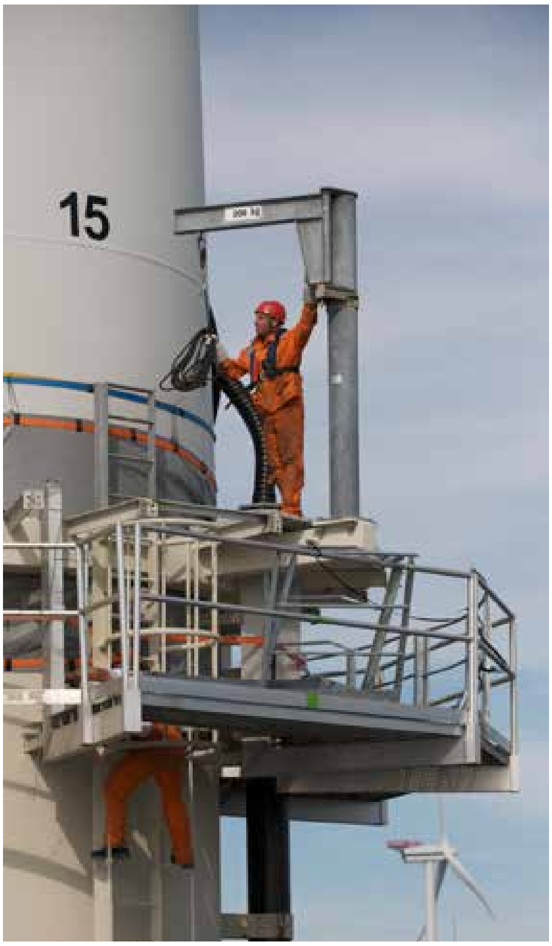

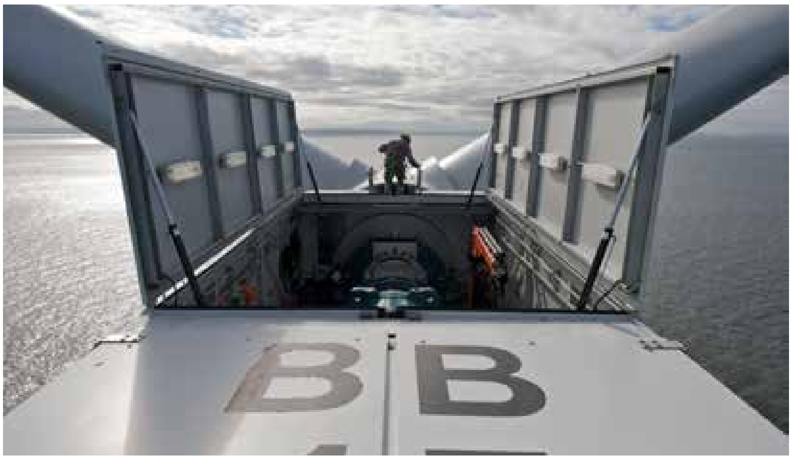

PERSPECTIVES ON HOW OPERATION & MAINTENANCE (O&M) INNOVATIONS CONTRIBUTE TO THE REDUCTION OF LEVELIZED COST OF ENERGY (LCOE) IN OFFSHORE WIND PARKS.

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READING GUIDE

The goal of this report is to provide broad insight into how Operation & Maintenance (O&M) innovations can contribute to the reduction of Levelized Cost of Energy (LCOE). If the reader is seeking a more focused approach, the issues of interest are listed in the table of contents of the report.

The report provides an understanding of the LCOE challenge with a relatively thorough introduction. Moreover, insight into the wind park context, the relevant literature, research findings, discussions of these findings and related initiatives are presented. Finally, the conclusions highlight the findings in practical terms and indicate where they can be found in the report. It is therefore possible for the reader to focus on issues of interest.

Please enjoy your reading.

EXECUTIVE SUMMARY

The goal of this research is to reveal how the reduction of LCOE can support lifetime sustainability of offshore wind farms. The research was conducted from June 2014 to May 2015 based on a focus group interview with 11 actors, and this was followed by individual semi-structured interviews with 20 actors in relation to O&M activities. Finally, the main findings were presented at a conference that was held in May 2015; in addition, 5 O&M actors presented their own assessment of the opportunities to reduce LCOE in the conference.

The findings in the report reveal several opportunities to reduce LCOE:

1. The **Triple Helix** concept shows the impact from collaboration between public bodies, private companies and research institutions. There seems to be substantial opportunities for Triple Helix actors to contribute positively to the reduction of LCOE, e.g., in the form of alignment of regulations across countries, standardization of education, training and support for the alignment of rules and procedures and funding of research and educational activities. In short, the Triple Helix Approach needs to be united – not fragmented as it is now

2. Governance is revealed to be under-developed with regard to the alignment of economic incentives, agency interests and organizational trust. To some degree, this implies 'open-book-calculations' to encourage transparency between partners. In short, governance needs to be strong - not weak as it is now.

3. Strategic innovation plays an essential role in the reduction of LCOE; several joint approaches to the development of the wind park should be introduced. This means focusing on several activities. In short, strategic innovation needs to be open, with a focus on the whole ecosystem of business development - not closed as it is now and with a focus on individual and fragmented initiatives on business development.

- **a.** Utilization of experience with O&M activities to improve construction, installation and O&M tasks.
- **b.** Development of preventive and remote solutions.
- **c.** Flexible standards on successful aspects of solutions.
- **d.** Qualified and shared IT-systems to manage documents.
- **e.** Integration of maritime approaches.

4.The essential issue of utilizing **networks** in the wind park industry is to overcome the present self-centred approach, which means being open and prepared to create joint business models with partners in addition to cre-

ating a joint culture for collaboration within the ecosystem as well as with outside partners. In short, networks require collaboration - not "islands".

5. Organisational knowledge sharing forms the basis for knowledge creation by the accumulation of concrete experience. This often leads to new concepts, which are then implemented to improve performance and reduce LCOE. In short, organisational knowledge needs to be united - not separated, as is the case now.

6. The wind park industry has specific requirements for the **attractiveness** of collaboration partners, which entail economic robustness, meeting the values of consumers, flexibility of operations, pro-activeness, etc. These requirements do not necessarily need to coincide, but several of them typically must be present. In short, the attractiveness of partners needs to be acknowledged - not neglected as it is at present.

7. Capabilities in **project program management** are important too. A specific emphasis on people and experience is needed due to the complex nature of the management of the project. In short, project management for the program needs to be perceived as a coherent system - not as a single project as it is now.

8. Consolidation includes different ways to approach and coordinate similar activities, different activities, and geographical proximity and data utilization. However, consolidation can also lead to 'exclusion-of-others' and might result in higher prices and a narrower strategic innovation focus. In short, consolidation needs to be based on opportunities - not on uncertainty as is the case now.

The opportunities to reduce LCOE are considerable and seem absolutely possible if the actors in the wind park industry change and pursue these opportunities. Reduction of LCOE can in the short term mean less business revenue from a specific O&M task, as time and resources for work on the wind park is reduced. However, in the long run, the reduction of LCOE increases the number of work-related tasks due to the improved competiveness of offshore wind parks in relation to traditional energy sources and other renewable energy sources. The opportunities for increased business revenue are thus multiplied by these future tasks, which then contribute to the reduction of LCOE in the industry.

Further research is needed on the opportunities mentioned for reduction LCOE

Photo: SEA INSTALLER at Borkum Riffgrund 1,
credit: A2SEA, photographer Matthias Ibeler.

1. INTRODUCTION

For several years, politicians and the wind farm industry have proclaimed the need for renewable offshore wind energy to become competitive with other energy sources. This can be observed in conferences and articles in daily newspapers. However, joint efforts are required for the offshore wind industry to achieve this competitiveness. This urge for collaboration to achieve competitiveness in wind energy was also stressed at the European Wind Energy Association (EWEA) Offshore Conference 2015 in Copenhagen; the need to reduce the levelized cost of energy (LCOE) was emphasized. The following headline from EWEA 2015 illustrates the goal:

'The offshore wind power industry has tremendous potential, but to achieve that potential, the industry must collaborate. MHI Vestas Offshore Wind, DONG Energy and Siemens Wind Power—three of the industry's biggest players and our event partners for EWEA OFFSHORE 2015—have initiated a joint declaration outlining the concept of a "United Industry." The goal of the declaration is to inspire the industry to come together around the promise of reducing its cost of energy'.

The goal of these three large actors, which include a wind farm owner and two wind turbine producers, is committed collaboration for the reduction of the overall lifetime cost of energy (LCOE) in wind farms. This is especially essential for offshore wind energy, which is typically 2-3 times more costly than, e.g., onshore wind energy (OpenEI, 2015). Onshore wind energy is on par with other traditional electricity sources, so offshore wind is severely lacking in competitiveness. In the period from 2010 to 2014, LCOE has decreased by 11% primarily due to the *'industry's early adoption of larger turbines'* (Offshore renewable Energy Catapult, 2015; p. 4). However, other energy sources, e.g., oil have declined in price over the last year by approximately 50% (Nasdaq 2015). Therefore, the target for LCOE is at the moment moving further down. The price on traditional sources of electricity production is thus very volatile and also influenced by the security of the supply of energy (Shiryaevskaya, 2015). However, at the end of the day, the 'commission priority' of the EU 'Energy Union' states the following: *'The Energy Union means making energy more secure, affordable and sustainable'.* Here, one of the priorities is 'affordable', which is enhanced in the overall political statement: *'New technological and renewed infrastructure will cut household bills and create new jobs and skills, as companies expand exports and boost growth'* (European Commission, Fact Sheet, 2015). Moreover, there is political pressure on the reduction of the LCOE of renewable energy and here especially on offshore wind energy due to the high cost encountered in this area (OpenEI, 2015). However, the issues of 'secure' and 'sustainable' are mentioned; energy sources must be stable and accessible to be 'secure' and must be renewable to be 'sustainable'. As other renewable sources exist, e.g., biogas, solar, geothermal, tidal and wave energy, this does not especially emphasise offshore wind energy production. Competition regarding LCOE is thus substantial also in relation to other renewable energy sources.

The reduction of LCOE in offshore wind energy seems to evolve slowly given the decrease in LCOE of 11% from 2010 to 2014 (Offshore renewable Energy Catapult, 2015; p. 1). It must be anticipated that the offshore wind farm industry first reaped the 'low hanging fruits' in the mentioned period. Offshore wind energy solutions need to be competitive in the cost of energy in the long term compared to other energy sources. Subsidies are expected to cease completely by 2020 (BVG 2015; p. 3). This puts pressure on the offshore wind farm industry for enhanced and thus more complex innovation over the lifetime of offshore wind farms.

The definition of LCOE varies and is subject to continuous debate. Briefly, LCOE can be seen as the lifetime cost of the wind farm per unit of energy generated. The following is a more detailed definition: the sum of the discounted lifetime generation costs (€) divided by the sum of discounted lifetime electricity output (MWh). Generation costs include all capital, operating, and decommissioning costs incurred by the generator or developer over the lifetime of the wind farm, including transmission costs (Crown Estate, 2012). It must be noted that the emission costs of CO_2 are typically not taken into consideration in the calculation of the required competitive target. This means a disadvantage for offshore wind energy because this energy source is completely free of CO_2 emission costs - other traditional energy resources typically have CO_2 costs.

LCOE can thus be understood in accordance with the valuation method of discounted cash flow (NPV) (Koller et al., 2010), starting with an initial large investment and followed by long-term (20-25 years) selling of wind-power generated electricity to society, which for comparison is discounted to the start time of the investment. The initial investment is dependent on the cost of construction and installation of the wind farm. The long-term yield is on one hand dependent on the Operation & Maintenance (O&M) costs over the lifetime and on the other hand the ability of the wind farms to produce electricity. The latter means efficient and effective production with the elimination of downtime to increase wind electricity production as much as possible. The main drivers of LCOE are the following:

- Amount of energy produced over the life time of the wind farm.
- Installation costs of the wind farm.
- O&M costs over lifetime of the wind farm.

The main drivers can be anticipated to be contradictory, e.g., a rise in energy production due to the increased quality of components, which often causes a rise in installation costs, and/or a rise in O&M costs. Another example is that reduced installation costs can cause a rise in O&M costs and thus a rise in downtime for electricity production. A balanced approach for the reduction of single cost components is thus needed to reduce LCOE. The goal is to achieve an efficient and effective composition of wind energy production, installation costs and O&M costs.

The decision on investment in a wind farm is dependent on the business opportunities and the yield during the lifetime of the wind farm; in short, a typical financial calculation can be described as being dependent on the following factors:

- Price/unit of electricity provided to the grid/year
- Amount of electricity produced/year
- Costs in general during the lifetime of the wind farm/year

As in a business case, the yield is calculated based on the price/unit of electricity multiplied by the amount of energy produced/year deducting the costs in general/year. With this computation, the amount in cash that returns to the wind farm owners/year can be derived. Normally, this cash flow is expressed as 'yield' (measured in percentage terms of the cash flow) and is calculated in accordance with the NPV method mentioned earlier (Koller et al., 2010). Hereby, the different variations over the years are not shown. Wind farm contracts typically last 15 years, which means that, typically, the business case for the decision of investment in a wind farm is calculated over 15 years. If the wind farm 'can live longer' and generate positive cash flow after 15 years, it is an upside on the wind investment and vice versa. However, after the 15 years, the price will be dependent on the prices in the market with lowest prices, when much electricity is produced and vice versa in relation to the demand for electricity in society

Different 'systems' for settlements of the price/unit delivered to the electricity grid exist. In the following, a short description is provided using the UK approach, as UK sites dominate the capacity installed, with approximately 50% (MW) of the European Market in 2014 (GWEC, 2014). Here, the price/unit of electricity is called the 'strike price' and represents the amount paid to a wind farm owner for each MWh of electricity produced over a 15 year Contract for Difference (CfD) term. Strike prices are intended to provide a certain level of yield and cover a certain level of risk connected to actually obtaining the expected yield to provide an incentive for investment in offshore wind farms. After termination of the 15 years, the wind farm owner is reliant on the market electricity price only. Strike prices (over the 15 year term) are therefore expected to be higher than the LCOE to provide an incentive for investment and to cover further costs connected to the grid deliverability (Catapult, 2015). The strike price is typically negotiated between potential wind farm owners and energy governmental bodies.

Moreover, the investment in the wind farm is dependent on the approval of offshore sites and the location and space of the site. Energy/governmental bodies decide this after a thorough process of information gathering on wind, water and weather conditions and the nature of the seabed and wildlife and sea traffic conditions. Once the wind farm site is approved, potential wind farm owners bid on the permission to develop the wind farm, and the negotiation of the price/ unit electricity for the grid takes place. This is an involved process between many stakeholders, e.g., governmental bodies, energy companies and wind farm owners, supplemented by research institutes, universities and private companies. A Triple Helix is therefore formed at the beginning of negotiations regarding the investment between governmental bodies, universities and private companies.

The Triple Helix means that many different interests are present (Etzkowitz and Leydesdorff, 2000). An overall framework for research on competitive renewable offshore wind energy is set forth, but it contains different approaches based on stakeholder interest. The research question in this report is thus formulated in terms of the overall framework for the industry and is termed as follows:

How can reduction of LCOE support the lifetime sustainability of offshore wind farms?

The goal of this study is to go beyond the official speak from conferences on the issue of LCOE and provide an understanding of the underlying forces for the reduction of LCOE and thus the establishment of lifetime sustainable of offshore wind farms. The research in this report focuses on the Operation & Maintenance (O&M) activities of offshore wind farms. In the O&M period of the offshore wind farm, the yield is revealed, and at the end of the day, how the reduction of LCOE can support the lifetime sustainability of electricity production from offshore wind farms is addressed. Hereby, the opportunities are revealed.

With this overall research question, this report attempts to enhance the knowledge of

- *Organisations participating in the wind farm industry* – providing an overview and enhanced understanding of stakeholder interests/roles in the wind farm industry as well as the necessary initiatives to reduce LCOE derived thereof.

- *Organisations with potential for value creation in the wind farm industry* – providing enhanced understanding of the forces in the wind farm industry – and the necessary initiatives to reduce LCOE derived thereof.

- *Governmental and energy bodies* - providing enhanced understanding of the forces in the wind farm industry and the regulative, political and economic initiatives necessary to support the industry/ society in the goal to reduce LCOE.

- *Universities and other educational systems* providing enhanced understanding of the forces in the wind farm industry and the necessary research and educational initiatives to support the industry / society in the goal to reduce LCOE.

- *Industry associations* - providing enhanced understanding of the forces in the wind farm industry and the support needed from associations.

The contribution of this report is therefore provided in a Triple Helix context, the goal of which is to understand the underlying forces in the wind farm industry for elaboration within industry, government and universities.

The Triple Helix context is relevant after the wind farm owner is found for the wind farm site. The next phases typically involve many and various actors in different projects: from wind farm owners to a range of larger and smaller suppliers within construction, installation and O&M activities. The actors in the wind farm industry are dependent on each other according to the LCOE approach, with materialization of LCOE during the long lifetime period based on installation costs and production of electricity and O&M costs. Collaboration with small and medium sized enterprises (SMEs) is especially important, as their portion of the work in offshore wind farms is estimated to be 60%-70% of the total cost of a wind farm (Danish Wind Industry, 2012). However, SMEs often lack time and resources, which places limits on their activities and interests. (Edwards et al., 2005; Murphy, 1996).

Additionally, different interests are anticipated from, on the one hand, wind farm owners with a lifetime perspective of wind farms and, on the other hand, larger wind turbine producers, foundation producers and cabling companies with primary interest in a single project for the purpose of company profit. These interests are not necessarily aligned. Moreover, the interests of stakeholders are typically situated within different levels, e.g., the institutional, organisational and individual/group level, which requires enhanced negotiation for the type of unified approach that is necessary to reduce LCOE (Hargadon, 2014). Support for a collaborative learning approach to integrate the necessary stakeholders/actors is therefore required for society to reap the potential of sustainable renewable offshore wind energy. Thus, the EWEA declaration of 2015 on industry collaboration is an important step towards the unified industry goal of reducing LCOE.

New and enhanced challenges have arisen for offshore wind farms compared with onshore wind farms. National and global offshore wind farm industries in general pursue larger investments, and thus, there is extended coordination and specialisation of operations across a range of stakeholders/actors (Crown Estate, 2012). In innovation theory, the notion of 'ecosystems' describes this range of 'value creating interactions and relationships between sets of interconnected organisations' (Autio and Thomas, 2014). The concept calls for fresh ways of thinking about specialisation, co-evolution and co-creation of value (Adner and Kapoor, 2010). The term innovation ecosystems is defined by Autio and Thomas (2014, p. 205) as *'a network of interconnected organizations, connected to a firm or a platform, that incorporates both production and use side participants, and also creates and appropriates new value through innovation'*. It means explicit focus on both the upstream (production side) and downstream (user side) activities. In the offshore wind farm, this is represented in both the production side, which involves the installation of wind farms and long-term energy production, and the user side, which involves first and foremost a competitive price for renewable energy for society but also the availability of energy when needed by the end-user. According to Gustafsson and Autio (2011), this means the evolution of networks of interconnected actors towards new states, rather than the optimization of the output potential of the existing and unchanged network configuration. The primary goal in the reduction of LCOE, which takes place within the platform of renewable wind farms, is to develop platforms to achieve 'new states' through innovations in the reduction of LCOE.

As highlighted in the ecosystem approach, offshore wind farms require highly complex activities that are very dependent on different actors over a long-term period. In project management theory, this is aligned with the notion of Complex Product Systems (CoPS). CoPS can be defined as *'high-value, capital goods systems, networks and infrastructural components, designed and produced by firms as one-offs or in small tailored batches to meet the requirements of large businesses or government customers'* (Brady & Hobday, 2012, p. 282). In the offshore wind farm sector, there are relatively small batches of wind turbines placed in a farm in different complex surroundings with different water depths, seabeds, water flows, cabling and wind conditions. Thus, standards regarding wind farms are difficult to obtain and call for complex project program management in a CoPS context. The lifetime issue of LCOE in the CoPS context makes project program management of offshore wind farms different from normal project management practices. CoPS does not follow a lifecycle approach to innovation (Abernathy & Utterback, 1988) but instead remains in the early fluid phase, as CoPS essentially continue with new development in relatively small batches as a consequence of the different contexts of wind farm context.

Programs are viewed in relation to the Project Management Institute (PMI) as a *'group of related projects managed in a coordinated way to obtain benefits and control not available from managing them individually'* (PMI, 2006, p. 16). Therefore, governance of the coordination of project program management is called for to enable strategic innovation across stakeholders/actors in wind farms.

Governance is understood as *'ultimately concerned with creating the conditions for ordered rule and collective action'* (Stoker, 1998; p. 155). The governance literature highlights the complementary nature of three perspectives of governance, namely, economical transaction cost economics (TCE) (Coase, 1937; Williamson, 1996), human agency theory regarding the different interests of participants and inter- and

London Array Credit: www.siemens.com/press intra-organizational trust and control issues (Müller, 2012; p. 305). Governance offers the opportunity to encompass the three areas to enable strategic innovation.

In this report, our definition of strategic innovation is in line with Grant (2012; p. 172): *'new approaches to doing business, including new business models'*. Strategic innovation typically involves creating value for customers through novel actions within new industries, new customer segments and new sources for competitive advantage. As Tidd and Bessant (2014; p. 21) highlight: *'innovation is about creating value through change', which is risky and therefore needs a clear sense of direction'* and a need to be *'clear about what to spend scarce resources on and why'*. Tidd and Bessant (2014, p. 22) note that this is not an *'accurate GPS-backed picture of a well-laid-out superhighway'*, but much more *'a rough sketch to help to find a way through the jungle'*. In this rough sketch, some kind of governance is essential to span both intra- and inter-organizational issues grounded in strategic innovation for the benefit of all participants. Strategic innovation focuses, on the one hand, on opportunities and threats within and across the participating organizations and, on the other hand, on capabilities and industry initiatives within and across the participating organizations. Within the complex context of wind farms, enhanced resources are called for both for network collaboration, organizational knowledge creation, collaboration partners, project management and consolidation of participants.

Research on the reduction of LCOE in wind farms thus needs to investigate opportunities and threats within:

- Triple Helix space
- Governance approaches
- Strategic innovation management with specific attention given to:
    - Networks.
    - Organisational knowledge.
    - Attractiveness of partners.
    - Project program management.
    - Consolidation.

The above issues are focused on in this report to contribute to the area of governance and support ecosystems for strategic innovation in the offshore wind farm industry. The level of analyses in this report focuses on industry actors and their collaboration efforts; this approach reveals the opportunities and challenges perceived by the forefront actors in the reduction of LCOE.

The goal of this report is to help the actors in the offshore wind farm industry. This means utilisation of conceptualization/theory, which represents an abstraction of practical experience and in the words of Lewin (1945) represents a practical approach: *'Nothing is as practical as a good theory'*. Basically, the patterns of practical experience are elaborated into theory/concepts in the research, which can be applied in new contexts that require practical action. Knowledge from other industries is carried forward to the wind farm area. This means that both theoretical concepts and practical experience with O&M activities need to be addressed in this report to answer the research question. The existing knowledge on theoretical concepts that are relevant to wind farms is revealed in a literature review on the issues mentioned. Practical experience with O&M activities is addressed using data from a focus group interview held in June 2014; 11 enterprises participated representing different O&M activities; there were 20 individual interviews from October 2014 to March 2015, with enterprises representing different O&M activities; and a seminar was held in May 2015 discussing the preliminary findings with the participants/ interviewees in the research. Through this explorative qualitative research approach, whether participants perceive that they need elements from the existing knowledge or new concepts to understand the subject can be revealed. Moreover, how they perceive opportunities to reduce LCOE based on their own experience can be assessed. Thus, researchers can enhance existing knowledge by incorporating the practical experience of O&M offshore wind farm actors and make a contribution based on these experiences to the Triple Helix participants in the offshore wind farm industry, governmental bodies and academia.

This report focuses on opportunities to reduce LCOE as observed by policy bodies and wind park owners. Therefore, a literature review is conducted on the innovation aspects regarding Triple Helix, ecosystems, governance, strategic innovation, project management and consolidation for the development of propositions. Moreover, the methodological approach is explained in further detail. Then, the findings are summarized and discussed in relation to the propositions developed to reveal what elements can be used in the offshore wind farm industry. A model summarises the findings from those firms with experience in O&M activities; this represents an enhanced contribution. The report concludes with a short summarization of necessary initiatives, with information provided for further elaboration of findings and policy implications as well as further research.

2. THE CONTEXT OF OFFSHORE WIND FARMS

Offshore wind farms are power plants on the sea that produce electricity from renewable source wind. The electricity is generated through wind turbines and converted into electricity with the aid of transformer platforms and cables. Offshore wind farms are created through complex construction projects, and each location is unique due to different weather and soil conditions (EWEA, 2014). Developing an offshore wind farm is characterized by a varying number of actors and a large number of interfacing issues in a value network-like structure that needs to be resolved at all stages of the development process, i.e., from the initial idea to the installation of the turbines to operation (Drejer et al. 2014). Moreover, the lifetime of offshore wind farms is characterized by different phases that are considered somewhat in isolation in relation to each other, e.g., construction, building and O&M phases; however, considerable spill-over is present between phases, and they can therefore be viewed as network systems (Drejer et al., 2014; Autio and Thomas, 2014).

The first offshore wind farm was established in 1991 in Vindeby in Denmark, and since then, the number of farms has increased rapidly, especially in Northern Europe. By the end of 2014, the capacity of the 74 wind farms that had been built totalled 8,045.3 MW, and the market is expected to remain stable in 2015; cumulative capacity is expected to reach between 9 and 10 GW (EWEA, 2015). In pace with the renewable forms of energy production winning terrain, offshore wind farms are under pressure to reduce the levelized cost of energy (LCOE) so that offshore wind energy may be considered a competitive alternative among non-renewable energy sources (Crown Estate, 2012). Due to different water, wind and soil conditions, offshore wind energy is at the moment 2-3 times as expensive measured by LCOE as onshore wind energy and other traditional energy sources. (OpenEI, 2015). For the time being, electricity produced in offshore wind farms is therefore subsidised by governments, and even though the cost of energy from offshore wind farms has decreased by 11% during the period 2010-2014, more efforts are needed to reach the target of competitive offshore wind energy of around £100/MWh by 2020 (ORE Catapult, 2015; Crown Estate, 2012).
The constant pressure to reduce LCOE has resulted in offshore wind farms with longer distances to the coast to achieve better wind conditions (Crown Estate, 2012). As a consequence, the companies in this relatively young industry continuously face new demands for technological product and process solutions. For example, by designing larger and more powerful wind turbines, the yield is expected to increase while reducing the number of wind turbines (ORE Catapult, 2015). This means that turbines of up to 10-12 MW of efficiency will replace wind turbines with a typical power of 2-4 MW.

OPERATION AND MAINTENANCE (O&M) OF OFFSHORE WIND FARMS

O&M activities can be carried out by the wind farm owner himself or can be outsourced to other enterprises through service contracts. Moreover, maintenance can occur either as scheduled maintenance (necessary to replace/adjust components/functions regularly on the offshore wind park) or as unscheduled maintenance (equipment/components/functions, which unexpectedly break down on the offshore wind park). Both scheduled and unscheduled maintenance can be done by the wind owner himself or can be outsourced to other enterprises on a service contract. When the work is outsourced

Credit: Courtesy of Vestas Wind Systems A/S both in an operation and scheduled/unscheduled maintenance context, the service providers perform the service for the wind farm owner. Different suppliers typically co-exist in O&M activities. They provide different equipment/components and also perform some of the work on offshore wind parks, e.g., by providing manpower. An overlap exists between O&M activities and integration of different services in O&M activities. A number of different roles thus coexist in O&M in offshore wind farms, including wind farm owners, equipment/component suppliers (an important component is the wind turbine) and different service providers of components and logistics regarding manpower, equipment and maritime services.

The O&M phase is characterized in Drejer et al. (2014, p. 56) as a phase undertaken by dominating actors (OEMs and utility/energy providers), and they refer to this by stating the following:

'O&M today is to a great extent an exclusive market, where wind turbine producers and energy providers so far define the regime of the collaboration'.

