Environmental Innovation and Societal Transitions 14 (2015) 128–148

Contents lists available at ScienceDirect

Environmental Innovation and Societal Transitions

journal homepage: www.elsevier.com/locate/eist

Broadening the national focus in technological innovation system analysis: The case of offshore wind

Anna J. Wieczorek[a,b,*], Marko P. Hekkert[a], Lars Coenen[c,d], Robert Harmsen[a]

[a] *Innovation Studies, Copernicus Institute of Sustainable Development, Faculty of Geosciences, Utrecht University, Heidelberglaan 2, 3584 CS Utrecht, The Netherlands*
[b] *Institute for Environmental Studies, Vrije Universiteit Amsterdam, The Netherlands*
[c] *CIRCLE: Centre for Innovation, Research and Competence in the Learning Economy, Lund University, Sweden*
[d] *NIFU: Nordic Institute for Studies in Innovation, Research and Education, Oslo, Norway*

ARTICLE INFO

Article history:
Available online 30 September 2014

Keywords:
Offshore wind
Systemic policy
Systemic problems
Technological innovation system
Territorial embeddedness
Transnational linkages

ABSTRACT

This paper empirically explores if and how the spatial dimensions of Technological Innovation System matter using the case of offshore wind in North-Western Europe. In particular, it demonstrates the territory-specific institutional embeddedness and transnational linkages effects between four national offshore wind innovation systems. The paper discusses the consequences of taking these spatial dimensions into account in the analysis of the domestic TIS performance. It argues that the acknowledgement of these dimensions contributes to better understanding of the systems' dynamics and leads to policy advice that is in sync with recent internationalisation developments in the diffusion of the offshore wind industry.

* Corresponding author at: Institute for Environmental Studies, Vrije Universiteit Amsterdam, The Netherlands. Tel.: +31 20 598 9504; fax: +31 20 598 9553.
E-mail address: anna.wieczorek@vu.nl (A.J. Wieczorek).

http://dx.doi.org/10.1016/j.eist.2014.09.001
2210-4224/

1. Introduction

The Technological Innovation System (TIS) perspective has become a popular analytical tool to explain the success and failure of the development and diffusion of renewable technologies and their contribution to sustainability transitions. The core of the TIS perspective comprises the analysis of the emergent structural configuration of the innovation system (actors, networks, technology, institutions) and major processes (also labelled as system functions) that support the formation and development of radically new technological fields (Hekkert et al., 2007; Bergek et al., 2008). Analyses based on the TIS perspective create insight in the weaknesses of the innovation system and suggest ways in which the development and diffusion of technology can successfully be improved (Wieczorek and Hekkert, 2012). The specific focus on analysing emergent technological fields distinguishes TIS from related frameworks (Coenen and Diaz-Lopez, 2010) like the sectoral (Malerba, 2002) and regional innovation systems (Cooke, 2001).

Technological Innovation Systems are essentially global systems. Initial conceptualizations of TIS have emphasised that technology development and diffusion are processes that cut across spatial boundaries (Carlsson and Stankiewicz, 1991; Carlsson, 1997). Hence, the most appropriate way to understand the emergence of new technology would be to study the TIS as a global system (Binz et al., 2014). However, many empirical TIS studies delineate their analysis to a single country, see e.g. Jacobsson and Lauber (2006), Negro and Hekkert (2008), Hekkert et al. (2007), Negro et al. (2007), Bergek et al. (2008) or Hillman et al. (2008). The choice for a *national* focus is often justified by the importance of national institutions for technology development and diffusion and by the aim to inform domestic technology and innovation policy. The international aspects that influence such nationally delineated technological fields are predominantly discussed under a broad term of *exogenous forces* without a clear explanation of their impact on the analysed TIS (Coenen and Truffer, 2012; Markard et al., 2012). By treating these influences as merely exogenous or contextual, there is a risk of overlooking the TIS' interconnectedness with other innovation systems, on national, regional or sectoral levels as pointed out in a recent reflection paper on TIS by Jacobsson and Bergek (2011). This weakness is further substantiated by recent observations made in sustainability transition literature concerning the spatial distribution and variation of structural configurations of the systems (Berkhout et al., 2011; Dewald and Truffer, 2011; Späth and Rohracher, 2012; Coenen et al., 2010, 2012; Truffer and Coenen, 2012; Binz et al., 2012; Raven et al., 2012). Without spatial sensitivity, it is argued, TIS studies overlook how national policies and resources may be conditioned by broader international networks, markets and institutional configurations and thus influence the impact of these policies and resources in considerable ways. A narrowly defined national focus may, for example, underestimate the importance of other countries in technology development and therefore overestimate the role of a national government in R&D stimulation. To avoid containerized TIS studies (Binz and Truffer, 2012) more attention to the spatial dimensions of TIS is therefore called for (Coenen et al., 2012).

In this paper, we concentrate on empirically exploring if and how the spatial dimensions of TIS matter using the case of offshore wind in North-Western Europe. Offshore wind is an emerging renewable energy technology with considerable potential and for this technology Europe is the leading continent in terms of installed capacity, key industrial players and profitability potentials (Makridis, 2013). Using insights from an earlier TIS analysis of offshore wind in Germany, the Netherlands, the UK and Denmark respectively (Wieczorek et al., 2013), we aim to demonstrate the implications of moving beyond a national TIS focus by highlighting the territory-specific institutional embeddedness and transnational linkages effects between the four national offshore wind innovation systems. In particular, we discuss the consequences of taking these spatial dimensions into account in the analysis of systemic problems. Due to our focus on four countries we acknowledge that we do not create a full picture of the global TIS for offshore wind and its implications for national development. However, the chosen scope does make it possible to analytically show what a spatially sensitive view adds to an (implicitly) nationally focused TIS analysis.

