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Established sectors expediting clean technology industries? The Norwegian oil and gas sector's influence on offshore wind power

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Abstract:
The development and deployment of clean energy technologies must be accelerated to avoid a more than 2-degree warmer world, which poses a major policy challenge. Utilization of the vast resources concentrated in established sectors is one possible way to advance clean technology industries. However, prior research on energy transitions tends to emphasize competition and conflict between established sectors and clean-tech industries. There is thus a need for studying how established sectors may positively contribute to clean-tech industries. We propose an extended analytical framework of the technological innovation systems (TIS) approach to study how established sectors influence clean-tech industries, and present new definitions and indicators. We present a case study of oil and gas sector and offshore wind power industry development in Norway. Our results show that while the oil and gas sector has several positive implications for offshore wind power, wavering priorities and commitment of diversified oil and gas firms to the new industry have negative implications. We conclude by discussing the relevance of our findings for policy and research targeting the development of clean-tech industries.

Highlights:

- We explore how resources from established sectors may be mobilized as part of the transition towards cleaner energy technologies.
- We present an extended technological innovation systems framework to study structural overlaps between sectors and a technological innovation system in formation.
- The framework is applicable to analyze how emerging clean-tech industries draw on resources from established sectors.
- Sector influence on offshore wind power in Norway is based on technology overlap (relatedness) which drives diversification of firms from oil and gas industry to wind power.
- Misalignment of institutions hinders the commitment of diversifiers to the offshore wind power industry, and, in turn, the overall wider industry development.

Keywords:
Technological innovation system; inter-industry relationships; Established sectors; Offshore wind power; Oil and gas industry.

1 Introduction

The world's endeavour to mitigate climate change and staying within a less than 2-degree warmer world is challenged by an enormous gap between what financial and technological resources are needed and what have thus far been committed to this task. In other words, a major acceleration of the development and deployment of clean energy technologies currently constitutes a major policy challenge (EC, 2016; IEA, 2016). Mobilizing the vast resources of established industrial sectors to support clean-technology industries is one possible way of meeting the challenge. The purpose of this paper is to discuss opportunities and barriers for creation of complementary linkages between established sectors and emerging clean-tech industries.

Within studies on sustainability transitions in socio-technical systems (Markard et al., 2012), the relationships between established sectors and emerging clean-tech industries have been studied in situations where established sectors react antagonistically to potentially disruptive innovations (Hess, 2013; Smink et al., 2015; Wesseling & Van der Vooren, In Press). Recent contributions have, however, moved the research agenda beyond the dimension of conflict and competition, and now also focus on how established sectors could contribute to development and diffusion of clean technologies (Berggren et al., 2015; Dewald & Achternbosch, 2016; Hockerts & Wüstenhagen, 2010), but more knowledge about these processes is still needed.

We approach this issue by developing and applying an extended version of the technological innovation system (TIS) framework. The TIS framework is a proven framework for analyzing emergence of clean-tech industries by use of a functions approach (see description of functions in Table 1) (Jacobsson & Bergek, 2011; Markard et al., 2012). Nevertheless, the approach has received criticisms for under-conceptualizing the context in which new industries form (Coenen & Díaz López, 2010; Smith & Raven, 2012). In response, TIS scholars have recently called for further attention to how TISs interact with different types of context, including other TISs, established sectors, geographical context, and politics (Bergek et al., 2015). Here we draw on these tentative observations to propose a framework for analysing how established sectors influence TIS formation. Our framework is based on the notion of structural overlaps between the TIS and the established sector in the form of actors, institutions, networks and technology.

We apply this framework to address a case study of oil and gas industry and offshore wind power in Norway. Our research question is: How do overlaps between the established Norwegian oil & gas sector and offshore wind TIS influence the latter? Accentuating structural overlaps in TIS analysis can, we argue, help us to systematically nuance the ways in which context elements (here an established sector) influence a TIS in its formative stage. This helps us understand parts of TIS formation that have not been fully appreciated. Our analysis thus contributes, firstly, to our understanding of formation of new clean technology industries in relation to established sectors, and, secondly, to conceptual and methodological advancement in TIS studies.

The structure of the paper is as follows. Chapter 2 reviews TIS literature with a particular focus on relationships between TIS and sectors. Chapter 3 introduces our case and outlines methods and data. In chapter 4 we identify and describe structural overlaps, and in chapter 5 we analyze the impacts of these overlaps on the emerging OWP industry. Chapter 6 discusses main findings and concludes the paper.

2 TIS formation and established sectors

We distinguish between two basic types of relationships between established sectors and emerging clean technology industries: competitive and complementary. When competition prevails, sector firms can attempt to block the growth of emerging industries through various channels and/or attempt to enter the emerging industry while keeping activities in established sector to learn about the novel technologies (cf. Introduction chapter). Complementary relationships may take two main forms. First, emerging industries can feed on the demand for productivity-enhancing technologies from established sectors (Hirsch-Kreinsen et al., 2005). In this case actor overlaps would consist of newcomers entering the sector as technology suppliers. Second, actors from the established sector can see the emerging industry as a new promising business opportunity, and on entry, they bring various resources to fuel further progress. Complementary relationships—particularly the latter—are often enacted by technological overlap (relatedness) between sector and emerging industry (Erlinghagen & Markard, 2012). Hence, if technological relatedness is strong, resourceful firms from an established sector are likely to dominate the emerging industry. In this paper we explore the latter type of complementary relationships.