The dominating role of OEMs is related to the fact that the installation of the wind turbines is followed by a guarantee period (typically 2-5 years), during which the OEMs usually are responsible for the O&M activities. Guarantee periods of 10-15 years are observed, but this is rare. In other words, a few large OEMs dominate the market, e.g., Siemens and MHI Vestas, together with a few larger utilities (wind farm owners from traditional electricity producing organisations), e.g., DONG Energy and Vattenfall. However, a large amount of small and medium sized enterprises (SMEs) participate in the offshore wind park industry (VMI & Deloitte, 2014). This typically means a blend of a relatively few larger actors and many SMEs that perform activities on wind farms, from construction and installation to O&M. The independent service providers (ISPs) can be divided into two main categories. One of the categories is concerned with the logistics to and from the offshore wind farms, and the other is focused on providing technically qualified manpower and equipment to undertake O&M–related activities. After the guarantee period, the wind farm owner is likely to take over the O&M, and thereafter, these activities are typically undertaken by the wind farm owner itself and/or by the ISPs. For the time being, the O&M market is primarily oligopolistic, often with restricted opportunities for SMEs to enter the market. This is due to both the activity structure described above and to the relatively high financial risk involved. Some consolidation in terms of capital partners acquiring smaller ISPs can be seen in the market.
The main objective of the O&M activities is to ensure that the turbines run as smoothly as possible and have a high performance in terms of electricity production during the operation lifetime. This can provide a higher yield for return on investments (Crown Estate, 2012). The early wind farms could be reached quickly by using boats originally used for, e.g., fishing, and the small number of technically relatively simple wind turbines was easy to access and maintain. However, these operations have been replaced by increasing complexity, as with more remote locations, the logistics and the efficiency of the O&M gain increased relevance when servicing the offshore wind farms. Hence, the demanding weather conditions result in a smaller weather window for access to the offshore wind turbine, which means that the main O&M for the wind farms must take place during April to October (DHI, 2013). Additionally, more remote distances also mean that it is crucial to design logistic solutions, which, on one hand, can ensure safe access to the turbines despite high waves and, on the other hand, bring the employees to and from the site faster, either from the coast or from the accommodation ships or platforms situated at sea. These logistic solutions call for combinations of crew transport vessels (CTV), service operation vessels (SOV), jack-ups and helicopters.

FUNDING AND OWNERSHIP OF WIND PARKS

The primary investors in offshore wind parks have traditionally been power producers (utilities) using their balance sheets by re-financing existing projects through debt (project financed bank debt or project bonds) or by selling equity (EWEA, 2013). Through joint ventures with other power producers or third party capital funds/institutional investors, power producers have enhanced their opportunities for financing further offshore wind parks and thus have also enhanced their own business. Currently, investors from engineering, procurement construction and installation companies (EPIC), wind turbine manufacturers (OEMs), Oil & Gas (O&G) companies and corporate investors are investing in offshore wind (EWEA, 2013), e.g., Siemens investing in the wind park Butendiek (Siemens Butendiek, 2013).

The power producers typically have a long-term interest in wind parks both in technical terms (construction, installation and O&M) and in terms of commercial interests relating to own business and to the return on investment obtained from the offshore wind park. Experience related to return on investment in offshore wind parks materializes in the O&M phase, where the electricity produced is sold to the market. Commercial experience thus typically lags behind the technical solutions of wind parks. Regulatory risk related to conflicting political support for offshore wind, which results in uncertainties in grid connecting regimes, the long-term stability of markets and the regulatory framework, is a key concern for third party capital (EWEA, 2013), as their interests are focused on securing return on investment for their own investors. A different approach according to governance of risk is thus present. Other investors in wind parks have a combined short-term interest in own business performance and long-term interest in the return on investment of wind parks. The latter is only present when they have invested in wind parks. The governance of wind parks is therefore driven by both technical and commercial business performance and by short-term and long-term considerations and the perception of risk by many involved parties in the lifetime of the wind park. Shifting partner constellations are observed, which emphasise different interests and governance approaches according to the actual ownership constellation of the wind park.

3. LITERATURE REVIEW

Due to the nature of research on the wind farm industry, the scope of the research in this report necessarily has to integrate several literature streams on the various interests in society as noted in Triple Helix theory, on the coordination of interests and actions as noted within governance theory and on strategic innovation approaches focusing on new value creation. As defined by Grant (2014, p. 172), *'Strategic innovation typically involves creating value for customers from novel products, experiences, or models of product delivery'*. Grant (2014) perceives strategic innovation as a key source for competitive advantage and highlights that strategic innovation often involves combining performance dimensions that were previously viewed as conflicting (Grant, 2014; p. 173; Baden-Fuller and Volberda, 1997). Tidd and Bessant (2014, p. 24) underpin strategic innovation as *'a kind of innovation compass'* exploring different, possible directions requiring space and blurred lines for reframing 'paradigms' and exploration. The notion of strategic innovation thus enhances the concept of innovation. Here, strategic innovation also covers a range of literature streams regarding innovation theory on both creativity and control of resources and is enhanced by recent conceptions of 'open innovation', 'collaboration on innovation' and 'organising innovation' and the development of innovation into 'business model innovation'. The literature streams addressing strategic innovation have implications for the understanding of innovation in wind farms, as they represent different approaches to industry innovations for the challenging goal of reducing LCOE.

Moreover, literature streams exist in relation to innovation in network theory, organisational knowledge creation theory, and attractiveness of collaboration partners. Project program management theory and consolidation play a role in understanding the strategic innovation frame and content. According to the literature review, propositions will be developed and presented and summarised at the end of the literature review. First, the concept of Triple Helix will be elaborated.

3.1. TRIPLE HELIX

Societies in general have an interest in taking care of climate change; e.g., the United Nations has established a Framework Convention on Climate Change where global parties meet every year at a conference for discussion of climate change (COP – Conference of the Parties) (UN conference in Bonn, 2015). An important issue within these discussions is to increase the use of renewable energy. Society in general thus has an important stake in renewable offshore wind energy. However, renewable energy sources are more expensive than traditional energy sources, so innovation is called for by society. Innovation in the complex area of offshore renewable wind energy, which carries economic, social and political issues, calls for enterprises to carry out innovation and universities to provide new research knowledge in technical and commercial fields, which helps society in general. This naturally leads to an institutionalised approach to innovation. As highlighted by Mowery and Rosenberg (1998), 'institutionalisation of innovation' represents a change in the process of innovation in the 20th century through the emergence of corporate, university and government sponsored R&D. This three party collaboration is referred to as a 'Triple Helix' by Etzkowitz and Leydesdorff (2000).

The three groups in the Triple Helix model typically have different interests (Leydesdorff and Meyer, 2006). Universities are interested in 'novelty production' of knowledge. Industry enterprises are interested in 'wealth generation' within business solutions, which means better economic performance by their operations and enterprises. Governmental bodies are interested in the 'public control' and 'public well-being' offered by renewable energy in society. Moreover, governmental bodies provide subsidies in different ways to offshore wind farms to support the investments in these farms. The subsidies are often the subject of public debates, which typically generate political requests for 'local content' in the wind farms, e.g., employing local labour and local suppliers for installation and O&M activities (Kuntze and Moerenhout, 2013). Governmental bodies therefore have a twofold interest in wind farms. Theory related to the Triple Helix notion emphasises the need for blurred boundaries between the three participant roles. Their interests often move in three different directions, and blurred boundaries enhance opportunities for commonality in joint collaboration and learning. Moreover, the need for a continuous balance between integration and differentiation of functions within and between the three parties needs to be recursive and reflected upon to find the balance to enable innovation among the three participants (Etzkowitz and Leydesdorff, 2000). Many dimensions are present in the Triple Helix notion both in relation to content and in relation to different interests from actors within the parties (Etzkowitz and Viale, 2010; Leydesdorff, 2012; Etzkowitz, 2014).

The notion of the Triple Helix provides an interesting embedded frame of cross-sector collaboration; however, it is complex as a result of the need for blurred boundaries and the combination of integration and differentiation within the many dimensions between participants. An understanding of the interests and actions upon them is needed for a range of participants. The proposition from the Triple Helix literature is noted as follows:

Proposition 1: In the wind farm industry, the interests of governmental bodies, universities and private companies can be integrated and differentiated in several dimensions to reduce LCOE.

The goal of the research, through proposition one, is to provide a contribution in different dimensions to integrate and differentiate innovation and reduce LCOE in the wind farm industry through concrete initiatives.

In the following, the governance issue will be elaborated.

3.2. GOVERNANCE

The governance literature highlights the complementary nature of three perspectives on governance (Müller, 2012):

- Economical through transaction cost economics (TCE) (Coase, 1937; Williamson, 1996).
- Human behaviour through agency theory (Eisenhardt, 1989b; Sundaramurthy and Lewis, 2003).
- Organizational through trust and control (Puranam and Vanneste, 2009).

As further highlighted by Müller (2012), the perspectives operate on several levels, e.g., institutions, organisations, individuals and groups. The perspectives are complementary, which means that they can be present in coordination, but not necessarily simultaneously. However, governance takes a point of departure in at least one of them.
First, the focus is set on transactional economic theory (TCE) (Coase, 1937; Williamson, 1996).

Essentially, TCE compares costs of competition and coordination in relation to its origin - either the market or the organization. Sometimes, it is cheaper to coordinate transactions through the external market (competition), and sometimes it is cheaper to have an organization oversee and manage cooperation, particularly within vulnerable transactions. The boundary between the external and internal body is here defined and managed for the economic benefit of transactions of goods and services – the economic perspective of governance. Value is added through these transactions, and value is created through the coherent entities in the whole value system from the beginning of the innovation to the value creation in the end.

Another approach referred to by Polenske (2004) as 'collaboration' results in another kind of cost, which she terms *adaption costs*. According to Polenske (2004), collaboration arrangements often lead to internal economies of scale, affecting the position of the firm on its long-run average cost curve. In other words, by collaborating, e.g., on the design and production of a product, two or more firms can lower their adaption costs in the long run. The collaborative firms can innovate new products faster, have workers acquire new skills and obtain more capital investment with less costs. The three approaches, competition, cooperation and collaboration, all have an impact on costs, although in different ways. Competition and cooperation have a direct impact on value through short-term typically value chain activities in the exchange of products and services. Collaboration has an indirect, more long-term impact on value through collaborative, innovative reciprocate activities, which again fuel long-term value creation. Here, the three economic governance structures are revealed, which all can support value creation through cost reduction.

Second, the focus is set on human interests with agency theory (Eisenhardt, 1989b; Sundaramurthy and Lewis, 2003). As highlighted by Sundaramurthy and Lewis (2003), agency theory contains tensions created by the economic self-interest of the agent, which can cause opportunism and goal conflict. Instead, they highlight a stewardship approach, which calls for collaboration on collective goal alignment through long-term relations. As highlighted by Campbell et al. (2012), managerial incentives affect decision making on governance initiatives. Therefore, alignment of incentives is required across actors for collaboration on a collective goal. In the offshore wind farm industry, the contracts span a relatively short time in relation to the lifetime of an offshore wind farm. Therefore, the interests of different agents will often differ according to time and the business conditions in contracts, e.g., providing a guaranty of the performance of the wind farm for a limited number of years. In the years after the guaranty period, equipment can break down because maintenance is only effective within the guaranty period. Alignment and motivation to collaborate on activities related to the wind farm is thus important to foster to reduce LCOE over the whole lifetime.

Third, the focus is set on the organizational approach of trust and control through, e.g., contractual relationships elaborated by Puranam and Vanneste (2009). According to them, setting up a contract can be perceived as distrust of the exchange partner and therefore hamper the relationship. Not setting up a contract can also cause misinterpretation between parties, which can also hamper the relationship in the longer run. Moreover, trust and the contractual relationship can be complementary, as trust can leverage the value of the contracts if the contracts are incompletely specified. In the wind farm industry, contracts are commonly used for regulation of transactions. Industry contracts cannot take into account all the complexities and/or changes according to dynamic changing wind, water and weather conditions and technologies, actor competences or different local geographies. Therefore, the complementary aspect of trust and control is important regarding the aim to reduce LCOE.

The proposition derived from the literature review on governance is as follows:

Proposition 2: Opportunities for governance through the alignment of economic, agent and organisational approaches can reduce LCOE.

The goal of proposition two is to contribute to the opportunities for governance initiatives to enable innovation and reduce LCOE in the wind farm industry.

In the following, strategic innovation is elaborated.

3.3. STRATEGIC INNOVATION

Innovation draws on a wide range of academic disciplines. As highlighted by Dodgson, Gann and Philips (2014, p. 5), innovation is often defined as *'the successful application of new ideas'*. This is affirmed by Tidd and Bessant (2014, p. 3): *'the process of creating value from ideas'*; this emphasises the process approach to integrating new ideas and learning initiatives for new value creation. On one hand, these aligned and widely accepted definitions of innovation indicate a need for creativity and on the other hand the ability of the organisation to successfully apply new ideas. According to this definition, innovation is placed on the organisational level, requiring a process approach to innovation.

In this literature review, the first issue is organisational creativity. Originally, Woodman et al. (1993) highlighted the notion of the '*interactionist model'* within organizational creativity. Here, organizational creativity is perceived as the overlap in creative resources between the levels of the individual, group and organisation. In their view, organizational creativity takes its point of departure at the individual level (Velthouse, 1990; Boone and Hollingsworth, 1990; Csikszentmihaly, 1997; 2002). Group and organizational levels (Amabile, 1997; Kao, 1989) are functions of the individual level in a cumulative way through the processes within and between individual, group and organisational levels. Creativity thus overlaps between the individual, group and organisational level. Organisational creativity can according to this notion be developed on all three levels.

Later, Puccio and Cabra (2012) enhanced the issue of generating ideas and the ability to evaluate these ideas as crucial to organisational creativity, which is understood as *'the manifestation of ideas that are both novel and useful'* (Puccio and Cabra, 2012; p. 191). This means both novelty through exploration and elaboration of usefulness through exploitation. The two approaches to the creation of knowledge in innovation are very different, as originally highlighted by March (1990) and later enhanced by March (2008). Generally, Puccio and Cabra (2012) highlight four different perspectives for idea generation:

- Cognitive, rational approaches – according to logical reasoning.
- Personality and environmental approaches – according to relationships and emotions.
- Motivational approaches – according to self-actualisation and meaningfulness.
- Psychodynamic and personal exploration approaches – according to unconscious daydreaming, Transcendental Meditation (TM), etc.

These four perspectives provide a way of analysing issues of organisational creativity within the offshore wind farm industry. Fischer and Amabile (2009) have highlighted the notion of 'improvisational creativity', which according to them is *'actions responsive to temporally proximate stimuli, where the action contains a high degree of novelty and a low temporal separation of problem presentation, idea generation and idea execution'* (Fischer and Amabile, 2009, p. 19). This is seen in contrast to the 'componential creative process', which is typically conducted in time-separated stages of idea generation, evaluation and execution (Tidd and Bessant, 2013, 2014)). The major difference between the two notions is the tight time connection between the creative idea and its execution in the notion of 'improvisational creativity'. In the offshore wind farm industry, activities are increasing rapidly in the establishment of new offshore wind farms. This means that time is a scarce resource, and therefore, some kinds of improvisational creativity could be needed. The notion of 'improvisational creativity' can also be contained within the different stages mentioned in the 'componential creative processes'. The perspectives of idea generation on cognitive/rational, Personality/environmental, motivational and personal exploration approaches are often in different ways tightly connected to the creative process. Opportunities for organisational creativity can thus be anticipated on the individual, team and organisational level and have perspectives of the cognitive, personality, motivational and personal exploration approaches. The levels and approaches seem to be linked to the creative process both in ordered and improvisational form to reduce LCOE. The listed issues can all support organisational creativity.

On the other hand, the ability of the organisation to successfully apply new ideas in new actions is grounded in some kind of organisational control. Here, institutional theory can provide insight. Scott and Davis (2014) highlight three conceptions within institutional theory regarding the regulative, normative and cultural-cognitive aspects. Regulations are anticipated to play a significant role in the offshore wind farm industry due to contracts for deliveries and certification of work processes. In addition, normative issues are anticipated to be high because of requirements on quality, health and safety settled in the normative work processes of the employed manpower. This is combined with time pressure related to the limited availability of favourable weather in the North Sea. Many people within the wind farm industry know each other, and some of them have been in the industry from its inception, so a 'wind culture' is anticipated for the work on offshore wind farms. Opportunities for institutional control can thus be anticipated in all three dimensions of institutional theory according to regulations, norms and culture to reduce LCOE.

Recent developments in the literature within the field of strategic innovation theory have highlighted the tools for enhancing creativity and control, which to some extent typically extend beyond a single organisation. Here especially, the following innovation issues can be anticipated to be of interest for strategic application in the offshore wind farm industry:

- *Open innovation*
- *Ecosystems and platforms*
- *Collaboration on innovation*
- *Organising innovation*
- *Business model innovation*

The complexity and challenges involved in the reduction of LCOE means that innovation can rarely be resolved by a single enterprise for the whole industry. Therefore, a degree of openness is required in the wider ecosystem for business and technological platforms to enhance reduction of LCOE. Moreover, collaboration and a degree of organising goals and activities are anticipated to be necessary to draw on primary knowledge and develop relevant knowledge to reduce LCOE. Here, more specific tools and processes such as business model innovation (BMI) can be anticipated to enable strategic innovation among participants in the offshore wind farm industry. In the following, the conceptions are revealed in short form and related to the offshore wind farm industry.

First, *open innovation* was conceptualised by Chesbrough (2003) and defined by Chesbrough (2006) as follows: *'Open innovation is the use of purposive inflows and outflows of knowledge to accelerate internal innovation and expand the markets for external use of innovation, respectively'.* Later definitions emphasise the *'flows of knowledge across the boundary of the firm, independent of the form and direction, that are deliberate and that aim to create and capture value to the firm'* (Dahlander and Gann, 2010). Recent research shows that an enterprise's engagement in open innovation positively affects its financial performance and market value (Stam, 2009). As noted by Laursen and Salter (2006), openness with respect to making use of external knowledge sources typically has a U-shaped effect on innovation performance. This highlights the need for an appropriate degree of openness. It means that both too little and too much 'openness' may be detrimental to the enterprise. Therefore, limits for openness exist, and the degree of openness needs to be strategically set by the enterprise to enhance innovation.

Open innovation is perceived as an important strategic approach for enhanced business modelling (Chesbrough, 2010; Badden-Fuller and Haefliger, 2013; Massa and Tucci, 2014). In the offshore wind farm industry context, it means that the involved parties can utilise opportunities to create value from openness across organisational boundaries both in relation to own context and for the benefit of the whole wind farm industry.

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Second, *innovation ecosystems and technological platforms* provide antecedents for resolving industrywide innovation challenges. An innovation ecosystem is defined as '*a network of interconnected organisations, connected to a focal firm or a platform, that incorporates both production and use side participants and creates and appropriates new value through innovation'* (Autio and Thomas, 2014). The wind farm industry does contain both the production and the use side participants, especially as the end-user side both consumes and pays the electricity bill and in addition provides subsidies for offshore wind farms through the payment of taxes that fund subsidies to offshore wind farm actors. The ecosystem construct is the broadest of the different network-based constructs in the literature. It is distinguished by its broad based coverage and by its focus on value co-creation and appropriation. Its definition means that ecosystems are collaborative arrangements through which firms combine their individual offerings into a coherent, customer-facing solution, which allows firms to co-create value in ways that few individual firms could manage alone. The eco-system thus extends the concept of the value chain to that of a system that includes any organisation that contributes to the shared offering in some way (Autio and Thomas, 2014). The eco-system approach is suitable for thinking about the offshore wind farm industry because a very close relationship exists between installation and O&M and production of electricity from the offshore wind farm, as highlighted in the introduction to this report. All actors, resources and activities are connected and dependent on each other, and therefore, co-creation is logically necessary and beneficial.

In the wind farm industry, there is no 'focal firm' that spans the whole eco-system and thus able to assume this role. Therefore, a technological platform approach is necessary to combine the ecosystem. Different definitions of innovation platforms exist as highlighted by Gawer and Cusumanu (2014, p. 652). They define industry innovation platforms as '*products, services and technologies that are developed by one or more firms, and which serve as foundations upon which a larger number of firms can build complementary innovations'.* This means that industry platforms have certain commonalities as a foundation, which in principle can be 'open' to outside firms. This is the case for the wind farm industry, where the wind farms are the basis of new developments in the industry. Industry platforms are different from traditional supply chain platforms common in assembly industries. The differences are connected to the development of complementary innovations, which Gawer and Cusumano (2014) highlight as being different from the 'value chain concept' in the following ways:

- Not necessarily buying or selling from each other.
- Not necessarily part of the same supply chain.
- Not sharing patterns of cross-ownership.

This means that no clear governance structure of the innovation platform is present, and this can bring about an emphasis on only incremental innovations between a limited number of firms and sub-optimisation of the whole ecosystem. However, an interesting potential network effect is present; defined as 'positive feedback loops', it can cause the *'value of the platform to grow, exponentially increasing rates of adoption of the platform, and the number of complements to rise'* (Gawer and Cusumano, 2014). Thus, positive feedback loops are important for innovation in the ecosystem. By developing a deeper understanding of the characteristics of their own ecosystem and its dynamics over time, managers will have a clearer sense of the position of their companies within the system in addition to a sense of the elements that are working to support their strategies and objectives and those that are not (Malerba and Adams, 2014). This places the focus on communication and dialogue for the purpose of knowledge co-creation.

Third, *collaboration on innovation* is interesting in the offshore wind farm context. Innovation collaboration is defined as *'the shared commitment of resources to the mutually agreed aims of a number of partners'* (Dodgson; 2014, p. 462). Dodgson (2014, p. 463) enhances this by stating: *'all contributors commit resources to it (the collaboration) and mutually determine its objectives'.* The logic behind the benefits of collaboration is based on complementarities. As Teece (1986) frames it, collaboration allows innovators to have access to complementary assets that are necessary for adequate returns on their investment. Access to these assets helps to overcome many of the bottlenecks that organisations face in getting their ideas successfully applied in markets. Moreover, collaboration can enable synergies between partners within the ecosystem platform (Dodgson, 2014). In this context, small and medium sized enterprises (SMEs) in particular can provide a 'dynamic complementarity' (Rothwell and Dodgson, 1991) through flexibility and responsiveness to new market and technological opportunities in ways that larger firms cannot. In this way, innovation collaboration combines the entrepreneurial behavioural advantages of SMEs for the purpose of exploration and the structure and resources of larger enterprises for institutional control of resources for the purpose of exploitation.

Moreover, collaboration can help reduce uncertainty by making sense of rapid changes and building shared expectations and approaches to innovation challenges (Dodgson, 2014). Collaboration thus provides a strategy of sharing control so that control is retained. Lokshin et al. (2011, p.305) describe it as *'A strategy based on exploration of these new opportunities, where firms persistently engage in joint innovation projects, rather than jointly exploiting cost efficiencies, lowers the probability of inter-organisational malfunctioning'*. An antecedent for radical innovation in the reduction of LCOE thus may be collaboration between complementary business partners in relation to the complementarity of capabilities and the size of enterprises. A close relationship is therefore necessary to organise for innovation.

Organising for innovation is an underdeveloped issue in the innovation literature (Lam, 2005; Philips, 2014). Organisation and management theory (OMT) provides insight into organisations and organising (Philips, 2014; Scott and Davies, 2014). Within this literature, organising emphasises *'culture, leadership and teams'* (Philips, 2014; p. 484). More recent developments within OMT emphasise the notion of culture as a repertoire or toolkit that provides new meaning for a product/process, e.g., the conception of Starbucks as a coffee shop, to enable innovation (Ravasi et al., 2012). This means exploring the '*sets of cognitive categories that members draw upon in order to interpret reality and to formulate strategies of action'* (Ravasi et al, 2012). The findings in this report help to reveal the 'sets of cognitions to interpret the reality' of opportunities so that LCOE may be reduced. As an enhancement to this notion of culture, Leonardi (2011, p. 360) focuses on strategies for organising, which organisations can use to '*reintroduce ambiguity into a process of innovation that has become relatively concrete too early to enable innovation'*. This is meant in relation to organisational theory to reintroduce exploration; in the terms of March (1991; p. 71), this means introducing actions relating to *'search, variation, risk taking, experimentation, play, flexibility, discovery'* into the cognitive categories that members draw upon. Further exploitation plays a role in ambiguity, which in the terms of March (1991; p. 71) means introducing actions of *'refinement, choice, production, efficiency, selection, implementation, and execution'*. Studies by Raisch et al. (2009) and Tushman et al. (2010) elaborate this ambiguity and develop the notion of 'organisational ambidexterity', which means being able to work on both exploration and exploitation in the organisation, thus utilising the ambiguity created by the simultaneous exploration and exploitation of activities to enable innovation in the reduction of LCOE.

Leonardi (2011, p. 367) shows that reorganising traditional boundaries in ways that make ambiguity a structural regularity may be one way to ensure innovation; e.g., creating an organisational unit for 'standardization' can challenge the traditional understanding of technical development in an R&D influenced organisation (Leonardi, 2011), or a report such as the this one can fuel debate on ambiguities in the offshore wind farm industry to enable innovation. Organising to create ambiguity across traditional boundaries is thus highlighted in the literature as important.

Moreover, leadership is an underdeveloped issue in relation to organising innovation (Philips 2014). Here, typically two forms of leadership are focused on: transformational leaders and transactional leaders; transformational leaders are characterized as follows: charismatic influence, admiration, respect and trust and the inspired motivation of followers. In contrast, transactional leadership is defined as *'emphasising the transaction or exchange of something of value the leader possesses or controls that the* *employee wants in return for his/her services'* (Oke et al., 2009). Recent research has shown a complex relationship between leadership and innovation that is often influenced by culture (Philips, 2014). No clear propositions can yet be drawn in the leadership area from the literature review that addresses organising to enable innovation.

Further team performance is an underdeveloped issue in relation to innovation (Philips, 2014). A number of studies have been conducted on teams, but only a few have researched the impact of teams on innovation. However, it has been identified that teams that are characterized by a different, preferred way of behaviour have an important and differentiated impact on innovation performance (Miron-Spektor, Erez and Naveh, 2011, Brink 2014). Therefore, organising the participation of different team members and their preferred way of behaviour seems to be important.

Fourth. *Business model innovation (BMI)* is a recently developed stream of literature (Massa and Tucci, 2014). Business models (BM) allow for considerable flexibility and interpretation and therefore have several potential applications (Zott et al., 2011). BM is defined as the *'conceptualization/depiction of the rationale of how an organisation (a firm or other type of organisation) creates, delivers and captures value (economic, social or other forms of value) in relationship with a network of exchange partners'* (Massa and Tucci, 2014; p. 423). The BM is a system-level concept centred on activities and focusing on value creation in a network context. The BM approach can both allow innovative enterprises to commercialise new ideas and technologies and can also be a vehicle for innovation itself, thus providing BMI (Massa and Tucci, 2014; Badden-Fuller and Haefliger, 2013). The BMI approach could be an interesting vehicle for the wind farm industry because the whole industry represents a system-level approach and the focus is very much on value creation in the industry, both in terms of enhancement of electricity production and reduction of cost; thus, LCOE is reduced in both these ways. Therefore, both the BMI approach to commercialisation and BMI as a vehicle for innovation can enable innovation.

The BMI offers several business applications as listed below (Amit and Zott, 2012):

- Reference language – fosters dialogue and understanding and collective sense making.
- Simplified cognition – offer opportunities for experimentation and discussion.
- Presentations – offer the articulation of value so that others engage in collaboration.

Considerable advantage is derived through the simplicity and parsimony of the concept. However, risks are associated with the concept.

A balanced approach is needed for BM in the trade-off between simplicity/parsimony and depth of analyses. The strength of the BM approach is the ability to provide abstraction as either of the following:

- A narrative (Perkman and Spicer, 2010).
- An archetype of BM (Zott and Amit, 2010).
- A graphical framework (Osterwalder and Pigneur, 2010; Johnson, 2010).
- A meta-model – built on system dynamics (Casadeus-Masanell and Ricart, 2010).

The limitations of the above BM approaches are grounded in the understanding of the BM beyond the provided abstraction. The abstraction typically has an intuitive logic. Moreover, the relative static description is a limitation unless dynamic questions of, e.g., 'what if's' are added. The application of the BM does require deeper knowledge beyond the immediate abstractions. However, when this knowledge is present, the BMI concept is perceived as an important vehicle for innovation (Kaplan, 2012) with the practical steps of mutual connection, inspiration and transformation.

The proposition from the literature review on strategic innovation contains a range of issues, which are summarized and noted as follows:

Proposition 3: Both opportunities of organisational creativity and institutional control can create value and reduce LCOE through

- ***Openness on knowledge flows across organisational boundaries***
- ***Ecosystem co-creation and positive feedback loops on the innovation platform.***
- ***Organising for the purpose of collaborating between complementary business partners to create both synergy and ambiguity across traditional boundaries.***
- ***Business model innovation as a tool for connection, inspiration and transformation at the organisational and ecosystem level for the industry.***

Given proposition 3, the goal of the research is to contribute opportunities for strategic innovation initiatives to enable innovation and reduce LCOE in the offshore wind farm industry.

Strategic innovation is a multifaceted approach that involves reaching beyond the single firm into the industry for collaboration partners. Therefore, additional literature on network theory is addressed. Moreover, organisational knowledge creation is important as a means of support for strategic innovation. In addition, the attractiveness of collaboration partners plays a role in enhancing strategic innovation. Furthermore, the execution of innovation is typically highly dependent on efficient and effective project program management. Finally, the issue of consolidation is reviewed, as this issue is often mentioned in the offshore wind farm industry as a possible answer to the challenges of reduction of LCOE

First, the literature review on network theory will be conducted.