For our analysis we draw on the TIS framework complemented by insights from economic geography on territory-specific institutional embeddedness and transnational linkages, explained in Section 2. In Section 3 we describe the methodology. In Section 4 having presented basic facts about offshore wind in Europe we discuss structural configuration and functional performance of four nationally delimited TISs: Germany, the Netherlands, the UK, and Denmark. We identify systemic problems of each system and sketch the required national policy response. In Section 5 we focus on the transnational linkages effects between the four TISs and the impact of broadening the analytical scale and in particular, the explicit inclusion of the linkages on the definition of systemic problems and policy in the studied countries. We conclude in Section 6.

2. Theoretical framework

The TIS perspective emerged in the early nineties from a quickly expanding innovation system literature, which is rooted in evolutionary economics and industrial dynamics (Freeman, 1987; Lundvall, 1992; Nelson, 1993). A Technological Innovation System is defined as 'a dynamic network of agents interacting in a specific economic/industrial area under a particular institutional infrastructure and involved in the generation, diffusion, and utilisation of technology' (Carlsson and Stankiewicz, 1991, p. 93). These actors, networks, institutions and technology constitute the structural components of the TIS following the more general systems of innovation framework (Edquist, 1997). A novel and quintessential aspect of the TIS perspective concerns its attention for the functional performance of the innovation system's components, conceptualised through a set of functions, as defined in two programmatic papers by Bergek et al. (2008) and Hekkert et al. (2007). This set of functions refers to: (1) *Entrepreneurial activities*: exploring and exploiting business opportunities on the basis of new technologies and applications. The applications create opportunities to learn about the functioning of new products, processes or services after exposure to market dynamics. (2) *Knowledge development*: the creation of knowledge lies at the heart of any innovation process. While science-based research and development are important key processes to generate new knowledge, these are not the only ones. Various other types of knowledge can also serve as input for innovation, including experience-based knowledge development through doing, using and interacting (Jensen et al., 2007). (3) *Knowledge exchange*: for the development of new or improved products, processes or services, the diffusion of knowledge can be as important as the actual generation. Successful innovators are often those firms that know how to make commercial use of ideas and knowledge generated by others (Chesbrough, 2003). (4) *Guidance of the search* is necessary for the selection or rejection of a particular direction of technological development. The formulation of expectations and visions, priority setting in R&D strategies and foresight studies contribute to such selection processes. Also user–producer interaction provides an important feedback mechanism in this context. (5) *Market formation*: innovation is by default couched in uncertainty as it often disrupts the status quo on existing markets. The more radical an innovation is the higher its disruptiveness. This means that incremental innovation, building forth on existing products, processes or services, is more likely to be accepted by existing users and markets while markets for completely new innovations often still need to be formed. (6) *Resource mobilisation* refers to the mobilisation and allocation of resources that are necessary to make the various processes in the innovation system, as described above, possible. Primarily they refer to the collective efforts to secure financial capital (seed and venture capital, policy support programmes) and human capital (through education, training and competence development). (7) *Creation of legitimacy* is required to overcome the liability of newness (Zimmerman and Zeitz, 2002), which constitutes an important but often neglected dimension of innovation. The purposeful creation of legitimacy by lobbying activities and advice activities on behalf of interest groups may be necessary in order to counteract resistance to change.

Apart from analysing the build-up of systemic support for innovation in an emerging technological field, the set of functions has also been applied to inform policy-making and formulate rationales for policy action (Negro et al., 2007). Here, the TIS framework follows the more general approach to policy legitimation found in the innovation systems literature concerning systemic failures or problems (Smith, 2000; Klein-Woolthuis et al., 2005; Laranja et al., 2008; Wieczorek and Hekkert, 2012). The underlying idea is that innovation systems are a problem oriented heuristic: resources and capabilities are mobilised and coordinated in order to find a solution to a problem (Metcalfe and Ramlogan, 2008; Gee and McMeekin, 2011). Once the TIS framework delivers an analytical output of how well the functions are fulfilled, this is followed by a definition of process goals in terms of a desired functional pattern (Bergek et al., 2008). Since weak functions signal the need for policy intervention, the identification of inducement and blocking mechanisms leads to specifying key policy issues–which are subsequently transformed into policy recommendations.[1] Wieczorek and Hekkert (2012) argue, however, that functions alone cannot form the sole basis for policy. Furthermore, functions cannot be influenced by policy in any other way than by intervention in the structure. The authors, therefore, propose a classification of structure-related systemic problems that are identified in the result of a coupled structural–functional analysis. They show that for such systematically identified problems, an integrated, systemic instrument can be proposed.

Against this policy context, the criticism on empirical studies of TIS for applying an implicit, often national scalar envelope around the system delineations becomes particularly relevant. As emphasised in pioneering work on TIS, the development of a technology or technological fields does not stop short of national borders (for an empirical illustration see Binz et al., 2014). Especially in light of on-going globalization processes, this suggests it would be rather short-sighted to govern TIS from a narrowly defined national policy perspective. International network relations and institutional interdependencies need to be acknowledged by policy-makers even though they may extend beyond their direct sphere of influence.

