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The triple helix frame for small- and medium-sized enterprises for innovation and development of offshore wind energy

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Abstract

This research reveals how small- and medium-sized enterprises (SMEs) can enable innovation and contribute to a reduction in the levelized cost of energy (LCOE) in offshore wind farms. The research provides findings from a longitudinal qualitative study of 10 SMEs for the understanding of the impact from integrating SMEs in a triple helix context.

The triple helix approach with government, university and industry participants typically include larger organisations. The research indicates that SMEs could join the triple helix and both contribute and receive benefit from their presence. The findings show that SMEs need access to market and industry stakeholders to understand, learn and select among business innovation opportunities. Universities, governmental bodies and industries can create a knowledge space for organisational reciprocal learning between SMEs and larger enterprises to enable innovation for the reduction of the LCOE in the wind farm industry. This knowledge space also provides important insight and understanding for the governmental and university helices for active contribution to offshore wind energy.

The governmental policy impact stresses the need for a more strategic long-term support of industry knowledge spaces for offshore wind energy. Governmental bodies would actively enhance political growth strategies regulating competition and collaboration. Universities can contribute actively towards knowledge creation and dissemination. All three helices could benefit from this approach to SMEs. Further research needs to be conducted on SMEs in the triple helix context.

Keywords: Innovation, Triple Helix, Knowledge, SMEs, Wind farm suppliers, Offshore wind energy

Resumen

Esta investigación revela cómo las pequeñas y medianas empresas (PYME) pueden permitir la innovación y contribuir a una reducción en el coste normalizado de la energía (LCOE) en parques eólicos marinos. La investigación proporciona los resultados de un estudio cualitativo longitudinal de 10 pequeñas empresas para la comprensión del impacto de la integración de las PYME en un contexto de Triple Hélice. El enfoque de Triple Hélice con los participantes gubernamentales, universitarios, y de la industria suele incluir solamente empresas grandes. La investigación indica que las PYMEs podrían unirse a la triple hélice y aportar y recibir un beneficio. Los resultados muestran que las PYMEs necesitan tener acceso a mercados y a la industria para entender, aprender y seleccionar mejor entre las oportunidades de innovación empresarial. Universidades, organismos gubernamentales, y las industrias pueden crear un espacio de conocimiento para el aprendizaje recíproco de organización entre las PYMEs y las empresas de mayor tamaño para permitir la innovación para la reducción del LCOE en la industria de parques eólicos. Este espacio de conocimiento también proporciona información importante y la comprensión de las hélices gubernamentales y universidades para contribuir activamente a la energía eólica marina. El impacto de las políticas del gobierno hace hincapié en la necesidad de un apoyo más estratégico a largo plazo de los espacios de conocimiento de la industria de la energía eólica marina. Los organismos gubernamentales podrían mejorar activamente las políticas para el crecimiento económico y a la vez regular la competencia y la colaboración. Las universidades pueden contribuir activamente a la creación y difusión del conocimiento. Las Triple Hélice se beneficiará, como programa de innovación y como programa de investigación, de incrementar el rol de las PYMEs.

Résumé

Cet article révèle comment les Petites et Moyennes Entreprises (PME) peuvent permettre l'innovation et contribuer à une réduction du coût moyen actualisé de l'énergie (LCOE) dans les parcs éoliens offshore. La recherche fournit les résultats d'une étude longitudinale qualitative sur 10 PME en vue de comprendre l'impact de leur intégration dans le contexte de la Triple Hélice. L'approche de la Triple Hélice avec des participants provenant des pouvoirs publics, de l'université et de l'entreprise inclut typiquement les grandes organisations. L'étude indique que les PME pourraient rejoindre la Triple Hélice et à la fois contribuer et tirer bénéfice de leur présence. Les résultats montrent que les PME ont besoin d'accéder aux marchés et que les industriels doivent comprendre, apprendre et choisir les possibilités d'innovation des entreprises. Les universités, les organismes gouvernementaux et les industries peuvent créer un espace de connaissances pour l'apprentissage organisationnel réciproque entre les PME et les grandes entreprises en vue de permettre l'innovation pour la réduction du LCOE dans l'industrie du parc éolien. Cet espace de la connaissance fournit également un aperçu important et une compréhension des hélices gouvernementale et universitaire en vue de contribuer activement à l'énergie éolienne offshore.
L'impact de la politique gouvernementale souligne la nécessité de la mise en place d'une stratégie à long terme pour l'appui aux espaces de connaissance de l'industrie de l'énergie éolienne offshore. Les organismes gouvernementaux renforceraient activement des stratégies de croissance politique régissant la concurrence et la collaboration. Les universités peuvent contribuer activement à la création et à la dissémination de la connaissance. Toutes les trois hélices pourraient bénéficier de cette approche pour les PME. Des recherches approfondies doivent être menées sur les PME dans le contexte de la Triple Hélice.

摘 要

这项研究揭示了中小企业能进行创新,并且能减少海上风电场的能源平准化成本(LCOE) 。我们通过对10个中小企业的纵向定性研究来理解在三螺旋框架中集成的中小企业的影响。大学、政府机构和产业实体能为中小企业和大企业之间的组织互相学习创造知识空间,有利于在海上风电场实现创新和降低LCOE。 有政府、大学和产业参与的三螺旋模式通常包括更大的组织 。研究表明,中小企业可以纳入三螺旋结构,两者都因彼此的存在贡献和获得利益。本项研究也发现,中小企业需要进入市场,产业相关人士需要了解、学习和选择商业创新机会。这个知识空间也为政府和大学积极贡献于海上风力发电提供了重要的观察和理解。政府政策需要强调对海上风能产业知识空间的长期战略支持。政府机构要积极加强政治发展战略、规范竞争和合作。大学能为知识创造和传播作出积极的贡献。这样中小企业能从所有三个螺旋中获益。三螺旋背景下的中小企业还需要进一步研究。

Аннотация

Настоящее исследование посвящено тому, как малые и средние предприятия могут создавать инновации и осуществлять вклад в снижение нормированной стоимости энергии (Levelized Cost Of Energy, LCOE) в береговых ветряных электростанциях. В статье представлены результаты долгосрочного качественного анализа деятельности 10 компаний, относящихся к сегменту малого и среднего бизнеса, позволяющие оценить влияние интеграции таких компаний в тройную спираль.

В рамках трехспирального подхода, основанного на взаимодействии государства, университетов и промышленности, обычно рассматриваются крупные компании. Настоящее исследование указывает на то, что малые и средние компании могут встраиваться в тройную спираль; при этом от их присутствия получают выгоду все участники. Полученные данные показали, что малые и средние компании нуждаются в доступе на рынок для того, чтобы понять, изучить и выбрать подходящие ниши среди существующих. Университеты, правительственные организации и бизнес могут создать образовательное поле совместно с малыми и средними компаниями, где будут освещаться вопросы снижения нормированной стоимости энергии в сфере энергосбережения. Такой формат обучения обеспечивает важный вклад во взаимодействие «правительственной» и «университетской» спиралей в вопросах ветровой энергетики.