3.3.1. NETWORKS

The ecosystem approach to offshore wind farms enhances the understanding of the network approach. It is of interest to investigate the organisational implications of the network approach, as many different firms are involved in the reduction of LCOE.

Within social organisational theory, Podolny and Page (1998, p. 59) have defined the network form as being distinctly characterised as follows: '*We define a network form of organization as any collection of two or more actors that pursue repeated, enduring exchange relations with one another and, at the same time, lack a legitimate organizational authority to arbitrate and resolve disputes that may arise during the exchange'*. Network theory typically highlights opportunities for networking participants to create value through their networking activities. The premise is that participants who engage in networks through an often loosely coupled system have easy and flexible access to necessary resources that they may not otherwise have had access to. This can create a competitive advantage, as noted by Burt (2000).

Powell et al. (1996) found a path-dependent cycle of learning in their longitudinal study in the biotechnology industry and argued the following:

'As a result of this reciprocal learning, both firm-level and industry-level practices are evolving, with boundaries becoming ever more permeable' (Powell et al., 1996; p. 143).

In the understanding of Powell et al. (1996), the term 'reciprocal learning' contains two learning processes that occur simultaneously and recursively on an organisational level. The notion of networks providing competitive advantage through enhanced access to resources and knowledge and the notion highlighted within firm networks of 'reciprocal organisational learning' provide in combination an interesting approach to enhance innovation and reduce LCOE. As noted earlier, collaboration theory enhances the notion of networks in the way that all participants in the collaboration are committed to providing resources. However, the more loosely coupled network concept also provides value in the network context.

As a result of the literature on network theory, we anticipate the following proposition:

Proposition 3a: Networks of reciprocal organisational learning can reduce LCOE

The goal of the research is, through proposition 3a, to provide a contribution to the opportunities related to network initiatives to enable innovation and reduce LCOE in the wind farm industry. In the following, the focus is on organisational knowledge creation; learning and knowledge as approaches to innovation are addressed.

3.3.2. ORGANISATIONAL KNOWLEDGE SHARING/ KNOWLEDGE CREATION

Branches of literature on knowledge creation have emerged during the past decades from different scholarly fields. As highlighted by von Krogh, et al. (2012) in their literature review on organisational knowledge creation, an important issue is the emergence in different scholarly fields of a continuum of leadership ranging from centralised to distributed leadership situated in three layers for knowledge creation: the core local activity layer, the conditional layer of resources/context and the structural layer forming the frame and direction for knowledge creation in the organisation.

According to the model developed by von Krogh et al. (2012, p. 268), this means the use of distributed leadership defined as a '*spontaneous, intuitive, participative, fluid, integrative diffusion of skills in formalising local practices'* (von Krogh et al., 2012, p. 254). Centralised leadership represents the hierarchical approach, with the manager taking/ influencing all decisions and setting the communication message externally and internally to the organisation. Centralised leadership imposes a top-down strategy and direction on the application of knowledge. This is beneficial when the organisation needs to join forces across functions and activities on actual new ideas for successful application. Centralised leadership thus provides direction for knowledge creation, and distributed leadership, on the other hand, provides utilisation of local knowledge for successful application. In the wind farm industry, both are anticipated to be important because, e.g., local distributed leadership and knowledge can improve local adaptation of solutions and centralised leadership can improve the sense of direction through joint initiatives.

Knowledge creation is considered decisive for establishing competitive advantages (Li and Gao, 2003). They argue that knowledge transfer is the basis for knowledge creation, and with an extensive knowledge base, new innovations can be implemented, which will result in an improved competitive position for the organisation. Knowledge creation and development of new innovations are an on-going process – implementation of new processes or products creates new knowledge and experience, which can be reused as a basis for reflection and further adjustment. This process is illustrated by the below learning circle in Figure 1 (Kolb, 1984):

When employees and leaders observe, reflect and discuss experiences from daily life, they are sharing knowledge and creating knowledge. Knowledge creation is the foundation for innovation, as noted by Li and Gao (2003). The learning model supports the development of new concepts that are able to support the competitive situation, e.g., by reducing LCOE.

Innovation is dependent on knowledge, which according to Davenport and Prusak (1998, p. 3-4; Leonard 2011, p. 14) can be divided into the following forms:

- *Data* – defined as: '*discrete, objective facts about events'.*
- *Information* – defined as: '*A message ... meant to change the way the receiver perceives something ..... data that makes a difference'*

Figure 1: The learning circle (Kolb, 1984)

- *Knowledge* – defined as: '*Information that is relevant, actionable and at least partially based on experience. It implies an understanding of processes, situations and interactions, and includes both skills and values. Knowledge may derive from science, history, structured education and vicarious as well as personal experience'.*

Because of the experimental and personal element of knowledge, tacit dimensions are present. The tacit dimension in knowledge creates difficulties for knowledge transfer, sharing and creation because the tacit dimensions are not articulated. 'Tacit knowledge' as such has not been discussed, as it is an underlying assumption (Hall, 1966) and is so personal that no one else can understand it (Polanyi, 1958), or it requires an investment in dissemination prior to the acquisition of the respective knowledge (Nonaka and Takeuchi, 1995). Knowledge transfer typically requires an effort so that sharing and creation can take place. Knowledge is 'sticky' and difficult to move across organisational boundaries. However, knowledge can also be 'leaky' – moving across boundaries unintentionally. Both 'sticky' and 'leaky' knowledge can hinder innovation.
Other knowledge issues can also hinder innovation. For example, Christensen and Raynor (2003, p. 177) noted that '*most often the very skills that propel an organisation to succeed in sustaining circumstances systematically bungle the best ideas for disruptive growth'*. Moreover, Leonard and Barton (2014, p. 125) indicate that '*less visible, but at least as potent a deterrent to innovation, are managerial assumptions that mascaraed as certain knowledge about the determinants of success'*. Management can therefore have an essential role in hindering innovation. The same is applicable for 'group think', the tendency for cohesive groups to seek premature consensus, and the syndrome of 'not invented here' (Leonard and Barton, 2014), which means that hierarchy and expertise can be serious hindrances to innovation.

As knowledge has both supporting and hindering implications for innovation, it is important to have flexible managerial approaches to enable innovation. Such flexible approaches are present in the notions of centralised and distributed leadership highlighted in the literature review on knowledge creation by von Krogh et al. (2012).

As a result of the literature on organisational knowledge creation, we set forth the following proposition:

Proposition 3b: Organisational knowledge creation can use both centralised and distributed leadership to reduce LCOE.

Through proposition 3b, the goal of this research is to contribute to the opportunities for knowledge creation to enable innovation and reduce LCOE in the wind farm industry.
In the following, the focus is on the attractiveness of collaboration partners; this will address the importance of partners as a means to enable innovation.

3.3.3. ATTRACTIVENESS OF COLLABORATION PARTNERS

The importance of collaboration partners for strategic innovation is highlighted in the innovation literature e.g., by Dodgson (2014) and in the network business relationship literature by, e.g., Mortensen (2012) and Ellegaard (2012), which draws upon the social psychology and social exchange literature. Dodgson (2014, p. 462) defines collaboration as *'the shared commitment of resources to the mutually agreed aims of a number of partners'*. The collaboration can have many forms and can occur both as 'vertical' arrangements involving parties engaged in complementary activities and in 'horizontal' arrangements involving parties engaged in similar activities (Dodgson, 2014, p. 463). Due to this definition, it is only collaboration if all contributors commit resources to it and mutually define its objectives. This means that the collaboration is more binding than the usually loosely coupled network (Weick and Orton, 1990) but less formal and binding than hierarchies and market contracts. Thus, different forms are acknowledged that have different degrees of obligation towards partners. As collaboration activities, according to the definition by Dodgson (2014), have a binding impact on an organisation, an awareness of the selection of attractive collaboration partners becomes meaningful. As highlighted earlier, according to TCE theory of competition, cooperation and collaboration can provide value (Williamson, 1996; Polenske 2004). Collaboration thus both provides economies of scale and scope to create value for the whole ecosystem – in this case, offshore wind farm sites.

Moreover, it is beneficial for organisations to work together. E.g., small and medium sized enterprises (SMEs) can add flexibility and responsiveness to the market as well as technological opportunities in ways larger firms cannot. This indicates the presence of both entrepreneurial behavioural advantages of SMEs and structures and resources of larger enterprises for support, thus forming a 'dynamic complementarity' of resources (Rothwell and Dodgson, 1991).

Hald et al. (2009) highlight the importance of acknowledging the notion of attraction in future business relationship research and argue that attraction is a force that fosters voluntarism in marketing exchange, supply chain management, and purchasing. Hald et al. (2009, p. 962) propose that a party's attractiveness can be defined as a function of P[Expected value]; P[Trust]; and P[Dependence]. They define attraction as *"the force fostering voluntarism in purchasing and marketing exchange, and further pushing a buyer and supplier closer together in a mutually advantageous relationship"* (Hald et al. 2009, p. 968). Several definitions of attractiveness co-exist as discussed by Mortensen (2012). In the wind farm context, the definition by Hald et al. (2009) will be used to highlight the expected value aspect, which can be revealed in the industry.
The issue of attraction is two-sided in terms of both customer attractiveness and supplier attractiveness, as highlighted in the literature review by Ellegaard (2012) and Mortensen (2012). Moreover, it has been noted that this two-sided relationship is dynamic and a reciprocal ongoing process (Ellegaard, 2012). Schiele et al. (2010) argue that customer attractiveness may lead to supplier satisfaction based on initial customer attraction. Supplier satisfaction can, over time, lead to a preferred customer status, which, again, can reinforce customer attractiveness (Schiele et al., 2010; 2011). In this way, an ongoing dynamic cycle is created that can be affected both positively and negatively.
It is hereby revealed that nurturing two-sided supplier and customer attraction has been proposed as a way to motivate opposing parties

to behave in a certain way or to draw them into a certain behaviour, thus influencing what are seemingly voluntary actions (e.g., Schiele et al., 2010). Furthermore, the concept has been seen as an alternative to using coercion in the management of suppliers (e.g., Ramsay and Wagner, 2009; Schiele and Krummaker, 2011). Thus, attractive collaboration partners can nurture a binding collaboration and enable innovation. The literature on innovation and business network relationships reveals notions on the attractiveness of collaboration partners, and thus, we anticipate the following proposition:

Proposition 3c:
Nurturing the attractiveness of a collaboration partner plays an important two-sided role in reducing LCOE.

The goal of proposition 3c is to contribute to opportunities for initiatives regarding the attraction of partners to enable innovation and reduce LCOE in the offshore wind farm industry.

In the following, the focus is on project program management to address the issues related to wind projects that enable innovation.

3.3.4. PROJECT PROGRAM MANAGEMENT

As highlighted by Davies (2014; p. 625), *'innovation and projects are closely connected'* as *'a project is a temporary organization and process established to create a novel or unique outcome'.* Söderlund (2012) highlights the theoretical foundations of project management. The complexity and uncertainty of projects are a significant issue within project management and are specifically explained by Shenhar & Dvir (2007) according to the diamond of four dimensions on complexity and uncertainty; novelty (how new are the crucial aspects of the project?), technology (are the projects low or high technical projects?), complexity (how complicated are the product, process and project?) and pace (how urgent is the work?). In the offshore wind context, all four dimensions are relevant and also uncertain. In addition, the very harsh wind, water and weather conditions in the North Sea make access to wind farms complicated and time-consuming, which adds to the uncertainty on all four dimensions.

According to Shenhar & Dvir (2007), high complexity within projects often causes up front failures because the extent of the uncertainty and complexity involved in the projects are underestimated, and this causes failures related to poor adaptation of the project management style to the situation. Project management in complex projects requires up front attention to uncertainty and complexity throughout the entire lifespan of wind farms, unlike in the case of the typical Stage Gate Model (Cooper, 2008), where sequential gates are loaded most heavily with participants and activities in the last gates of the projects. Early gates in the Stage Gate Model use relatively few resources to foster 'no-go' decisions in the project or program, with less resource waste as possible.

Uncertainty is mirrored in different approaches, which often distinguish between risk and uncertainty (Knight, 1921). Risk can be calculated from previous data using analytical techniques. Uncertainty cannot be calculated because information is missing to greater or lesser degrees (Winch and Maytorena, 2012). Classification of uncertainty can be done in the following way (Winch and Maytorena, 2012; p. 357):

- Known unknowns, where possible threats and opportunities can be identified; however, their impact is unclear.
- Unknown knowns, where others have identified threats and opportunities; however, they are not disclosed to the current decision maker for whatever reason.
- Unknown unknowns, where threats and opportunities have not been identified and therefore are ignored by the current decision maker. An example is the concept of 'black swans' (Taleb, 2007), which are events the decision maker ought to have known after the event has occurred – 'predictable surprises', e.g., the financial crisis in 2008.

The key issue to address both risk and uncertainty is data, information and knowledge about underlying antecedents to the event used for decision making. These were also the important elements mentioned for organisational knowledge creation and underpin the connection between knowledge and uncertainty.

A wind farm is a Complex Product System (CoPS); according to Brady and Hobday (2012, p. 282), CoPS are defined as *'high-value, capital goods systems, networks and infrastructural components, designed and produced by firms as one-offs or in small tailored batches to meet the requirements of large business or government customers'*. In the offshore wind farm sector, there are relatively small batches of wind turbines placed in different and complex surroundings with different water depths, sea beds, water flow, cabling and wind conditions. Differences are highlighted in the overview on wind farms that have already been established and those that are to be built in the future (LORC, 2015). This list contains approximately 80 wind farms, which contain 1-175 wind turbines and the size of them ranges from 500 kW (1 kW=1000 watts) to 6 MW (1 MW=1000 kW), e.g., wind turbine producers have now developed an 8 MW offshore wind turbine (Børsen, 2014); the nacelle weighs 375 tonnes and the blades and rotor weigh 35 tonnes, with a blade length of 80 m and a rotor diameter of 164 m. This enables the wind turbines to be produced in comparably "small tailored batches" with special requirements for handling components according to the ever increasing size of the offshore wind turbines. Thus, standards regarding wind farms are difficult to obtain, which hinders economies of scale in assembly line production, as seen in the automotive and white goods sectors. Project management of CoPS projects is difficult and underdeveloped (Brady and Hobday, 2012). The lifetime aspect of LCOE in the CoPS context makes project management of project programs in offshore wind farms different from normal practice. CoPS does not follow a life-cycle approach to innovation (Abernathy and Utterback, 1988) but instead remains in the early fluid phase, as CoPS essentially continues with new development in relatively small batches. Programs are viewed in relation to the Project Management Institute (PMI) as *'a group of related projects managed in a coordinated way to obtain benefits and control not available from managing them individually'* (PMI, 2006, p. 16). The lifetime issue regarding the reduction of LCOE calls for project management of the project programs.

Research within CoPS industries shows that *'competitive advantage stems from systems innovation capabilities and experience and strong customer relationships rather than economies of scale or scope'* (Brady and Hobday, 2012, p. 284). This means that CoPS projects call for up front attention to activities, which can create system integration and foster relations with customers and suppliers, thus enabling innovation within LCOE.

Thus, we put forward the following proposition:

Proposition 3d: Project program management requires up-front attention to uncertainty and complexness.

The goal of proposition 3d is to provide a contribution to the project program management initiatives to enable innovation and reduce LCOE in the wind farm industry.

In the following, the focus is on the issue of consolidation, which is often mentioned in the offshore wind farm industry.

3.3.5. CONSOLIDATION

In accordance with strategic innovation thinking, the consolidation of O&M actors could also be one of the initiatives to reduce LCOE. Consolidation of organisations in the offshore wind farm industry has the potential for both creating economies of scale and economies of scope. Grant (2014, p. 353) elaborates economies of scale and economies of scope in the following way: *'the key difference is that economies of scale relate to cost economies from increasing output of a single product; economies of scope are cost economies from increasing the output of multiple products'*. Consolidation from mergers and acquisitions could therefore both aim for economies of scale and of scope and thus reduce LCOE. However, a related impact will typically be increased market share for the consolidated enterprise, and thus, more pricing power in the market can be obtained. A further impact of consolidation is the reduction in the variety of approaches, and this leads to a reduction in innovation (Ahuja and Novelli, 2014). Thus, consolidation can both decrease and increase LCOE.

Consolidation offers the advantage that managers can oversee the strategic position of the consolidated enterprise and thus provide a more clear direction. However, empirical evidence

(Kaplan, 2006; Pautler, 2001) shows small gains for mergers and acquisitions (M&A) because the premium paid by the acquirers to the acquired enterprises seems to be too high to create value for the consolidated firm (Grant, 2014; p. 400). Moreover, post-merger activities can create problems as a result of organisational and national cultures, and thus, there is a learning threshold for acquisitions (Zollo and Singh, 2004). Basically, many of the management challenges will still be present after the consolidation unless integration activities are carried out.

In their seminal work, Haspeslagh and Jemison (1991) indicate that there are different types of integration approaches in relation to M&A activities. On the one hand, there is the need for strategic interdependence and, on the other hand, the need for organizational autonomy. The different combinations of these two forces lead to the following integration approaches: preservation (low need for strategic interdependence and high need for organisational autonomy), absorption (high need for strategic interdependence and low need for organisational autonomy) and symbiosis (high need for strategic interdependence and high need for organisational autonomy) (Haspeslagh and Jemison, 1991; p. 145). In the wind farm industry a need for symbiosis can be anticipated through the coherent measurement of LCOE.

The recent research on innovation in relation to M&A has been developed from different literature streams (Ahuja and Novelli, 2014). One of these is the resource-based logic where M&A can be seen as a way to acquire new complementary resources and capabilities and thus enhance innovation (Kaul, 2012). Another view is the transaction-cost-economics perspective where the acquisition is a way to expand firm boundaries (Keil et al., 2008). Finally, M&A can be viewed as an organisational-learning perspective that expands the absorptive capacity of the organisation (Makri et al., 2010).

In the Schumpeterian (1934, 1942) view, understanding innovation emerges from the recombination of existing knowledge elements. All the literature streams add to the understanding of the organisational recombination of new complementary resources, the expansion of organisational boundaries and the absorption capacity within the organisation. Again, it is indicated that the more tacit and socially complex the underlying knowledge, the more difficult it is to comprehend and transfer for new applications. However, it is the effective integration that determines the success of M&A activities (Ranft and Lord, 2002). This means that the coordination–autonomy dilemma exists in the need for simultaneous exploitation and exploration (Ahuja and Novelli, 2014). We thus anticipate the following proposition:

Proposition 3e: Consolidation can help reduce LCOE

The goal of proposition 3e is to contribute to considerations of consolidation initiatives to enable innovation and reduce LCOE in the wind farm industry.

3.4. SUMMARIZATION OF PROPOSITIONS

The literature review has provided us with several propositions, which can be supported or not due to the findings in the research material. An overview on the propositions is given below:

Proposition 1: In the wind farm industry, the interests of governmental bodies, universities and private companies can be integrated and differentiated on several dimension to reduce LCOE.

Proposition 2: Opportunities for governance through the alignment of economic, agent and organisational approaches can reduce LCOE

Proposition 3: Both opportunities for organisational creativity and institutional control can create value and reduce LCOE through

- ***Openness on knowledge flows across organisational boundaries.***
- ***Ecosystem co-creation and positive feedback loops on the innovation platform.***
- ***Organising for collaboration between complementary business partners to create both synergy and ambiguity across traditional boundaries.***
- ***Business model innovation as a tool for connection, inspiration and transformation at both the organisational and ecosystem level for the industry.***

Proposition 3a: Networks of reciprocal organisational learning can reduce LCOE.
Proposition 3b: Organisational knowledge creation can use both centralised and distributed leadership to reduce LCOE.

Proposition 3c: Nurturing the attractiveness of the collaboration partner plays an important two-sided role in reducing LCOE.

Proposition 3d: Project program management requires up-front attention to uncertainty and complexness to reduce LCOE.

Proposition 3e: Consolidation can help to reduce LCOE.

The summarization of proportions reveals important opportunities to have an impact on the reduction of LCOE. A number of literature segments provide knowledge on the opportunities for reducing LCOE. The summarization is presented graphically in Figure 2. It shows that the propositions are grounded in the Triple Helix and governance literature and notions of the combined effort of the three parties of governmental bodies, universities and enterprises in addition to the need for a wide range of governance mechanisms within economic, human agency and cultural notions. Strategic innovation draws upon the literature streams of the Triple Helix and governance literature in the context of offshore wind farms. This helps frame the groundwork for creating opportunities in innovation and reducing LCOE.

Strategic innovation involves decisions on positioning in relation to notions of open innovation, innovation ecosystems and platforms, organising innovation collaboration and business model innovation. All these notions and the associated literature streams are essential parts of strategic innovation in the wind context, as highlighted in the literature review, and provide guidance on positioning the ecosystem to enable innovation. Moreover, several essential initiatives resulting from access to resources are part of strategic innovation, especially in relation to networks, organisational knowledge creation, attractiveness of partners, project program management and consolidation. Again, the literature streams can provide guidance on important initiatives to enable innovation.

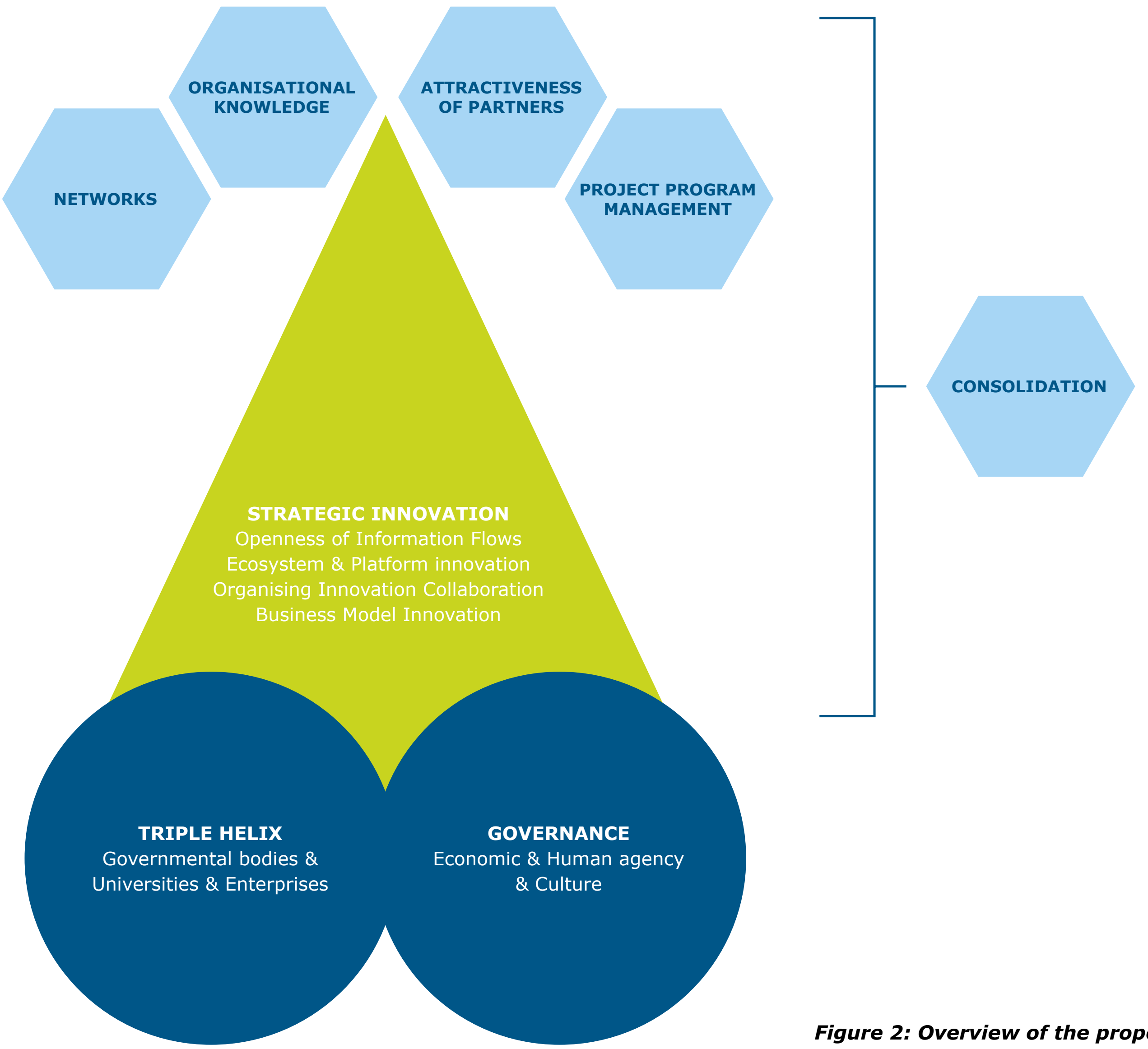

Figure 2: Overview of the propositions

4. METHODOLOGY

The research is based on qualitative semi-structured interviews from June 2014 to May 2015 with actors operating within O&M activities in offshore wind farms.

In the beginning of the qualitative research, a focus group interview was conducted with 11 participants who were invited due to their different roles in O&M activities within offshore wind farms. The participants in the focus group interview revealed challenges and phenomena in terms of a broad spectrum of offshore O&M activities. The challenges increase when the yield from the offshore wind farms starts to materialize. The capture of yield starts after the wind farm is commissioned. '*Generally commissioning is understood to cover all activities after all the components of the wind turbine are installed. Commissioning tests will usually involve standard electrical tests for the electrical infrastructure as well as the turbine and inspection of routine civil engineering quality records. Careful testing at this stage is vital if a good quality wind farm is to be delivered and maintained'* (www.wind-energy-the-facts.org). After commissioning, the O&M activities begin, which are the focus of this report.

The participants in the semi-structured focus group interview held in June 2014 were managers from various companies with different roles, e.g., a wind farm owner, a wind turbine producer, equipment suppliers, service providers of equipment and/or staffing. Eleven different companies working on offshore projects participated in the focus group interview with at least one management person from each company. Five of the participants gave a short 15-minute presentation on their view of the O&M challenges in reducing LCOE. Afterwards, a discussion of the challenges was conducted among the participants, resulting in a lively debate. The focus group interview was transcribed to analyse the findings (Eisenhardt, 1989; Charmaz, 2006; Yin, 2009). Different roles and interests were distinguished in this material on service providers offering manpower/equipment/components and service providers offering transportation/maintenance solutions using logistic solutions on ships, helicopters and jack ups. The maritime logistic facilities offshore are relatively capital intensive. Also, capital partners such as venture and capital associations play a role in the supply of capital for the wind farm and O&M offshore wind farm activities.

After the analyses, semi-structured open-ended interviews were conducted from October 2014 to March 2015 with actors from twenty additional companies participating in O&M activities in offshore wind farms, including wind farm owners, wind turbine producers and small and medium sized enterprises (SMEs) operating as suppliers and service providers to O&M activities. Furthermore, industry organisations connected to suppliers to wind farms were interviewed. Through this individual interview approach, more in-depth interviews could take place regarding the challenges and lessons learned for reducing LCOE at different offshore wind farm sites. An interview guide was developed, which on the one hand provided overall strategic structured information on innovation to reduce LCOE in the wind farm area and, on the other hand, provoked the interviewees to think about how to reduce LCOE. The interview guide created opportunities for the researchers to follow interesting new/enhanced phenomena emerging from the interviews. Moreover, the interviewees were directly asked about their views on the reduction of LCOE. The interview guide was sent to the interviewees as an agenda previous to the meeting.

The researchers were looking for rich information from the interviewees, and therefore, confidentiality was agreed upon with the participants. This confidentiality was important to the majority of the interviewees and mentioned by several of the interviewees as essential. Citations in our report are thus anonymous to the reader.

All interviews were recorded and transcribed for thorough analysis. The first analysis of the data was conducted after 5 interviews in a collective discussion. The discussion was focused on needed adjustments to the interview guide. In the discussion of the preliminary findings, it was revealed that the interview guide worked well. However, the discussion on preliminary findings did sharpen the attention and focus in the remaining interviews. Here, it must be emphasised that the interview guide is explorative and allows interpretation on the part of the interviewees. Moreover, the researchers have worked together on other offshore wind research projects since 2011 and thus have previous knowledge about the field. The interview guide is provided in appendix 1. The interviewees were primarily selected from companies and/or managers the researcher did not have contact with during previous research. New understanding and insight could be obtained through this approach to the interviews. In Table 1 below, an anonymous overview is provided for the individual interviewees regarding the role of their organisations and their own role within the enterprise.

Table 1: Anonymous overview of the interviewees.

