LCoE. In addition, the wind farm planners try to reduce their purchasing costs by using increased volume discounts for higher quantities.

To achieve lower LCoE, manufacturers develop larger rotors and more powerful wind turbines[5], but this leads to less products required to achieve the capacity quantities for a wind farm. This trend will further reduce their profits and works against declining LCoE, as fewer economies of scale will result in production. The economies of scale are additionally influenced by the various market requirements of the global sales regions. Because of different market requirements, new components may have to be developed to meet these requirements or even new products. This makes it even more difficult to achieve economies of scale, but a high amount of product sales worldwide is necessary to survive in this cost competitive environment.

These challenges are also underpinned by the four current megatrends observed in Europe[6]. The trends toward a competitive industrialized and global industry, subsidy-free wind power and technology-neutral tenders, an integrated and distributed energy system and digitalization. From these megatrends, the following innovation drivers could be identified[6]: increasing performance and efficiency, decreasing technical and financial risks, increasing the system value of wind power, shortening the time to market and reducing environmental and societal impacts.

With this basic knowledge about the current market conditions, megatrends and innovation drivers, the challenges for product development for wind turbines could be identified.

3. Challenges for product development

Two rounds of interviews were conducted to identify and to validate the current challenges and potential for product development of wind turbines. In the first round of interviews, the challenges and potentials were identified by using an open-ended-question interview outline. The results obtained did not allow any statements about the special relevance of the challenges or potentials. Due to a missing mention, it could not be excluded that this point was not regarded as a challenge or potential by the experts. The results of the first round of interviews are shown in figure 1 (challenges) and figure 2 (potentials)[7].

To secure the confidentiality of the seven interviewed wind turbine manufacturers, the experts were anonymized and given a number as shown in Table 1. This allows comparison and interpretation of the statements and opinions without violating the participant protection.

All experts named “overcoming the cost pressure” and the “trend towards larger rotors and hub heights” as the superior challenges from which further challenges are derived. In order to meet the cost pressure, lower LCoE must be achieved. This is necessary to remain competitive too[7].

The surveyed experts do not see any technical limits in the trend towards more powerful wind turbines, but rather regulatory or logistical ones. Regulatory limits include, for example, the permitted level of noise emissions or the current limitation of the maximum height of wind turbines. The logistical limits result, for example, from the increasing size of the components, such as the rotor blades or the nacelle, which lead to transport-related limitations. Especially in the case of onshore wind turbines. Experts No. 4 and No. 7 therefore assume that the power limits for classic offshore and onshore wind turbines will soon be reached. Expert No. 7 believes a maximum output of 15 MW is possible and points out that there will be systems with several rotors in the near future.

Due to the missing validity of the challenges and potentials from the first round of interviews, a quantification of the high-level challenges and potentials were carried out in the second round of interviews. As a result, “reduced time for development”, “integration of the value chain”, “reduction of complexity” and “digital transformation” could be identified and validated as current challenges, which
are discussed in detail in the follow-up. Potentials in "integration of the value chain" and the "digital transformation" are confirmed too. According to the surveyed experts, the "implementation of new technologies" will always be necessary, but this has already successfully done in the companies, therefore, this cannot be classified as a current challenge. The "network system services" lacks the necessary market pressure to be a current challenge. According to experts, however, this will change in the coming years.

Figure 1. Identified challenges for product development of wind turbines as the evaluation of the first round interviews

Figure 2. Identified potentials on product development of wind turbines as the evaluation of the first round interviews
3.1. Reduced time for development
The requirement to offer faster new wind turbines results in a trend towards a reduction of the product life cycle. As a result, the period in which a generation of wind turbines can be developed and sold has been shortened.