Правительственные инициативы оказывают влияние на возникновение необходимости в долгосрочной поддержке образовательных инициатив, связанных с ветровой энергетикой. Государственные организации могут стимулировать разработку соответствующих стратегий и обеспечение сотрудничества в данной сфере. Университеты могут также внести существенный вклад в генерацию знаний и их распространение. Все три спирали могут выиграть от взаимодействия с представителями малого и среднего бизнеса. Дальнейшие исследования предполагают изучение вклада малых и средних компаний в трехспиральную модель.

Resumo

Esta pesquisa releva como pequenas e médias empresas (PMEs) podem permitir a inovação e contribuir para a redução do custo nivelado de energia (LCOE) em parques eólicas offshore. A pesquisa fornece resultados de um estudo longitudinal qualitativo de 10 PMEs, para a compreensão do impacto da integração de PMEs no contexto de hélice tríplice. A abordagem de hélice tríplice com participantes do governo, universidade e empresas inclui tipicamente grandes organizações. A pesquisa indica que PMEs poderão aderir à hélice tríplice e ambas contribuirem e receberem benefícios de sua presença. Os resultados mostram que PMEs precisam de acesso a stakeholders do mercado e da indústria para compreender, aprender e selecionar as oportunidades de inovação de negócios. Universidade, organismos governamentais e empresas podem criar um espaço de conhecimento para a aprendizagem organizacional reciproca entre PMEs e grandes empresas para permitir inovação na redução do custo nivelado de energia (LCOE) na indústria de parques eólicos. Este espaço de conhecimento também fornece insights importantes e o entendimento da contribuição ativa para as hélices do governo e da universidade para a energia eólica offshore.O impacto da política governamental sublinha a necessidade de mais apoio estratégico de longo prazo para espaços de conhecimento da indústria para a energia eólica offshore. Os órgãos governamentais aprimorariam ativamente as políticas estratégicas de crescimento que regulam a competição e a colaboração. As universidades podem contribuir ativamente para a criação de conhecimento e difusão. Todas as três hélices poderão se beneficiar desta abordagem para as PMEs. Futuras pesquisas precisam ser conduzidas para as PMEs no contexto hélice tríplice.

Multilingual abstract

Please see Additional file 1 for translation of the abstract into Arabic.

Introduction

At the European Wind Energy Association (EWEA Conference 2015) in Copenhagen, the need was highlighted for a united aim in the wind farm industry for a reduction in the levelized cost of energy (LCOE), as shown in the below headlines of the declaration (EWEA 2015):

> 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 aim of these three large actors within the wind farm industry is thus set on an agreement for a committed reduction in the overall lifetime cost of energy in wind farms. This is particularly essential for offshore wind energy, which typically is two to three times more costly than, e.g. onshore wind energy (OpenEI 2015). Offshore wind energy solutions need to be competitive in regard to the cost of energy compared to other energy sources. Existing subsidies are expected to cease completely by 2020. This development puts pressure on the offshore wind farm

industry to come up with a +complex and enhanced project management over the lifetime of offshore wind farms to be competitive on the LCOE. The definition of LCOE varies and is subject to continuous debate. Briefly, LCOE can be defined as 'the sum of the discounted lifetime generation costs (£) divided by the sum of the value of the discounted lifetime electricity output (MWh)'. Generation costs include installation, operating, and decommissioning costs incurred by the developer/owner over the lifetime of the wind farm, including transmission costs (Crown 2012). Typically, the transmission costs are not integrated in the calculation of LCOE, as noted by the International Energy association (IEA 2015). This means that the measurement of the reduction of LCOE is focused on the performance of the industry, although governmental bodies have a considerable responsibility regarding the transmissions costs and the political will to invest in the grid for electricity transmission. Actually, the industry and the governmental bodies must have the same incentives for the reduction of the LCOE. This means that an integrated measurement is needed for LCOE, as indicated by the Crown (2012) definition of LCOE.

LCOE is thus, on the one hand, dependent on investments and operation and maintenance (O&M) costs; on the other hand, it is dependent on the ability of the wind farms to produce electricity. The latter means efficient and effective production with the elimination of the downtime of the wind turbine to increase the production of electricity. Moreover, the sale of electricity will be dependent on the price/unit of electricity, which typically is negotiated with governmental bodies in a long-term contract before investments for the wind farm are decided upon. Here, the governmental bodies have a direct influence on the decision of industry parties to establish a wind farm.

The governmental bodies have also a direct influence on LCOE through the political will to lower the cost of capital, as highlighted by the European Parliament member Claude Turmes (Delony 2015). Turmes considers the "creation of a de-risking fund for countries that are penalized by capital markets with high interest rates for renewable energy projects to be one of the most important possible outcomes of the 2015 Paris Climate Conference (COP21) in December". Therefore, this aspect also has great relevance for LCOE. This is a political issue that the triple helix could help to address. Moreover, universities could help to bridge the challenge of the reduction of the LCOE (Etzkowitz 2014; Gawer and Cusumano 2014; Brink et al. 2015) with a collaboration of knowledge creation and dissemination, as well as developing research verified innovation platforms for the reduction in the LCOE.

The installation and operation of wind farms require different actors in many projects, including the wind farm owners, as well as a range of larger and smaller suppliers within construction, production, installation and O&M activities. The actors in the industry are all dependent on each other, according to the LCOE calculation approach. Collaboration with small- and medium-sized enterprises (SMEs) is particularly important, as their part of the work in offshore wind farms is estimated to be 60–70 % of the total cost of a wind farm (Danish Wind association statistics 2012). SMEs often lack time and resources in their organisations. Moreover, SMEs are typically more creative and flexible than larger organisations (Brink and Madsen 2015; Edwards et al. 2005; Murphy 1996). Integration of SMEs to reap the potential innovation present within renewable energy is therefore beneficial from society's point of view. Based on the

previous highlights, the research question in this paper is framed as follows: *how can SMEs enable innovation and contribute to a reduction in the LCOE in offshore wind farms?*

The wind farm industry has emerged within a relatively short period of time. The first commercial onshore wind farms were established at the beginning of the 1970s (Madsen et al. 2012). The requirements for equipment and effective and efficient processes in the offshore wind farm industry are markedly enhanced due to the harsh environmental, wind and water conditions. A dominant design has not yet emerged. New and different challenges arise offshore compared with onshore for wind farms. Offshore wind farm industries, in general, pursue larger investments with extended risks of operation (Crown 2012). These issues put pressure on the offshore wind farm industry to collaborate for innovation to reduce LCOEs. They also put pressure on governmental bodies to create infrastructure, e.g. transmission grids, suitable harbours and roads for transportation. In the same way, universities are encouraged to develop new knowledge of new solutions, both technically and commercially.