To conceptualise such interdependencies Coenen et al. (2012) highlight the importance of territorial embeddedness of technological innovation systems and in particular the need of a more spatially differentiated view of TIS structural components. They argue that the TIS elements operate at various geographical scales and in different locations and, thus, have varied access to different resources. To approach the territorial embeddedness of TIS, two interrelated dimensions should be accounted for: (1) institutional embeddedness and (2) transnational linkages.

To explain the uneven geography of innovation, economic geographers have extensively drawn on the notion of institutional embeddedness. It draws attention to the existence of territory-specific sets of institutions that conditions innovative behaviour among agents located in such regions and countries (Storper, 1997; Cooke and Morgan, 1993; Gertler, 2004; Asheim and Coenen, 2005). Here, institutions are broadly defined as formal and informal rules that both enable and constrain organisational and individual behaviour relevant for innovation processes (Nooteboom, 2000), Similarly, the literature on national innovation systems has provided ample proof that country-specific institutions have a sustained effect on the innovation performance of the actors in the innovation system (Lundvall and Maskell, 2000). A classic example is provided by Edquist and Lundvall (1993) where they contrast the high degree of public–private coordination conducive to joint industry–university research in Sweden with more local community/industrial district mode of coordination conducive to user–producer learning in Denmark. In a related manner, the Varieties of Capitalism literature (Hall and Soskice, 2001) has argued that coordinated market economies (such as found in Germany, Japan and Scandinavia) offer institutional advantages in supporting incremental innovation based on complementarities between close inter-firm as well as public–private collaboration, high-levels of industry-specific technical skills, secure employment and a financial system able to supply long-term (*patient*) capital. This can be contrasted with liberal market economies (such as the UK and US) offering institutional advantages for radical innovation in fast-moving technology sectors based on high rates of labour mobility, inter-firm relations primarily based on markets, equity markets with dispersed shareholders and venture capital. Following Jacobsson and Bergek's (2011) call for a better understanding of TIS' interconnectedness with other innovation systems, a first step would thus entail a more explicit acknowledgement of the institutional embeddedness of the actors involved in the TIS. This is particularly pertinent for policy implications and recommendations as interventions are more likely to take hold in areas with already developed and relatively well-functioning institutions (Rodríguez-Pose, 2013). In his review, Carlsson (2006) identifies a consensus in the literature that in spite of increased globalization (see below) institutions relevant to innovation systems only change very gradually and remain largely persistent within territorial boundaries.

However, in a globalising economy, knowledge and other innovation related resources circulate and are recombined in globally distributed *networks* of firms, universities, policy-makers and interest

[1] It is perhaps not by necessity that the weak functions require a policy intervention (i.e. action by public sector) but may also call for collective intervention by private actors.

groups (Binz et al., 2014). Also in TIS, firms engage in global innovation networks to source critical knowledge for the development and diffusion of technologies. In the case of multi-national companies, the firm itself even acts as a conduit through which knowledge and resources circulate across national borders. Even though the lion's share of corporate R&D is traditionally performed in the home nation (Patel and Pavitt, 2000), there is an increasing internationalisation tendency for these activities (Dunning and Lundan, 2009). This can be manifested through foreign direct investment, subsidiary firms, supplier networks, joint ventures or relocation. Partly these internationalisation trends are fuelled by motives to access particular knowledge pools, partly to get access to distant markets. Research activities carried out in universities and other research organisations is probably even more internationalised through social networks in globally distributed epistemic communities involving active interaction with distant ties (Amin and Cohendet, 2004). Saxenian (2005) demonstrates how even individuals, in this case engineers, act as conduits of international knowledge flows by their personal mobility and thus bridge professional and economic ties to technologies and markets across developed and developing economies. Institutions, despite their territorial stickiness, are also susceptible to travel internationally, but at a markedly slower pace than knowledge or actors. Institutional flow occurs, for example, when stringent quality standards are adopted by more lenient jurisdictions from highly regulated foreign markets through global supply chains (Vogel, 1997; Corbett, 2002). Through these global networks, innovation systems are becoming internationalised, even if many of the institutions that support them remain territory-specific (Carlsson, 2006). Wieczorek et al. (2014) refer to these flows as transnational linkages and classify them as actor, technology, institutional, capital and knowledge flows.

3. Methodology

This study builds on the analysis of four national offshore wind innovation systems situated around the North Sea that had the largest online offshore wind capacity in Europe at the end of 2011: the UK – approx. 1600 MW, Denmark – 850 MW, the Netherlands – 250 MW and Germany – 200 MW. An interesting difference between these countries is their level of offshore wind political ambition and varying strategies that these countries deploy, which have led two of them (the UK and Germany) to progress rapidly, while the other two (Denmark and the Netherlands) to actually have a lower speed of offshore wind deployment.

The analysis was based on the review of scientific and grey literature, internet sources, Global Offshore Wind Farms Database 4C as of 2010, journal publications in the Web of Science (for knowledge networks identification), CORDIS database (for European project participation) and European Patent Organisation (for patents identification). *Offshore wind* served as a key word. This review was complemented with Lexis–Nexis-based media events analysis for 2010–2011 and semi-structured interviews with over 30 offshore wind stakeholders. Among the interviewees were representatives of leading industries; financial organisations; knowledge institutes and NGOs in the four studied countries. They were all experts in managerial positions (Appendix A). The interviewees were asked to assess their home offshore wind TIS in the context of the European dynamics. A five-tier scale of 1–5 (absent to excellent) and a set of diagnostic questions (presented in Appendix B) guided the discussion on each system function.