The development towards a shorter time for the development of wind turbines can be deduced from the current competition to reduce electricity production costs. Wind turbine manufacturers are forced to offer modern wind turbines faster than their competitors, which can produce electricity at a lower cost. This requirement for the fast supply of modern wind turbines results in a trend towards a reduction of the product life cycle for wind turbines. Accordingly, the period in which a generation of wind turbines can be developed and sold has been shortened. This change in the product life cycle due to the new market conditions is shown in figure 3.

3.2. Integration of the value chain
The closer integration of all value creation partners into the process of product development is the challenge of “integration of the value chain”. This is induced by the pressure to innovate and faster development of new products. The leverage here is the access to the know-how of a broader spectrum of specialists. The protection of intellectual property, the development of a common basis of trust, the supplier strategy to be chosen and the removal of barriers between companies involved must be discussed while implementing actions for this challenge.

The integration of the value chain is not limited to suppliers of the wind turbine manufacturers. The involvement of wind farm developers and planners, as the direct customers of the manufacturers, must be considered too. An illustration of the value chain in German wind industry is shown in figure 4.
Figure 4. Value chain in German wind industry

Many of the most important information need to optimize wind turbines for different locations are gathered by the wind farm developers and planners. Therefore, the integration of the wind farm developers and planners is indispensable for product development to enable a further reduction of LCoE. The survey of experts on this challenge showed that the “integration of the value chain” was partially classified as a very relevant and urgent challenge, while the potential is clearly more relevant and urgent. This classification is justified by the good progress in recent years or the current implementation of actions. Expert No. 6 rates the integration of the value chain as the most relevant and important topic.

3.3. Reduction of complexity

In the current market situation, it is necessary to adapt wind turbines to new regional requirements, which increases the complexity of wind turbines. To keep the number of different models and variants for individual requirements as low as possible, it is imperative for the manufacturers of wind turbines to meet the emerging product diversity with standards. With the introduction of a platform system, it was possible to reduce the wind turbine variants and the development effort strongly. For wind turbines, the nacelle with the contained components inside is the platform. A detailed analysis of which components in the nacelle are attributed to the platform could not be carried out. The rotor blades and tower are the exchangeable components. The implementation of such a platform system is shown in figure 5, using the manufacturer Vestas as an example.

Figure 5. Development of generations of wind turbines using Vestas as an example
Despite this enormous progress, the reduction of complexity is described as one of the most relevant and important challenges for the product development of wind turbines. The use of standardization and the resulting economies of scale in production can further reduce the LCoE. According to the experts, modularization approaches should be pursued to further reduce complexity. The use of different single parts, on the other hand, would open too many possibilities for individualization, which would make it impossible to master the complexity. The optimal complexity depends on the value chain as well. By going through the learning curve in dealing with complexity, it can be further increased, and more individual parts will emerge. In this context, it must be clarified for each ordered amount of products, if the turbines should be site-specific optimized by individual hardware modifications or only by an adaptation of the control software. A too high standardization rate leads to a decline in the number of suppliers. This causes risks such as supply bottlenecks, ambiguities in the intellectual property or price increases by suppliers. These risks must be considered when making decisions about standardization or the integration of the value chain into product development. The experts mention the issues of missing industry-wide standards for wind turbines. These standards could help the wind energy industry to achieve competitive advantages over other forms of power generation.

3.4. Digital transformation
The challenge of "digital transformation" is identified as a general, current challenge with different potentials, with a distinction in short-, medium- and long-term challenges, each with different urgencies for their implementation. The topics are not only relevant for the product development of wind turbines, but also for the wind energy industry in general. For example, potential can be found in the digitization of various processes and calculation tools, as well as in the use of robot and drone technology to maintain wind turbines. Potential s are in new electricity marketing opportunities and other data-related digital business models. In addition, the evaluation of operating data must be continuously improved by identifying cross-correlations in the various parameters using artificial intelligence technology. It is not possible to create a uniform picture of the industry to the challenges of digital transformation. It is discussed, that a change of thinking in research and development departments is to be mastered, to design hardware in such a way that it can be used for digital transformation and monetized in the future. The challenges also include the right timing between the wait for suitable solutions and application forms from other industrial sectors and the transfer to the wind industry. In the opinion of Expert No. 4, these challenges are only to be overcome once. As it was the case after the successful development and implementation of the internet. Arguments against the classification of digital transformation as a challenge are the good implementation today, such as the 98% technical availability of the wind power systems and the progress in predictive maintenance. This view is considered by two experts. Digital transformation therefore requires careful consideration in advance, requires a broad spectrum of expertise and reliable partners. For a specification or further concretization of the topics in the individual areas of the digital transformation, further investigations need to be carried out.