Innovation requires learning and knowledge generation in the context of the wind farm industry. In this way, both the wind farm industry and the framing conditions play a role concerning governmental bodies and universities. The three participants in the triple helix notion have different interests. The industry aims primarily for growth in private business development terms. The governmental bodies have an aim to support sustainable energy for public well-being and sustainability of the 'triple bottom line' of people, planet and profit (Silvius and Schipper 2014). Universities have the aims of research and communication of new knowledge and the application of this knowledge in society. The three different perspectives illustrated in the triple helix means that three different interests must collaborate with the same overall aim of innovation to reduce LCOEs. The different interests of participants are often highlighted in the triple helix context, as noted by Etzkowitz and Leydesdorff (2000). However, in the wind farm industry, SME suppliers also have an important impact on reducing LCOEs. Our research, therefore, focuses on SME suppliers and their opportunities to enable innovation. The research conducted is financed by Region South Denmark and the EU.

The outline of the research is a literature review on the state-of-the-art understanding on the triple helix, business networks, knowledge creation and business model innovation (BMI) literature. Moreover, the methodological approach is explained. Then, the findings are summarised and discussed in a model for integrating SMEs into the triple helix approach. A conclusion finalises the paper with notions on policy implications for governmental bodies, university strategies and industry strategies. Additionally, the need for further research is elaborated.

Literature review

The triple helix concept provides a model for transformational processes between universities, private corporations and governmental bodies (Etzkowitz, 1998; Leydesdorff and Meyer 2006; Etzkowitz and Viale 2010; Leydesdorff 2012; Etzkowitz 2014). As highlighted by Mowery and Rosenberg (1998), the 'institutionalisation of innovation' represents a change in the process of innovation in the 20th century through the emergence of corporate, university and government sponsored research and development

(R&D). In our research, we take further steps beyond the R&D approach to reveal how SMEs can join a triple helix frame to enable innovation. The single SME has typical limited resources. However, joining a SME network with other suppliers and joining a triple helix network provides interesting access to resources and enhancement of knowledge for utilising opportunities in their own SME business context. Our literature review will thus examine triple helix and business network theory to reveal the context, it will examine organisational learning theory to reveal knowledge transfer and it will examine innovation theory to reveal value creation. First, the triple helix and business network literature streams will be elaborated according to our research question.

Business network theory embedded in triple helix

The Triple Helix model in Fig. 1 shows the participants in our research and highlights the three different roles of university, private enterprises in the industry and governmental bodies represented by, respectively, the University of Southern Denmark, SME suppliers in the wind farm industry and the governmental bodies consisting of the EU, the regional body of Region South in Denmark and Offshore.energy.dk. This is different from a classical triple helix approach where typically larger enterprises in the industry participate.

The three participating groups in the triple helix model typically have different interests (Leydesdorff and Meyer 2006). Universities are interested in the 'novelty production' of knowledge. Industry enterprises are interested in 'wealth generation' within business solutions, which means better economic performance of their operations. This is the case for both SMEs and larger enterprises. Governmental bodies are interested in 'public control'; 'public wellbeing' in society is summarised in the 'triple bottom line' (Silvius and Schipper 2014). The theory within the Triple Helix notion emphasises the need for blurred boundaries between the three different participant roles. Their interests often move in three different directions, and blurred boundaries support spaces of common aspects for joint collaboration and learning. Moreover, the need for a

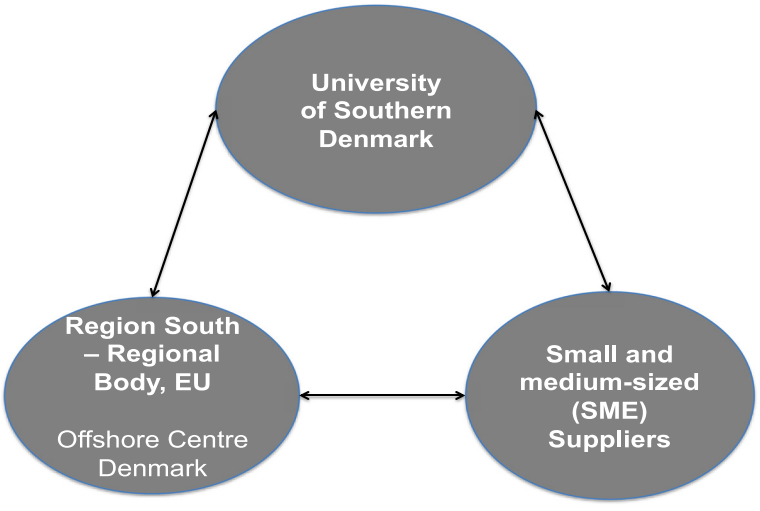

Fig. 1 Participants in the Triple Helix Model in our research

continuous balance between integration and differentiation of functions between the three categories of participants needs to be recursive and reflected upon to find the balance to enable innovation (Etzkowitz and Leydesdorff 2000). The University of Southern Denmark has, in our research, the role of 'regional and local innovation organiser' (Etzkowitz and Leydesdorff 2000). This means that the university organises recursive information overlaps with 'knowledge flows' for action and reflective elaboration on innovation. The literature also anticipates the selection conducted on innovation and business development to be either driven by the market, technology or coordination mechanisms (Leydesdorff 2006; Leydesdorff and Meyer 2006). The drive for selection provides an important insight to the organising mechanism in loosely coupled SME networks, as presented in this paper.

The notion of the triple helix with blurred boundaries and a combination of integration and differentiation between participants raises the following questions: How should the boundaries be blurred? How should the combination of integration and differentiation be done? Answering these questions requires an enhancement of competition and cooperation. Polenske (2004) reveals interrelationships among competition, cooperation and collaboration in networks of firms at the regional level. According to Polenske (2004), this triangle of connections reduces costs. The relationship and the subsequent results on competition and cooperation and the resulting reduction on transaction costs were initially identified by Coase (1937) and later elaborated upon by Williamson (1996). The transaction costs approach compares the costs associated with two sources of origin for the transaction—the external market and the internal organisation. In this notion, it must be revealed whether it is more cost-effective to coordinate the transaction through the external market (competition) or to have the organisation oversee and manage the transaction (cooperation). According to Polenske (2004), value is also a result of collaboration, which is termed as the reduction of adaption costs. As reported by Polenske (2004), collaboration arrangements among firms often lead to internal long-term economies of scale. The result of collaboration on innovation may well affect the firm's position on its long-run average cost curve. For example, by collaborating on the design and production of a product, two or more firms can lower costs and more quickly create new products for utilisation on a longer time horizon. This leads, in turn, to workers acquiring new skills and firms sharing capital investments and the risks of operations. Network connections among firms thus enhance a flexible structure of the enterprise driven by the interests of the networking firms on competition, cooperation and collaboration activities to enable innovation. In the offshore wind energy context, a call for collaboration is present because of the size of the offshore wind farms (small power plants at sea) and the many organisations in private, public and university context participating on the reduction in LCOEs. Research studies have previously noted that the triple helix notion does show a beneficiary impact from different forms of collaboration (Etzkowitz and Viale 2010; Leydesdorff 2012; Etzkowitz 2014). Here, SMEs with an entrepreneurial approach on value creation in public-private ventures could make an even more positive contribution. The docile approach on teachability and educability and inter-subjective interaction between SMEs, as noted by York et al. (2013), has the opportunity to enhance the contribution through network activities among SMEs. The anticipation is therefore a positive impact from integration of SMEs in triple helix collaboration on innovation for the reduction in LCOEs.