In this line of research, previous studies have shown that established sectors can indeed exercise significant influence on an emerging TIS. Wirth and Markard (2011) show how the formation of a biogas TIS in Switzerland benefitted from established sectors such as agriculture and forestry but also that prior industry routines and values (informal institutions) led to different types of tensions in the TIS. Also, Haley (2015) reports how structural overlaps between the established hydropower regime and electric vehicle TIS in Quebec have supported the growth of the latter through e.g. legitimacy benefits and knowledge development.

We build on and add to these recent studies by constructing an analytical framework comprised of the following conceptual building blocks. First, the TIS framework focuses on emergence of new industries and/or knowledge fields (Carlsson & Stankiewicz, 1991). A TIS is defined as a set of the actors, networks and, institutions and technology engaged involved in developing, diffusing and utilizing new products (goods and services) and processes related to a certain technological field or industry (Jacobsson & Bergek, 2011). Second, our object of analysis is a focal TIS as defined above. We explore how overlaps with an established sector impact the functions of this focal TIS. Structural overlaps are defined as components shared by the sector and the TIS. Third, we use the term established sector (or sector) to refer to an established, technologically mature industry including stable supporting institutions, and supply chains such as agriculture, steel, cement, automobiles, coal, or oil and gas. An emerging TIS can have structural overlaps with one or more sectors. Fourth, sectors and TIS fundamentally have the same "texture" i.e. they can be conceptualized by the same structural components: actors, networks, institutions, and technology (Markard & Truffer, 2008). This is the foundation for discussing structural overlaps between sectors and TIS. Fifth, we follow Bergek et. al. (2015) in distinguishing between two types of linkages. First, structural overlaps (or couplings) that refer to a situation with shared components between a TIS and a sector, possibly resulting in a 2-way interaction between systems. Second, external links refer to 1-way influence from context on a TIS such as sudden price shift in a relevant market, national institutions, or politics. Sixth, in early stages of its development, a TIS is likely to be heavily influenced by its context e.g. in terms resources and new entrants, but not have significant impact on the established sector. However, in later stages such feedback loops may appear as the TIS develops and becomes self-sustained (Markard, 2016).

Having outlined our conceptual starting point, we next discuss how we approach overlaps with regards to the specific TIS components.

2.1 Structural overlaps

"Overlap actors", which could be e.g. firms, research institutes and public organizations, are per definition active in several industries. This is contrast to specialized actors which operate only in one industry. We focus on diversified firms from established sectors venturing into emerging TIS. We expect these diversifiers to play a dual role. On the one hand, they may contribute positively to the TIS for instance by bringing with them various resources as new technologically related industries offer growth opportunities by use of e.g. existing knowledge (Montgomery & Hariharan, 1991; Penrose, 1959). On the other hand, diversifiers are likely to continue pursuing activities also in their primary market. Diversifiers thus may abstain from full commitment to novel areas due to fear of cannibalizing existing activities or uncertainty (Geels et al., 2008). Thus, multiple overlaps with sectors might also constrain the TIS, e.g. through conflicting interests for firms present in two competing systems (Bergek et al., 2015).

We define "institutional overlap" as institutions shared by the sector and focal TIS. We distinguish between formal and informal institutions, the former referring to typically visible and codified entities such as regulations, standards and policies, and the latter to non-explicit practices of organizations and industries, such as routines, norms and visions. In general, we expect that a TIS in a formative phase enjoys few, if any, support from formal institutions, thus making informal institutions of prime interest. Formal and informal institutions within a TIS interact and can be more or less (mis)aligned. The formation of a novel TIS requires the creation of new supporting institutions in a process where the wider institutional setup becomes aligned with its needs (Jacobsson & Bergek, 2004). Success in such alignment is more likely if informal and formal institutions are also aligned within the TIS (Wirth et al., 2013). Firms need to engage in collective efforts to achieve this alignment—to "run in packs" (Musiolik et al., 2012; Van De Ven, 1993). However, institutional alignment and collaboration can be compromised if actors hold diverse visions and expectations about the future—factors that define perceived problems and goals for the TIS (Smith et al., 2005). For instance, the informal institutions held by diversified firms have been shaped by prior industry experience, but influence the decision-making also in the new market (Benner & Tripsas, 2012).

We see “network overlaps” as networks that connect actors between the focal TIS and the established sector. Participation in such networks can provide access to novel information, knowledge, and other resources (Nahapiet & Ghoshal, 1998), and may create opportunities for collaboration and institutional alignment.

We define “technology overlaps” as knowledge and artefacts which are used in both sector and TIS. Technology is here understood as relevant knowledge bases underpinning the TIS and sector. Technology overlaps (or relatedness) enable the transfer of competences from one system to another by outlining the possibility to use existing resources (Teece, 1982). Indeed, having technology overlaps with established sectors strongly contributes to the development prospects of new industries (Boschma & Frenken, 2011). Hence, established sectors often shape the direction of future industries through technology overlaps (Hidalgo et al., 2007).

2.2 Analytical framework

Against the backdrop outlined above, we illustrate our analytical framework in Figure 1. We assess how different structural overlaps influence our focal TIS by considering whether overlaps result in positive and negative implications on focal TIS functions. As we focus on a TIS in its formative phase we do not consider how the focal TIS influences the established sector (indicated by the arrows, we focus entirely on time period 1).