4. Recommendation for action
The identified challenges and potentials are all linked to reducing the Levelized Cost of Electricity. This leads to a trend towards more powerful wind turbines. It can be assumed that the prevailing cost pressure will continue in medium-term because of globally dropping LCoE's. An appropriate response to the identified challenges is therefore indispensable. Within the framework of this study, eight general recommendations for action are elaborated and presented in the following paragraphs: To deal with the demand for decreasing development times due to a shorter product life cycle, for the further development of existing wind turbines and for customer-oriented new developments, it is recommended to break down silo mentality between specialist departments or in the value chain by integrating agile approaches in the product development process. As a part of the optimization of innovation culture, appropriate incentive systems should be introduced to generate sufficient ideas for product development. It is advisable not to leave the implementation of
ideas exclusively to the idea’s creator and to involve appropriate competence centers or technology experts - both internal and external[8].

Due to the need of an increasing integration of various value partners, the first step to optimize cross-project and cross-company cooperation is to build a common basis of trust with the value partners[9]. This is the only way to improve the integration of value partners in product development and the implementation of further recommendations for action.

Another recommendation is that the establishment of multi-company development networks[10]. In this process, the different ways of thinking and the existing cultures in the companies must merge. The protection of intellectual property in such multi-company product development needs to be considered carefully. Furthermore, development of networks would strengthen and intensify the integration process with the participating value partners.

Communication during product development should continuously be optimized by increasing the compatibility of various tools and automation of the corresponding processes. In this context, consideration can be given to integrate value partners into internal planning and process tools.

To reduce complexity of the product "wind turbine" and to achieve additional cost-based advantages, it is advisable for manufacturers of wind turbines to develop a long-term, multi-platform strategy, if one does not exist yet. Thus, the conflict of interest between standardization and individualization possibilities in the product architecture of wind turbines must be addressed to secure long-term competitive advantages.

The available capacities for predeveloping wind turbines should be expanded too. Through a more comprehensive predevelopment, requirements could be more specific and communicated to the suppliers. This would minimize changes in the specification book after the start of product development[11].

It is also recommended that wind turbine manufacturers ensure access to the wind turbine operating data. The evaluation of operating data is indispensable for a continuous competitive development of future wind turbines. This access could be ensured by maintenance and service contracts or digital business models. The implementation of further potentials in digital transformation should occur with careful consideration and serve to secure long-term competitiveness.

The challenges and recommendations presented in this paper are specific to product development. However, the relevance of these results for other business areas cannot be ruled out and could also be of great interest.

5. Appendix

Table 1. Area of business and industry experience of the surveyed experts from wind turbine manufacturers

| Expert         | Area of business                         | Industry experience |
|----------------|------------------------------------------|---------------------|
| Expert No. 1   | Product Management – Onshore Wind        | + 11 years          |
| Expert No. 2   | Product Management – Onshore Wind        | + 4 years           |
| Expert No. 3   | Portfolio Manager – Onshore Wind         | + 12 years          |
| Expert No. 4   | Product Management – Offshore Wind       | + 20 years          |
| Expert No. 5   | Product Management – Offshore Wind       | + 9 years           |
| Expert No. 6   | Technology Evaluation and Concept Development – Onshore Wind | + 16 years          |
| Expert No. 7   | Business Development – Onshore Wind      | + 10 years          |
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