These traditional analyses of the four innovation systems were further complemented with a brief assessment of the systems' institutional embeddedness and transnational linkages. Although we did not apply any rigorous set of indicators, we did pay attention to spatial configuration of domestic value chains (presence of foreign actors, participation of national actors in foreign projects, etc.), country-specific cultural and historical aspects determining the systems' institutional structures, commitment of the actors (government, industry, society) to offshore wind; level of (university–industry) interaction, etc. Further, we looked at what the influence of the interplay of institutional embeddedness and transnational linkages on linkages effects between the four national TISs. In particular, we explored how the interrelations between the systems influence the definition of national systemic problems and how this changes the potential national policy implications. The issue of collaboration and transnational linkages emerged as a pertinent theme out of the interviews with actors.

With this focus on four countries we miss out on the rest of the global offshore wind TIS. The goal of this paper, however, is not to present a complete picture of transnational influences but to empirically support the recent theoretical contributions on the institutional embeddedness of innovation systems. Focusing on the potential interaction between four countries is empirically sufficient.

4. Four offshore wind innovation systems: a national perspective

In order to keep climate change below 2 °C, the European Council reconfirmed in February 2011 the EU objective of reducing greenhouse gas emissions by 80–95% by 2050 compared to 1990 (EU, 2011). Although in the current European policy landscape more technologies ask for attention, it is believed that without offshore wind, which is in EU projections the fastest growing renewable (Capros et al., 2010), achievement of the ambitious European goals will be very difficult, if not impossible (Jacobsson and Karltorp, 2013).

Offshore wind has developed quite remarkably in the recent years. While in the early 90s the industry was still in its infancy with the first offshore wind turbine being set up in Denmark, in 2011 the total installed offshore wind capacity in Europe reached approximately 3300 MW and provided jobs to 35,000 people (EWEA, 2011b). The 2020 deployment potential of offshore wind is estimated by the European Wind Energy Association (EWEA) at the level of 40.000 MW, which is similar to the sum of the offshore wind ambitions expressed by the EU Member States in their National Renewable Energy Action Plans (NREAPs). Realisation of this potential would mean that offshore wind can supply 5% of the EU's total electricity demand (Capros et al., 2010), provide significant employment opportunities (170,000 jobs in 2020) and help various countries diversify their energy sources (EWEA, 2011a). Many sources, however, emphasise a number of substantial obstacles that block a wider diffusion of offshore wind in Europe (Wieczorek et al., 2013; Heptonstall et al., 2012; Deutsche Bank, 2011; De Jager et al., 2010; Jacobsson and Karltorp, 2012).

In the following paragraphs we therefore look at the structural configuration and functional performance of the four nationally delimited TISs: Germany, the Netherlands, the UK and Denmark with the aim to identify systemic problems of each system and to shortly discuss necessary national policy response. The section is based on Wieczorek et al. (2013) and presents only a summary of a much wider set of findings complemented by observations about institutional embeddedness of the various TISs.

4.1. Germany

The German offshore wind TIS is characterised by the presence of a complete value chain, strong and highly skilled industrial players, many of which are multinationals with subsidiaries in the other three countries and heavily involved in the construction of wind farms abroad. German firms are world leaders with regard to dedicated R&D, ground-breaking wind turbine development, and the implementation of advanced offshore wind technology. For example, Siemens is one of the largest multinationals of German origin supplying 51% of European wind turbines in 2011 and one of the world's leading firms in terms of offshore wind patenting (193 patents). Enercon GmbH, the fourth-world-largest wind turbine manufacturer was the first in the world to install an offshore 4.5 MW turbine in 2002: the Enercon E-112. The German innovation system builds on a strong manufacturing culture that translates to strong engineering knowledge and on tight industry–university collaborations. Well-known knowledge institutes in the field are the University of Bremen, Leibniz University Hannover and the Alfred Wegener Institute for Polar and Marine Research. They are, however, publishing less than the Dutch and Danish institutes.

Germany can further be characterised by a more dispersed wind farm ownership structure compared to the UK, Denmark and the Netherlands. Only 39% of approved offshore wind projects are owned by large utilities. The remaining shares in German wind farms are held by a substantial number of developers, financial investors and municipal utilities (KPMG, 2010). To meet the offshore wind challenges, there is a drive towards cluster strategies for offshore wind manufacturing in geographically closely located ports (e.g. German cluster Bremerhaven, Cuxhaven, Emden). These initiatives are the result of close cooperation between public and private sectors (EWEA, 2011a).

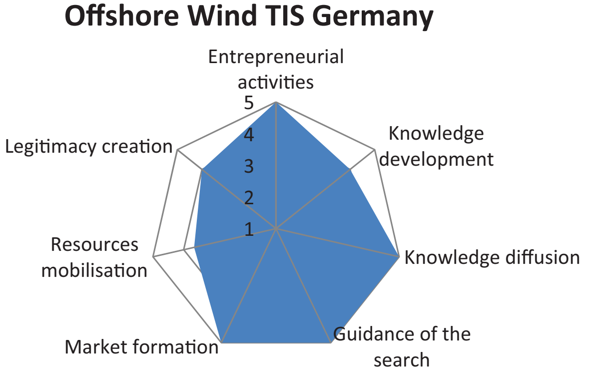

Fig. 1. Overview of system function fulfilment in Germany (Wieczorek et al., 2013).