ROLE	LEVEL/FUNCTION IN THE ORGANISATION	NUMBER
Windfarm owner	Manager – Wind farm responsible	2
	Manager – O&M/ service responsible of wind farms	5
Wind turbine producer	Manager – Wind turbine responsible	1
	Manager – O&M/ service responsible of wind farms	2
Service providers, manpower, equipment / component suppliers	Manager – Service/ supply responsible	3
Service providers logistics	Manager – Service/ logistic responsible	3
Capital partners	Manager – Investment responsible	2
Industry associations	Manager	2
TOTAL		20

be addressed by the experienced managers in the O&M field. '*Converging lines of inquiry*' (Yin, 2009; p. 115) started to emerge on the issues for research, and was prominent in the last 25% of the interviews. This means that the interviewees highlighted predominantly the same answers as already gathered to the research question – just from different perspectives.

Further analyses were conducted after the researchers ended the interviews in March 2015. During the analyses, a deductive approach regarding the propositions already listed was used to reveal the most interesting findings based on the literature review. The goal is to select the most interesting findings in relation to the existing literature streams. Therefore, a contribution is made to the research for the benefit of the parties directly involved in the research, the wind farm industry, and governmental bodies; in addition, new research knowledge is also an important contribution.

Table 1 shows the different roles of the interviewees and the level and function in which they operate in the organisation. It can be seen that the information from the interviews is based on six very different roles in the offshore wind farm business supplier network. Rich information drawn from different interests and roles is thus present. Moreover, different management levels are also present; however, all have a connection to the O&M field of offshore wind farms. Strategically important issues are anticipated to

The researchers went through all transcriptions and picked interesting quotes on the different propositions. These quotes were typically 1- 10 lines and picked according to the ability to capture the meaning in the answer of the respondents. They were filed in a joint word document, which in the end contained 88 pages. An anonymous system was developed to present the findings and still keep the ability to trace the source of the quotes. Then the quotes went through a joint selection process done through discussions of the researchers on a more focused capture of meaning for display in power point slides. The material selected was filed in a joint power point file of 225 slides and printed for physical display of the quotes.

The researchers used a large room to display, sort and discuss the similarities and differences across the rich information provided by the various actors. The material was sorted according to the themes in the interview guide (see Appendix 1). The material was displayed to reveal patterns in the research material. The displays were captured in photographs to keep opportunities for later consultation. For several days, the researchers analysed the data and discussed the meanings and findings according to the relevant themes. A heuristic inquiry process (Hiles, 2008) combined with a phenomenological inquiry approach (Creswell, 2007) was thus used with the integration of a critical theory (Budd, 2008) stance on the findings and methods employed (Fuglsang and Bitsch Olsen, 2007). The most interesting findings and patterns of findings were during the analysis highlighted directly on the slide displays. This material was also captured in photographs for later consultation in the writing process of the findings in this report.

In May 2015, a seminar was held for presentation of the preliminary findings from the research and for the representatives of the offshore wind farm industry to discuss the necessary steps to reduce LCOE. The researchers presented the most interesting preliminary findings, and five industry actors with different roles (see Table 1) presented their view on needed initiatives afterwards. Overall, 60 participants from different O&M actors provided a foundation for comments on the findings and thus a discussion was able to unfold. The presentations and discussions afterwards were recorded for analysis, which could supplement study of LCOE reduction.

The cross-disciplinary approach to the research on both methodology and theory requires an understanding of the processes and concepts. As highlighted by Kuhn's (1962, 1996) notion of *'incommensurability of competing accounts of reality, which cannot be coherently reconciled'*, cross-disciplinary research is challenging. According to Kuhn (1962), there is no way that one can compare theories because no universal criteria exist. In other words, the accumulation of knowledge is not possible. Instead, there are paradigm shifts in knowledge. Kuhn's (1962) argument has been criticised by Popper (1965), as overlaps of theoretical concepts exist in his elaboration. Fuglsang and Bitch Olsen (2007) summarise the antecedents for communication across frameworks as a linguistic formulation of beliefs, openness to discussion, interest in the same problems, interest in the consequences and willingness to employ a positive attitude in the discussion. In the applied research, within which the research in this report is situated, the cross-disciplinary issue is an antecedent for research; and it is often necessary to use in the research as a practical application is often grounded in different cross-disciplines. Therefore, the philosophical position of this report acknowledges communication across frameworks. This means that the comprehension of science can never rely on full 'objectivity'. There must be an account for subjective perspectives, which can be very difficult to communicate across paradigms and disciplines.

In the following sections, the findings will be revealed.

5. FINDINGS
5.1. TRIPLE HELIX

Based on the literature review in section 3, the following proposition was derived*:*

In the wind farm industry, the interests of governmental bodies, universities and private companies can be integrated and differentiated on several dimensions to reduce LCOE.

First, it is important to stress that many projects and cooperatives have been developed in the offshore wind park industry, often with the participation of organizations from 'industry', 'academia' and 'public bodies'. The following citation illustrates this:

N18:'There are many initiatives and it´s a big advantage for the industry.
One of them is the Carbon Trust consisting of, among others, 9 energy companies and partly financed by the English department of energy and climate change.'

N19: 'Even if company X is big, they are very happy to cooperate in the development of new and cheaper foundations for the wind turbine. One institution is project managers and perform all the administrative work. A technological institution is as partner delivering specific knowledge to the project. The project is financed by the EU'.

The first citation is about the Carbon Trust organization, which coordinates the work among governments and innovators with the goal of accelerating the commercialization of low carbon technologies in companies from a general and worldwide perspective. The last example involves a concrete development process in a larger company with the clear goal of minimizing the cost of a vital component in an offshore wind park.

It is shown that different interests from different types of organizations ("public body", "academia" and "companies") can be integrated into temporary organizations ("projects"). The overall purpose of the projects is to make the industry more attractive, e.g., by lowering the costs of important components.

As indicated above, different projects have been launched. Here, we can take a closer look at the incentives and potential for participating in developmental processes.

Different interests, incentives and potentials can therefore be identified. First, participation in a concrete development process offers possibilities for financing some of the expenditures. Second, external financing from the EU, regional funds, private funds, etc. means a great deal of administration, which public business organizations can effectively manage. Third, technological organizations can contribute with specific knowledge about welding principles and steel construction – primarily knowledge transferred from the oil and gas industry. Fourth, universities for the social sciences can contribute to the integration of business development and network knowledge for SMEs as well as collaboration with larger organizations. Combining complementary knowledge from different partners thus contributes to the reduction of LCOE.

Value creation, business development and competitive advantages for the purpose of reducing LCOE can be initiated by the implementation of relevant project based results.
To prevent specific companies from being supported, many restrictions exist; e.g., the Danish power supply companies are included in the EU tender law. This means that the companies cannot cooperate closely with another company on concrete product and service innovations – see the following citation.

*N9**:** 'The power supply companies are included in the EU tender law. Therefore, we (subcontractor) can go to a turbine producer and - in cooperation with them - develop new services to be used by power supply companies. This is not permitted according to EU legislation as it is viewed as disturbing 'arms-length' competition'.*

Different kinds of EU laws regulate competition. The tender law has the purpose of hindering larger companies from closer cooperation with concrete companies without a public tender. The tender process is both time and resource demanding and thus has a negative effect on the reduction of LCOE if lower prices are not obtained through the tender.

National laws also differ in relation to the way the same activities are regulated. Again, an alignment among countries will have a positive effect on the reduction of LCOE

*N20**:** 'It would be a very good idea if the national laws could be aligned across different countries. E.g., in country A, you have to make inspections of service lifts 4 times a year, whereas in country B, one inspection every second year is sufficient….. and it´s possible that the service lift hasn't been used since the last inspection. You don't respond to the concrete problem but concentrate on following the law and that doesn't´ reduce LCOE…'.*

Many informants expressed an equivalent desire for more uniform or standardized processes. Different kinds of rules and procedures exist for the same types of jobs at different companies.

Clearly, such different ways of organizing the O&M jobs have a negative effect on LCOE.

N10: 'Try to think about this situation: yesterday we worked in country A on a turbine from company X, today we work in country B on a turbine from company Y and tomorrow we will work in country C on a turbine from company Z – the same type of jobs to be performed, but companies require a company specific way to do it …. And this can be combined with country specific differences…harmonizing doesn´t exist'.

*N14: 'The industry has chosen that GWO (Global Wind Organization) has to develop **minimum** standards for practical training, so the different companies agree on the same level of practical training….. GWO presents some overall practical standards. The purpose is useable solutions. The starting point for the work is the STCW convention, which is applied to the maritime sector. In this convention, all is regulated into details, and this is not appropriate to the wind sector. Therefore, we have to develop our own standards for practical training'.*

N9: 'You can be a little worried when energy company A talks about industrializing and standardization of products and processes as we now have to change all the <specific component> of all the turbines. It is problematic when you standardize products which not are fully developed'.

Thus, the different kinds of regulations and standardizations can have both a negative and positive impact on LCOE. The EU tender law has an unintended negative impact on LCOE due to high resource and time consumption. Some of the larger companies try to develop company specific rules and procedures for exactly the same processes – clearly it hinders optimization of processes – with a negative influence on LCOE. On the opposite side, the GWO has managed to develop some minimum standards for practical training – with a positive effect on LCOE. However, these standards are only to a limited degree coordinated with equivalent maritime standards. This is a safety issue because accidents happen in the interfaces.

The ownership of a wind park can have a significant influence on how the O&M activities are organized and geographically embedded as the citations below indicate:

N5: 'In developing the new park, we decided at an early time to place the O&M activities in country A as we already had a setup in this country. The park was owned by 2 energy companies – one in country A and the other in country B. The politicians in country B argued for placing some of the activities in their country (B) – even though costs would be higher. The argumentation for placing the activities in country B was primarily because the taxpayers financed a part of the park due to the subsidies'.

N5: 'If you want to do business in this country (C), you have to organize some local activities – local content. An understanding of this is important. In Denmark, the problem is not important at the moment as the foreign companies are not competitive compared with Danish companies'.

Many political interests are attached to the establishment of wind parks. Taxpayers are paying 2 – 3 times more for wind park electricity compared to conventionally produced electricity. It is understandable that politicians want local activities as compensation for higher prices – even if it has a negative effect on LCOE. This means that the subsidies in the long term will be necessary for wind farms if these competing self-interests are not solved somehow.
Slow political processes can have a negative effect on the efficiency of a wind park. When a park has to be developed, the public authorities have to treat the application as quickly as possible. Otherwise, there is a lack of turnover and inefficient construction of the park, as also illustrated in the following citation:

N5:'…the new park was designed for 750 KW turbines, but the processing times at the public authorities took nearly 10 years, and in the meanwhile, new turbines were developed and the park was provided with 2.3 MW turbines. The consequences of this is a park where the turbines are placed too close to each other – which produces a negative effect on electricity production and on LCOE'.

Traditionally, many research and development activities have focused on the development of new components such as wings, gears, operation systems, etc. Many Danish research institutions have contributed to this process (Risø, Lorc, Østerild, etc.). However, little attention has been paid to O&M activities, as also stated by one of the respondents:

N5: 'In relation to the Ph.D. project in O&M, we have established a reference group, and at the last meeting, we found out it´s the first time you have research at the university level in this area…. In addition, the Ph.D. student has established many contacts with other relevant actors in the industry and research field'.

The following examples illustrate that companies in the industry and public teaching institutions can collaborate and use each other's competencies.

N3: 'We cannot use the services from the local technical school at all. They have to use up-to-date equipment in the teaching situation. We discussed the problem with them and decided to try to find a solution. However, they didn´t have 2 mio DKK to invest in modern equipment - just to provide courses for us. Therefore, we entered into an agreement so that the technical school could use the equipment at the company. It´s an advantage for all parties…'.

N13 '10 years ago, an education program for serviceman was introduced. In the beginning, many problems were related to the qualifications of the candidates. Cooperation and discussions among partners have meant that the problems have been identified and solved. …. In addition to this education program, many park owners, turbine producers are buying different education programs at the publicly owned technical schools'.

The citations indicate that the interaction and cooperation between partners is quite new but in a growing phase. It is realistic to expect a positive contribution to the reduction of LCOE from research and teaching institutions in the near future – there is at least the potential to intensify cooperation.

In sum, the Triple Helix issues can be highlighted as follows:

- Obvious advantages for companies can be identified by participating in development projects consisting of partners from 'public bodies' and 'academia'.

- Differentiations in national laws regulating the same process have a negative effect on reducing LCOE.

- Descriptions of how to perform the **same** type of jobs of **different** companies differ – lack of standardization means higher LCOE.

- GWO has developed minimum standards for practical training – the initiative is an example of a positive contribution to reducing LCOE.

- Politicians are often interested in creating local activities that can mean inefficient coordination and management of the O&M activities.

- Considerable potential exists to intensify the cooperation between research and teaching institutions and the industry.

In general, it can be concluded that the cooperation among 'industry', 'academia' and 'public bodies' in the Triple Helix context shows both positive and negative contributions to the reduction of LCOE. Many concrete development projects illustrate the potential to reduce LCOE in such forms of cooperation. On the other hand, politicians in different countries and regions try to sub-optimize by arguing for local activities in their country despite the increased costs. In this way, competing companies try to build obstacles to developing standards for the same type of jobs, and it is therefore difficult to achieve economies of scale. However, tendencies in terms of larger coordination and interaction can be identified. The GWO has together with representatives from the industry developed common standards for practical training; however, they are not integrated with the maritime area, which has similar regulations.

Additionally, the potential of research and teaching institutions ('Academia') is only used to a smaller degree based on the fact that, traditionally, focus has primarily been on development and construction phases and not on O&M activities.

The findings thus illustrate the challenges in an important industry in its early development phase. Politicians try to maximise their influence by establishing local activities. The cooperation among the industry, research and development institutions and state is in an emergent phase –

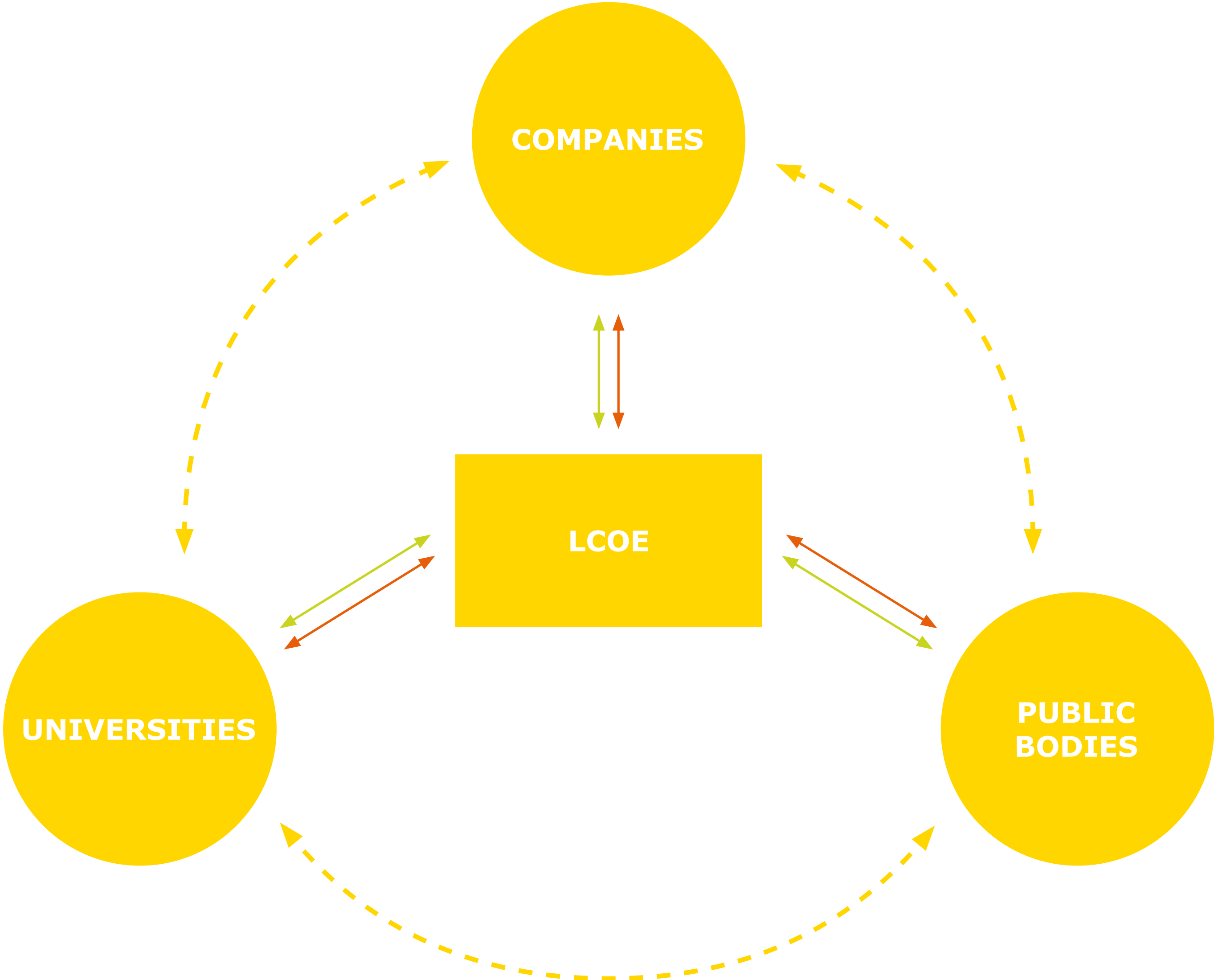

Figure 3: Triple Helix and the impact on LCOE.

the intensification and development of the activities seem to support a reduction of the LCOE. Figure 3 illustrates central aspects of the cooperation among 'companies', 'public bodies' and 'academia' and the consequences of closer interaction with regard to the reduction of LCOE.
The dotted line between the actors in Triple Helix indicates the level of cooperation and mutual impact on the involved organizations. The influence of the cooperation may be a result of both hindrances and positive incitements.
The green arrows illustrate the **positive** effects on LCOE from the interaction of the involved partners, and the red arrows indicate the **negative** impact

The findings thus show that the interviewees support proposition 1. LCOE can be influenced in a positive direction as a result of the cooperation and interaction of the 3 involved partners. The degree of interaction of the partners depends on the concrete problem. However, at the moment, the Triple Helix collaboration is lagging behind. Examples of necessary Triple Helix initiatives can be derived from the interviewees' comments as follows:

- Much faster decision process regarding political decisions and legal aspects regarding wind parks

- Creating rules that can support value creation and reduce the risk aspects. This typically means some kind of trade-off between flexibility and alignment regarding the following:
    - Flexibility of rules in relation to local context
    - Alignment of rules for common activities across nations
    - Alignment of rules for common activities across enterprises
    - Alignment of rules for common activities between maritime and other actors.
    - Funds for research on reduction of LCOE both in terms of technical issues and commercial issues.
    - Creation of educational initiatives regarding wind parks between actors in the wind industry and educational institutions.

5.2. GOVERNANCE

According to the literature review on governance in part three, the proposition derived the following highlights:

Opportunities for governance through the alignment of economic, agent and organisational approaches can reduce LCOE.

The wind park context in section 2 highlighted the opposing interests of participants in the wind park industry, which were identified as the forces of technical governance and the lagging behind of commercial governance. Furthermore, short-term and long-term governance approaches were identified together with risk reduction, in particular with regard to capital partners.

The citations support the anticipation from the literature review regarding the beneficial overlap of the economic, agent and organisational approaches for the reduction of LCOE. There are a few comments on the 'pure' agency approaches to offshore wind farms. One of them is cited in the following regarding the clear economic approach:

N11: 'We are in the offshore market purely to make money'.

On the opposite end, we find a citation on the non-economic approach that is much more in line with agent and social trust issues as follows:

N10: 'We are offshore priests. We believe that renewables and offshore wind is one of the rescue blocks of this world'.

This means that strong agency is also present in the industry, driving solutions to obtain sustainable energy and competitive advantage for social wellbeing. This governance approach is in varying degrees present in other citations but not as clearly stated as in the opposing citations above.
Another dimension of agency regards the time period of contracts and the interests this creates regarding uncertainty and O&M activities. This is generally addressed as a challenge as in the following citations:

N20: 'The issue is to get the risks located in the right place. Any risk gets a price tag (price premium). When LCOE needs to be reduced, somebody must take the risk connected to the contracts. Here, the longer the time horizon, the better because the risk can be levelized over a longer time period'.

N9: 'Development is possible, but who takes the risk of investment?'.

N10: 'When you normally build a capital-intensive asset, you can get a contract for 10-15 years. Here, you cannot even get a two-year contract. You may well assume some risks if you are able to control it. If you are not, then it's like going to a casino. And current wind, water and weather conditions are uncontrollable'.

N1: 'There is a need for a longer time horizon because 'the machines' get bigger and bigger and the investments in infrastructure that can produce the devices become larger. Costs increase instead of being reduced. A longer time-horizon will provide a longer period for return on investments'.

The time horizon seems to be a general challenge. The performance risk connected to the wind farms are often commented on by all the interviewees. No easy solution is found because different solutions have different drawbacks for agency behaviour. It is not enough to think of a longer time horizon if no incentive is present to operate O&M activities efficiently and effectively given the uncertainties over the lifetime of the wind park. The issue of necessary alignment of incentives in relation to the reduction of LCOE is addressed in the following citations:

N4: 'Typically, incentives are operating in the time period of the contract. For O&M activities, the incentives are aligned for events within the contract period, but not after the contract has expired, which supports short-term O&M interests and initiatives'.

N5: 'A risk exists for non-aligned activities on O&M through the limited time horizons of contracts. This could create a focus on maintenance within the period of responsibility and break downs afterwards due to unsustainable long-term maintenance activities'.

N10: 'There is too much emphasis on economic interest leading to sub-optimisation of activities over the lifetime of the wind farm'.

It is shown that agents have different interests due to the different contract time horizons, which can lead to economic sub-optimisation.

Furthermore, agency interests in local content are viewed as necessary for international cooperation on offshore wind farms:

N6: 'Danish actors in the wind industry need to engage in activities locally, e.g., sourcing of manpower and equipment locally and establishment of offices and production/assembly facilities locally to get projects on international offshore wind farms'.

This will often have an impact on economic governance, making tasks more expensive in the short term due to, for example, requirements to train local labourers and local suppliers (Kuntze and Moerenhout, 2013).

Several comments are related to the organisational–economic overlap on governance:

N1: 'This is an industry with large oligopolistic companies that do not trust each other, and it has historically been quite difficult to work together'.

N6: 'People are holding their cards close, and each time a competitor has a problem, then you say: 'Ha-ha – one man's loss is another man's gain'.

N13: 'Valuable knowledge is kept in own organisation and not shared with relevant partners'.

N5: 'There is a need for closer cooperation between owners, wind turbine suppliers, foundation contractors, independent service suppliers and vendors of infrastructure. Discuss how to make things more appropriate. All agree on this claim. However, where "somebody loses it" is when you look each other in the eyes and request "open books". This can be difficult – it is livelihood that we are talking about. There are some limits to be exceeded, and at the same time, there is "core knowledge" to be protected'.

These citations seem to be informed by the widespread perception that critical knowledge is not shared in the industry. '*They keep their cards close to their chests'*. This means that opportunities for the ecosystem to create economic benefits for the whole industry are lost. Trust between the main actors also seems to be low. This means at the end of the day that governance in the industry is weak because nobody supports a common approach to *'how best to reduce LCOE'*, which involves joint incentives and trust.

In summarization, the findings regarding the governance issue reveal that:

- Both economic and non-economic issues play a role for actors.
- Agency is split due to different time horizons on contracts, creating short-term incentives for O&M activities rather than long-term reduction of LCOE.
- Agency on local content increases costs in the short term.
- There is low organisational trust for knowledge sharing between organisations.

In general, this creates a fragmented and weak governance structure in the industry as a whole, with no joint incentive and/or mutual understanding of the approach to O&M activities. Each organisation has its own governance logic, which is either economic and/or more idealistic. The interests of agents are fragmented and conflicting according to the different time periods involved and the risks associated with contracts. Moreover, trust is low, and there is therefore little sharing or knowledge creation between organisations. This creates opportunities for suboptimal approaches and fragmented, dispersed incentives that are not aligned. It is therefore likely that governance initiatives are underdeveloped in terms of economic incentives, regulatory alignment and mutual trust; opportunities to reduce LCOE in the industry are therefore few. This is illustrated in Figure 4, which is related to Figure 2 in the literature review.

Figure 4: Overview of findings on governance structures

The findings thus show that the interviewee support proposition 2 regarding opportunities for the alignment of economic incentives, agents and trust. The interviewees perceive the governance issues as being important for the reduction of LCOE. However, at the moment, the governance issues are anticipated to be weak and fragmented.

The alignment of incentives between actors is important; however, alignment is at the moment not supported by O&M actors due to different time horizons and issues of risk.

The following examples of necessary governance initiatives can be derived from the interviewees' comments:

- Alignment of incentives across the lifetime of the wind park. This means avoidance of short-term contracts and more focus on contracts with a longer time perspective.
- More strategic approach to the whole wind park eco-system. Alignment of the overall direction and incentives either in the form of one 'focal firm' or the creation of a more thorough and open platform for wind parks.
- Building trust among participants by intensive collaboration and creating organisational knowledge to reduce LCOE
- A degree of 'open books', although this can mean lower revenue in the short term for some actors, as their work may be reduced according to the approach to reducing LCOE. However, the solution is to provide additional enhanced tasks/contracts in the future.

5.3. STRATEGIC INNOVATION

According to the literature review on strategic innovation in part three, the proposition derived indicates the following:

Both opportunities for organisational creativity and institutional control can create value and reduce LCOE through

- *Openness on knowledge flows across organisational boundaries.*
- *Ecosystem co-creation and positive feed back loops on the innovation platform.*

- *Organising collaboration between complementary business partners to create both synergy and ambiguity across traditional boundaries.*

- *Business model innovation as a tool for connection, inspiration and transformation on both the organisational and ecosystem level*

The findings relating to strategic innovation naturally contain several cross-disciplinary approaches on the strategic level, ranging from creativity to institutional control, as well as a range of issues on the openness of knowledge flows, ecosystem co-creation, organising for ambiguity and business model innovation. The goal of the analyses of our research is to provide a contribution to the following research question: *How can lifetime sustainability of offshore wind farms be achieved by the reduction of LCOE?* This is done through a comparison of the existing knowledge in relevant literature streams; propositions are created with comparisons to the findings from the research material gathered. The findings are listed below and summarized in this section to create an overview of the multifaceted issue of strategic innovation. We start by addressing the call for organisational creativity within offshore wind farms.

ORGANISATIONAL CREATIVITY

The interviewees have highlighted several areas that demand organisational creativity. The highlighted areas can be categorized into several topics. The first topic is the offshore wind farm. Here, two issues are highlighted

- Size of the wind turbine.

- Design for easy service on the wind farm.

The size of the wind turbines determines the amount of electricity produced measured in MWh. Larger wind turbines can produce more MWh. Forces for the development of larger wind turbines are thus present. This was indicated by several interviewees and is suggested in the following citation:

N20: 'An even larger wind turbine is probably under development just now'.

In relation to the development of offshore wind farms, incremental innovation is mentioned as a viable way to reduce LCOE considerably:

N16: 'When you have components with a good track record, you can build upon them to improve the existing design. Considerable gains can be achieved in terms of the reliability of production of the wind turbine'.

Moreover, service issues can to a larger degree be an object of focus in the design of offshore wind farms, as specifically addressed in the following citation:

N20: 'Now, the first offshore wind turbine types begin to emerge from development due to an O&M perspective. This means that they are developed from 'the service point of view'. Here, the O&M area has formed the specification of requirements for the new wind turbine type. Offshore wind farms are much more dependent on efficient and effective service than onshore wind farms because of the very different and changing conditions for providing O&M offshore. This fact has caused some headaches among actors in the history of offshore wind farms'. Equipment related to offshore wind farms is focused on organisational creativity, as highlighted in the following citation:

N3: 'I participated in discussions on busting performance (on equipment) six months ago when it was a secret in the market. Now, it has been revealed in the market. It is a solution we believe in'.

In relation to the development of the wind turbine, the time frame has been highlighted as important, as indicated in the citation below:

N16: 'The timeframe for developing new wind turbine types is very different for different wind turbine producers. However, 'time to market' is important to improve both efficiency and effectiveness. It can be done with new interface designs on well-known and tested modules of the wind turbine. So, 'time to market' can be reduced considerably – by three times or more'.

The interviewees have highlighted innovation concepts of both radical and incremental innovation as well as specific areas to improve the production of energy by the 'wind farm'. An important dimension to take into consideration is therefore the increased electricity production from the offshore wind farms.

In general, the costs relating to offshore wind farms have also been addressed and are typically framed as in the following citation:

N20:' There is basically two ways of addressing the costs;

1. *The cost of establishing the offshore wind farm.*

2. *The cost of service relating to the offshore wind farm, which is driven by*

   a) Manpower.

   b) Replacement of the main components (e.g., generator,gears etc.).

   c) Logistic solutions (e.g., ships, jack-ups, helicopters etc.)'.