Within business networks, SMEs can organise boundaries of individual SMEs much more loosely than large enterprises have the opportunity to do. Within organisational theory, Podolny and Page (1998) have defined the network form as being distinctly characterised in the following way:

> We define a network form of organisation 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 organisational 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 access to. This can create a competitive advantage, as noted by Burt (2000).

Powell et al. (1996), in their longitudinal study in the biotechnology industry, found a path-dependent cycle of learning and argued that '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). In the understanding of Powell et al. (1996), the term 'reciprocal learning' includes two processes that occur simultaneously and recursively on the individual and organisational level. First, SMEs are increasingly using ties to enhance the inflow of specific information, resources and products. Second, SMEs are becoming much more adapted at and reputed for the general practice for collaboration with diverse partners as present in the triple helix notion. The context is framed by docility and inter-subjective interaction (York et al. 2013).

The notion of business networks provides competitive advantage through enhanced access to resources and 'reciprocal organisational learning' to enhance innovation and reduction in LCOEs. The literature thus makes us anticipate the following proposition regarding SMEs in an embedded triple helix frame:

P1: The embedded triple helix context on reciprocal organisational learning can organise innovation activities to reduce LCOEs.

Next, organisational learning theory will be elaborated according to our research question.

Organisational learning theory

A key issue within the triple helix notion is knowledge and learning as noted by Leydesdorff (2010). Concepts of process and stocks, called, respectively, 'organisational learning' and 'stocks of knowledge', have emerged in the literature (Appleyard 1996; DeCarolis and Deeds 1999). Moreover, Boisot (1998, p. 41–55) suggested the presence of an information space in active interpretation of learning and knowledge, or I-space in his terminology, with three scale dimensions:

Codification—the scale and the process of codification creates perceptual categories that facilitate the classification of phenomena. The act of assigning phenomena to categories is known as coding. The scale ranges from 'uncodified' to 'codified'.

Abstraction—the scale and process of abstraction works by teasing out the underlying structure of phenomena. It requires the revelation of cause-and-effect relationships to

an extent that acts of codification does not. The scale ranges from 'concrete' to 'abstract'.

Diffusion—the scale and process of diffusion refers to the proportion of a given population of data-processing agents that can be reached with information operating at different degrees of codification and abstraction. The scale ranges from 'undiffused' to 'diffused'.

In Boisot's (1998) notion of the information space, this three-dimensional shape with all three dimensions are present. The dimensions of information transformation can then be mapped and moved on the three scales for different economic utilities of knowledge in the active interpretation of meaning, described by Boisot (1998) as 'personal knowledge', 'propriety knowledge', 'textbook knowledge' and 'common sense' (Boisot 1998, p. 59). In Boisot's (1998) notion, knowledge is at one end produced in ordered regimes with the characteristics of high codification, high abstraction and high diffusion, which often is the case in the university context utilising 'textbook knowledge', or 'Ivory tower' knowledge, in the terms of Etzkowitz (2014). At the other end, knowledge is produced in chaotic regimes that are uncodified, concrete and undiffused, which is the case in the daily operations within the offshore wind farm industry utilising 'personal knowledge'. In between, a complex regime of knowledge exists on the three scale dimensions utilising both 'proprietary knowledge' (high codification, high abstraction and undiffused) and 'common sense' (uncodified, concrete and diffused).

In Boisot's (1998, p. 69) perception: 'Firms will have to learn to be comfortable in all regions of the I-space …. This will call for a major shift in the way we think about organisations because it will modify every aspect of their operations. For one thing, it invites firms deliberately to allow for—indeed consciously to plan—the destruction of knowledge assets as well as their creation'.

Hereby, an interesting reciprocal organisational learning approach is provided for the triple helix participants on creating useful organisational knowledge and destroying not useful organisational knowledge through movements in the I-space.

A further extended angle on organisational learning is knowledge as interpreted by the receiver within business and industry as highlighted by Håkansson and Waluszewski (2007) in a practical business context. A key aspect is that businesses use knowledge in a very specific way, which can make the diffusion of 'knowledge from others' provided in coding and abstraction artificial, and possibly even useless or harmful, for the firm. Thus, even if the transformation of knowledge is successful, the reaction from the receiver 'on knowledge from others' in very specific business contexts, such as the offshore wind context, can cause problems and negative impacts. 'The knowledge from others' needs a focused, meaningful interpretation by the receiver to enhance innovation in a specific business context, as highlighted by Håkansson and Waluszewski (2007). The offshore wind farm industry has a very specific business context due to the newness of industry with many actors/firms coming from other industries. Moreover, the harsh weather, wind and shifting wave constellations challenge both personal and material operations employed at sea.

The notion of the specific impact of business contexts on knowledge provides the need for direct active interpretation of meaning and reciprocal organisational learning in a business application. The literature thus causes us to anticipate the following proposition in relation to the organisational learning literature:

P2: Reciprocal organisational learning on active interpretation of meaning can enable innovation.

Next, innovation theory and value creation will be elaborated according to our research question.

Innovation and business model theory

Innovation is a very broad concept, as highlighted in The Oxford Handbook of Innovation (Dodgson et al. 2014), which contains many different approaches. In our research, innovation is a core issue, and our understanding of the term has an organisational approach in accordance with the definition by Amabile et al. (1996) on innovation:

> Innovation is the successful implementation of creative ideas within an organisation. In this view, creativity by individuals and teams is a starting point for innovation; the first is a necessary but not sufficient condition for the second. (Amabile et al. (1996: 1154–1155)

Here, Amabile et al. (1996) highlight both the ideation of the new creative idea and the ability to implement it successfully. This means using both the new idea and an organisational learning approach to execute collective successful implementation. The approach requires a variety of knowledge resources, from the new idea to learning how to apply and control resources for economic benefit on the new idea in a BMI, as highlighted by Osterwalder and Pigneur (2010) and Zott et al. (2011).