Procedures for offshore wind construction are administered by a large number of authorities even though the government is working on combining the licensing for offshore wind farms into one single process. The government has a coherent vision to phase out nuclear energy (in the aftermath of Fukushima accident) and to support renewables with consistent policies as well as long-term contracts to renewable energy producers (the feed-in tariff mechanism). All these factors create a strong interplay of supporting institutional conditions for offshore wind in the country.

Fig. 1 shows the functional pattern for Germany with very strong entrepreneurial activities, knowledge diffusion, guidance of the search and market formation. The German offshore wind market is extremely attractive with huge orders and may very soon take over the leadership from the UK. The knowledge development is also good especially the *engineering* type. Lower legitimacy of the technology is caused by the high costs and the ownership structures of offshore wind parks. Markard and Petersen (2009) state that part of the success of renewable energy policies in Germany (and Denmark) was due to the fact that individuals (local stakeholders but also citizens in general) could benefit from investments into these new technologies, which in turn fuelled broad political support. For offshore wind this is not the case. A growing number of vocational and academic trainings cater for an inflow of skilled experts but do not cover the full demand making human resource mobilisation somewhat problematic. A serious obstacle that Germany faces in further offshore wind expansion lies in grid connection and capacity.

Summarising, this national analysis would suggest that German policy, in order to stimulate further expansion of offshore wind, should continue to strengthen demand in its home market, make investments to academic knowledge development and training programmes. Most importantly, however, it should undertake a national action for grid renovation and improvement.

4.2. The Netherlands

Even though Dutch industry is well represented across the value chain, its activities are more geared to international markets due to a relatively weak domestic market and lack of support from government. The Netherlands' very strong offshore industry finds its origin in maritime construction and engineering. This knowledge base has been transferred to the construction of offshore wind farms making the Dutch offshore industry a very important player in the construction of European offshore wind farms. Especially construction companies (focused on foundations, substations, and wind farm installation) are involved in many international projects. There is also a strong academic tradition in wind research resulting in a solid scientific knowledge base. Dutch knowledge institutes rank very high internationally in terms of the number of publications on offshore wind. This research is more concentrated than in Germany or the UK. In particular, Delft University of Technology (TU Delft) excels in the number of journal articles per institute (44 articles), which in 2011 resulted in a 13th position in the world. TU Delft is also a leader in academic and polytechnic training in offshore wind in the

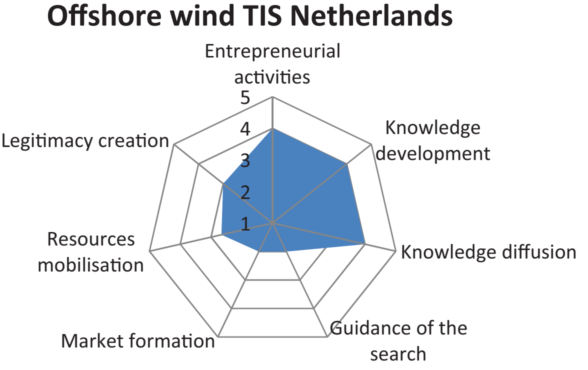

Fig. 2. Overview of system function fulfilment in the Netherlands (Wieczorek et al., 2013).

Netherlands. The university closely cooperates and co-publishes with various other Dutch institutes (especially the Energy Research Centre in the Netherlands) as well as foreign knowledge institutes. Joint publications with industry are, however, less abundant. This can partly be explained by its focus on scientific research whereas industry is more concerned with developing engineering based knowledge. It seems that Dutch offshore construction industry mainly innovates in a more applied and tacit way. A good framework condition for offshore wind is related to the numerous and state-of-the-art harbour facilities in the Netherlands.

In 2011, the strong industrial lobby, composed of many offshore firms working for oil and gas but diversifying their business into offshore wind, persuaded the government to close a so-called Green Deal, in which the government committed itself to supporting offshore wind development.[2] Critics, however, argue that the deal is only meant to camouflage the government's lack of vision and determination to act and take its earlier renewable energy commitments and obligations seriously (De Vries, 2012). Given substantial national gas reserves and austerity measures in light of the financial crisis, the Dutch government is primarily interested in cost-efficient ways of reducing carbon emissions. The Dutch feed-in premium SDE+ (Stimuleringsregeling Duurzame Energie+) implies that all renewable energy technologies need to compete for one (limited) budget. Under prevailing cost-structures, this means that offshore wind has little chances to compete with cheaper renewable energy technologies such as biomass combustion. This implies that the Netherlands has a very well-developed national industry and good harbour infrastructure, but, as a consequence of national policy, a small home market. This might change however. In the recent Energy Covenant (SER, 2013) it has been agreed to strengthen national efforts to meet 14% renewable energy in 2020, for which the contribution of offshore wind is considered essential.