In this citation, the complex and multifarious tasks needed to provide O&M activities are highlighted. Furthermore, the costs for establishing the wind farm and providing service are related through the concrete construction and installation of the offshore wind farm. The construction of the offshore wind farm has a spill-over impact on service costs, as highlighted in the citation below regarding access to the offshore wind turbine:

N7: 'It is important to have easy access to the wind turbine. It is a very costly affair to have ships and helicopters waiting for access to the wind turbine both in direct relation to the cost of the ship/helicopter and also in relation to the 'lost production' of the wind turbine, as energy production typically has stopped from the specific wind turbine'.

This leads us to the need for new logistic solutions to provide service to offshore wind farms, as mentioned by several interviewees:

N20: 'Different logistic solutions are necessary according to the distance to the offshore wind farms. Different set-ups are required for different wind farms on, e.g., Crew Transfer Vessels (CTVs), helicopters, accommodation ships and jack-ups'.

N8: 'New crew transfer solutions are under development, which will require different approaches on different offshore wind farms'.

Enhanced ideas are also suggested for remote solutions, as indicated in the following citation:

N6: 'Some of the service issues can probably be taken care of remotely. This will be important to develop further as the access to the wind farms are so troublesome and costly'.

Random development of new solutions for service does occur, as highlighted in the following citation:

N9: 'It was a chance encounter at a Christmas party in (country), where we outlined the first drawings on a napkin for a novel design on the equipment. Now, we have the intellectual property rights (IPR) on the idea'.

In general, a primarily technological approach is highlighted for frames for offshore wind farms rather than a market approach.

N16: 'In reality, "engineering technical solutions are developed" based upon specific requirements from customers or previous experience with existing technology and/ or harsh events offshore'.

The need for 'space/time' in the idea phase is further highlighted, as underlined in the following citation:

N3: 'Bubbles of time are necessary for development but can be a waste of time if not related to a specific need/project. This has been seen not only at our company but at many other companies'.

The ideas require close collaboration with customers. It calls for business model innovation in collaboration with customers and partners as elaborated later in this section.
Moreover, frustration is present regarding organisational innovation, as highlighted in the citation below:

N1: 'We use the same solutions over and over again. On occasion, we fall into the 'outdated trap' if we do not do something else quickly'.

Based on these citations, organisational creativity is needed to mobilise production of MWh on the wind farms. Hence, direct cost reduction is needed for construction/installation in addition to the O&M costs for service afterward. Here especially, new logistical solutions are called for that combine efficient and effective use of manpower resources, replacements of main components and customised logistical approaches with integrated development of specific parts and services connected to scheduled and unscheduled O&M activities. The interviewees seem to be highly focused on practical technology applications and not on the bigger market picture. A degree of randomness seems to be present in relation to development. Frustration can also be observed from doing too much of the same thing with no subsequent innovation, which disposes the industry to failure, specifically with regard to reducing LCOE.

Proposition 3 is thus supported on the need for creativity in reducing LCOE:

- Improved electricity production either as a result of better performance from the wind turbine or less down time.
- Creative service and logistical solutions.
- Creative ways of constructing the wind farm for easier service during the lifetime of the offshore wind farm.

In the following, the perceptions of the interviewees are analysed in terms of the control of resources issue.

INSTITUTIONAL CONTROL

Institutional control involves the stabilizing factors for innovation. Here, the interviewees also list certain factors. In general, several interviewees note the relatively late focus of the wind farm industry on R&D and testing facilities, which can provide data for improving the performance of the wind turbines. This is elaborated in the following citation:

N6: 'R&D functions have, generally speaking, had a relatively late focus on testing facilities for new developments. When did the first larger testing facilities emerge? 5-10 years ago. From that time, larger investments were made in R&D'.

In general, stable operations are highly valued as highlighted in the following citation:

N6: 'Stable operations – above all. We do not need a 10 MWh wind turbine. We need a 1st, 2nd, 3rd or more generation of, e.g., an 8 MWh turbine instead, which can be produced under all conditions. However, there are issues you cannot predict. You cannot design a wind turbine that will never have a breakdown because, e.g., the gearbox will need to be so large according to the required specifications that it will not fit into the wind tower'.

Here, it is acknowledged that the stability of operations are first and foremost required, but they will never be fully obtained. There is a continuous trade off between the stability of production and other practical issues. In general, stability is perceived by the establishment of standards on solutions and operations, as specifically highlighted in the following citation:

N4: 'Standard solutions are required on, e.g., foundations for the wind farm dependent on the water depth of the site. It may well be that we compete, but we need to compete on the standard after it is created. Then, we can show how good we are within our core business'.

Competition is here perceived as being most valuable in core areas, and beyond these areas, standards must be created in collaboration. Division of the activities among the actors, who are best at performing them, seems to be a prerequisite. Moreover, there is a need for stability and documentation on the IT-platforms to support knowledge sharing across geographically separated locations and organisations. This is highlighted in the following citation:

N10: 'We spend very little time on paper documentation. We exchange documents on IT 'share-platforms' with our customers and partners. It both secures documentation and operations, and it is possible to control the versions of documents. The industry is characterized by new employees who do not have any idea what they need to do'.

This stabilization mechanism also has a sup-

Credit: Windpower Works, Danish Wind Industry Association portive effect for new employees and thus offers several stabilising and controlling dimensions to support reduction of LCOE. A further stabilizing mechanism is seen in thinking ahead for service solutions:

N3: 'We try to think a few steps ahead for solutions. We do not only think as others do when they send employees on courses: "Well, we have some people ready". No, we think about what they (customers) need for actual readiness for operation offshore'.

Here, the issue of manpower readiness is viewed as essential for stable offshore operations, requiring the foresight of suppliers who are able to see future challenges.

Based on these citations, several dimensions provide control for, first and foremost, the stability of operations, as follows:

- Standard versions of products and services to support MWh production and cost reduction through standardization
- Qualified IT document exchange
- Thinking ahead on manpower capabilities for operational tasks offshore.

Proposition 3 is thus supported in terms of both the need for creativity and the need for control of resources for the purpose of increasing electricity production, either as a result of improved performance of the wind turbine or less down time, service and logistical solutions, or methods of constructing the wind farm for easier service during the lifetime of the offshore wind farm.

The findings on the combination of organisational creativity and control of resources show, on the one hand, opposing forces of:

- Ever-higher wind MWh exploration >< Standardized wind MWh exploitation.
- Customised service solutions >< Standardised service solutions.
- Technical solutions >< Logistic solutions on (maritime) manpower under harsh conditions.

On the other hand, the findings show the need for knowledge flows combining construction of the wind farm and subsequent O&M activities on the same/equivalent offshore wind farm. A customized combination of creativity and control of resources seems to be needed, highlighting the importance of a clear approach to innovation at the strategic level in the ecosystem and an understanding of the organisation of collaboration on these issues in an ecosystem co-creation; in addition, business model innovation is necessary for the reduction of LCOE.

The next part will more closely elaborate the strategic innovation in relation to the key issues mentioned regarding openness of knowledge flows, ecosystem co-creation, organising collaboration on synergy and ambiguity and business model innovation.

Examples of necessary strategic innovation initiatives can be derived from the interviewees' comments as follows:

- Development of the performance of the wind turbines and/or the reduction of their downtime
- Development of preventive and/or remote service of wind parks.
- Flexible modules with each module standardised according to well-functioning elements/processes from experience in the O&M phase.
- Development and integration of maritime solutions for the O&M activities in the wind park.
- General utilization of O&M experience in previous wind parks in the planning of new wind parks.
- Qualified IT-shared systems for efficient and effective tracking and sharing of documents to eliminate time wasted on waiting for approvals and correct information to perform the work.

OPENNESS AND KNOWLEDGE FLOWS

The need for openness regarding knowledge flows across organisational boundaries is highlighted in the literature review and derived in proposition 3. Openness is also underpinned by several of the interviewees and emphasised in relation to the acknowledgement of knowledge in areas beyond the offshore wind farm production set-up. This is emphasised in the following citation:

N10: 'It is necessary with an open dialogue. Knowledge sharing is difficult between organisations. Examples of difficulties of knowledge sharing within large organisations can also be provided. If only the persons had met from the different projects in the canteen, the challenges of the rising costs for O&M could have been avoided'.

N10: 'It is necessary to accept each other's roles and knowledge within specific areas. I do not discuss with the baker how he should bake the bread I eat. I expect that he knows how to bake bread. It is necessary in the same way in the offshore wind industry to draw on each other's specific knowledge, which is acquired thoroughly'.

This highlights not only openness but also the willingness to accept knowledge from other parties as valid instead of pursuing own perceptions in 'foreign knowledge domains'. This is underpinned by the need for more objective information, as highlighted in the following citation:

N9: 'We have developed a system for providing us with data on vibrations. In this way, we can document our decisions in relation to these vibrations. It is necessary to create more objective information to avoid subjective discussions with customers'.

Openness in relation to the integration of suppliers is also demanded, as highlighted in the following citation:

N3: 'Suppliers can really make a large difference, when they are integrated very early in the wind farm project. Maybe before the project has begun at the manufacturing unit'.

It seems there is a need for frontloading suppliers because they know alternative solutions, unlike the typical larger organisations operating in the offshore wind farm industry.

There is also a need for joint work on concepts, as highlighted in the following citation:

N6: 'There is a need for conceptualising the technical solutions for less frequent O&M activities offshore'.

Conceptualisation makes it possible for other parties to contribute to innovation, as in the case of grounded thinking on open innovation of technical platforms. Conceptualization represents an abstraction of practical experience and in the terms of Lewin (1945) means a practical approach to solving the challenge, as 'nothing is as practical as a good theory'. Thus, the patterns of practical experience are fashioned into simplistic theories/concepts, which again can be applied to practical action within different wind park context by actors in the wind park industry.

Moreover, it highlights the need for organising innovation, as underlined in the following citation:

N1: 'In the wind farm industry, "green bananas" are sold because few of the present wind turbines have actually run on a site long enough to prove their sustainability. Therefore, an enormous need for coordination across units is required in our own organisation'.

Here, the potential for conceptualisation within an organisation to enable innovation is acknowledged. Based on these citations, interviewees from different positions perceive an enhanced need for openness regarding knowledge flows. A high potential for reaping 'low hanging fruit' seems to be present regarding the issue of openness of knowledge flows and practical conceptualization. Proposition 3 is thus supported by the interviewees on the need for openness of knowledge flows to reduce LCOE. However, at present, a lack of open information flows is detected.

Examples of initiatives on openness regarding strategic innovation can be derived from the interviewees' comments as follows:

- Open dialogue with suppliers before the O&M task is planned.
- Accept and draw upon other suppliers

with specific knowledge, e.g., from the maritime area.

- Time and space for open dialogue in own organisation before and during the O&M task.
- Conceptualise the practical experience from O&M tasks for dissemination to other O&M project teams and thereby improve performance in general.
- Open information can reduce risk because preventative initiatives can be launched, thereby reducing risk and the tag for risk in LCOE calculation.
- The knowledge obtained from an open dialogue can reduce uncertainty (the unknown unknown) through readiness of employees/ managers to act reasonably efficient and effective on new events emerging.

ECOSYSTEM CO-CREATION ON INNOVATION PLATFORMS

The need for ecosystem co-creation and positive feedback loops on the innovation platform is highlighted in the literature review and derived as an underlying issue in proposition 3. This means that enterprises combine their individual offerings into a coherent, customer-facing solution in a co-creational approach. The analyses of findings from the wind farm industry do stress the issue of co-creation and how this can also have an impact on risk through more thorough and longer term collaboration. This is highlighted by the following citations:

N8: 'In Oil & Gas they are forced to co-create and they can see the advantage in co-creation. It is a maturation process that is not really taking of yet in the offshore wind farm industry. Better collaboration in the larger enterprises, e.g., between construction and O&M units, could enable innovation. Also, more professionalism and co-creation in the logistical approaches would improve performance'.

N15:'Co-creation would probably mean that roles within O&M have to change with different risk profiles and longer terms of contracts'.

Furthermore, it has been highlighted that co-creation reaches beyond the offshore wind farm industry, as highlighted in the following citations:

N18: 'The ships might have to be constructed with facilities for use on something else so that the ship is easy to prepare for other functions in other industries. This can be necessary for the sale of services to other markets'.

N3: 'Coordination of ships is really bad. Sometimes the ships sail after each other from wind turbine to wind turbine with different O&M crews for different operational tasks to be conducted on the specific wind turbine. The people planning O&M in the larger enterprises do not always talk with each other. This lack of co-creation on the logistic solutions is very expensive'.

A hindrance to co-creation is often perceived regarding the rules and procedures created by different organisations, as the following citation shows:

N9: 'They all have their own rules and procedures. Own rules and procedures are established due to lack of time for co-creation of interfaces between the tasks. Therefore, opportunities for alignment can be reached for a more efficient and effective operation as well as enhanced security for the personnel employed'.

N9: 'Lack of information on, e.g., water depth can make a task impossible to do, so resources are wasted for nothing'.

Based on these citations, the interviewees perceive a potential for co-creation that applies to the wind farm industry as well as single offshore wind farm organisations. In particular, potential is seen for logistical solutions. However, there are hindrances related to self-made rules and lack of appropriate information to handle the tasks. Proposition 3 is thus supported by the interviewees with regard to the need for ecosystem co-creation and positive feedback loops on the innovation platform. However, at present, a lack of co-creation is detected, which provides opportunities for enhanced reduction of LCOE.

Examples of strategic innovation initiatives for ecosystems can be derived from the interviewees' comments as follows:

- Utilise experience from other industries, e.g., Oil & Gas and other maritime sectors, to enhance co-creation of new solutions, thus reducing LCOE.

- Discuss and change risk-taking profiles if they hinder co-creation between actors.

- Focus on co-creation of more effective and efficient maritime solutions.

- Focus on co-creation of rules and procedures, which can reduce LCOE.

- Co-creation can reduce uncertainty and risk because initiatives can be launched with more thorough knowledge, thereby reducing uncertainty and risk and the associated price premium.

ORGANISING FOR COLLABORATION ON INNOVATION

The need to organise for purposes of collaboration between complementary business partners to create both synergy and ambiguity across traditional boundaries is highlighted in the literature review and reflected in proposition 3. One of the opposing forces is related to uncertainty and risk with regard to the performance of the wind farm, as the following citations shows:

N6: 'LCOE can be reduced considerably by reducing the responsibility of suppliers for risk associated with electricity production on the offshore wind farm. Today, there is a considerable price premium to cover uncertainty and risk connected to components and services for the offshore wind farm'.

The viewpoint expressed in the citation is that prices from suppliers can be reduced by organising initiatives to reduce uncertainty and risk. However, some uncertainty and risk will probably still be present. All parties seem to avoid uncertainty and risk. The question then becomes how to encourage risk taking to achieve lower risk premiums? The extreme answers are either to accord a portion of risk to each supplier or to pool risk in a kind of 'insurance organisation'.
It seems that the market logic at the moment would favour the first approach. However, this requires open information regarding the issue of uncertainty and risk and co-creation to reduce it.

Another opposing force is the interest in providing O&M in the future. Here, several forces are present, as highlighted in the following citations:

N8: 'Within some years, the independent service providers (ISP), which are typically manpower based at the moment, will be able to take over O&M work and hold a competitive advantage. At the moment, the wind turbine producers provide the O&M work during the guarantee period, and the wind farm owners provide the O&M work afterwards. Both have a considerable interest in O&M work because the potential market is huge. However, maritime based ISPs could be interested in providing O&M work'.

N19: 'Consolidation of ISPs will give them a competitive advantage. It requires integration not only of the front-end towards the customer but also the backend to deliver the most efficient and effective O&M service and to gain competitive advantage'.

N10: 'Who is the best to do what in relation to O&M activities'?

The citations indicate the battlefield that is emerging in O&M work on the market. Several major categories of actors are present now:

- Wind farm owners
- OEM wind turbine producers
- ISPs manpower based
- ISPs maritime based
- Larger service providers from other markets

The amount of actors interested in this O&M market creates ambiguity and also different interests within the ecosystem. In the long run, it is a question of who will be able to gain competitive advantage in the shifting and harsh circumstances in the North Sea. Here, the consolidation issue is seen as a tool for ISPs as elaborated in the consolidation section later in this report. However, as highlighted in the citation, this requires 'back-end integration' of typically entrepreneurial enterprises, which can be difficult and risky to pursue for ISPs. However, it will also be difficult and risky for other actors if they cannot collaborate with ISPs because ISPs generally offer higher flexibility and enhanced complementary competences not present in the other O&M actor-organisations. In particular, manpower based ISPs offer flexibility in competences available at the right time at the right place. The maritime based ISPs own the very important maritime heavy asset based equipment and the manpower to operate the equipment at the right time at the right place. The ISPs thus have an interesting position with regard to highly requested flexibility and maritime knowledge of essential importance for the reduction of LCOE on offshore wind farms.

A third opposing force is to reduce the O&M market through remote surveillance. Monitoring the wind turbines and wind farms to gather data, conducting analyses and finding algorithms for prevention and efficient and effective O&M actions based on harsh circumstances in terms of wind, water and weather at the offshore wind farm site is highly interesting for many O&M actors. The question at stake in this situation is who owns the data? How to analyse the data for application of effective and efficient O&M actions? In short, the battlefield regards knowledge creation for practical application to reduce LCOE. Typical for successful knowledge application is that actors need both theoretical knowledge and practical experience to know how the application can be performed in the most effective and efficient way. The opposing force of remote surveillance is therefore related to the competitive battle related to who is actually the best at executing the O&M work. It is also related to who is developing the wind turbine types because O&M is dependent on the construction of these machines. New wind turbines require new data, new analyses and probably new local applications as highlighted in relation to the need for organisational creativity.

Based on these citations, it is apparent that the interviewees very much perceive strong opposing forces, which can be damaging for the ecosystem and for the reduction of LCOE and can also have the potential to boost both if the ecosystem is able to evolve and provide space for the best performing actors to perform the O&M work.

Proposition 3 is thus supported by the interviewees based on the need to organise for collaboration between complementary business partners to create both synergy and ambiguity across traditional boundaries. However, at present, a battlefield of opposing forces is detected, which in the longer run can both hinder and develop opportunities for enhanced reduction of LCOE.

Examples of initiatives on organising regarding strategic innovation can be derived from the interviewees' comments as follows:

- ·Discuss the ambiguity related to risk in the wind park with different actors and organise action for joint reduction of risk.
- Discuss ambiguities in general to organise for the best way to conduct O&M tasks in the ecosystem in relation to reduction of LCOE.

BUSINESS MODEL INNOVATION

The need for business model innovation as a tool for connection, inspiration and transformation on both the organisational and ecosystem level is highlighted in the literature review and derived in proposition 3. The research material shows that business models are primarily used for business development in an organisation. Here, time is an essential issue as highlighted in the following citations:

N9: 'Time is a scarce resource for us. We have made a business model based on our opportunities; however, the business model is already out-dated. In our field, the development is really fast. It is difficult to make business models when everything is developing so fast. I can understand it within mature industries, but it is very difficult here'.

N3: 'We have not yet come to the point where we can make business models. Everything is developing very fast'.

The citations indicate that business models are viewed as a time consuming task. This is not actually the case if graphical frameworks are used, which are known for simplicity, as highlighted in the literature review. However, the citations from the participants highlight that the interviewees do not seem to get value from business models neither in their organisation nor in a wider context of collaboration with customers and partners. However, in the following citations, concrete business model opportunities are requested for reduction of LCOE:

N6: 'It is a question of doing the right thing – not the cheapest. It is about using the right tools and the right manpower in the right places. It can mean that a task can cost 1.5 times the cheapest offer, but if it means that performance can be improved, it may still pay off'.

N10: 'When you are offshore, it can be difficult to get access to the wind turbine; therefore, crossover collaboration on tasks regarding the wind turbine can be beneficial. However, it means that you cannot "shop around" for the cheapest price because the people you need for crossover actions need to be experienced people. It is therefore necessary to choose the 1-2 partners you want to collaborate with for growth in your businesses'.

N8: 'It could be possible for us to collaborate on tasks on the wind turbine. However, we have not done this yet. It could be interesting for enhancement of our business development'.

Actually, it seems that a range of opportunities are present in the development of beneficial business models. Therefore, it is strange that BMI is so scarcely used in wider collaboration within the offshore wind farm industry.

Based on these citations, the interviewees do not perceive BMI as important in a wider context in the wind farm industry. An opportunity is here revealed for enhancing collaboration through application of some of the easy and fast versions of BMI. Some focus is hereby set on the opportunities for value creation without too much time spent on the issue. Opportunities for business model innovation are actually revealed from the citations.

Proposition 3 is thus supported by the interviewees with regard to the need for business model innovation as a tool for connection, inspiration and transformation on both the organisational and ecosystem level. However, at present, barriers are detected due to perceptions of no time and limited value from business model innovation. If these barriers are reduced, it seems that opportunities can develop for enhanced reduction of LCOE.
Examples of initiatives on business models regarding strategic innovation can be derived from the interviewees' comments as follows:

- Utilise the BMG approach for elaborating concrete opportunities for new business models in own organisation.

- Utilise the BMG approach for creation of opportunities between organisations in the network.

SUMMARIZATION OF THE PROPOSITIONS ON STRATEGIC INNOVATION

Proposition 3 highlights the necessary conditions for strategic innovation in the offshore wind farm industry. The findings show a high relevance for strategic innovation in the offshore wind farm industry. In particular, the following opposing forces play an important role:

- MWh exploration versus MWh exploitation.

- Solutions customised versus standardized.

- Solutions on technical issues versus maritime issues.

Some of these opposing forces can also be integrated due to standardisation of modules, where the integration of interfaces between modules is customised and modules as such are standardised. Alignment of forces between construction of offshore wind farms and the following service solutions for O&M activities connected to the offshore wind farms also play an important role for reduction of LCOE. Strategic positions on focused innovation initiatives need to be taken for these opposing forces.

Innovation management in the offshore wind industry is therefore highly complex and needs specific strategic enhancement regarding several issues according to the citations. First, openness and knowledge flows are important to reap opportunities for innovation. Second, the perception of ecosystems and innovation platforms for co-creation provide enhanced opportunities

Figure 5: Findings on strategic innovation

for reduction of LCOE. Third, organising for the purpose of collaboration is important for opposing forces, disturbing the usual logic enhancing solutions. Fourth, the wider application of business model innovation contains opportunities to support innovation between organisations with complementary resources. These findings are summarised in short in Figure 5

As shown in Figure 5, the management of innovation in the offshore wind farm context does need strong support and specific attention from the offshore wind ecosystem for collaboration on innovation. As highlighted in the citations, the industry is aware of the initiatives that are required. However, it also seems that it is difficult to move beyond the realm of conferences and seminars and to transform innovation initiatives into a more thorough and trustful approach to 'who is actually the best performing O&M organisation'? This question needs more open and thorough analysis for open transparency on actions to reduce LCOE. Strategic innovation is context laden, so the concrete necessary activities exemplified in each area of strategic innovation need to be adapted to the concrete context in the organisation/ecosystem. So, the examples can serve as inspiration, which the actors can decide upon.

The findings thus show support from the interviewees for proposition 3 on opportunities for strategic innovation to reduce LCOE. The interviewees mention these issues as important for reduction of LCOE. However, at the moment, they are not utilized according to the potential revealed. An important issue is thus to approach innovation at the strategic level in the organisation and in the whole ecosystem.

5.3.1. NETWORKS

Based on the literature review, the proposition 3a was formed as follows:

Networks of reciprocal learning can reduce LCOE.

The findings regarding how the companies use the network to carry out O&M activities reveal two major characteristics. First, the O&M activities can be divided into two major areas, i.e., the activities directly related to operating and maintaining offshore wind farms and activities for further development of the O&M activities. Second, no company can solely be responsible for the O&M activities; thus, collaboration with other relevant network actors is necessary.

The activities related to the operation and maintenance of offshore wind farms can be divided into three main types of services, namely, scheduled, unscheduled and preventive service. Scheduled service is, for example, annual service, where such service activities as tightening bolts and lubricating the gear are carried out according to an activity schedule planned beforehand. Unscheduled service, in turn, is the service activity that takes place when something unexpected breaks down in the wind farms (like gears stopping and wing friction), and responses are therefore needed. Finally, preventive service is concerned with types of activities that are carried out as extra maintenance, e.g., when visiting a wind turbine for some other purpose. In this context, extra tightening of bolts can be mentioned.

Development activities, in turn, are concerned with ensuring well-performing parks with a specific focus on safety, easier access to the wind parks and improved yield of the wind turbines. The objective of all these development activities, together with the different types of services, is to reduce LCOE in the offshore wind farms.

As mentioned earlier, the O&M activities are dominated by the OEMs and offshore wind farm owners who are likely to determine who undertakes the given activities. In relation to this, non-core and 'less interesting activities' are likely to be delegated to the other network actors. Crucial network partners in this context are those ISPs focusing on logistic solutions. However, due to the relatively short order pipeline, these ISPs experience only limited commitment from the OEMs and park owners. The interviewed actors highlighted this fact as follows:

N8: 'Building a vessel is a large investment, and we are not going to build any unless we know that we will get a contract for it'.

N9: 'OEMs want to sell their turbines with 5-10 years of service contract. So, you can get a 1-year contract in the installation phase and thereafter 4 years, if you are lucky. However, you don't know anything about the remaining 15-20 years. And that is a problem'.

Moreover, in pace with the growing number of wind farms and in some cases the relatively close location to one another, coordination and bundling of the O&M activities is gaining importance. In this context, the different roles of the ISPs are of interest. In relation to this, ISPs providing manpower and specific competences are becoming more important, as indicated in the citations below:

N15: 'What we can offer is a palette of services that enables us to bundle the activities'.

N7: 'We need to figure out how these O&M activities are arranged in the best possible way. Who is best at what'?

N12: 'Collaboration among ISPs creates synergies, and in this way they can also obtain a larger customer base'.

O&M, as well as the development activities, call for extensive forms of collaboration among the actors. However, the interviewees revealed that the collaboration is somewhat limited. On one hand, those activities that are not core business to the OEMs or park owners are delegated to the other partners. The following citations illustrate that:

N15: 'Not everybody considers it attractive to remove bird droppings from the wind turbine wings. However, somebody has to do it, and our manpower does not have any problem with that'.

N8: 'We use subcontractors for tasks like scheduled service, controlling the safety equipment and tightening the bolts'.

On the other hand, collaboration is limited to finding solutions for everyday practices, as shown in the citations below:

N7: 'We have succeeded in collaborating between wind parks on environmental monitoring. This means that instead of both park owners renting a plane and controlling how the wind turbines affect flora and fauna in the sea three-four times a year, we do this together'.

N11: 'Everyday challenges are figured out in collaboration'.

Moreover, collaboration seems to be limited to those who know one another well and thus have established long-lasting relationships. However, the impression of the collaboration is characterized by lack of collaboration and distrust combined with the fact that some regulations hamper the collaboration as indicated in the citations below:

N1: 'I think that they need five years to agree that there are synergies, which is caused by the approach 'I'm the one who decides upon this'. If we can decide that I do the service of these two parks, it is fine by me'.

N10: 'Offshore is a cowboy land and the companies are keeping their cards close to their chests'.

N9: 'No, they seem to be somewhat closed and think too much about the regulations regarding the procurement'.

Based on the above, we can summarize that proposition 3a was generally supported, but in the current stage, the themes for collaboration are based on 'solving everyday problems' rather than collectively trying to reduce LCOE. Moreover, bundling of activities and competences seems reasonable for the actors but is to some extent hampered by actors' individual ambitions with the business and lack of trust.

Examples of concrete initiatives regarding networks can be derived from the interviewees' comments as follows:

- Utilise collaboration with partners and suppliers for joint benefit and reduction of LCOE.
- Overcome the self-centred approach on collaboration by creation of joint business models and specific joint incentives and change to a more collectivist culture to succeed in the ecosystem and reduce LCOE.

5.3.2 ORGANISATIONAL KNOWLEDGE SHARING/ KNOWLEDGE CREATION

Based on the literature review in section 3, the following proposition was derived:

Organisational knowledge creation can use both centralised and distributed leadership to reduce LCOE.

As an introduction to this section – which addresses findings on how organizational knowledge creation can contribute to the reduction of LCOE – a few cases will be presented as illustrative examples. At the conference on May 07, 2015, the CEO from one of the wind farm companies presented two cases about knowledge creation as the basis for reduction of LCOE.

N5: 'Some time ago, we initiated an operation *excellence program with focus on reduction of costs. In the beginning of the project, we asked all the technicians "on the floor" if they could see some possibilities for reducing costs. The process resulted in many proposals, and the implementation of some of these meant cost reductions of several million DKK. The proposals were implemented without problems as the employees were involved and very motivated'.*

The program was easy to carry out and the imposing results were characterized as "low hanging fruit". Another example illustrates how knowledge creation can form the basis for new innovations.