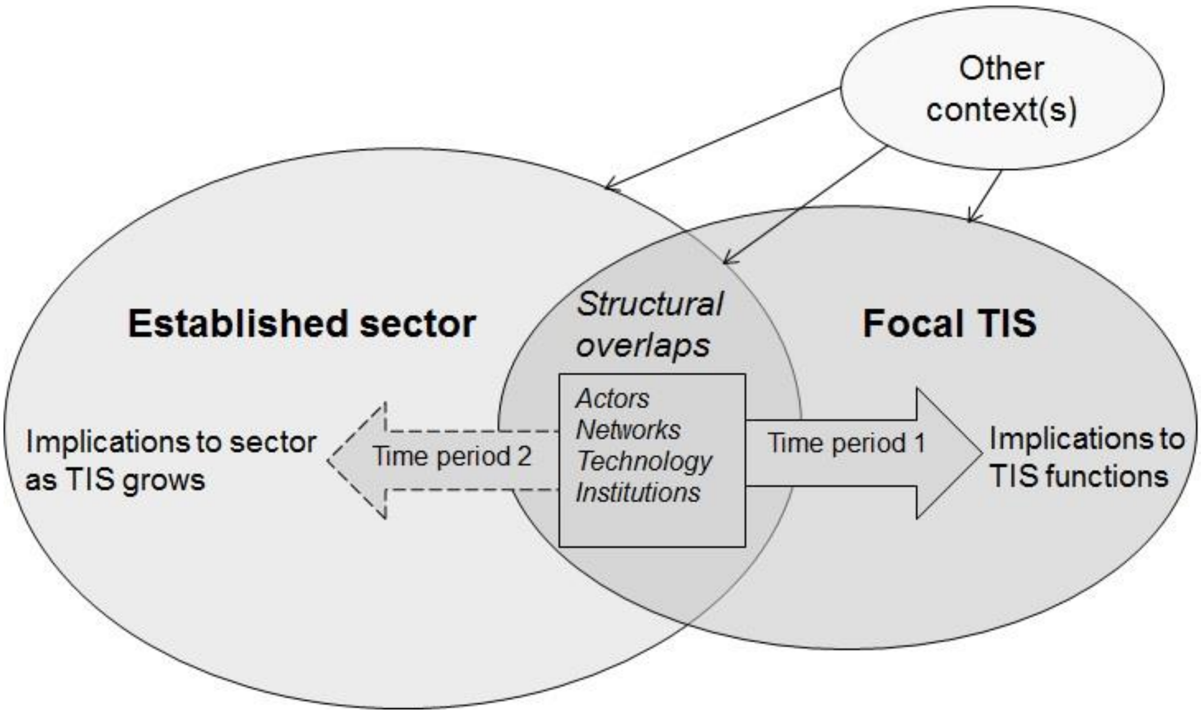

Figure 1 Analytical framework.

3 Case, methods and data

3.1 Case description

3.1.1 The Norwegian Oil and Gas sector

The Norwegian oil and gas (O&G) sector was established in the late 1960s and has since evolved through an interplay of international oil firms, Norwegian suppliers, large R&D institutes (e.g. SINTEF) and universities, and supportive policies (e.g. local content requirements and R&D tax exemptions) orchestrated by, amongst others, the Norwegian Petroleum Directorate, Ministry of Oil and Energy, and Statoil (national oil company) (Engen, 2009; Saether et al., 2011). Known for its capability to develop technologies for oil extraction adapted to the difficult weather conditions in the North Sea, the sector now dominates Norwegian economy by accounting for about 25-30% of GDP and 67% of export (anno 2013). Most segments of the supply chain are technologically mature with established practices, standards, and dominant designs. The O&G sector is inherently volatile and goes through boom and bust periods. While rising oil prices since the early 2000s have resulted in high profits and cost levels in the sector, the most recent downturn in prices (since late 2014) is currently pressing firms to cut cost (Jacobsen & Fouche, 2015).

3.1.2 The Norwegian offshore wind TIS

Offshore wind power (OWP) is an emerging industry with promising prospects for growth; especially in the North Sea (EWEA, 2015). Despite having some of the best offshore wind resources in Europe, Norway has limited installed capacity. As current electricity supply is 98% renewable, there are few possibilities for decarbonizing via deployment of more renewables without increasing demand (e.g. via electrifying transport and/or trading more with continental Europe) (Gullberg, 2013; Hanson et al., 2011).

The first plans for large-scale (bottom fixed) OWP in Norway came with the Havsul project in 2005. Shortly after, Statoil developed the floating OWP project Hywind Demo (a single full-scale turbine) to experiment with electrification of offshore O&G activities, but regulatory issues hindered it and the turbine was eventually connected to the mainland electricity grid in 2009 (Normann, 2015). It is by 2016 the only OWP project realized in Norway. Despite meager deployment, about 150-200 Norwegian firms are involved in OWP (Steen & Hansen, 2014). They focus on e.g. subsea foundations, engineering and installation services as well as design and varied offshore related consultancy. These firms are mainly export-oriented and focused on the North Sea region (Normann & Hanson, 2015). While political support for demo projects and a domestic market has been weak, R&D activities have received more support via state actors such as Norwegian Research Council, Innovation Norway and Enova.

3.2 Methods

We perform an industry-level and a single-country case study. A case study approach is suitable for such analysis as it allows an analysis of context specific processes (Yin, 2009). As is apparent above the Norwegian O&G sector and the OWP industry corresponds to our conceptualization of an established sector and a TIS under formation. Moreover, previous research has indicated complementary overlaps between them (Steen & Hansen, 2014). Hence, our case represents an opportunity for exploring complementary sector-TIS relationships.

Our analysis takes a snapshot of sector-TIS interaction in a formative phase of TIS during the period 2005-2015. Geographically we limit our analysis to Norway although both O&G and OWP have internationalized supply chains. In fact, several diversifiers from O&G are more active in international OWP markets than in the Norwegian market (Normann & Hanson, 2016). Instead of discussing the weak performance of the domestic OWP TIS, we use the case to examine sector-TIS relationships in more depth and detail. We can do this without considering international linkages extensively. Analytically we limit ourselves to a partial study of the OWP TIS as we only consider how overlaps influence TIS rather than all relevant factors.