As per the functional performance shown in Fig. 2, knowledge development is well developed, mainly thanks to strong scientific knowledge. Knowledge diffusion through scientific publications is good, though university–industry collaborations could be strengthened. Entrepreneurial activities also score relatively high due to foreign activities of the large multinationals of Dutch origin (Van Oord, Sif, Balast Nedam). Guidance and market formation processes are very weak (there were no new farms constructed in 2011, some of them were delayed), so is resources mobilisation, especially human and financial. Physical infrastructure in the form of harbours and grid, although in need of renovation and adjustment is relatively better off than in Germany or the UK. A serious problem for the Netherlands is legitimacy of technology. Due to the high costs of offshore wind, the current political preference is for cheaper renewable energy technologies. Dutch policy and strategy would, therefore, need to

[2] Key concepts in this Green Deal included a substantial cost reduction through innovation and policy changes, strategic growth of the offshore wind market, achievement of the climate goals, as well as further experimental and shaping of the legislation.

focus on the development of home market, strengthening legitimacy and on investments in domestic programmes to support university–industry collaboration.

4.3. The United Kingdom

The United Kingdom does not have a long offshore wind tradition. Nonetheless, in October 2008, it became the world leader of offshore wind power generation (Alok, 2008). Despite a huge market, the UK innovation system is mostly dominated by foreign actors. Unlike Germany and Denmark, it does not have a single manufacturer of the required 3–7 MW wind turbines. Also, the supply chain for local components is small and not very complete. Still, in 2010/11 the UK had the highest installed capacity and more offshore wind farms than any other European country. That indicates that the UK has got a developed market (demand) but a small national industry (supply) (see also Douglas-Westwood, 2010). Large foreign utilities such as Nuon, Eneco, E-on, Centrica, RWE, Vattenfall, Dong Energy dominate as owners, developers and operators of the farms. The production of scientific knowledge in the UK is scattered (170 knowledge institutes are involved in publishing), while the UK knowledge institutes rank lowest of all four analysed countries in terms of a number of publications on offshore wind. Similarly, the UK does not have a tradition in offering education in offshore wind energy. However, since the country is expected to lead European offshore wind implementation in the coming years (EWEA, 2011a), it took serious measures to address the demand voiced by industry, especially for qualified engineers.[3] No specialisation can yet be observed in the UK in any particular knowledge area, rather the attempt seems to be to keep up with rapid market developments and to train specialists who could operate and manage the newly built wind farms. These circumstances as well as a specific consultancy culture may have been the reasons why the UK has the most consultancies involved in advising on offshore wind out of all the analysed countries.

In technical terms, the UK has the greatest potential for wind energy out of all the analysed countries (EEA, 2009) and thus good conditions for offshore wind farm development. Offshore wind is a crucial element of the government's plans to reduce the carbon intensity of the power sector, increase energy security and provide affordable energy to consumers. The UK regulatory framework for offshore wind is currently based on Renewable Obligation Scheme (ROC). The scheme works through electricity suppliers needing to possess a certain amount of ROCs in order to avoid *buy-out* penalties in case of underachievement. The financial resources that become available through the penalties are granted to the holders of the ROCs, providing an additional incentive to invest in renewable energy.

The financial certainty in the UK is assured until 2014 with an average of 2 billion pounds per annum. In expectation of a large market and following the ambition of the UK government to make offshore wind a part of the UK renewable energy mix, investigations started to identify additional sources of capital that would allow for funding the projects in the period 2017–2022 (The Crown Estate, 2011). The UK has also allocated significant investments to harbour infrastructure.

The functional performance of the UK is reflected in Fig. 3. Legitimacy of technology, guidance of the search and market formation are strongest. Knowledge development and diffusion are weak but there is the perception of quite easy access to foreign knowledge. What is problematic for the UK, given this national analysis, is the lack of domestic industry, complex and lengthy permitting procedure, poor grid access and capacity and a severe lack of skilled personnel of various kinds. National policy in support of the offshore wind system should, therefore, focus on capacity building, investments in knowledge centres and training programmes, simplification of the procedure and grid improvement.

4.4. Denmark

Denmark is a pioneer and world leader in developing commercial wind power thanks to lessons learned over the years of setting up wind turbines across the country and in Europe. The Danish

[3] For example, in 2011, £6.5 million was allocated to engineering education in the UK in the hope of ushering in a generation of competent renewable energy workers. As a result, several UK universities (University of Edinburgh, Strathclyde and Exeter) have been preparing doctorate programmes starting in 2012 for up to 50 engineering students in technical aspects, as well as, in business and economics of offshore wind energy.

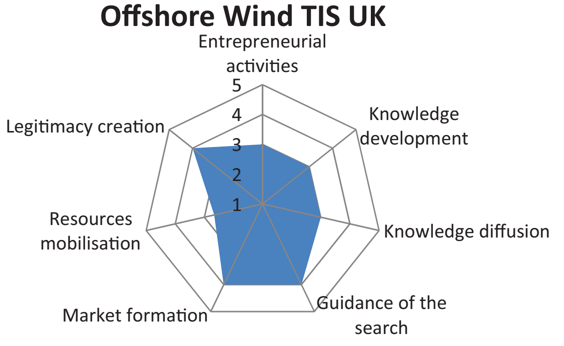

Fig. 3. Overview of system function fulfilment in the UK (Wieczorek et al., 2013).

industry has developed through systematic innovation and experience-based learning (Karnøe and Garud, 2003), which have helped to create core competencies in production, design and installation of wind turbines that are sought worldwide. Vestas dominates in Europe, having supplied 39% of installations in 2011 and having a large number of patents on its account (344). Although Dutch companies are main suppliers of vessels (they own a total of 20 vessels compared to Danish owning 10 vessels), Danish companies are in the lead in terms of heavy vessel *installation* contracts in Europe. The Danish industry is backed up by Megawind, a public–private partnership for mega wind turbines, established in autumn 2006 as part of the Danish government's action plan to promote eco-efficient technology. Denmark is also the world leader in integrating renewable and distributed energy sources into electric power systems. The country currently has about 25% wind power penetration into the system and a very good harbour infrastructure. Douglas-Westwood (2010), one of the leading energy business analysts in the world, considers Esbjerg (DK) as a European leader when it comes to the supply chain for offshore energy.