N5: 'We asked ourselves how to optimize the planned service activities – how can the flow of service activities in the wind turbine be optimized. Normally, we start with the first activity of the service checklist provided by the turbine supplier and continue in the sequence indicated on the list'.

The project in the latter example resulted in 3 innovations and a reduction in service time of 25% as a result of the following initiatives:

- More intensive and detailed planning of all necessary activities (tools, components, check weather conditions, etc.).
- Place the activities in periods with traditionally good possibilities for fine weather.
- Organize all service activities in a more natural way; e.g., more service technicians can work together in the turbine at the same time.

These two cases illustrate in an easy way the practical use of the learning circle model (a more detailed description is available in the literature review on organizational knowledge). The model consists of 4 important activities – concrete experience, observation and reflection, forming abstract concepts and testing in new situations. An application of the concepts in the O&M industry will be presented in the following.

The starting point in both cases is the **concrete experience** of the technicians and service workers. The next phase is a reflection on how we can perform existing processes in a more efficient way. Is it possible to change existing processes, introduce new ones, do the jobs in another sequence, plan in more detail, etc.? In other words, the employees **reflect** in a motivating and involving way upon their daily work processes. The result of these discussions and reflections is the creation of new knowledge, which is the starting point for proposals on how to make processes more efficient. In these cases, **new abstract concepts** (new ways of doing things) have been formed with the purpose of reducing LCOE or increase time of production. In both of these small cases, the new concepts have resulted in concrete innovations, and the implementation of these have been tested, resulting in a positive contribution to the reduction in LCOE or service time. Over time, new experience will be formed, and the circle can start again – learning, knowledge sharing and knowledge creating as a basis for new innovations is a never-ending process.

Having presented the principles of the learning circle on the basis of the abovementioned cases, we will focus on the following four situations and discuss the elements that have been mentioned by the interviewees from an O&M point of view:

A. Concrete experience

B. Reflections

C. Forming of new concepts and

D. Implementation

A. CONCRETE EXPERIENCE IN O&M

Concrete experience can be described from different angels. Processing data from the wind turbine, registering vital O&M activities, general knowhow of experienced workers or partners, etc. can be considered concrete experience. The content of this phase thus consists of 'data', 'information' and 'knowledge' – as highlighted in the literature review.

Collection of data

Data are the basis of information, and a huge amount of process data is collected in the wind park industry. It is important to constantly monitor all the most important and relevant processes in the wind farm. The following citations demonstrate this.

N4: 'All our vital components are monitored by vibration sensors. The data are automatically registered'.

N1: 'We have vibration sensors on our turbines, so it´s possible for us to detect many of the failures up to 6 months before we must repair the component. In this way, we can bundle events'.

N11: 'We have systematic collection of data – data mining – from all processes in the wind turbine'.

Thus, there is a line of systematic and automated methods to collect larger batches of relevant data, which through centralised and distributed leadership can be used for developing new initiatives to reduce LCOE.

Collection of information

Part of the documentation of the processes is stored in the companies' ERPs systems. By using a systematic collection and storing of data, it is possible to reuse the information that the employees can retrieve from the system, as noted in the following citations:

N12: 'For every job description, we have a specification of the job, pictures of the process, what you have to do when you get home as a case – a story'.

N4: 'We develop reports about market investigations, project experience, inventions, etc. In this way, we have a structured "lessons learned". Those working on new projects can then use our experience'.

N11: 'We coordinate the different roles in the individual projects. Transfer of knowledge is in this way increased in a conscious way'.

N3: 'They have not really improved knowledge sharing between the individual sites. They do not learn from each other in the company. They do not think crosswise'.

Again, it may be shown that there are systems that collect and structure information in preparation for use by others. As described previously, information can be defined as 'data that makes a difference'. Data, therefore, have to be read, and this can be difficult as stated in the last citation.

Collection of knowledge

Knowledge is '…information that is relevant, *actionable*…and knowledge may derive from *personal experience*…' In the literature, it is emphasized (e.g., Hansen et al., 1999) that personal experience is crucial for the development of innovations that improve competitiveness. The below citations highlight the difficulties and possibilities when collecting and using personal experience.

N6: 'The people who originally developed the turbines are no longer in business. Today, the development engineers are young people with less than 10 years of experience. Of course, you use "lessons learned", and it has been written down but is never used. If you really want to hold on to knowledge, then you have to use the same people'.

N8: 'We have some dedicated employees who present constructive suggestions for improvements. In this way, we have changed a component 3 to 4 times. Thus, we use the employees' knowledge about the customers to develop the products'.

In the experience part of the learning circle data, information and knowledge are collected to be integrated into the activities to reduce LCOE.

These concrete experiences thus consist of data, information and knowledge. The O&M industry is new, and thus, no valid models or methods have yet been developed. Activities and innovations are to a large extent based on the experience of the companies and individual persons:

N12: 'Even the big customers are overgrown smithies that are based on experience from that time'.

N19: "This supplier is a "blue print supplier". They produce what the drawing indicates. All service suppliers are manpower suppliers. They have no engineering departments. They are good at producing but have difficulties in spot-

ting the solutions. It is not sufficient to be good at producing if the final product doesn't make sense'.

In sum, construction of the knowledge base will be performed with decentralised and centralised leadership – see proposition 3b.

It is clear that the question about what **data** and **information** have to be collected is the result of **central management decisions**. Documentation of processes and product characteristics is crucial for development of the organisation. The experience base of knowledge is on the other hand far more personal and attached to the experience of the individual employees. **Distributed leadership** has far more influence, as personal knowledge is built on the results of the diffusion of capabilities in formalized local practices.

B. OBSERVATIONS AND REFLECTIONS.

This activity in the learning circle takes its starting point from the experiences described above. Observations and reflections form the basis of knowledge creation. In relation to proposition 3b, this section will show how leadership style influences knowledge creation in the organisational learning process. Citations concerning distributed leadership and centralised leadership are stated first in this section, and at the end, conclusions regarding the relation between the concepts are presented.

Distributed leadership and science creation

Distributed leadership allows the opportunity to create new knowledge through participation and integrative activities, whereby the individual or group of employees are enabled to execute new or different tasks. The data material points to 3 central areas:

- Mentoring arrangements
- Peer-to-peer training and
- Cooperation.

Training through mentoring arrangements:

N4: 'Therefore, we hire workmen and identify what they can do and match them with one of our service engineers. We have a plan they have to go through'.

N4: 'When we started a new park, we looked for a place to train new employees. It can be the existing park x, y or z. Although it is not the same turbine, this doesn't mean so much. The most important thing is to be able to manage. Maybe things are a bit different at the actual site, but it doesn't matter. They need an understanding of working methods and work culture'.

Peer-to-peer training:

N5: 'We use peer-to-peer training, especially in connection with new wind parks'.

N3: 'We often match a new and an old experienced person, but that is not always possible in practise'.

Cooperation:

N20: 'We work with teams. Half of them are the customer's employees, and we are frank about this'.

*N13: 'At first, orientation about experiences with service activities and working methods was based on **verbal** information'.*

The citations above emphasise the importance of transferring and sharing valuable knowledge in a local context, as it is crucial for the employee within O&M to have the correct skills to execute the necessary operations. A relevant distributed leadership can therefore contribute significantly to the employees gaining the right competences to reduce LCOE. The above citations and others indicate many successful activities in which distributed leadership creates knowledge.

Centralised leadership and knowledge creation

Centralised leadership in the process of knowledge creation makes it possible to outline the methods and instructions for obtaining relevant information, which can be used in a production connection. The necessary information can be both in-house organisational information and externally based, e.g., from customers and business partners. The data material point to the following areas that contribute to knowledge creation:

- Education and research
- Use of IT-systems
- Transferring knowledge from onshore to offshore
- Transferring knowledge from oil and gas to offshore wind
- Suppliers acting as initiators of knowledge sharing by the customers
- Knowledge sharing between business partners

Education and research:

N5: 'You should be better at educating your own employees (apprentices)'.

N13: 'Employing OEM staff (and the knowledge thereof) – "steal" employees'.

N5: 'In connection with the research project, a steering group has been formed and at the latest meeting, we realised that it was the first time that research had been conducted in the operation and maintenance of wind turbines'.

N5: 'We have a team that has to receive further education, so we give them something more challenging, e.g., replacement of the transmission system. That results in motivation.'

The increasing growth of this industry has created great demand for qualified employees. The easy solution is to "steal" employees from other companies. In the long term, both education and research initiatives are needed to handle the situation. Also, in-house education has to be a focus.

Use of IT systems:

N5: 'Ask-and-share systems are developed – but only a few make use of this'.
N5: 'Use of films – YouTube'.

N20: 'At production, we are good at sharing knowledge. We have a central "technology" department that collects all these data. They compare the wind turbines crosswise'.

N4: 'We get an alarm on the monitor immediately from our system about a rise in temperature. Next, we have to make decisions about what to do'.

N11: 'We have a "data-monitoring" system. By testing many parameters and benchmarking the same type of turbine from different parks, we create new information regarding performance'.

*N13: 'In the beginning, **verbal information** was used to inform about experiences with service activities. Now, it is systematised. This originated from the manual from the OEM producer and is also supplemented by personal experiences. There are x technicians attached to the wind park, and they are divided into teams with a team leader, who makes sure that a weekly letter is written if there is important information to be shared'.*

Enormous amounts of data in connection with the automated monitoring of the performance of the turbines are collected. The organisations with access to these data can create valuable knowledge. Knowledge can be generated automatically ('alarms') and can be, for example, produced ad hoc and added to 'ask-and-share' systems.

Transferring knowledge from onshore to offshore:

N2: 'The onshore industry has been through a big process of change like the oil industry in the eighties. Everything has been streamlined. It is the "white collar" guys who sit and do the purchasing now. Expectations are high, and the responsibility has been placed with us. It has changed from "the wild west" to an industry. The offshore industry has quietly built on this'.

There are big differences between running a wind park onshore and offshore – both with regards to installation and maintenance. Offshore can never be a copy of onshore. On the other hand, there are probably sub-processes in connection with offshore O&M that – centrally – could be considered outsourced with full responsibility given to the partner. This statement can be illustrated by the following citation:

N2: 'Offshore is something different from onshore. However, there are similarities. Preparation of the components at the harbour is exactly the same process – both onshore and offshore. The difference is the geographical location. Onshore, the work is carried out close to the wind turbines, and offshore, it´s done at the harbour. Another difference is the full responsibility taken by the ISP for onshore turbines, whereas hourly paid labour is used offshore. We all know that hourly paid labour is "a cash cow"… we have no incentive to optimize and reduce LCOE'.

Transferring knowledge from the oil and gas industry to offshore wind:

N8: 'Until now, it has been thought that the activities in the oil and gas industry have been too expensive. However, maybe you have to accept the expensive solution up-front – but looking 15 years ahead, it might be the cheapest. Attention has to be paid to this'.

N12: 'There is small synergy because of very different work conditions and work planning in the two industries, but synergy can be created on the basis of high documentation requirements in both industries'.

Many companies in the offshore wind industry have experience in the oil and gas industry. As indicated above, you cannot copy working methods from other industries – but there are opportunities for inspiration.

Suppliers acting as initiators of knowledge sharing by the customers:

N2:'Knowledge sharing ***between*** *customers. We learn the best from one another, which we then transfer to somebody else – and both of us can gain from this. We have learned a lot from the customers, and this means that we can ask another customer, "Why don't you do it like this'?*

*N2**:** 'Knowledge sharing by the* ***individual*** *customer. They do not talk to each other. They are actually such very big organisations. Then, we ask them: "Listen, you have operation staff who is not working for the next 3 weeks. Why don't you send them out to do maintenance"?'*

Knowledge sharing and knowledge creation can thus be initiated from the external side, e.g., suppliers. The bigger the capacity that a customer (organisation) has for entering into a dialogue with an external partner, the greater is the possibility for absorbing new knowledge (Cohen and Levinthal, 1990).

Cooperation between partners:

N9: 'Lack of cooperation. We could state that there were 500 things that "the customer" hadn't thought of and that we could have included in the product in time. However, because "the customer" didn't tell us or we haven't made a thorough review of the project, the basic understanding of the project was insufficient'.

N9: 'Possibilities in cooperation. I have many examples of sub-suppliers' knowledge that could be used in better ways. It is not just us sitting on knowledge. Other people's knowledge could also be used a lot more'.

N6: 'During the stage of development, we have used other people's knowledge. We used, e.g., company X to find out how a bigger component could be developed and produced because we do not have sufficient knowledge for this. In this connection, many Danish companies can contribute with relevant experience'.

N1: 'It is necessary for providers to have documentation from partners. Later, they find out that the documentation they are entitled to is not sufficient. We would like to help them with this but don't think it should be free of charge. We then discuss how to do this at great length. Equally, another provider has also realised that they can't monitor and control their turbines because they can't build a system that is reliable like ours. This information can then be bought by us'.

One of the most significant challenges in connection with running central leadership tasks is to create possibilities for a beneficial exchange of external knowledge. As stated in the citations, there are enormous possibilities. However, a central issue for the industry is that there is no consensus at the moment regarding how this should be realised. It appears that the partners 'keep their cards close to their chests'. The possibilities are not realised, which is a central management challenge.

The citations above illustrate some of the many central management initiatives that have been launched. Many of them are advanced and crucial for the development of the industry so that LCOE may be reduced. However, there are many central areas where new knowledge could contribute to further reduction of LCOE.

C. FORMING ABSTRACT CONCEPTS

According to Li and Gao (2003) knowledge creation (illustrated above) is the basis for innovation processes. Before the specific innovation can be developed, some concepts regarding the innovation (models, methods, procedures, etc.) have to be put forward.

The data points to 2 examples of innovation concepts.

1. Quick development.
2. Differentiation of staff.

1.Quick development

N16: 'We don't spend 4 years designing the product. We may take 6 months on a concept and 6 months on a detailed design. The result is that within this period, we don't manage to include all inputs, and some errors will appear. We bring these errors up for discussion and decide how we can optimize to make the next version. It is not something we like to do, but it is a result of the way we work. In that respect, we are probably relatively faster than our competitors, who spend longer time on development'.

Creating a product based on the front-load principle can have the disadvantage that the development time of the product grows as more actors' knowledge (O&M, partners, other wind farms, etc.) and suggestions become part of the process. If the time perspective is crucial for the success of the quick development concept, subsequent errors must be corrected afterwards.

2. Differentiation of staff:

N1: 'Today, we have technician apprentices and technicians who can do everything, and we are moving away from this because we want some technician apprentices and some maintenance technicians who only have to perform prescribed activities (oil change, for example). And then we have trouble-shooters who can repair the wind turbine when it breaks'.

N2: 'This often involves our customers inviting us to 'emerging markets'. The challenges can be solved via some kind of 'open book', or we charge a fee for training staff locally. It is common practice to receive a fee for being the first who trains locally. The reason that we receive these demands is that our customers receive the demands. So, 'local content' demands are spread down through the supplier lines'.

The citations illustrate the development of new concepts within types of staff. A higher specialisation within the O&M area seems to be part of future development. It also appears that 'local content' demand can form the basis for new education concepts and business foundations.

D. TESTING IN NEW SITUATIONS

In this activity, ideas based on the concept phase are implemented according to the theoretical model. In practise, one can talk about a "blurred model" – indicating that some activities in the model are often skipped. If you have a problem – just fix it! Reflecting, forming new concepts and testing new ways of doing things are often neglected:

N18: *'We just do it… Finger in the mouth and then pointing in the sky and hopefully things work. And when you build parks – we just do it. We don´t talk together – we do not involve groups from other departments'.*

Summarizing, how organisational knowledge creation can use distributed and centralised leadership, the following can be stated:

- The experience base of data and information is comprehensive and systematic. The base is to a great extent established from central management decisions.

Credit: Windpower Works, Danish Wind Industry Association

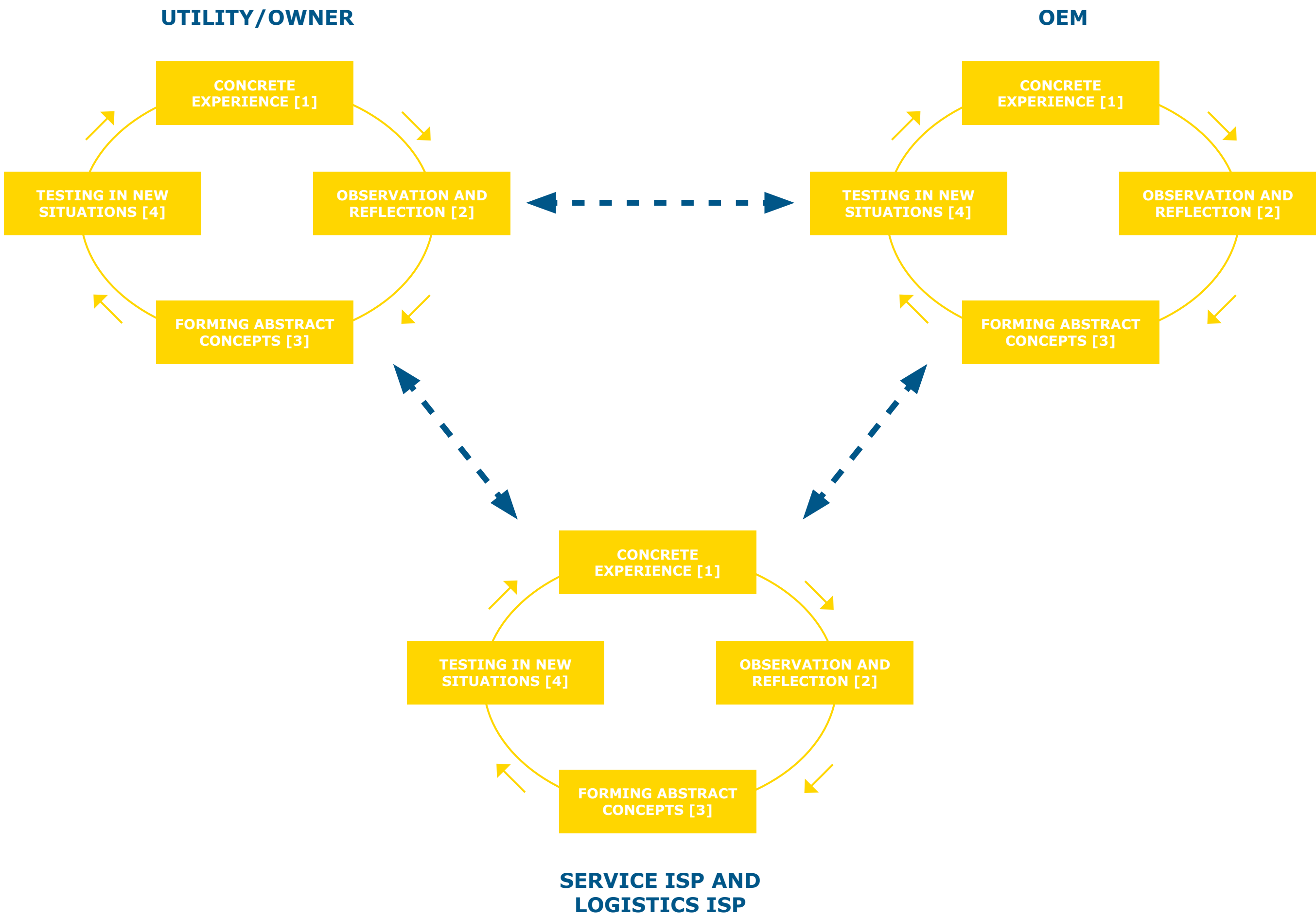

Figure 6: Knowledge creation – in organizations seen intra- and inter-organizationally

- The experience base of personal knowledge is connected to individual employees, and the development of this knowledge is primarily through the decentralised management's processes.
- The knowledge level of many suppliers could be larger so that they could support customers in the development processes to a greater extent.
- By means of distributed leadership, a line of relevant knowledge creation processes is accomplished that has a positive influence on the reduction of LCOE.
- Centralised decisions have led to the use of many different systems for knowledge creation.
- There are evident educational and research challenges that are being overlooked.
- To a greater extent, possibilities for transferring knowledge from onshore to offshore are present.
- The greatest hindrance to effective knowledge creation and thus to the reduction of LCOE is a lack of long-term cooperation and interaction between providers, OEM producers and ISP's. No forum and no relationship of trust have been established to optimize the use of the involved competences.

In general, this depicts an industry that collects large amounts of data and information. Each company has many differentiated learning processes at a **decentralised** level, resulting in a large amount of knowledge creation. At the company's **central level**, a number of initiatives with a beneficial effect on knowledge creation have been established, although there are still areas that are 'white on the map'. It is acknowledged that education and qualification upgrades for employees are preferable to 'stealing' employees from others. Most likely, the largest problem is entering into long-term binding relations with partners. 'The cards are kept close to the chest'. This is illustrated in Figure 6.

In each company ('circles'), especially at the decentralised level, there are a number of activities that show knowledge creation and are thus a basis for reducing LCOE. In each company, there are a number of initiatives at the central level, but it may be stated that there are a number of opportunities for improvement. Figure 6 illustrates the larger opportunities for knowledge creation **between** companies ('arrows') and thus the development of new innovations that have a positive effect on LCOE. As the arrows in the figure indicate, many cooperation activities have been implemented between the partners – but this practice can be intensified. The dotted arrows illustrate a low level of cooperation.

Based on the above, it can be concluded that proposition 3b can be supported – creation and use of relevant knowledge is crucial in the LCOE reduction process. To succeed in the reduction process, it is important to use both centralized and distributed leadership. Based on the results from interviews, it can be argued that centralized leadership in particular is insufficient in relation to relevant knowledge.
Examples of initiatives regarding organisational knowledge sharing can be derived from the interviewees' comments as follows:

- Utilise the learning circle as shown in steps A to D.

- Develop both decentralised and centralised leadership to create and accumulate a relevant and necessary knowledge stock as a basis for innovations to reduce LCOE.

5.3.3. ATTRACTIVENESS OF THE COLLABORATION PARTNER

Based on the literature review on attractiveness, the following proposition is set forth:

Nurturing the attractiveness of the collaboration partners plays an important two-sided role in reducing LCOE.

The earlier findings have revealed that collaboration in the offshore wind farm context is imperative, as no actor alone can either take command of the O&M activities or be responsible for all the risks involved in the activities. Complex processes characterize work in the offshore wind farms (e.g., tendering), and therefore, great efforts are required in the initial phase from the actors. In a similar way, operation and maintenance activities are characterized by specific characteristics.

First, to be able to take part in the offshore activities, a certain financial robustness is required. This applies to all the actors willing to work in the offshore context. In this sense, attractiveness can be considered as being both attractive to the banks and to one another.

N6: 'It is your balance sheet that decides whether you get the projects or not'.

N11: 'You need to be financially robust'.

Second, the interviews revealed how important it is for the customer that their supplier be able to meet the values of the customer. In this context, the areas of security and deep technical knowledge were emphasized.

N13: 'An ideal supplier must understand our philosophy, our way of working. They have to be 'a customer's man'. For example, if our subcontractor observes a failure when doing scheduled service, I appreciate when they come and tell me'.

N20: 'We select those subcontractors that work seriously with health and safety according to our experience'.

N3: 'We can't use these 'cowboys' who just come and go, meaning that we - in this way - lose knowledge. You need to take one another seriously'.

Third, apart from being economically robust and meeting the customers' values, the interviewees highlighted the flexibility of the collaboration partners. The importance of this feature can be explained by the rapidly developing nature of the industry, where processes are not always well-defined, and also the ad hoc nature of some of the operation and maintenance activities

N1: 'Our supplier needs to be flexible and capable of planning on our behalf. This is something we are not always good at'.

N18: 'Our need for manpower varies a lot, and an attractive collaboration partner is able to meet these varying needs, also in the short run and on an ad hoc basis'.

Fourth, the pro-activeness of the suppliers was mentioned as one of the important parameters. This can be a challenge for smaller actors in an industry that is dominated by large and relatively well-established actors. However, special competences are asked for, and smaller and perhaps more unknown actors need to make an extra effort.

N7: 'To begin with, I met with challenges in obtaining project jobs, as the company was small. However, after I had received my first task, my client was good at recommending me to others'.
N8: 'We like those suppliers who take initiative and come up with new ideas'.

Working in the offshore wind farm context is characterized by uncertainty in terms of political inconsistency and a somewhat biased focus on reducing LCOE. In these terms, it is essential to enhance the attractiveness of the industry and in that way ensure that the most qualified suppliers are willing to be suppliers.

N4: 'Previously, suppliers visited me on a regular basis and told me about new products and solutions. However, they don't do it anymore. And do you know why? It's because all these smart purchasers have just one main aim: to reduce the price and to get a good deal. This means we get products of worse quality and *might have difficulties in finding suppliers that are willing to deliver'.*

In sum, proposition 3c was confirmed*.* The offshore wind farm context is characterized by certain requirements that are antecedent before an actor can be considered attractive. Economic robustness is a major requirement combined with an understanding of security. Although the industry is dominated by a limited number of crucial players, it is important to highlight that these actors also have to remain attractive in a challenging business environment in terms of the uncertainty of the order pipeline. Moreover, the LCOE can only be reduced if there is a greater focus on the lifetime aspect of the wind farms. In this way, the focus on cutting costs is not applied to the suppliers, who can again consider the industry attractive – as long as they can fulfil the requirements for being attractive as set forth by the industry. Finally, becoming an attractive supplier is a question of conscious networking and being proactively aware of the competences they can provide.

Examples of initiatives regarding the attractiveness of collaboration partners can be derived from the interviewees' comments as follows:

- Develop a clear and simple formulation of your business model, indicating your attractiveness.
- Address the lifetime issue in your offerings.
- Focus on close collaboration with actors, taking LCOE reduction seriously.

5.3.4. PROJECT PROGRAM MANAGEMENT

According to the literature review on project program management in part three, the proposition derived highlights the following:

Proposition 3d: Project program management requires up-front attention to uncertainty and complexness to reduce LCOE

The complexity and uncertainty of projects are typically an important issue in project management theory. This is underscored by the comments from the interviewees in the offshore wind farm industry. They generally perceive project management as important, as shown in the following citations:

N3: 'Project management – the whole flow of the project design and execution is extremely important'.

N20: 'If something really costs a lot, it is certainly bad project management. You see that too many times'.

N3: 'Projects are developmental tools. Some project managers are really good. They involve actors from the start. Sometimes, it is necessary to involve both the customer and the customer's customer. Moreover, partners within the project that engage in complementary activities need to be involved. Some project managers are really bad. They come late when everything is nearly settled. That is too late, which is very costly'.

It seems that project management is uncertain and complexness in particular is highlighted in terms of the dimensions of Shenhar and Dvir (2007). Here uncertainty on all 4 dimensions highlighted in the literature review is increasing as noted in the earlier parts of this report. Technology needs to be more advanced, novelty is required to a higher degree, pace is more and more time-critical and complexity is becoming multidimensional to reduce LCOE.

This creates a need for 'frontloading' with the initial involvement of actors within the relevant 'system of actors' in the eco-system. Several relevant issues for frontloading are highlighted in the citations as follows:

N5: 'Utilisation of experience from projects similar to the new project is important. At the moment, our experience is not systemized and utilized enough'.

N13: 'Identification of opportunities for parallel components, which makes it possible to conduct an easy switch from the broken down component to a new one'.