3.2.1 Analysis and data

We approach our analysis in two overall steps. In a first step we identify the structural overlaps between the industries and collected information about their characteristics. Diverse firm level data (e.g. financial and ownership data) is publicly available in Norway (Brønnøysundregistrene), which offers good possibilities to investigate structural overlaps. We compiled a database of Norwegian firms active in OWP by gathering data from industry reports, industry organization membership, 4C database and desk research. We found 161 OWP firms (firm sub-units excluded) out of which 22 firms were specialized in OWP. We collected employee and ownership[1] data.[2] Additionally, we conducted a survey of OWP firms (response rate 109/183: 60%, for details see Normann & Hanson 2015) which collected information e.g. about the engagement with and expectations to OWP, and technology overlap with O&G. Regarding O&G, we compiled a database of 621 O&G firms in Norway by using reports from industry associations and clusters. By comparing our data material and performing desk research, we concluded with 107 overlap/diversified firms.

We also investigated board interlocks between the two industries. By using Brønnøysundregistrene, we analyzed if the board directors of the 54 (161 minus 107) remaining OWP firms held a director position in an O&G firm. Additionally, we analyzed the membership lists of five Norwegian OWP networks and investigated how many of the member firms are active in O&G sector. In terms of institutional and technology overlaps, we analyzed survey results, OWP technology standards as well as secondary literature.

1 We included owner firms and public organizations until second degree (owners and owners of owners) which held at least 10% share of an OWP firm, and excluded private individuals.

2 We used proff.no website.

Additionally, we searched and analyzed all OWP related patents from Global Patent Index and determined the share of Norwegian O&G firms as applicants[3].

In the second step, we assessed and analyzed the implications of overlaps for TIS functions. This step called for methodological advancement. Prior TIS literature has identified indicators to assess the performance of functions (e.g. Bento & Wilson, in press; Vasseur et al., 2013) but has not adjusted these indicators for analyzing structural overlaps. Therefore we developed a set of indicators to evaluate such implications from structural overlaps at the function level (see Table 1). Effects of overlaps are generalized to each of the TIS functions to compile an overall assessment of the sector-TIS relationship. However, due to lack of benchmarking, these evaluations are done at a rudimentary level, i.e. positive and negative implications without assessing the relative strength of the effects.

Table 1 Description of TIS functions and indicators. Structural overlap of indicators: A=actors, I=institutions, N=networks, T=technology.

Function	Definition	Indicators (implications for TIS from structural overlap)
Knowledge development and diffusion	Development and diffusion of knowledge. Includes depth and breadth of different types of knowledge (e.g technological, scientific) and their evolution.	Diffused knowledge from sector to TIS (T) Patents developed by diversified firms (A) Interlocking directorates and other networks between sector and TIS (N) References in TIS standards to context sector standards (I)
Influence on the direction of search	Strength of incentives/pressures to join the TIS, as well as mechanisms directing the TIS through competing technologies, applications and markets.	Diversification of firms from sector (A) The ease of transferability of diversfiers' experiences from sector to TIS (T)
Entrepreneurial experimentation	Uncertainty reduction through experimentation by trying out different technological concepts and applications where many technologies fail and few emerge as winners.	Entrance of diversified firms (A) TIS utilizing technological concepts from sector (T)
Market formation	Activities which drive market formation through different phases, starting from nursing markets and ending in mass markets.	Sector as a niche market for TIS (I) Coordinated advocation for demonstration projects (A)
Legitimation	Social acceptance of technology and compliance with relevant institutions. Processes of institutional alignment, conformance and creation.	Media attention on diversifiers' TIS activities (A) Alignment of TIS institutions with sector institutions (I)
Resource mobilization	Ability to mobilize human and financial capital e.g. to learning processes and investments.	Sector investments in novel technology and start-up firms in TIS (A) Access to human capital of sector (A)
Development of positive externalities	Positive internal dynamics of TIS functions as well as other positive externalities, e.g. pooled labor markets, emergence of specialized goods and services etc.	Diversifiers' level of engagement(A) Influence from market developments of sector on TIS (A)

3 We searched Norwegian applicants under CPC category Y02E10/70 (Wind energy) and its subcategories with offshore related key words (offshore, floating, buoyant, water, marine, sea and/or vessel).

4 Identifying structural overlaps between the oil and gas sector and the offshore wind TIS

4.1 Actor overlaps

TIS actors consist of firms, educational organizations, public bodies and varied interest organizations (Bergek et al., 2008). However, in a small economy as Norway, the rather few research organizations and universities tend to be involved in everything which complicates the analysis of actor overlaps. For this reason, we focus our actor analysis primarily on firms.

The majority of the firms in Norwegian OWP industry (~66% or 107 firms) are diversified O&G firms. In terms of the OWP supply chain, logistics, installation and vessels formed the largest group of diversifiers (32 firms), followed by consultancy, IT and R&D operations in engineering, as well as activities related to sub-sea OWP foundations and surveying operations. In contrast, only three diversified firms were related to top-side technologies, i.e. generators, blades etc., thus representing activities where little technological relatedness exists between OWP and O&G. Diversified firms were, on average, larger and older than other O&G firms. 28% of diversified firms were large enterprises with more than 500 Million NOK annual turnover and had 1997 as median founding year, while same figures for O&G firms in general were 19% and 2000, respectively. This suggests that principally large and established corporations have diversified into OWP. In contrast, specialized OWP firms were all micro-sized start-up firms with less than 20M NOK annual revenue in 2013.