The Danish knowledge institutes rank highest internationally in terms of the number of publications on offshore wind of all the four studied countries. In particular, Risø National Lab for Sustainable Energy excels in the number of journal articles ranking 6th in the world. Two other Danish universities that closely follow Risø are Aalborg University and Technical University Denmark (DTU). Academic and polytechnic training in offshore wind in Denmark is, like research, concentrated in the same organisations. The three universities have been the forerunners in enrolling and releasing yearly a number of individual master and PhD graduates with a specialisation in various aspects of offshore wind. They also give annual dedicated master programmes with focus on or with specialisation in offshore wind technology. The universities collaborate tightly with industry. DTU (Risø) has particularly good connection with industry through a number of DTU (Risø) start-ups; Dong Energy collaborates with the Department of Energy Technology at Aalborg University; Vestas sponsors PhDs at Aalborg University while Vestas, (and Siemens and LM) have offices at DTU (Risø) and in Aalborg.

The most important incentive to promote offshore wind in Denmark is a fixed feed-in tariff. However, despite being (after the UK) the country with the second-highest technical potential for offshore wind (based on area) (EEA, 2009), the offshore market ambitions of the Danish government are limited. The reasons may be relative low energy intensity (as compared to e.g. the Netherlands) and an already high share of renewable energy in the electricity mix.

The functional analysis presented in Fig. 4 shows that, while knowledge development and diffusion is very strong, guidance of the search, market formation and entrepreneurial activities are less so. At the time of the analysis, in 2011, Denmark had a low rate of increase in installed capacity and in consented projects (EWEA, 2011a) and thus limited entrepreneurial activity. However, since autumn 2011 a new *greener* government[4] was established, which planned to set the goal to 50% of energy from

[4] http://www.denmark.dk/en/menu/About-Denmark/Government-Politics/ (accessed on April 2012).

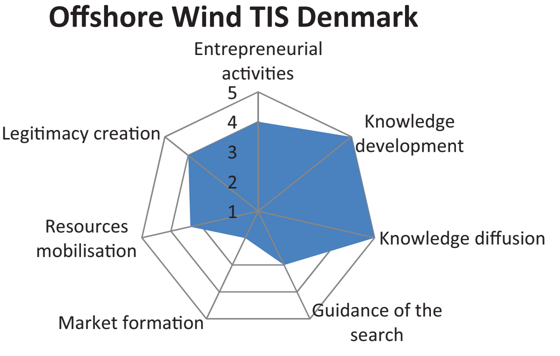

Fig. 4. Overview of system function fulfilment in Denmark (Wieczorek et al., 2013).

wind and other alternative energy sources.[5] This raised hopes among the offshore wind industry for better times and increased legitimacy of offshore wind as well as higher levels of taxes on coal and gas. Regarding financial resources, Denmark has many pension funds that invest substantially in wind. They see a long-term profit from such investment because turbines are considered very reliable and wind is generally perceived as a safe business. What is problematic is the expected lack of human resources and in particular the generation gap that can occur when current professionals will have to retire. National policy, given these findings, should focus on national market formation and investments in training programmes.

5. Beyond a national focus: domestic problems, international solutions

The analysis of the particular national systems presented in the previous section demonstrates that the countries face a number of nation-specific obstacles to the wider diffusion of offshore wind energy. Some of these obstacles may be deeply embedded in the institutional structure of the country's innovation system and, thus, not that easily changed through policy interventions. Broadening the analytical scale reveals, however, that not all national weaknesses are necessarily problematic because the actors in the different innovation systems are to a great extent internationally oriented. As a result cross-border, transnational linkages complement for missing resources and capabilities at the national level.

5.1. Transnational linkages

Exemplary is the offshore wind innovation system in the UK which, due to the lack of national manufacturing capacity and dominance of conservative fossil-fuel-based industries and power plants (KBR, 2011), is particularly open to foreign companies (actor and knowledge linkages). The international orientation of the value chain implies that significant amounts of money flow to other countries (capital linkages). Mainly Dutch companies (e.g. Balast Nedam, Mamoet van Oord, Jumbo), given

[5] At the moment of this research the New Danish Energy Agreement outlined the framework for the Danish climate and energy policy until 2020 and the direction until 2050. According to this agreement CO_2 emissions in 2020 will be 34% less than they were in 1990. Energy consumption will decrease by 12% in 2020 compared to 2006. Around 35% of the country's energy will come from renewable sources and almost 50% of electricity will come from wind. It has also been decided to build a total of 3300 MW new wind power. A part of it is two new large offshore wind farms at Kriegers Flak between Denmark and Germany (600 MW) and at Horns Reef off the west coast of Jutland (400 MW) http://www.offshorewind.biz/2012/04/16/new-danish-energy-agreement-makes-denmark-safe-investment/ (accessed on April 2012).