The literature on business development is typically substantial and difficult to acquire and apply for SME managers (Eibe Sørensen 2012). A theoretical explanation for an easier understandable graphic approach on BMI is provided through the notion of Osterwalder and Pigneur (2010) on the 'Business model Canvas'. This illustration of BMI, with a focus on the central delivery of a value (gift package in the middle), shows key resources (person standing with equipment), activities (person digging) and partnerships (the rings) providing the cost base (the bill in the lower left corner), while relationships (the heart), distribution channels (the lorry) and customer segments (person standing in the right to watch the rest) provide the revenue base (cash register). The illustration is easy to understand intuitively through the graphical illustrations and is thereby suitable for SME participants with limited resources and time for reading several hundred pages of literature on BMI.

The central theme in the model in Fig. 2 is to reveal the value proposition (the package) and map the connections to the other areas to provide this value. The notion can hereby be utilised for communication and discussions on value creation in the business network and by SMEs.

The BMI notion is suitable for addressing the most important issues on innovation. Without an overview, the SMEs could become lost in unimportant details and miss implementing action towards opportunities that could reap value from the business context, network collaboration and reciprocal organisational learning. In particular, the need for communication of BMI is related to a more broad sense of innovation and value creation (Brink et al. 2015; Dodgson 2014). This is anticipated to be beneficial in a triple helix frame where participants, in principal, have different interests, according to the triple helix literature elaborated upon earlier.

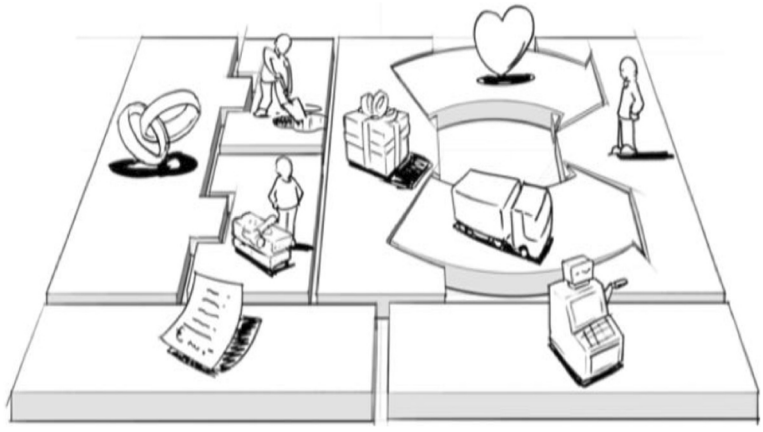

Fig. 2 Issues in business model innovation (BMI)

The BMI approach can be anticipated to be able to bridge the blurred and difficult context in a joint value creating aim with many different human agents and interests present. The literature thus causes us to anticipate the following proposition in relation to innovation and value creation:

P3: The SME's active interpretation of meaning on its business model can enable innovation.

Next, a summarisation will provide an overview on the propositions.

Overview on propositions

Our literature review has provided us with three propositions. An overview is shown in Fig. 3.

Figure 3 shows the connection between the propositions with P1 as an antecedent on the triple helix and reciprocal organisational learning for P2 on the active interpretation

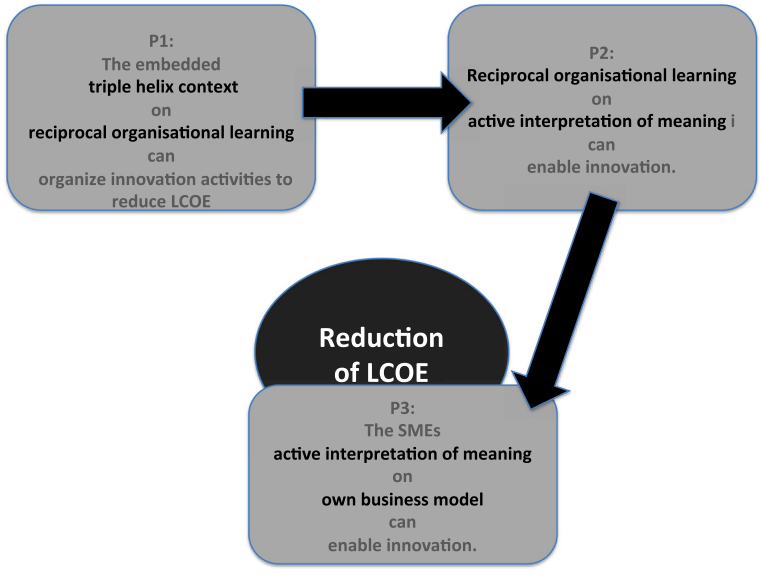

Fig. 3 Overview on propositions

of meaning, and it shows P1 and P2 for P3 on working with own business model innovation for SMEs to enable innovation. The integration between the three propositions means that the entire potential for SMEs to contribute to the reduction in LCOEs is not reaped unless the SMEs are situated in a triple helix context with inter- and intra-reciprocal organisational learning. Their own active interpretation of meaning within business model innovation both in society, governmental, university and industry contexts, as well as in its own SME context is essential. This sheds light on the important overall issues concerning the integration of SMEs to reduce LCOEs.

The methodology in our research is described in the following.

Methodology

The research method is based on a qualitative approach. We employ deductive analyses that are based on propositions derived from existing theory, which are either supported or not supported by our qualitative data (Eisenhardt 1989; Yin 2009; Charmaz 2006). We employ a longitudinal research period of approximately 2 years. We began with a project-based network and training course with 15 SME suppliers within the offshore wind farm industry, which lasted from September 2011 to March 2012. The study was finalised with follow-up interviews with 10 of the original participating SMEs, running from September 2013 to December 2013.

The network learning and training course aimed to create a platform for the SME suppliers to apply knowledge acquired by action learning (Leitch 2007; Moss et al. 2007). Diversified sources of knowledge were provided for research on innovation and value creation in the offshore wind farm industry. The network days were planned with a range of different knowledge sources, such as different university lecturers spanning disciplines of business development, value chain management, globalisation and project management according to specific projects selected by the SMEs. Different market and industry actors gave presentations on the network days. Here, the owners of offshore wind farms, such as DONG Energy and Vattenfall, producers from different areas of the value chain, such as Siemens and AVN, service enterprises, such as the lawyer Bo Sandroos at Sandroos Law firm, Grontmij and the Enterprise Europe Network, and industry organisations, such as the Danish Wind Association and Global Outsourcing, participated in the network days with presentations to the SME suppliers. During the network days, the SME suppliers had occasions where they could share knowledge with each other through team assignments. Additionally, the SME managers provided presentations. Dialogue among the participants was encouraged for reciprocal learning and the capture of knowledge.

The participating SME suppliers were significantly involved in the selection and discussion of relevant topics to create reciprocal organisational learning. The researchers addressed selected topics towards larger key actors within the offshore wind industry. Generally, the essential larger key actors within the offshore wind farm industry were entreated to give presentations to the SME suppliers about the needed contribution required from SME suppliers. The researchers used an entrepreneurial approach for reciprocal learning to enhance innovation opportunities by discussing the concrete meaning and activities needed with the SME managers.