The share of fulltime employees dedicated to OWP in diversified O&G firms was generally low. 60% of diversified firms had less than 10% of their employees working specifically in OWP. However, in large firms even a small share of employees might amount to large numbers, and a handful of firms were heavily engaged in OWP with more than 100 employees.

4.2 Network overlaps

We found out that 41% of specialized firms had ownership ties to O&G sector. The O&G sector has thus channeled financial and other resources into several specialized OWP firms, most of them being small start-up firms. 64% of specialized OWP firms had board interlocks with O&G, which constitute a network spanning connection between industries. These shared board members thus act as knowledge brokers between O&G and OWP. Board interlocks are often linked to ownership, as shareholder firms often have their representative in the board of their owned OWP firms. However, the amount of board interlocks exceeds the level of ownership ties, showing the robustness of social network overlaps between OWP and O&G in Norway.

Diversified firms were—despite forming the majority of OWP firms—the minority in all of the five identified OWP networks (see Table 2). This indicates that, despite their dominant presence in OWP and superior resources, these firms were less active in knowledge networks than specialized firms.

Table 2 Share of diversified firms in five OWP networks in Norway (in November 2015).

	NORCOWE	NOWITECH	Arena NOW	Windcluster Mid-Norway	INTPOW
Diversified firms in OWP networks	25% (2/8 firms)	42% (5/12)	8% (1/12)	33% (18/55)	47% (8/17)

4.3 Institutional overlaps

As often in the case for emerging industries, OWP in Norway enjoys rather limited support from formal institutions wherefore we observe only weak direct overlap. However, we do observe that OWP standards build on accumulated experience from O&G sector. For instance, the OWP standards of DNV GL—an important maritime and offshore classification and standardization organization in Norwegian offshore market—have references to offshore O&G standards[4]. Also, established practices for giving concessions for OWP projects have roots in O&G practices. The Norwegian state reserves the right to regulate and grant concessions for OWP parks which aim to use the natural resources on its continental shelf – a principle which was developed for O&G explorations 1960s (Ryggvik, 2010).

Informal institutions embodied in diversified O&G firms account for most of the institutional overlap in the form of firm identity, expectations, and preferences that have been shaped in the O&G sector. Regarding expectations to OWP, diversified O&G firms fall in two categories. First, firms that can easily use extant products in OWP (e.g. logistics) see OWP as a market for delivering generic offshore services. Second, capital good firms, that need to adapt current products, see OWP as a future market as oil eventually declines (Edwards, 2011; Hansen & Steen, 2015). In addition, all these firms predominantly see OWP as an auxiliary market—particularly important due to inherent volatility of oil markets—which should not affect the core activities in O&G (Steen & Hansen, 2014). These perspectives and expectations suggest that diversified O&G firms are currently reluctant to dedicate major resources into promoting OWP technologically or institutionally, and thus not conducive for engaging in collective entrepreneurship necessary for promoting a new industry. In comparison, specialized OWP firms hold much higher expectations to OWP as a growth industry and an opportunity to innovate in the short term (see Figure 2).

4 Standards analyzed: DNV-OS-J101, DNV-OS-J103, DNV-OS-J201 and DNV-OS-J301.

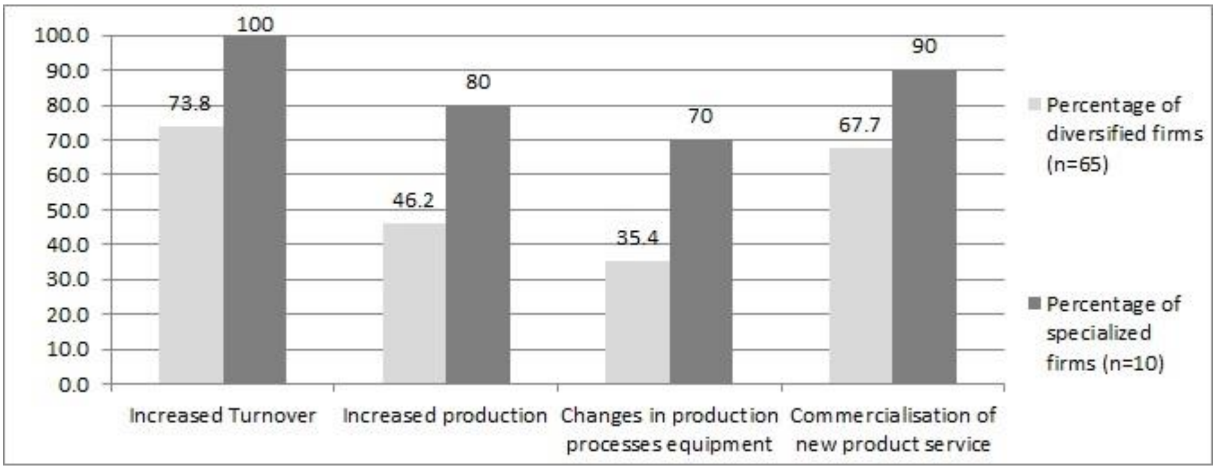

Figure 2 OWP firms' expectations to own performance in the OWP market for the next three years: diversified versus specialized firms (percentages, source: survey).

Moreover, diversified O&G firms often find it difficult to communicate and work with new firms in OWP projects that have different industry and cultural backgrounds (Hansen & Steen, 2015). Also, diversified O&G firms prefer bilateral partnership over multilateral networks in R&D collaboration (Steen & Hansen, 2014). Such firm routines inhibit new network formation in an emerging industry.