N6: 'It is important to involve the responsible O&M people in the construction and installation phase. Every project is unique, and therefore, it

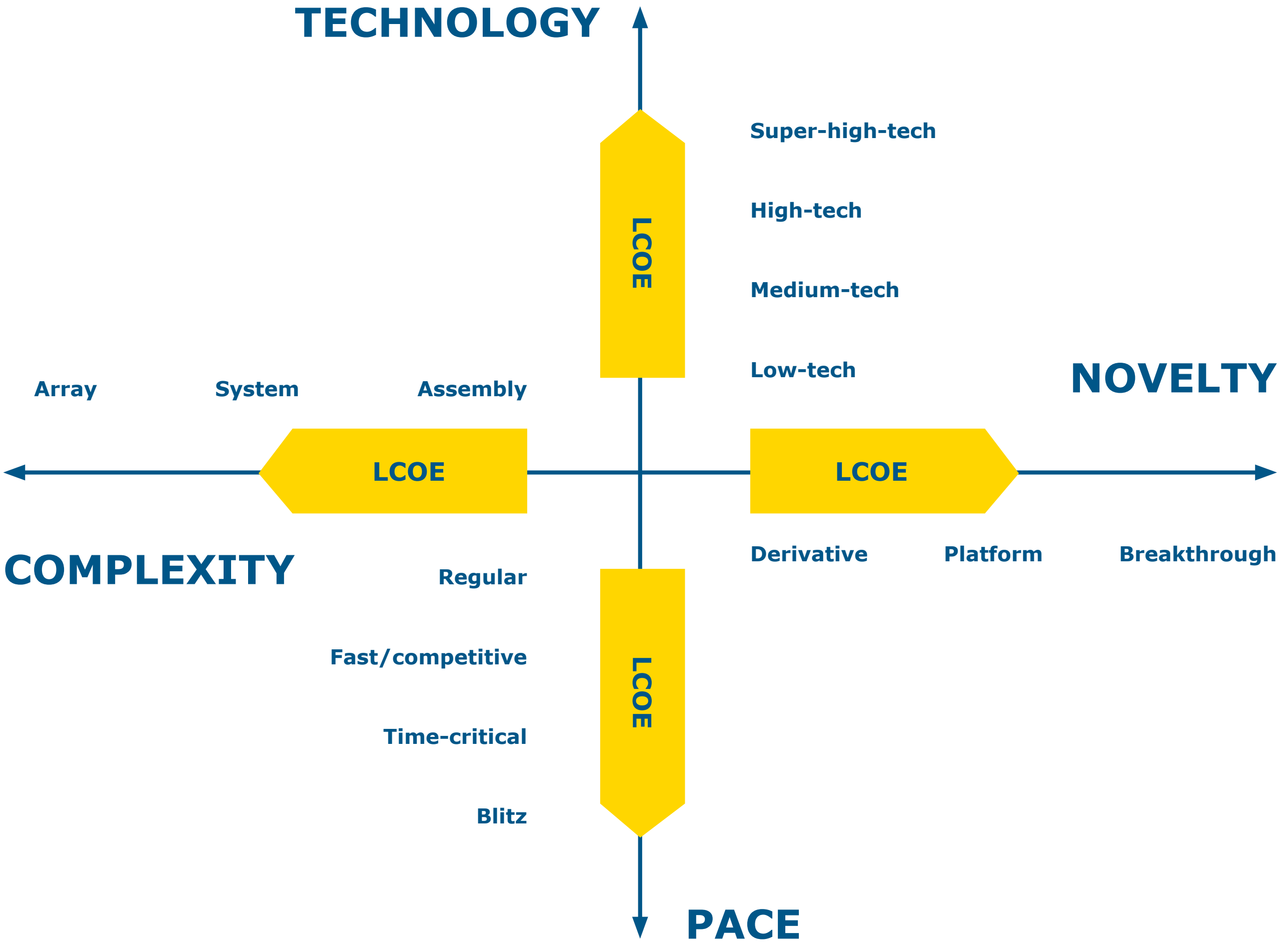

Figure 7: Uncertainty dimensions for reduction of LCOE in project management

is important to get the O&M people involved as early as possible. This is perceived as an expensive solution. However, it is more expensive not to involve them'.

N3: 'It is important in early phases to establish alternative plans – plan A, B and C, so that the needed actions are prepared beforehand. Alternative plans create readiness for fast adaptation under changing circumstances as well as support flexibility'.

N6: The execution of parallel projects makes job training possible in practice'.

The citations reveal a demand for communication across actors and experience bases wherever they are and as much as possible. This is also highlighted in the uncertainty literature stream that addresses the categorisation of uncertainties, as noted in the earlier literature review. As a wind farm is a complex product system (CoPS), flexible and fluid information is required, and this is strongly supported by the interviewees. The importance of inter-organizational relationships is also supported in the quotes from the interviewees.

An important opportunity regarding project program management is thus seen as a 'frontloading' developmental tool, making more efficient and effective project management possible. This is also highlighted in other citations on project programme management:

N11: 'We deliberately organise project programs to consist of people who have coordinating roles from parallel projects that have to be carried out, and we shift among projects and participants. Project organising is not a random issue in our projects'.

N20: 'Hard-core people are working on projects in one organisational unit. They are fully occupied on projects, and very often, they exchange experiences among themselves. Project experience is pooled in this organisational unit'.

The interviewees note the disadvantages of isolating the project from the base organisation and from other projects:

N10: 'If everything on the single project is done to optimize just that project, you risk sub-optimization regarding the rest of the base organisation, as the resources could maybe be used better in another project'.

N9: 'If you focus on a single project and, for example, clean everything up at the end of the project at the harbour, you have to establish everything again a week later for the next project. That is not efficient and effective'.

Moreover, project program management can add synergies:

N11: 'Already in the design phase, we begin to think of synergies across the programme of projects, so that they are organized and can be reaped during the lifetime of the wind farm'.

Costs can thus be reduced through organising. In general, the interviewees voice the concern that too much optimization on paper beforehand can be a disadvantage:

N20: 'You make a mistake by too much optimization on paper – squeezing suppliers and schedules instead of looking at: How do we execute in the right way'?

It seems that flexibility is needed as indicated by the need for alternative plans. The initiatives mentioned are all in different ways able to reduce complexity and uncertainty by providing more insights on the project tasks and their connection to the project program. The findings are summarized in Figure 7.

In summarization, the quotes indicate that project program management is important. Moreover, they show that project program management is a developmental tool that can be supported by frontloading previous experience, utilising parallel projects, and involving people with O&M experience early in the construction and design phases; suppliers are perceived as being able to make a difference due to their extensive knowledge of solutions. Further synergies can be obtained across projects by flexible organisation of project program management. Too much paper optimization – disturbing flexibility – does not seem to be beneficial. Neither is the isolation of single projects perceived as beneficial.

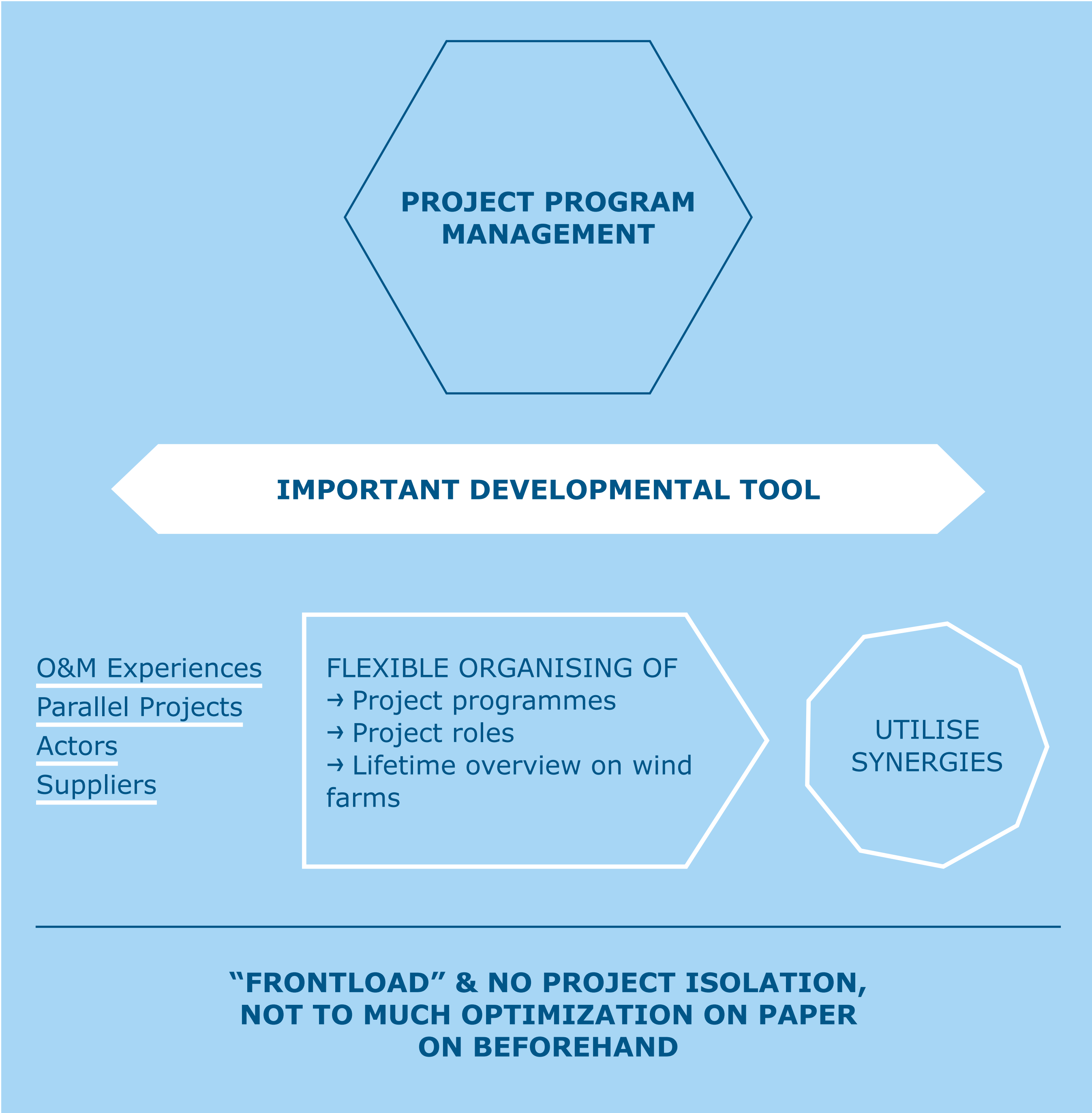

Figure 8: Overview of findings according to project program management

Figure 8 shows in brief the important elements of present O&M experiences, experiences from parallel projects, actors in the ecosystem and especially suppliers to organize projects flexibly. Flexible organising involves issues related to project program management, project role management and a lifetime overview of offshore wind farms in relation to the current project; this creates the synergies necessary for LCOE reduction. The findings thus show support by the interviewees for proposition 3 regarding up-front attention to uncertainty and complexness to reduce LCOE.

Examples of initiatives regarding project program management can be derived from the interviewees' comments as follows:

- The importance of project program management for successful reduction of LCOE involves the development of capable project managers and efficient and effective project programs.
- Emphasis on frontloading relevant experience and prioritisation of activities.
- Enforce systematic approaches to capture related experience both within accessible systems and between project managers and project teams.

5.3.5. CONSOLIDATION

According to the literature review on consolidation in part three, the proposition derived highlights the following:

Consolidation can help reduce LCOE.

The idea behind consolidation is often economic considerations of economies of scale and economies of scope, as highlighted in the literature review. In the offshore wind farm industry context, this thinking is aligned with the theoretical approach in the literature and specified in the following citations:

N5: 'It makes sense to have some kind of consolidation. The tenders for service contracts are heavily loaded with requirements for resources, documentation, safety and the risk assessment abilities of the service provider'.

N10: 'Consolidation will inevitably take place. It has already started, and it can perhaps go faster than we believe possible at the moment because larger players are involved. It could be utilities, wind turbine producers or some of the larger shipping enterprises. They have all started to show interest in the offshore wind farm O&M area. Here, we have large global actors within all categories'.

N9: 'There is a need for some coordinating enterprises for O&M tasks, as we perceive it. There is a need for capital funds, which can merge enterprises to larger entities. Many SMEs cannot take command, and consider how the coordination can be done for service tasks on the offshore wind farm. There is a difference in the service above water and the service under water. Service above water – any 'tractor mechanic' can work that out. Service under water requires divers and special education. It means that service contracts will probably change and contain several enhanced tasks in the future'.

N8: 'There is a need for collaboration on the logistical part of the service tasks to get "economies of scale here". It does require that the parties talk with each other. This is difficult with the ownership structure of the wind farms having many different owners involved, e.g., different utilities, capital funds, pension funds, etc.'.

N2: 'When larger service contracts are signed, there is a need for more funding to be able to meet the contractual obligations. Therefore, SMEs are forced to find alliance partners, which can provide the funding to work on the larger service contracts'.

N3: 'The coordination of ships needs much more attention. We can sail one after the other on single tasks around the wind turbines on the wind farm. The project managers on the tasks are sitting in the same office – sometimes 50 people, and they do not talk with each other'.

N15: 'If an enterprise can both advise and execute the work, the enterprise will have a competitive advantage. As service providers, it is possible to save money for other partners due to specific knowledge on the most effective and efficient way to do the service work in practice'.

N19: 'Collaboration through consolidation can be a good thing. However, it is necessary for prices to be lowered as a consequence of the consolidation. Otherwise, the consolidation will only bring greater rigidity to the industry. This means that a business model that provides value by reducing LCOE is needed beforehand'.

The citations highlight several relevant considerations regarding consolidation. Both economies of scale and scope are noted regarding bonding (economies of scale) and bundling (economies of scope) of resources, shared documentation and coordination of service tasks as relevant for reduction of LCOE. This indicates integration, which, according to Haspelagh and Jemison (1991), is close to 'symbioses'. This is the most difficult integration approach, as both a need for strategic interdependence and a need for organisational autonomy is noted in the interviewees' comments. Moreover, the interviewees note both the need for utilization of complementary resource bases and transaction cost economies, so awareness of both these issues is present. Indirectly, organisational learning is also called for, specifically if there is no organisational learning present due to lack of communication between O&M project managers.

Moreover, the issue of safety and risk assessment is of special importance for consolidation. It requires capital from suppliers to be able to shoulder the risk of operations. This issue alone forces SME service providers to consolidate with capital funds providing the resources needed to guarantee operations. This means that initiatives on risk reduction of any kind will enhance the opportunities to reduce LCOE because the risk issue can cause both production loss and increased costs due to unforeseen/unscheduled O&M activities. In the wind farm industry context, consolidation considerations are enhanced when customers require suppliers to shoulder the risk of operation. This does not necessarily reduce the overall risk of operation in the whole eco-system of wind farm operations. However, it does put pressure on suppliers to take on the risk of O&M activities if they want to grow their operations. The overall risk of O&M operations is only reduced if suppliers are better able to manage the risk and have the necessary information to prevent and monitor it as well as contingency planning to avoid pitfalls/utilise opportunities and utilise knowledge, so that risk is priced correctly according to events and customers. This does require suppliers to have a great deal of data, information and knowledge about the eco-system. As noted in the literature review on project program management, there are several classifications of uncertainty depending on how much information and knowledge is present due to the uncertain events. It is therefore very important to have sufficient communication to acquire data, information and knowledge regarding the uncertainties.

The interviewees call for coordinating enterprises in relation to the O&M activities. However, as highlighted earlier, no single enterprise actor is able to do this at the moment as even the ownership of the wind farms is split into different owners with different interests. It has also been shown that consolidation does not provide the only answer because communication challenges are still present within, for example, the logistical solutions of an organisation. Thus, different forces are present: consolidation, which comes to bear as a result of the economic and Uncertainty/risk reducing considerations of customers, and the importance of close communication, coordination and channelling of information, which are supported by consolidation. However, communication can also be totally missing in large 'silo-organisations', where everyone only takes care of own tasks and projects, as highlighted by the interviewees.

Moreover, it is noted by the interviewees that knowledge provides competitive advantages from the opportunities to save costs and enhance electricity productivity. Consolidation of data, information and knowledge is specifically noted in the following citation:

N10: 'If many wind farms in a geographically close area are being managed, it is possible to consolidate data for more effective and efficient operation of the wind farms. It does require a practical approach to catching relevant data and information. The opportunity is to streamline the knowledge for LCOE reduction'.

The ownership split in geographically close areas, as a result of 'closed doors' in the exchange of information between firms, can hinder reduction of LCOE independent of the consolidation of specific actors. The investment risk of the single owner is reduced through split ownership, but this can come at too high of a cost in relation to the reduction of LCOE. A dilemma between activities for overall investment risk reduction and activities for reduction of LCOE is shown to be present across wind parks under different ownership.

Consolidation thus occurs in multiple dimensions. First, consolidation takes place regarding enterprises, which in the offshore wind farm industry means more of the same activities and/or complementarity of activities/capabilities and risk reduction for customers in terms of the

O&M tasks. Second, a geographical dimension is also relevant for O&M coordination of activities across close geographical offshore wind farms. Finally, a communication issue is present for consolidation of data, information and knowledge for the reduction of LCOE. This is required across whatever level of consolidation is reached on the enterprise and geographical dimensions.

In summary, Figure 9 highlights the consolidation forces and issues considered. It shows the consolidation forces in the O&M offshore wind farm industry. Both consolidation of enterprises and close geographical consolidation of activities are relevant. Moreover, the essential drivers of the logic of consolidation are revealed as combining similar activities, bundling different activities and reducing uncertainty/ risk through prevention and monitoring, accepting uncertainty and risk as long as it is backed by contingency planning, and price setting of the uncertainty/ risk in relation to customers. A very important issue regarding these consolidation activities and drivers of consolidation is the access to communication, data, information and knowledge.

The findings thus show support for proposition 3e regarding opportunities for consolidation to reduce LCOE. The interviewees mention consolidation as important for reduction of LCOE. However, consolidation also has drawbacks: Market power and pricing power are more concentrated, and thus prices can increase; in addition, there is a narrower range of solutions. The interviewees do not mention these drawbacks.

An important issue here is consolidation, which is already happening in the wind farm industry and will only accelerate in the future due to the interests of different O&M actors.

Example initiatives regarding consolidation can be derived from the interviewees' comments as follows:

- Explore and coordinate opportunities for combining similar activities.
- Explore and coordinate opportunities for bundling different activities.
- Explore and coordinate geographical nearness.
- Explore and coordinate data, information and knowledge of uncertainties and risks.

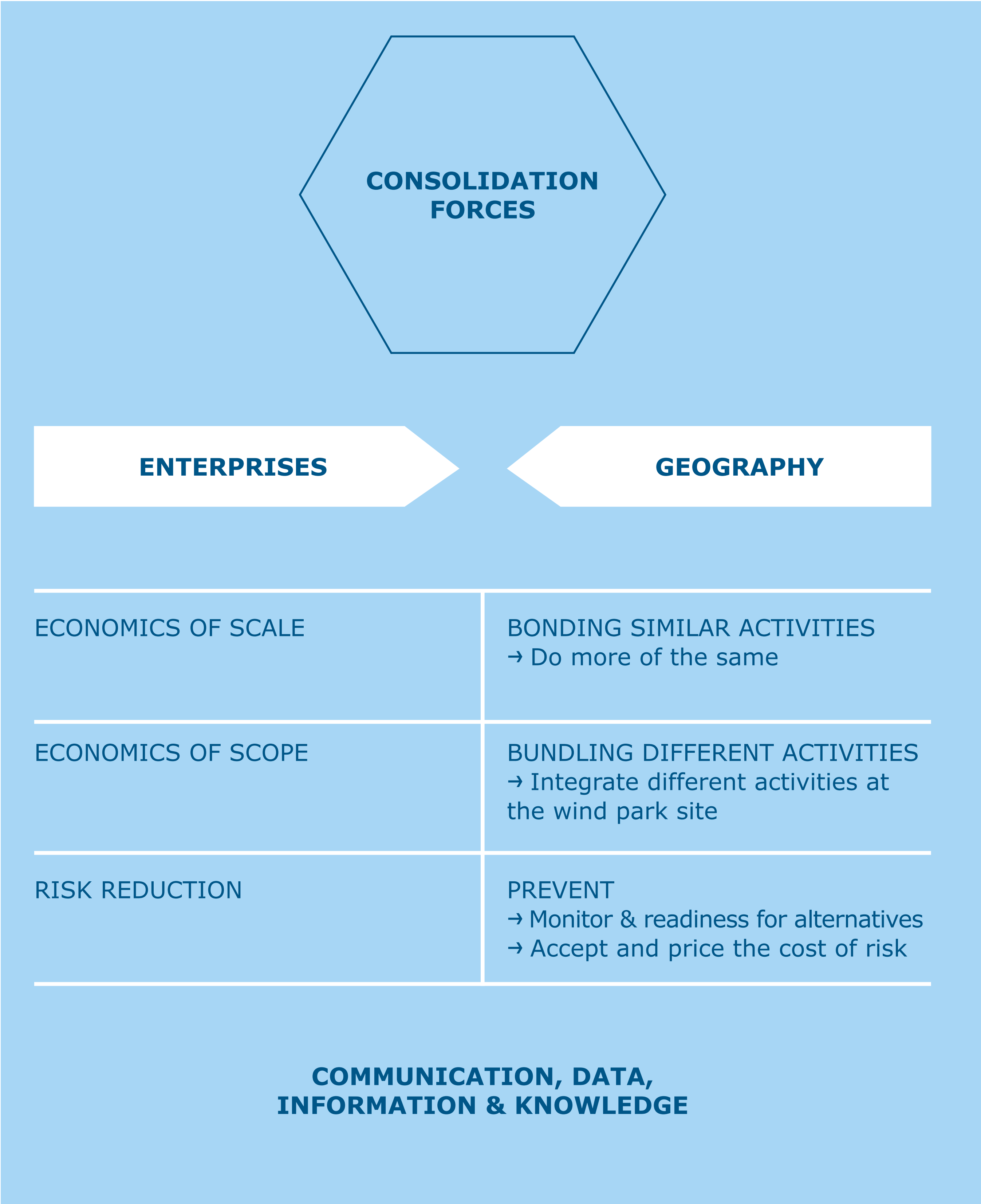

Figure 9: Overview of the consolidation forces

5.4. SUMMARIZATION OF THE FINDINGS

For a very short summarization, Figure 10 provides an overview on the findings in the research. First, it must be noted that a relatively large number of theoretical concepts can actually contribute to enhanced understanding of the offshore wind farm industry. This is verified by the interviewees support for the propositions across all the literature streams. On one hand, this makes the analyses comprehensive and complex. On the other hand, this also creates many opportunities from existing knowledge, which can be utilized to reduce LCOE.

Figure 10 shows that all propositions are basically supported. The interviewees do comment on
the issues highlighted in the propositions derived from the literature streams as being beneficial for LCOE reduction. In the different sections, the meanings of the propositions in relation to the offshore wind farms are revealed in the comments by the participants themselves. Specific initiatives are listed in these sections. This basically means that the literature and evidence-based knowledge derived from other industry areas can be applied in the offshore wind farm industry for the reduction of LCOE. Support is hereby provided due to existing knowledge already compiled, which can be utilized by the wind park industry actors.

The interviewees moreover note different drawbacks in existing activities in relation to the propositions, which are summarized briefly in Figure 10. These words represent the present perception of O&M offshore wind farm activities in relation to what the interviewees see as important. All interviewees have extensive experience with offshore wind farms and are engaged in activities associated with the industry. Primarily bias is anticipated by the interviewees based on the questions. The issues, which are performed satisfactorily, will naturally not be emphasized in an interview. Due to this bias, it must be anticipated that the interviewees have provided answers on what they really perceive as being important for the reduction of LCOE. This means that the offshore wind farm industry can perform adequately now; however, there is room for improvement. It is very promising that these opportunities exist. The goal of reducing LCOE thus has a good probability of being met in 2020.

Gaps are revealed in all areas. The Triple Helix goal is too fragmented and the governance is weak. This provides an unstable framework that does not support the strategic innovation initiatives for LCOE reduction. Moreover, strategic innovation to accelerate initiatives is present to a limited degree. The perceptions of the interviewees reveal limited openness. The focus is on own organisation for business development, which means limited information flow, limitations in the ecosystem and platforms, limited organising for collaboration and limited business model innovation. Moreover, networks are perceived as islands where some organisations work closely together and the majority has limited access to the network. Organisational knowledge is utilized to a limited degree due to weak learning cycles for knowledge creation. Attractiveness of partners is cultivated to a limited degree. Project program management is applied in a limited fashion over the lifetime of the offshore wind farm

Finally, consolidation of downstream actors seems primarily driven by reduction of uncertainty by larger actors. All these limitations are depressing in one sense; however, in another sense, they also provide opportunities for enhanced reduction of LCOE. A specific challenge is the complexness of knowledge, which has to be applied. As highlighted by Lewin (1945) '*nothing is as practical as a good theory*'. In other words, the simplicity of theory/concepts can encourage the reduction of complexity to support practical action. However, the complexness of the tasks requires thorough understanding of both the concepts and the specific practical issues and application. It is promising that the interviewees themselves have many ideas and suggestions to reduce LCOE. This shows willingness and capability regarding the needed initiatives.

Examples of initiatives for the reduction of LCOE were provided in the end of each section of the findings. They will be further elaborated in the upcoming discussion section.

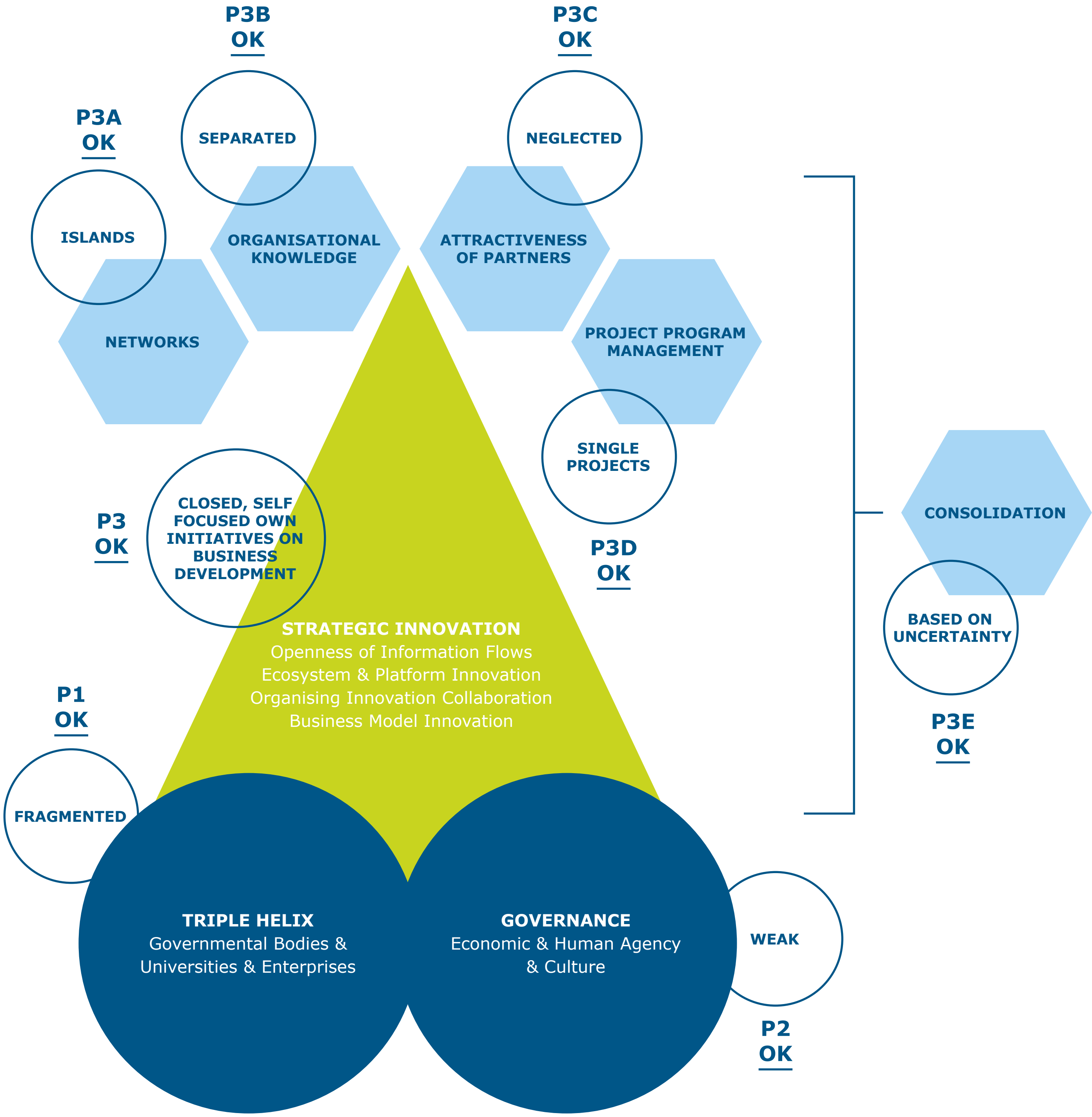

Figure 10: Overview of the findings and support for the propositions.

6. DISCUSSION

TRIPLE HELIX

The findings in part 5.1 revealed both positive and negative contributions from the Triple Helix concept on the reduction of LCOE. In other, more mature industries, the tendencies are moving in a direction where the actors in the Triple Helix (companies, public bodies and research and education organizations) have developed partnerships as the basis for common projects. In these industries, partners know each other very well through long-term interaction and have developed trust and accepted the different competence profiles of the interacting partners. In these ways, competitive advantages for all the participating actors – and the industry as a whole – can be reached for the benefit of all.

O&M in the offshore wind farms can be characterized as an emergent industry. The cooperation and interaction between actors in the Triple Helix can be described in an opposite way to a mature industry – limited trust, acceptance and cooperation.

The findings in section 5.1 illustrate several cases where the cooperation between actors results in a positive impact on LCOE. It can be argued that the following circumstances and premises are part of the development of a mutual understanding:

- Accept the different goals and intentions of the actors.
- Accept the complementary competences of the actors.
- Accept the fact that the solution to complicated challenges must include contributions from partners with complementary competences.
- Accept that all participating actors must gain in relation to their respective goals and intentions.