The themes initially were established by a reference group associated with the research project, with three participants from the University of Southern Denmark and

industry actors from Vattenfall, Siemens, DONG Energy, A2Sea, Hytor and the Danish Wind Association. The content of the network days are outlined in Fig. 4.

Figure 4 shows the total content of the eight network meetings. Business development through BMI was the theme of the first two meetings. Next, a network meeting on value chain activities and the role of SMEs in the industry was held. The last network meeting in 2011 focused on globalisation and the role of SME suppliers here. Thus, SME suppliers created a shared understanding of their individual businesses and the demands from key actors in the offshore wind farm industry. The project-based network and learning course continued in 2012 with a concrete project on business development that each SME trained and shared during the last four network meetings.

Two managers from each of the 15 SMEs participated, which resulted in 30 participants during the network days from the beginning of September 2011. During the period, four SME suppliers decided to leave the research project for various reasons: the first SME supplier experienced severe financial problems, the second SME supplier was acquired by a large-scale industry player, the third SME supplier became seriously ill and the fourth SME could not continue in the research project due to a limitation of resources, as the SME both attempted to gain a foothold in China and Brazil during the period. After the finalisation of the network days in March 2012, an additional SME left the research project due to refocus on another business area. As a result, it was possible to conduct follow-up interviews with 10 SMEs from September 2013 to December 2013. It shows that the conditions for research on SME suppliers are characterised by volatile events.

Initially, the participating SMEs were participating according to their own self-selection based on a meeting about the research project on June 14, 2011. The self-selection was combined with a further selection conducted by the researchers on

2011	2012
1st meeting: Business Development *Concept, tools,* *External presentations*	5th meeting: Project Management own company *Concept, tools,* *External & internal presentations*
2nd meeting: Business Development, continued *Concept, tools* *External & internal presentations*	6th meeting: Project Management own company *Concept, tools,* *External & internal presentations*
3rd meeting: Valuechain *Concept, tools,* *External & internal presentations*	7th meeting: Project Management own company *Concept, tools,* *External & internal presentations*
4th meeting: Globalisation *Concept, tools,* *External & internal presentations*	8th meeting: Project Management own company *Concept, tools,* *External & internal presentations*

Fig. 4 Overview of the content of the network days

criteria, such as having different value chain activities, no direct competition with each other, both production and service activities and a geographical distribution within the Danish area. The selected SMEs all operate in project-based organisations. Data on the SME suppliers were supplemented from interviews conducted with each SME participant from start. The aim was to prepare a strategic profile based on the BMI illustration developed by Osterwalder and Pigneur (2010), shown in Fig. 2. All of the strategic profiles of the SMEs were created prior to the project-based network and training course in September 2011 and distributed to all participants as an opportunity to gain knowledge about the other SME participants. Thereby, a shared understanding of business models and opportunities was created for employment on the training days in the context of the offshore wind farm industry.

At the end of the network and training course in March 2012, a semi-structured evaluation was conducted using a 7-point Likert scale. The evaluation was discussed in a focus group meeting on the last network day. The following data are thus available for our research:

- Strategic profile of each SME supplier from 1–2 h interview—September 2011
- Network education and training material—from September 2011 to March 2012
- Evaluation of the project-based network and learning course from a survey and focus group interview—March 2012
- Follow-up interviews with 10 SME suppliers with duration of 1–2 h—from September to December 2013

In the following section, we examine the findings of our research in relation to our propositions and discuss them in a later section.

Findings and discussion

Overall, the evaluation of the network days was positive, and the highest contribution was provided from the flexible form with information on a wide range of issues within the offshore wind farm industry. In particular, market and industry knowledge was important for the selection of opportunities for business model innovation as perceived by the SME participants. They did not emphasise the two other selection mechanisms highlighted in the literature review on technological knowledge and on coordination mechanisms (Leydesdorff 2006; Leydesdorff and Meyer 2006) nearly as much as knowledge regarding market and industry. Many of the SME participants were technology-based and also operated in business areas other than the offshore wind farm industry, making them technologically capable in different business contexts. The SME participants had a strong drive for organising their activities and business model on information about the market and industry within the offshore wind farm sector. In relation to proposition 1, the triple helix platform provided reciprocal learning for market and industry knowledge, which otherwise would not have been accessible to the SMEs to enable innovation.

Time constraints of only 8 network meetings during approximately 6 months made it difficult to implement the knowledge obtained during the period due to feedback from the SME participants. The implementation level was relatively high – over one half of the knowledge was implemented; however, there is room left for enhanced

implementation aiming for the remaining half of the knowledge obtained. In relation to proposition 1, it means that reciprocal organisational learning did occur for innovation and reduction in LCOEs. However, most of the impact was on cooperation and short-run implications, such as cross sales to customers and mutual cooperation among two to three SMEs on specific tasks. Collaboration on long-term implications were started up and also elaborated upon in discussions during the network meetings, but the time horizon of the training was not long enough to reveal the actual potential. Extracts of quotes are provided below on the dialogue regarding the triple helix context provided for the SMEs where they had access to industry, universities and governmental bodies:

> It is fantastic to meet essential larger actors in the offshore wind farm industry and to talk and connect with them during conferences and events in an informal way – it provides creditability.

> About communication - the senders and receivers of information do not have the same brain convolutions.

> We run customer-specific courses in a selection of the customers' own applications, which the customer can utilise in a beneficial way.

The quotes highlight the eagerness of SME suppliers to support the larger essential players in the offshore wind farm industry in different ways. It also shows the difficulties in 'talking the same language'. Dialogue on essential specific issues is required to support a common understanding.

Proposition 1 is thus supported through the empirical research; however, it is supported mostly in the short run and on actions in one's own SME organisation. The triple helix platform does provide an enhanced innovation opportunity for SMEs. Thereby, a spillover is present in the industry through SME suppliers contributing to

- The offshore wind industry aim to reduce LCOEs.
- The university knowledge creation regarding SMEs and regarding innovation on huge challenges in society as reduction in LCOEs.
- The governmental bodies through support of the 'triple bottom line' and the aim to reduce LCOEs to make wind energy sustainable.

Further research needs to be conducted to reveal the long-term potential of the triple helix context.