These differences in expectations, identity, and preferences indicate a misalignment of informal institutions among firms in the OWP TIS that are likely to impede formation of "strong" networks and "running in packs". Indeed, these differences resonate with the weak representation of diversified O&G firms in OWP networks. "Weak" networks, in turn, are one explanatory factor for the absence of strong supporting formal institutions (e.g. to support market creation in Norway) (Normann, 2015).

4.4 Technology overlaps

OWP technology requires specialized skills and services related to offshore technologies and operations (Jacobsson & Karltorp, 2012). Offshore structural design, transportation and installation of offshore objects and cables are therefore fields where the OWP has benefited from the expertise of the O&G sector. For instance in floating wind power technology, specific experience from O&G sector related to floating and mooring techniques and wave conditions can be utilized (DNV, 2013, pp. 118-119). According to our survey, especially firms engaged in subsea foundations activities, survey and subsea operations as well as in operations and maintenance were drawing on prior experiences in O&G sector, while firms in topside and electrical activities did so in a lesser degree (see Table 3). However, O&G experiences often need to be adapted to the OWP market. 68% of the diversified firms (n=41) claimed that their experiences from O&G were transferrable to OWP after minor changes, while 15% reported that major changes are needed, and 17% did not perceive any changes necessary.

Table 3 Share of OWP firms drawing on O&G experiences, categorized in OWP supply chain positions (n=103).

	Top-side	Foundation	Electrical and Grid	Installation & Vessels	Metocean, Survey & Subsea	Consultancy, IT & R&D	Offshore operations & Maintenance	Other
Experience in O&G (n)	44% (9)	93% (14)	44% (9)	48% (27)	64% (11)	60% (20)	71% (7)	50% (6)

Turbine foundations, i.e. the construction fixed to the seabed which supports the tower, use technology where transfers from O&G to OWP have taken place. An example is the gravity-based foundation technique of Seatower, a specialized OWP firm, which reuses the condeep oil platform concept (hollow concrete pile attached to the sea bottom), originally developed during the early decades of Norwegian O&G extraction. Additionally, necessary technologies in OWP, such as dynamic positioning systems, meteorological installations and offshore construction vessels, were originally developed for offshore O&G (Edwards, 2011).

5 Implications for the functions of offshore wind TIS

5.1 Knowledge development and diffusion

As noted above, many firms in OWP have related competences from O&G sector. Diversified firms thus contribute to knowledge development in OWP by transferring products and services either directly or after changes. Thus, new knowledge is either transferred or developed by these actors. These technological overlaps enable firms to create and design OWP specific products faster. Diversified firms are furthermore active in patenting. Of all Norwegian OWP patents[5], 42% are held by diversified firms from O&G. Arising from network overlaps, we observe that almost two thirds of specialized OWP firms had access to tacit knowledge regarding offshore business management via interlocking directorates between specialized OWP firms and O&G firms. Such knowledge is an asset for novel OWP firms (O' Hagan & Green, 2002). Additionally, institutional overlap in technical and safety standards, as well as concession regulation, draw on knowledge from O&G.

5.2 Influence on the direction of search

Technological overlaps and relatedness between OWP and O&G independently constitute a motivation and an incentive for O&G firms to enter OWP (Hansen & Steen, 2015). Technological overlap thus facilitates diversification. Several firms from O&G with related knowledge have sought to enter the blossoming North Sea market for OWP. Some have also joined the Norwegian R&D projects and networks to build capabilities and to qualify products (Normann & Hanson, 2015). Moreover, when important O&G firms (such as Statoil and Kvaerner) have entered OWP, smaller firms (e.g. technology suppliers)—whose businesses are intimately linked to the activities of the larger O&G incumbents—have felt encouraged to diversify as well (Hansen & Steen, 2015).

[5] We identified 65 patents.

5.3 Entrepreneurial experimentation

Most of the firms in OWP TIS are diversified O&G firms, which suggests exploration and diversification as the key mode of entrepreneurial experimentation. Norwegian O&G experiences have inspired the development of technological solutions in OWP TIS, such as gravity-based foundations and floating turbines. Other examples include motion compensated gangways for accessing towers offshore developed by firms with experience from O&G. Additionally, OWP has attracted a handful of start-up firms which draw on O&G technologies and finance, but are yet to experience high growth rates.

5.4 Market formation

Weak market formation has been an obstacle for nurturing an OWP TIS in Norway. Three quarters of OWP firms report lack of a home market as a challenge for successful entering in international markets (Normann & Hanson, 2015). Normann (2015) further reports that creation of home market for OWP has suffered from weak networks among OWP actors. For the part of diversified O&G firms, such problems are likely to be related to the observed misaligned informal institutions between O&G and OWP.

Electrification of O&G platforms is touted as a niche market that can be served with floating offshore wind turbines such as the ones developed by Statoil. Gas turbines for electricity production on offshore O&G platforms are a relatively large carbon polluter in Norway. However, such intentions to reduce carbon emission from oil extraction have not yet been realized.

5.5 Legitimation

Due to their status and reputation in O&G sector, the involvement of powerful O&G incumbents, such as Statoil, Fred. Olsen and Kvaerner, enhances the legitimacy of OWP because they bring business credibility to an emerging market in the eyes of a wider business community and public at large (Hansen & Steen, 2015). For instance, Statoil's endeavors to develop OWP technologies have broadly attracted media and policy attention. However, the failure to promote a domestic market indicates that OWP doesn't enjoy sufficient legitimacy e.g. among policy makers and other influential established sectors. We infer that the misalignment of informal institutions and associated inability to "run in packs" (cf. section 4.3) partially explains a lack of legitimacy for OWP policies beyond R&D support.