Public bodies, companies and research institutions are fundamentally quite different with different goals and intentions – but are able to contribute to the further development of the wind park industry. However, the process of accepting the fact that other organizations with quite different competences are able to contribute to solve the challenges in the industry may be difficult. As it is a young industry, there are tendencies such as *'we can manage the problems ourselves – we keep our cards close to our chest'*. This may result in sub-optimization with distortion of the competition in the industry.

Politicians in different countries are very interested in developing offshore wind parks, so a greater proportion of the electricity supply is based on sustainable energy resources. The production of wind-based electricity is subsidized, and at the same time, politicians are supporting the development of local activities with the purpose of creating local wealth ('the local content' concept).

Establishing local activities may be a distortion of competition – Danish companies may be more competitive but don't have the right to work. The answers from Danish companies can be divided into two groups:

- The reactive – accepting the conditions and that there is no business for them.
- The proactive – entering into dialogue with local authorities, local companies, local institutions and perhaps establishing subsidiaries in cooperation with foreign partners.

The case illustrates in a simple way that a hindrance can be changed into a possible advantage.
In a wider perspective, we see much potential in a closer, mutual interaction in the Triple Helix with the goal of reducing LCOE. Trust in partners and proactivity from the individual actors are important elements in realizing the possibilities.

The findings highlight that governmental bodies play an important role in the reduction of LCOE; they offer concrete initiatives on faster decision making processes for establishing wind park sites, acknowledge flexible rules and procedures according to local context, and align rules across nations and across maritime and other actors for more efficient and effective exchange. Here, the EU and regional bodies can play an important role for the development of wind parks and renewable energy in the North Sea. At the moment, this seems to be handled in a very fragmented way without the resources and power of institutions to provide support.

Moreover, universities and other educational bodies play an important role for knowledge dissemination between wind park O&M actors both in relation to research and educational activities. An antecedent will be funding to universities to support the reduction of LCOE. Thereby, the Triple Helix can provide robust support for strategic innovation in LCOE reduction for the benefit of society.

GOVERNANCE

The findings in part 5.2 revealed weak governance. In the wind farm industry, everything is emergent. Thus, there are opportunities to take the business in new directions. These opportunities are necessary for the reduction of LCOE. The many opportunities create a competitive environment among participants, which generates different interests and agency initiatives; thus, there is little trust among offshore wind farm actors.

However, the challenging political demand for the elimination of subsidies and reduction of LCOE in 2020 combined with the complexness generated by harsh wind, weather and water conditions in the North Sea create another agenda for the governance approach: to support the whole offshore wind farm system in the challenging task of reducing LCOE. Emerging and planned approaches to the reduction of LCOE need to be shared, aligned and further developed on the platform that is available. The need for governance has recently been acknowledged by three of the larger actors in the industry, as highlighted in the declaration of the EWEA conference in Copenhagen in 2015. The research findings in this report reveal that this governance approach will be extremely difficult to achieve due to the first agenda on emergent competition, which is also needed for innovation in the reduction of LCOE.

A combination of the two agendas is thus needed to reduce LCOE. Innovation has to be more strategically applied. Here, the Triple Helix actors can form a framework for governance of the offshore wind farm industry. Moreover, the offshore wind farm industry actors themselves need to focus on innovation at a more strategic level and not let innovation emerge primarily in relation to operational tasks and in limited fragmented areas in the whole ecosystem. The board and executive committee of the participating organisations have to discuss, decide and act upon the important issues of strategic innovation within own organisation. The research conducted reveals important strategic innovation issues on exploration and exploitation, which are discussed in more detail in relation to strategic innovation. Answers to the question of how to position and direct the organisation of strategic innovation can make the governance of the whole ecosystem stronger and more sustainable for the reduction of LCOE. The research reveals that all three approaches to governance on economic, agency and organisational trust dimensions are perceived as valuable for application in the offshore wind farm industry. Governance initiatives are thus antecedents for reduction of LCOE.

The findings highlight that governance plays an important and concrete role in aligning incentives across enterprise agents and building trust through higher transparency in the wind park industry.

STRATEGIC INNOVATION

The findings in part 5.3 on strategic innovation revealed ambiguity towards exploration and exploitation of solutions, as well as the need for open information in the ecosystem to build on platforms for collaboration and business model innovation. At the strategic level of the actors in the offshore wind farm industry – the board/executive committee/middle management – there is a need to integrate innovation into the strategic positioning and direction of the organisation with regard to the offshore wind farm challenges. The research findings point to specific issues regarding the MWh size of the wind turbines, the degree of customization of solutions and the degree of focus on technical and logistic solutions. It must here be noted that these issues are important at the moment but can change over time. Once the offshore wind farm industry has overcome these issues, other important issues will emerge. New and 'hot

issues' should be continuously monitored to stay current in strategic focus areas.
A more fundamental issue within strategic innovation is the willingness on a strategic level to participate in open flows of information. As highlighted in the literature review, research evidence shows the beneficial impact of open innovation; however, a limit to openness is typically also present. Fundamentally, the whole ecosystem of the wind farm industry based on the available platform has to be in focus – not only own organisation. This can support the future growth of the whole offshore wind farm industry. In this way, there is space for everybody, and well-performing organisations can be selected for future jobs. The others perish. It is also important at a strategic level to acquire the capability to organise collaboration for innovation, i.e., to organise for success in the ambiguity of exploration and exploitation. Business model innovation can support the organising for collaboration approach.

The abovementioned issues of strategic innovation are challenging; they require a different mind-set with regard to concrete initiatives on business model innovation, and in the findings, they are viewed as difficult. Interesting opportunities are present in these areas if the board/ executive committee/middle management takes up the challenge on strategic innovation and, moreover, on a more tactical/operational level, utilise networks, organisational knowledge, attractiveness of partners, and project program managements and create awareness of the benefits of consolidation. A more robust strategic innovation approach is thus important for the reduction of LCOE.

NETWORKS

The findings in part 5.3a related to the networks disclosed that while collaboration on both daily and development practices is necessary, the use of networks is somewhat limited at the moment.

There is no doubt that the actors recognize the urge to collaborate as an important factor in the battle to reduce LCOE. In this context, the relatively young age of the offshore wind farm industry is often considered as the main reason for the lack of collaborative solutions. However, the ability to collaborate is not likely to change from one day to another because the industry becomes more mature. For example, a piece of Danish industry history vanished when the pine furniture manufacturers went bankrupt one by one at the beginning of this century. A lack of collaboration was characteristic for this industry, and the companies did not increase their collaboration because the industry became mature.

Therefore, the ability to collaborate is something the actors within the offshore wind farm industry ought to be actively aware of and working towards. In relation to this, taking even small steps is better than neglecting the importance of collaboration. However, it is crucial to bear in mind that there is not unlimited time for realizing the reduction of LCOE; many small collaborative steps are needed to make real improvements.

The findings revealed some characteristics that are worth paying more attention to. First, the emerging consolidation within the O&M activities is a natural way to diversify the activities among the most appropriate and qualified actors. Second, the long-lasting relationships among some of the actors have proved that a joint development work is fruitful and paves the way to more innovative and sustainable solutions.

In general, it is important to pinpoint concrete initiatives in crucial areas for better coordination of the existing activities and development efforts. Plenty of qualified actors are ready to contribute to the collaborative efforts to bring LCOE down. Collaboration will not take place miraculously but requires a concrete joint acknowledgement that within the limited timeframe available, more collaborative actions are imperative.

KNOWLEDGE MANAGEMENT

The findings in part 5.3.b emphasized the many possibilities for creating new knowledge as the basis for innovations and reduction of LCOE. Reflections on some of the possibilities follow below.

Learning and competence development result in changes in the individual employee's mental models (Kim, 1993). This is illustrated in section 5.3.b. by activities such as mentoring, peer-to-peer training, cooperation, etc. The individual employee´s mental models must be transformed and embedded in the company´s shared mental models. The shared mental models consist of routines (standard operating procedures), which can be understood as methods and ways of doing things, which are not questioned. The routines become autopilot reflexes of the organizations. The development of effective routines is a long process and requires continuous efforts from experienced employees. The problem of attracting and maintaining experienced employees to shape and formulate the design of the routines is a very big challenge – which means it´s very difficult to embed the knowledge in the company.

As an introduction to section 5.3.b, two illustrative cases show creation of knowledge by using the learning circle. The activities in the cases are initiated by a centralized management decision. First, one can ask why the involved employees did not start the change process themselves by questioning the existing way of doing things. Obviously, the dynamics of the learning circle could have been increased by more effective decentralized decisions.

ISPs, utilities and OEMs offer different kinds of services, and the organization of O&M in offshore wind farms can be seen as a combination of these services. The business area is very attractive as the industry is growing very fast and earnings are favourable. At the moment, the intensive competition among partners seems to damage the industry, as better exploitation of the other partners' capabilities could contribute significantly to a reduction in LCOE. If the service activities are provided by the OEM, it is necessary for the OEM to have access to data about production (which are in the provider ownership), and in the same way, the provider must have detailed documentation from the OEM if the provider (owner) wants to take over the O&M activities. However, both partners keep the information to themselves. The progress in development can be encouraged by good examples. At the conference on May 7th, an illustrative example of how a binding cooperation between a logistic ISP and an OEM for the delivery of jack up ships was presented. Setting up the service from these ships is very complicated, and the process takes a long time, as several legal contracts have to be prepared, which can take up to 3 months. The partners decided to develop a standardized contract, which could be adjusted to the context (time, price, the extent of work, etc.). The result was a reduction in start-up time to approximately only 2 weeks.

Several substantial challenges in the centralized management decision process seem obvious when knowledge creation and use of knowledge are taken into account. The dynamism in the learning circle has to be accelerated, and the competence level of the employees has to develop in such a way that individual knowledge can be retained as organizational knowledge. This is complicated, as employees are often "stolen" from partners. It is a central management challenge to develop a reliable basis of organizational knowledge. This implies the possibility of constantly seeking new and more effective methods. Autonomy in the learning circle has to be enhanced.
Next, it is up to CEOs and the boards of the OEMs, utilities and ISPs to take concrete initiatives together on the development of solutions to reduce LCOE in ways that exploit the competences of the companies. This process is very complicated and difficult, so the solution calls for openness and trust. Experiences as shown in this section show that it is possible – but difficult.

ATTRACTIVENESS

The findings in part 5.3c related to attractiveness did not raise any hesitation that the actors have a clear understanding that an attractive partner is innovative, proactive, and financially well-established and often a larger company. However, the interviews revealed that a large number of smaller actors in the offshore wind farm context are agile, proactive and willing to work on behalf of the counterpart. However, they might not have the necessary balance sheet and financial robustness to meet the relatively high risk that characterizes the industry. In these terms, the emerging consolidation through capital partners is one of the options for smaller companies to increase their attractiveness. Moreover, the findings also disclosed that even smaller companies might have a chance, but it requires intensive networking and from time to time a good portion of luck. Therefore, the offshore playground is not an impossible arena for smaller innovative and qualified actors to enter. They just have to bear in mind the necessity to network and to make themselves visible whenever possible.

The emerging offshore wind farm industry has the potential to become one of the future employment areas. However, given that the companies experience political uncertainty in terms of postponing or cancelling the planned offshore wind farms, those companies that consider diversifying their activities to this field may become hesitant and allocate their resources to other fields instead. In a similar way, the short-term project environment does not necessarily invite qualified actors to invest in developing their activities in this industry context, as it often requires extensive financial investment. The interviews especially revealed the challenge of attracting logistic ISPs. They emphasized the necessity of having a quick and safe transfer to the wind farms within an enlarged weather window as one of the crucial development needs. However, developing a vessel suitable for offshore circumstances is a costly affair and calls for a long-term commitment from the collaboration partners. Therefore, an attractive business environment in terms of stability and long-term engagements is necessary to be able to develop the solutions that contribute remarkably to the reduction of LCOE.

Overall, attractiveness within the offshore wind farm industry calls for concrete mutual efforts. A large number of attractive actors are willing to work within renewable energy but they might need to make themselves more attractive to be taken into consideration. At the same time, the more established industry actors and their surroundings should ensure that offshore wind remains an attractive business environment.

PROJECT PROGRAM MANAGEMENT

The findings in part 5.3d revealed that project program management is an important tool for utilising synergies, in particular when experience with various resources is frontloaded. This amounts to a more holistic ecosystem approach to project program management than is typically applied within project management. The reason is found in the complexness and uncertainty factors involved in projects concerning offshore wind farms. The challenge is to have a holistic ecosystem approach over the lifetime of the offshore wind farm. The projects, tasks and actors change over this lifetime. How to be able to focus on a holistic lifetime approach? The research findings underpin the usefulness of cross-fertilization between construction and O&M experiences, parallel projects, actors and suppliers. In short, this means a high level of interaction as early as possible among these potential sources of knowledge; it is referred to as 'frontloading'.

It is challenging to find out who and what to 'frontload'. On one hand, this will increase costs due to meetings and communicating with people. On the other hand, frontloading can save a great deal of money, e.g., within O&M activities on the offshore wind farms. A trade-off is present between the certain costs experienced now and the more uncertain value from the 'frontload' reaped later after many years of operation. The pressure to reduce LCOE can cause a bias to focus more on avoiding the increase in present costs.

Moreover, the amount of people/knowledge involved in the 'frontload' can be challenging. Too many actors can be involved, which creates a great deal of talk, adds no value and/or places demands on time in the form of reports, which do not create value. Therefore, limitations to the 'frontload' issue are present. However, this research reveals that these limitations have not yet been reached in the offshore wind farm industry. The time from initial costs to reaping the benefits is long, and therefore, the incentives to boost the value of the 'frontload' are anticipated as being weak. Nonetheless, several of the interviewees find it very interesting to participate in 'frontload' activities to reduce LCOE – even when their own specific task is reduced so that the invoice at the specific task at the end of the day is reduced as well. They explain this phenomenon as the motivation to improve operations and expand the scope of work to enhance invoicing in the future. Thus, some of the interviewees trade money now for interesting work and enhanced invoicing in the future. Therefore, the timeframe is an acknowledged factor in the offshore wind farm industry.

All in all, concrete initiatives are needed for the qualification of project program management, and in particular, the issue of frontloading with a focus on reduction of LCOE is important.

CONSOLIDATION

The findings in part 5.3e revealed the consolidation issue for both enterprises and 'geographical nearness', which refers to having a large part of O&M activities in a certain area. The rationale for consolidation is the typical arguments for economies of scale and economies of scope, which offer more efficient and effective governance/management of activities in the case of consolidation. One argument in the offshore wind farm area is the opportunity for uncertainty and risk reduction through consolidation. This issue is essential in offshore wind parks with complex and harsh wind, weather and water conditions and many different tasks to be carried out by different actors.

The research shows a need for consolidating data, information and knowledge. Moreover, communications to disseminate and understand the innovation is called for so that it may be applied in a practical sense. At the moment, much effort is focused on data gathering from the O&M activities. 'Ownership' of the data is important. Moreover, the information to be derived from the data is in certain areas applied to present O&M activities. Here, a very interesting opportunity to enhance knowledge of O&M activities is present with spill-over in construction and installation.

Moreover, the uncertainty issue is extremely important. At the moment, risk is pushed 'upstream' to the suppliers, which are typically smaller than the larger actors. All suppliers need to be able to put a price on uncertainty. When the uncertainty and risk is pushed upstream to the suppliers, this creates an incentive for the suppliers to reduce the risk in the period they have to address it. Several of the interviewees have highlighted the uncertainty and risk issue as especially important, and the following claim was raised: *'The challenge of reducing LCOE by 2020 would be solved if the issue of uncertainty and enhanced price was not present'*. Nevertheless, uncertainty will not disappear in real life. Somebody has to take responsibility for the uncertainty on offshore wind farms. The question is how to handle uncertainty efficiently and effectively. None of our interviewees came up with a meaningful suggestion. Solving the uncertainty/risk issue provides an extremely interesting opportunity to reduce LCOE. Here, information and knowledge play a crucial role because they represent antecedents for dealing with uncertainty and risk and set a reasonable price on the concrete risk event. The research reveals that the notion of consolidation is interesting in different ways for enterprises, geography and knowledge. However, the most interesting issue in relation to consolidation is handling uncertainty in an efficient and effective way. Concrete initiatives are necessary on disclosure of risk through information and knowledge of events.

SUMMARIZATION

The discussions of the findings underpin the opportunities for reduction of LCOE. There seems to be considerable opportunities as a result of reflection on the underlying forces in all areas.

Figure 11 shows the challenges as experienced by the interviewees in achieving LCOE reduction.

In short, the listed challenges need to be met with initiatives as follows:

- The Triple Helix approach needs to be united – not fragmented as it is now.
- Governance needs to be strong - not weak as it is now.
- Strategic innovation needs to be open with a focus on the whole ecosystem for business development - not closed as it is now and with a focus on own initiatives on business development.
- Networks need to collaborate - not operate on islands as is the case now.
- Organisational knowledge needs to be united - not separated as it is now.
- Attractiveness of partners needs to be acknowledged - not neglected as it is now.
- Project program management needs to be perceived as a coherent system - not perceived as single projects as it is now.

- Consolidation needs to be based on opportunities - not on uncertainty as it is now.

In the previous sections, the interviewees specify the more detailed answers to the question. In the discussions, it is also highlighted that it will be challenging due to, e.g., issues of uncertainty, complexness, and collaboration and strategic innovations for openness and organising for exploration and exploitation. However, improvement is revealed as a strong motive among actors in the offshore wind farm industry.

Further research is needed within the specific topics mentioned on gaps between the necessary initiatives mentioned by the interviewees and the actual behaviour revealed for reduction LCOE

At the end of the day, several sustainable opportunities exist within the offshore wind farm industry to pursue the goal of reducing LCOE. The gaps provide opportunities to reach the goal of reducing LCOE by 2020.

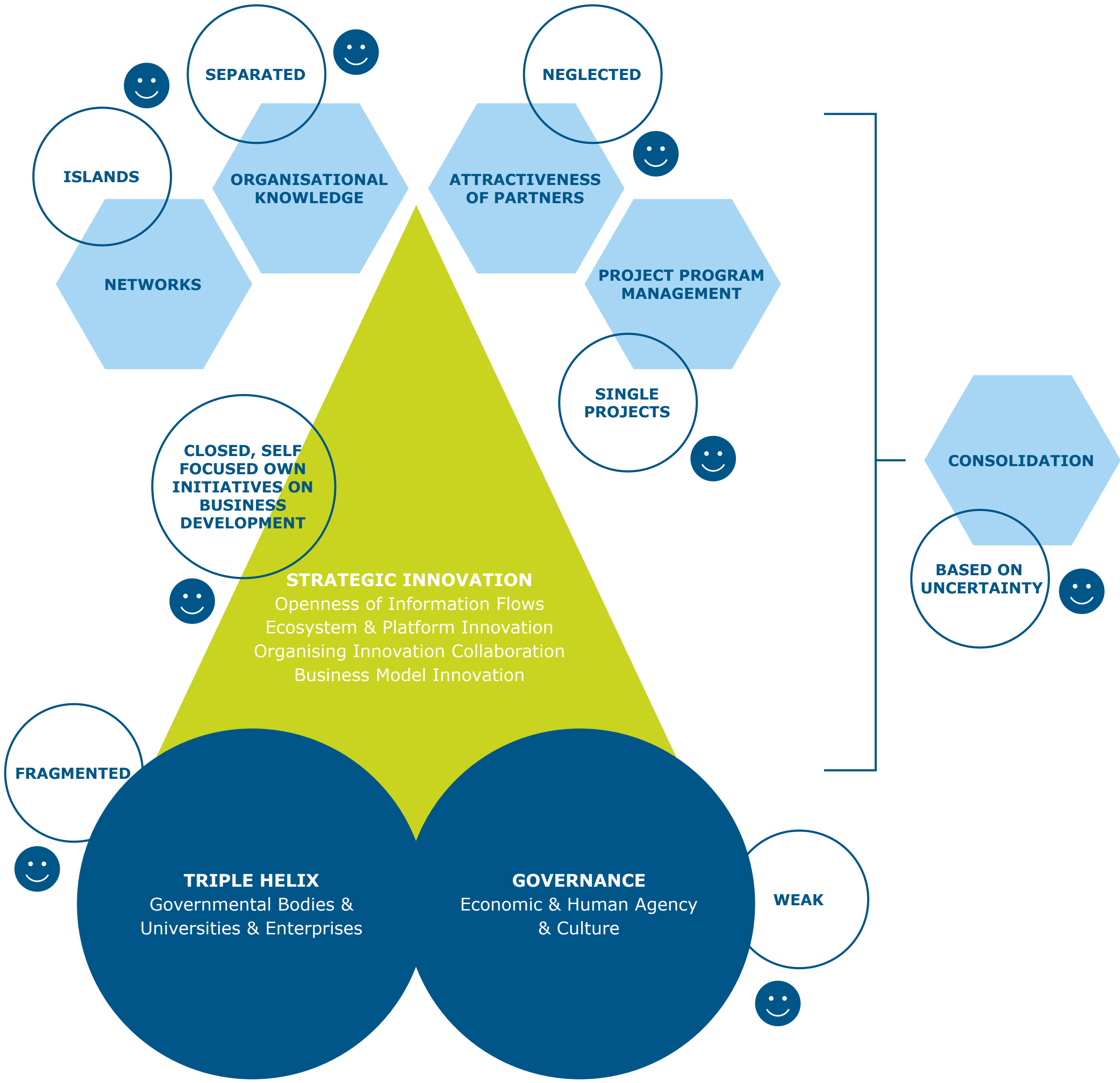

Figure 11: Overview of the gap between the propositions and the current status.

7. CONCLUSIONS

The goal of this research was to reveal how reduction of LCOE can support the lifetime sustainability of offshore wind farms. The research was conducted from June 2014 to May 2015 starting with a focus group interview on O&M activities for the reduction of LCOE, with 11 actors from the wind farm industry participating. After that, individual semi-structured interviews were conducted with 20 actors in relation to O&M activities. Finally, a conference was held in May 2015 with a presentation of the main findings from the research and 5 O&M actors presenting their own assessment of opportunities to reduce LCOE. A literature review provided propositions according to existing knowledge on key issues on innovation related to the offshore wind farm industry. The interviewees provided their own perception of the necessary initiatives generated through their comprehensive understanding of the offshore wind industry. Through this approach, it was possible to reveal whether the interviewees actually perceived the elements within existing knowledge as relevant for application to the offshore wind industry for reduction of LCOE. Accordingly, gaps could be revealed based on the current states of initiatives and the theoretical concepts/models forming opportunities for reduction of LCOE.

The findings in the report revealed several opportunities that can contribute to reduction of LCOE. Some of the most important and interesting opportunities are presented below in relation to the literature stream; they support the interviewees' perception of opportunities. The opportunities will here be presented in a very brief way, with references to the corresponding sections in the report, where the reader can see the argumentation in relation to the opportunity in more detail.

→ The **Triple Helix** concept (see 5.1 and 6) shows the opportunities in the collaboration between public bodies, companies and research institutions. The findings reveal substantial opportunities for Triple Helix actors to contribute positively to reduction of LCOE, e.g., in the form of alignment of regulations across countries, standardization of education, training and support for alignment of rules and procedures and funding of research and educational activities.

→ **Governance** (see 5.2 and 6) through economic incentives, agency of stakeholders and mutual trust in the ecosystem plays an important role for reduction of LCOE. The alignment needs to be present on all three governance issues of economic incentives, agency interests and organizational trust between actors. To some degree, it means 'open books' to pursue transparency between partners.

→ **Strategic innovation** (see 5.3 and 6) plays an essential role in the findings for reduction of LCOE through several joint approaches on the development of performance of the wind park. This means focus on several activities, such as:

- Utilization of experiences from O&M activities for improvement of construction, installation and O&M tasks.
- Development of preventive and remote solutions.
- Flexible standards on successful parts of solutions.
- Qualified and shared IT-systems to manage documents.
- Integration of maritime approaches.
- The strategic innovation initiatives are thus manifold and challenging but to a large extent rooted in organizational issues that are possible to pursue strategically. In the findings, the following issues enhance the strategic innovation approach:
- *Open and transparent information and knowledge creation* for reduction of LCOE means open dialogue with partners in terms of their specialized knowledge, accepting other partners' specialized knowledge for efficient and effective division of labour, and conceptualization of specific practical experiences for dissemination. Moreover, utilization of knowledge in other practical contexts and open information and knowledge exchange on risk events is essential to reduce risk in the wind park. Openness is thus required in several dimensions.

- Utilization of the wind park *ecosystem* as platforms for innovation. This means enhanced focus on co-creation of O&M solutions and rules and procedures for reduction of LCOE. Co-creation can also reduce uncertainties in the wind park through more thorough understanding and insights of the operation of wind parks. Co-creation can be expended to other relevant industry platforms.

- *Organising collaboration* across ambiguities for reduction of LCOE is a further essential issue. Here, a discussion needs to touch upon the importance of diversifying the O&M activities based on actors with the relevant competences and agreeing upon a workflow that contributes to reduction of LCOE. Experience with O&M is now developing through practice on different wind park sites, and this experience needs to be qualified and acknowledged to organise roles and tasks among actors. This will also help to reduce uncertainty and risk in the wind parks, as the organising can be run smoothly.

- *Business Model Innovation* for setting joint direction for reduction of LCOE is an obvious tool to utilize in the wind park industry ecosystem. Business opportunities can through discussion relatively easily proceed through the first joint acid test on applicability and point at business opportunities between organisations in the ecosystem.

→ **Networks** (5.3.1 and 6) provide in the findings a wider framework for reduction of LCOE. They can be within or outside the wind park ecosystem. The essential issue to utilize networks in the wind park industry is to overcome the present self-centred approach, which means to be open and prepared to create joint business models with partners as well as a joint culture for collaboration within the ecosystem and with outside partners.

→ **Organisational knowledge sharing/knowledge creation** (5.3.2 and 6) is a core issue in the findings for reduction of LCOE. The learning circle accumulates concrete experiences, reflects on the experiences, forms and implements new concepts. This requires leadership competences among actors, which need to encompass both centralized leadership, providing united direction, and distributed leadership, providing local specific knowledge, engagement and momentum.

→ **Attractiveness of the collaboration partner** (5.3.3 and 6) is in the findings an often underdeveloped issue for collaboration. However, as shown the wind park industry, it has specific requirements for the attractiveness of collaboration partners as listed in the following: economic robustness, meeting the values of customers, flexibility of operations and pro-activeness (thinking ahead on behalf of the interviewees). These requirements do not necessarily coincide, but several of them typically need to be present. The requirements to be an attractive partner are thus challenging. They can serve as a way to understand the basic requirements of network partners in the ecosystem.

→ **Project program management** (5.3.4 and 6) is very important in the findings for the reduction of LCOE, and therefore, it is important to develop capabilities in this area. A particular emphasis on frontloading people and experience is needed due to the complex nature of project program management. This means a need for systematic accumulation of experience both in IT systems and within and between project managers and project teams.

→ **Consolidation** (5.3.5 and 6) provides in the findings different ways to explore and coordinate similar activities, different activities and geographic proximity and data utilization. These elements represent different dimensions of consolidation, which is mentioned as being beneficial for reduction of LCOE. In this context, it is relevant to note that consolidation can also lead to 'exclusion-of-others'. This can cause higher prices and narrows the range of ideas and strategic innovations due to the power of the consolidated company.

The opportunities to reduce LCOE are considerable and seem absolutely possible if the actors in the wind park industry make changes and pursue them.

Reduction of LCOE can, in the short term, mean less business revenue for a specific O&M task, as the time and resources for work are reduced. However, in the long run, reduction of

LCOE increases the number of tasks due to the improved competiveness of offshore wind parks in relation to traditional energy sources and other renewable energy sources. The opportunities for increased business revenue for actors are, as a result, multiplied.

Further research is needed on the opportunities mentioned for reduction LCOE.

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APPENDIX 1

AGENDA FOR INTERVIEW:

Operation and maintenance in offshore wind farms

THE INTERVIEW IS DESIGNED IN THE FOLLOWING WAY:

- We have some questions on which we would like to hear your opinion

These questions are listed below.

- We would like to hear about issues, you consider important to service and maintenance of offshore wind farms.

QUESTIONS FROM OUR SIDE:

- How do you perceive your opportunities?
- What are the core issues/ challenges?
- Can industry initiatives help? If, yes, how?
- What innovation is needed?
- What network collaboration is needed?
- How do you gather knowledge for application in further projects?
- How do you perceive an attractive collaboration partner?

WE WOULD LIKE TO HEAR YOUR OPINION ON THIS TOPIC!

The interview from our side is seen as a dialogue about the topic in which our questions are integrated, when it suits the conversation. For research use, it is necessary to record the interview.

The information is of course confidential.

All material from our research will basically be anonymous unless the firm wants its name mentioned. If this is the case, the citation will be submitted for approval in full text before publication.

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