The knowledge was, during the network days, applied in all areas of the information space noted by Boisot (1998). Concrete and undiffused knowledge was provided by the SME suppliers and by major stakeholders talking about their specific needs according to the market. Larger actors interpreted their needs for the development of SME suppliers. Codified research-based knowledge was provided on key definitions by the university researchers for SMEs on BMI. Furthermore, research-based abstract models derived partly from other industries were also made available by university researchers. Diffusion of knowledge occurred at the network meetings between SME suppliers, major stakeholders within the wind farm industry and

university researchers. The information space provided by the governmental bodies to finance the network meetings opened different knowledge spheres for participants to connect on BMI. In summary, the information space provided knowledge in the following way in our research:

- Concrete and undiffused knowledge as highlighted through the citations—partly tacit employed and owned in the windmill industry by
  - SME suppliers.
  - Larger essential stakeholders in the wind turbine industry.
- Abstract and codified research-based knowledge also from other industries—provided explicit by university researchers.
- Space provided for the combination of knowledge between participants.
- Diffusion and employment of knowledge is in the hands of SMEs and larger essential stakeholders in the wind turbine industry.
- Regional bodies finance the loose-coupled network for elaboration of content by participants on the aim of sustainable innovation.

The summarisation highlights the knowledge regimes employed in conceptual form and supports proposition 2 on SMEs engaging in reciprocal learning through both creation and destruction of the meaning of knowledge by codification, abstraction, and diffusion that are obtained in the direct interpretation of the concrete offshore wind context. In the SME supplier context, there is a need for access to market and industry knowledge and a need for reflection and interpretation of the knowledge in one's own SME context. Several comments from the SME participants emphasised the benefit of the joint interpretation of business challenges supporting implementation of business opportunities in one's own enterprise. Extract of quotes are provided below on this reciprocal organisational learning approach creating knowledge spaces:

> We are now aware of how important it is to plan the necessary resources for the implementation of our projects. Our own understanding of the necessity of sufficient resources has really made a huge improvement to the success of our projects.

> It is important for us to work with knowledge creation in the organisation. We have a few employees with essential knowledge for our business model. We have now found a way to diffuse the knowledge – it takes time, but is extremely important.

> We have implemented a matrix organisation with the aim of more focus and adaption to specific customers.

> We have implemented a management backup system so that all central management areas can be operated by at least two managers. The aim is always to be able to serve the customers well.

> We have developed and implemented project findings in databases so that these findings are a part of the results from the projects. They can be used in new projects.

The quotes highlight the understanding of the SMEs to support their own learning and capture of knowledge in the system for new application. Proposition 2 is hereby supported through the empirical research. Further research needs to be conducted to reveal the limitation of the access to continuous creation and destruction of meaning; a counterbalance can be anticipated to occur when first hand opportunities are exhausted. Again, the impact of these SME knowledge spaces is anticipated to have a spillover effect on the triple helix parties of industry, universities and governmental bodies, as already noted in relation to proposition 1.

The importance of knowledge implementation to enable innovation in the offshore wind farm industry was acknowledged by the SME participants. It meant that the SMEs in the focus group interview at the end of the course wanted to continue the work on the following:

- More formal cooperation and collaboration based on business needs
- Obtaining business development through, e.g.
  - One's own business performance improved by use of the tools provided
  - More holistic business information, which provides further opportunities and better selection of business opportunities
  - Connection to important stakeholders in the wind farm industry for further elaboration of innovation and business development

In summation, the close interaction of knowledge flow between participants and the variety of contributions in the triple helix context are found to support BMI. It means that propositions 1 and 2 have a close recursive interaction for supporting each other to enable innovation. Both the triple helix frame and the participation of governmental bodies, university and larger enterprises in the industry and the process of reciprocal organisational learning are important to enable innovation.

The value proposition of the SMEs in relation to the wind farm industry highlighted the reduction in LCOEs as extremely important; however, richer requirements of increased quality in the harsh environment and easy, robust and safe maintenance also turned out to be key issues within offshore wind projects. An overlap exists among the increase of quality and the easier and more robust maintenance, which can reduce LCOEs on a levered long-term basis. It is thus a major challenge to reduce LCOEs, but other issues are complementary and open for reaping according to business opportunities of SME suppliers. Ideas for improvements and new actions/collaborations were born during the meetings through the access to information on opportunities for BMI, e.g. an interesting solution on providing a plug and play cabin for the painting of wind turbine parts was presented by one of the participating SMEs (Air Tech link: http://www.airtech.dk). This fuelled innovative discussions.

The SME suppliers' approach to their own business model and active interpretation of meaning in their own firms are important ingredients to enable innovation, e.g. discussions among participants on the requirements within the PPAP ('Production part approval process', which is a standard process developed within the automotive industry on the 'automotive supply chain' for creating the ability of component suppliers to meet the required quality standards) quality

system challenged organisational learning on BMI. The PPAP system is increasingly applied in the offshore wind farm industry because of the harsh weather conditions at sea and the requirements of the robustness of components and solutions under these circumstances. It means for SMEs that standard processes need to be established and operated in the same detailed way every time. This is not a typical approach to the operation processes in SMEs, which often have a more explorative approach (Brink and Madsen 2015). This is an example of hitherto behaviour and knowledge in SME context, which needs to be destroyed to create new learning to operate 'robustness' in the SME organisation. Extracts of quotes are provided on BMI in the following:

> We have participated in proactive specific development of certain intermediate products and processes (said by 6 of the 10 SME suppliers participating).

> We realised during the network and training days that our planned business model was wrong in an offshore wind context – now we have created a new business model.

> We have not gotten anywhere in our business challenges – no time to work on it.

> It is cool to be able to obtain access to a new model Osterwalder and Pigneur (2010) that can impress customers and partners.

The quotes show the span of results on BMI; some have employed the models proactively both in their own context and in relation to customers. However, others have not been able to benefit from BMI, primarily because of time constraints. Proposition 3 is hereby supported partly in the short run and cannot be verified in the long run in our empirical research.

The three propositions are closely connected and primarily supported in the short term by our findings. However, challenges arise in the long term on collaborative BMI. In the university context, the networking days were interpreted as demanding through the flexible entrepreneurial approach and the high emphasis on the interests of participants. The flexible entrepreneurial approach to learning was positively evaluated by the participants. However, the likelihood of some 'Hawthorne Impact' is present. The fact that the participants were focused in a research context during the research period probably motivated them to employ more knowledge than if no research attention had been present. Here, only repeated research 'normalising' the research impact can reveal the bias from 'SME participation in research'.

It is interesting that the triple helix context can provide coordinated knowledge and joint efforts on opportunities. The SMEs have continued on more intensified bilateral activities on cross sales and cross-assistance on making resources available. As of December 2013, no significant efforts were being made by the participants to pursue coordination and joint development of further BMI. No longer having an available knowledge space probably makes coordinated innovation too difficult to pursue for the SMEs. Additionally, the cost of investing time on collaboration, which has a longer time horizon before the benefits can be harvested, naturally plays a role for SMEs with limited resources.

The three propositions were all in the short term supported on the following:

1. A beneficial impact from a triple helix platform for reciprocal learning
2. A beneficial impact from reciprocal learning through knowledge assets, flexible transformation between knowledge spaces and the direct approach of SME interpretation in the learning situation to enable innovation
3. A beneficial impact from an overview of their own business model and active interpretation of meaning done by SMEs themselves in their own organisation

This provides an important insight and understanding of the integration of SME suppliers in a triple helix context, as shown in Fig. 5.