5.6 Resource mobilization

The presence of large and resourceful O&G firms has enabled the mobilization of human and financial resources for OWP. For instance, the vast resources of Statoil have been utilized to develop floating wind power technology. O&G firms have also invested in OWP start-up firms, and several of them had access to different types of resources (e.g. information about supply chain management or export) via interlocking directorates.

Large diversified O&G firms have also brought human capital to OWP. Even though the majority of diversified firms had only a small share of their employees dedicated to OWP, most of the OWP employees in Norway work for diversified O&G firms due to the small size of specialized OWP firms. However, OWP can also pose as a competitor to O&G in the labor market, as renewable energy often is more attractive to new graduates than hydrocarbon industry (Hansen & Steen, 2015). Also, existing physical infrastructure, such as harbors and yards, developed for purposes of O&G are mobilized to support activities in OWP (Steen & Karlsen, 2014).

5.7 Positive externalities

While structural overlaps have supported the formation of the OWP TIS by making available existing structures and resources, low engagement of O&G firms have limited actual application of those resources, inhibiting positive and self-sustaining feedback between functions.

The interest from the O&G sector in OWP has seemed to be cyclical and subjected to market developments in O&G. By being a diversification option during market downturns in O&G, OWP can suffer from decreased interest from diversified firms during upswings in primary market (Normann, 2015). Combined with the misalignment in informal institutions, such volatility could undermine the necessary perseverance and strength of networks aiming to promote the OWP TIS. These factors undermine the development of positive externalities.

5.8 Overview of analysis

In Figure 3 we summarize our analysis regarding the key impacts of O&G on formation of OWP TIS. While the O&G sector can be seen to have had mainly positive implications for e.g. knowledge development and diffusion and direction of search functions, this have not translated into significant benefits in crucial TIS functions such as market formation and development of positive externalities. We discuss this further in next section.

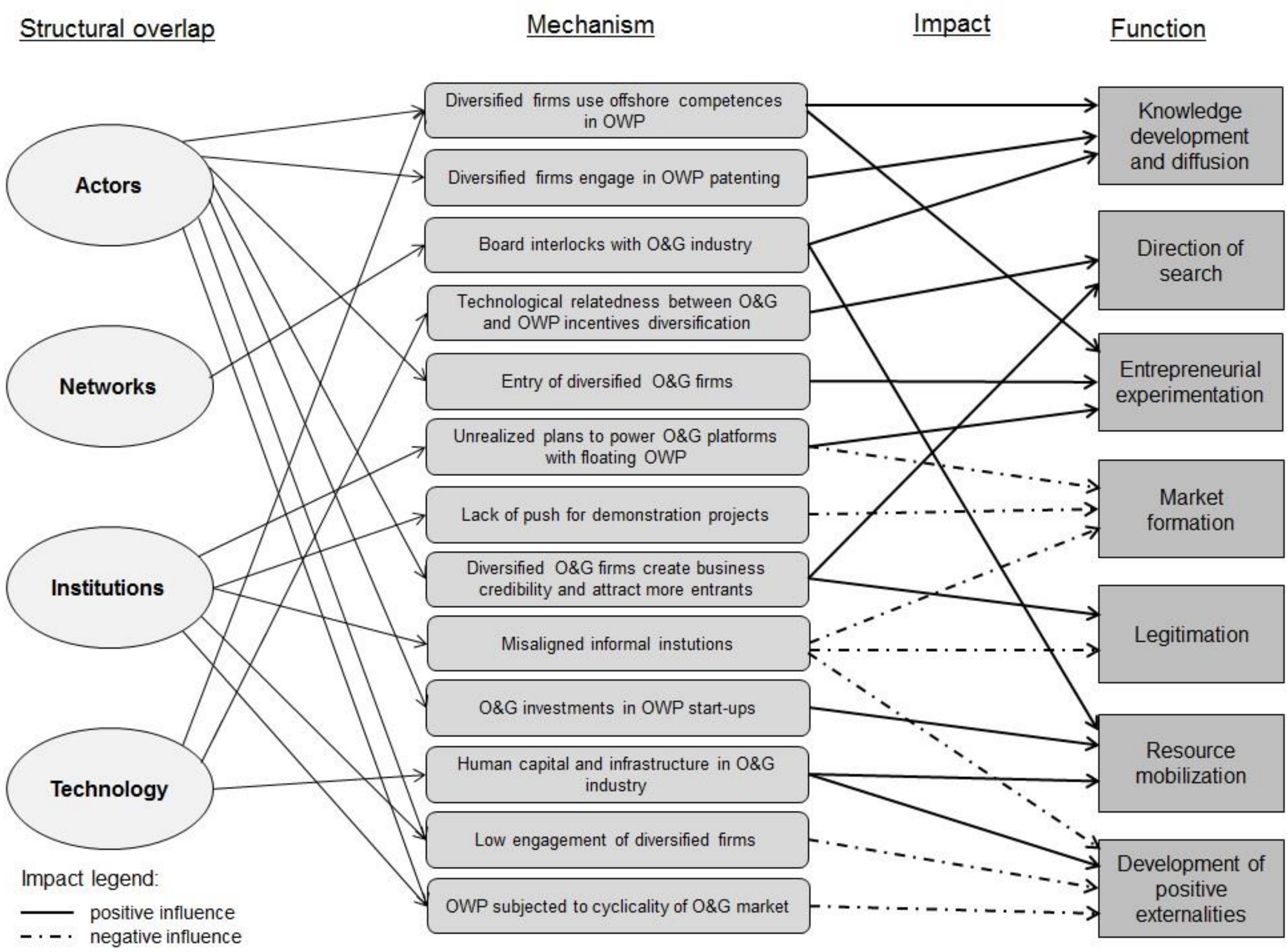

Figure 3 Main implications for OWP TIS from structural overlap with O&G sector.

6 Discussion and conclusion

The purpose of this paper was to analyze opportunities and barriers for how established sectors may positively influence an emerging clean-tech industry. We proposed an analytical framework drawing and expanding upon recent developments in the TIS framework regarding relationships between a focal TIS and established sectors (Bergek et al., 2015; Wirth & Markard, 2011). We analyzed how overlaps between the Norwegian oil & gas sector (O&G) and offshore wind industry have influenced the latter. We found, as anticipated by Bergek et al. (2015), that the relationship between sector and TIS can simultaneously have both positive and negative implications for the TIS. In this chapter, we discuss the results of our analysis and outline conceptual and policy implications.

6.1 Implications for the technological innovation system framework and the study of established sectors and clean technology industries

In terms of TIS analysis, we find that our proposed framework is applicable and valuable. It helps to reduce the complexity of implications from sector-TIS overlaps by outlining positive and negative implications at the TIS function level. Such functional analysis allows having a look “under the hood” of industry linkages.

A key insight from our analysis is that structural overlaps are of rather ambiguous nature. We found that technology overlap (relatedness) was unequivocally positive for OWP by strengthening numerous functions including entrepreneurial experimentation, knowledge development, and resource mobilization ultimately facilitating emergence of a new industry in Norway (cf. Boschma & Frenken, 2011). However, other overlaps—particularly institutions and actors—tended to restrain the potential benefits for the emerging industry from fully unfolding. This is particularly visible in the reluctance of diversifying firms to commit to the new market.

The diversified O&G firms consider themselves first and foremost as O&G firms with OWP acting as an auxiliary market of secondary importance. While such firms enter the OWP TIS they stay primarily committed to their primary market. Therefore, they employ strategies in OWP that are not sufficiently conducive for new industry formation. They take a wait-and-see approach to scope the market as a potential future opportunity without committing to nurturing it, or see OWP as a market for (incrementally adapted) O&G products and services. Such diversification strategies to related markets may be rational from the perspective of individual O&G firms (Montgomery & Hariharan, 1991), but are less fruitful from an industry formation point-of-view, which would require committed and willing firms “running in packs” (Van De Ven, 1993). Aggravating the situation is that the size and international experience of these O&G firms enable them to seek out primarily international OWP markets, thus leaving the smaller specialized OWP firms behind. Moreover, the O&G sector is notoriously volatile with upturns offering exceptionally high profits and downturns that generate crisis and bankruptcy. While downturns in O&G increase the interest of O&G firms in alternative markets such as OWP, upturns in O&G tend to lure them back with the promise of high profits, thus reducing their engagement in alternative markets. This implies that the sector’s volatility transmits from sector to TIS causing instability in the latter.

Our analysis thus demonstrates that technology relatedness is important but insufficient for realizing potential synergies between sector and TIS. In our case study, institutions are constraining these resource flows. Hence, we argue that when investigating how established sectors influence clean technology industries, it is necessary to acknowledge overlaps not only in terms of technology (Boschma & Frenken, 2011; Neffke et al., 2011), but also in terms of e.g. actors, institutions and networks because these different dimensions tend to interact. Our analysis has shown that such inclusion of structural overlap can assist in achieving more complete view of the implications of overlaps between established sectors and clean technology industries, which is necessary for designing effective policies for the latter.

However, by focusing on sector-TIS relationships some external linkages important for TIS evolution escaped our analysis, such as energy policy and politics. A “standard” TIS analysis would account for these external linkages but would not be able to illustrate how the self-reinforcing interaction among different types of structural overlaps between a sector and TIS contribute to stalling further TIS growth. Hence, although we took some initial steps in developing relevant indicators, more methodological, empirical and conceptual advance regarding analysis of TIS-context interactions is needed. For instance future research could focus on how bi-directional interaction between sector and TIS emerges, and how and to what extent activities in new industries also feedback on learning dynamics in established sectors. Also, further longitudinal studies observing the evolution of sector-TIS interaction are necessary for understanding how such relationships may change over time.

6.2 Policy implications

Our results point to four main implications for policy.

First, when dominant firms in an emerging industry are diversifiers from an established sector and share prior industry experience and informal institutions, it is challenging to make all firms in the emerging industry to run in packs to facilitate resource flows. This suggests that it is important for new industry formation that a sound balance between diversifying established firms and newcomers exists.

Second, our analysis also suggests that while a diversification *opportunity* for firms in established sectors is necessary for their entry into emerging industries, it may not be sufficient to ensure sufficient commitment. As reduced opportunities in the primary market incentivizes diversification, discontinuing state support for activities in O&G, e.g. through incentives for exploration of new oil extraction areas, could make firms more serious about diversification. Hence, policies that support emerging clean-tech industries need to be seen in conjunction with policies that affect profitability of established sectors. Kivimaa and Kern (2016) suggest that such policies could include cutting R&D funding, removing subsidies and tax deductions, or balancing involvement of incumbents in policy advisory councils.

Third, even if firms from an established sector are “willing” diversifiers, they face risk and uncertainty in the new market, which can hinder the decision to diversify. We suggest that policy measures could facilitate resource transfers between industries by establishing “safe corridors” between sector and emerging industry for example by offering subsidies for staff re-training, engagement in networks or other investments necessary for diversification.

Finally, our findings indicate that solely relying on diversifiers for resource flows from sector to TIS is not sufficient. Other channels such as entrepreneurship with experience in O&G, spin-off firms, or labor mobility would be less likely to suffer from the institutional barriers identified in this paper. A mix of policies, which broaden the set of channels for resource transfer, could increase synergies between the sector and the emerging industry.

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