Figure 5 reveals the consequences of governmental bodies to provide funds for SME suppliers with the aim of fostering cooperation and collaboration for dialogue in the industry. Thereby, a bridge is provided between the pure self-interest of 'market driven competition among profit-driven firms' and the concern for wellbeing in society and the triple bottom line. Moreover, universities need to provide more flexible entrepreneurial research, education and learning contexts for SMEs. The research has to consider the point of origin in the interests of the SMEs and the requirements for BMI. Organisational learning in the required fields provides important new knowledge for SMEs ready for application by the SME suppliers when needed. Thereby, learning creates value and provides opportunities for more widespread applicability and communication. The SMEs need to provide themselves time for participation in such network activities, which can give them value both on the short- and long-term horizon. SME participants must create space for both network activities, as well as reflection on information and learning and for concrete BMI in their own organisation and with

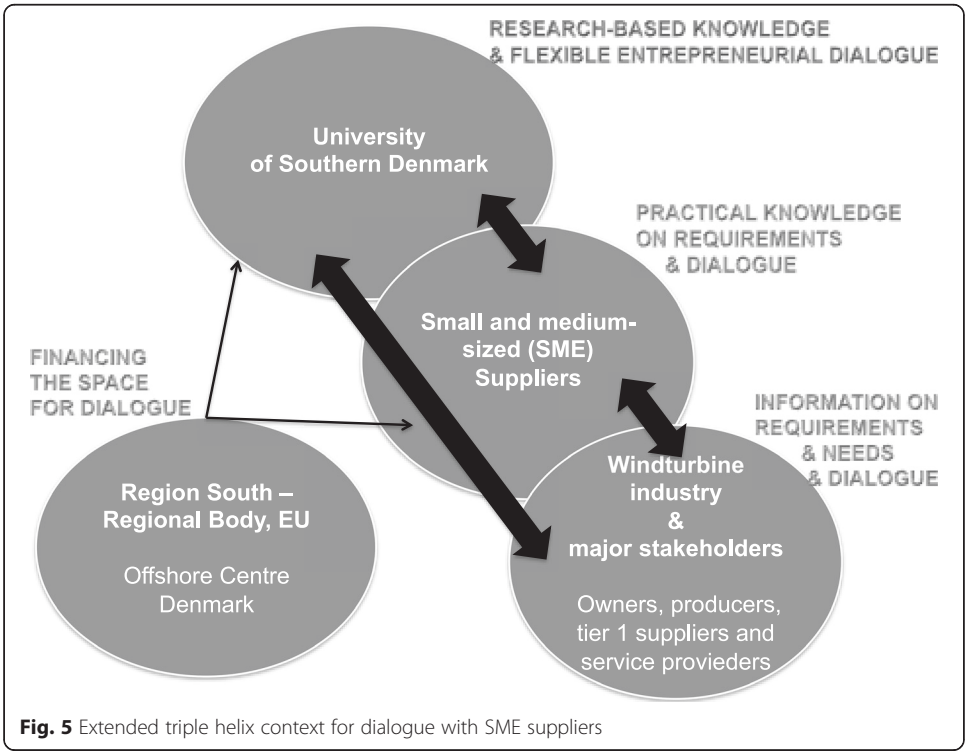

Fig. 5 Extended triple helix context for dialogue with SME suppliers

collaborative partners. Furthermore, the larger essential actors within the offshore wind farm industry must provide time for discussion with networking SMEs to share both specific and strategic knowledge on applications. This activity will probably not have an immediate impact on their own business. However, in the long term, BMI and qualification of suppliers can help considerably regarding the challenges for innovation and a reduction in LCOEs. In general, an agenda has been set for bridging the different interests of enterprises, governmental bodies and universities to enable sustainable innovation.

Policy implications

The findings in this study have important policy implications on providing guidance for utilising the innovation forces present within SMEs, which can be difficult to access due to a lack of resources in these enterprises. The triple helix concept provides an interesting frame, which actually has an opportunity to support the access and utilisation of SMEs' innovation capabilities. It does not only benefit the SMEs but it also benefits the entire offshore wind industry, the political aim for renewable energy and sustainability and the knowledge creation and dissemination in society.

The implication for the university is to create both more researched-based learning for abstraction in new models applicable in the offshore wind farm industry and to achieve a thorough understanding and communication of important business details specific to the SME suppliers and the wind farm industry. For the governmental bodies/EU, the implication is to provide more strategic long-term financing for the creation of knowledge spaces, which will have some immediate impact but will probably need a long-term view for utilising the full potential. Moreover, the governmental bodies have a direct impact on the cost of capital within offshore wind parks and the regulation of competition, cooperation and collaboration. For the SME suppliers in the wind farm industry, the implication is to become aware of the importance of knowledge spaces and the need to prioritise time for reflection on information and knowledge. For essential larger stakeholders in the wind farm industry, the implication is to prioritise time for providing knowledge to various SME suppliers to give them a chance to work on innovation and reduction in LCOEs in collaboration.

The contribution of our research paper is to make the triple helix participating stakeholders understand the extended impact of SMEs participating in the triple helix context in the offshore wind farm industry. It means a better promotion and exploitation through more effective actions of the public bodies and the universities to support the offshore wind industry and, in particular, SME suppliers.

Conclusions

Our research reveals how SMEs can enable innovation and contribute to a reduction in LCOEs in offshore wind farms. Empirical verification is provided in this paper from a longitudinal study of 10 SMEs for the enhanced understanding of the impact of integrating SMEs in a triple helix context.

The findings show a positive impact of an enhanced and flexible triple helix approach, in which major market and industry stakeholders participate. This provides valuable information for SME organisations to understand, learn and select from among

various BMI opportunities. Our empirical evidence on the propositions employed reveals a positive impact of the triple helix frame for organisational reciprocal learning to create business model innovation to enable innovation and reduce the LCOEs in the wind farm industry. This study also provides valuable knowledge to governmental bodies for political strategies contributing to growth and sustainability and to universities for knowledge creation and dissemination.

The findings show the importance of providing a knowledge space, where different forms of knowledge transformation among participants can meet for reflection and implementation. Our findings reveal the need for different knowledge regimes to be applied in an easy way for continuous reciprocal interaction and organisational learning. This requires more effective action of the triple helix partners.

Further research must be conducted in different contexts to verify the role of SMEs. It is anticipated that industries with innovation challenges can have a positive impact of integrating SMEs in the triple helix context. Further light needs to be shed on the necessary antecedents and how these processes evolve in offshore wind and in other industries.

Additional file

Additional file 1: Translation of the abstract into Arabic. (PDF 250 kb)

Competing interests
The authors declare that they have no competing interests.

Authors' contributions
All authors read and approved the final manuscript.

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