conditions of a limited home market, strongly rely on the availability of markets abroad, the UK in particular (Ecofys, VSF, Van Oord, 2011).[6]

The broader spatial perspective shows that the UK, being one of the biggest offshore wind markets in Europe can take advantage of the presence of competent foreign actors, several of them established offshore firms such as Van Oord, Shell, Amec and large utilities (Nuon, Eneco, E-on, Centrica, RWE, Vattenfall, Dong Energy) (actor and knowledge linkages). These companies are often transnational enterprises with sufficient resources and experience to move across borders and are not hindered by different national regulatory schemes and permitting procedures. By setting up activities in various countries, on the one hand, they contribute to national economies of the host as they make use of and contribute to localised assets (markets, knowledge, and skilled labour). On the other hand, they reach out to the global networks, through which the assets are spread and utilised (capital linkages). By using the domestic market and wind potential of the UK, foreign companies provide the domestic innovation system with access to foreign knowledge and skilled personnel (knowledge and actor linkages) and contribute to national employment creation. Given that building domestic industrial capacity in the UK may take time, attracting international actors to enter the national value chain and to make knowledge intensive investments might be a more viable short and medium-term strategy for the UK. This may of course raise legitimacy issues. If, however, the UK policy manages to stimulate these subsidiaries to become active innovators and establish linkages to local industry, such policy may also contribute to domestic industry build-up. Simplification of the permitting procedure to attract foreign firms could form the first step of this strategy.

From the Dutch national perspective stimulating the domestic market might help the Netherlands to reduce its dependency and vulnerability to decisions of the UK and could motivate domestic entrepreneurial activities of smaller companies. A functional Dutch market is also necessary for the creation of a strong European offshore wind innovation system. However, national market formation requires strong political support, stable renewable policy across consecutive government terms, an encouraging regulatory regime and effective support programmes. These, however, are either deficient or they continue to fail in achieving the ambitious goals (Ecofys, VSF, Rabobank, 2011). Under these conditions it is not surprising that Dutch firms are tapping into other markets (actor, knowledge, capital flows) and rely on higher legitimacy for offshore wind in Germany and the UK. Also, when market conditions are well taken care of nationally, firms still get involved in foreign projects.

The cross-national initiatives are not only restricted to reaping the fruits of foreign markets. Also in the area of knowledge development and exchange many international relations exist (knowledge linkages). The leading Dutch university in wind research, TU Delft, interacts more frequently with German suppliers of turbines than with national players (Wieczorek et al., 2013). In EU-funded programmes many cross-national research collaborations take place (Wieczorek et al., 2013) (knowledge linkages). These collaborations are not limited to research organisations and knowledge collaboration but also encompass companies such as Vestas, Dong, Lloyd, Garrad Hassan and Partners and involve a degree of human resource mobility (actor linkages).

Denmark does not have a very big home market. It is a small and comparatively not very energy-intensive country. It does not need all the offshore wind electricity that it has the potential to produce. Excess would need to be sold abroad. This would increase Denmark's dependence on foreign markets and given that offshore wind is still very expensive and the country operates with a feed-in tarrif, this would also imply that the Danish tax payers would have to subsidise the country's electricity exports. In case of Danish knowledge institutes and entrepreneurs, they do need foreign markets to sell knowledge and technology and stay internationally competitive (technology, knowledge and capital linkages).

The German TIS is most optimised of all four analysed systems and its operation does not seem to directly depend on the other countries' markets. It could therefore operate without a strong dependence on international collaboration. However, a well-functioning German TIS is important for the other

[6] For a detailed discussion see Wieczorek et al. (2013) where all four national value chains have been presented and discussed from the national and international perspective, i.e. who builds wind farms in the UK and how internationally active are the UK actors.

Table 1
Overview of problems based on the national TIS analyses, the linkage effects between the countries and their policy implications.

	Problem	National response	Linkage effect	Implications for problems and policy
DE	Scientific knowledge development could be better	Additional investments in national knowledge centres	Knowledge in DK and NL	Not a big problem if cooperation with foreign knowledge institutes is possible
	Lack of trained personnel	Investments in national training programmes	Cross-cutting problem	Need to cooperate to have access to wider set of resources
	Poor grid access and capacity	National action for grid improvement	Cross-cutting problem	Need to cooperate on supra grid development
NL	Lack of home market	Domestic market formation	Market in the UK and DE	Market formation less of a problem if access to neighbouring markets is possible
	Lack of legitimacy	National lobby and framing	Higher legitimacy in DE and the UK	Potential spill-over's when coordinated
	Lack of knowledge exchange	Programme to support university–industry collaboration	International knowledge exchange	No serious problem due to mobility of multinationals
	Grid in need of renovation	National action for grid improvement	Cross-cutting problem	Need to cooperate on supra grid development
	Lack of trained personnel	Investment in national training programmes	Cross-cutting problem	Need to cooperate to have access to wider set of resources
UK	Lack of home industry	Capacity building in the country	Industry in neighbouring countries	Capacity building and labour creation by foreign firms
	Lack of knowledge and experience	Investments in national knowledge centres	Knowledge in DK and NL	Need to coordinate cooperation with foreign knowledge institutes
	Lack of trained personnel	Investments in national training programmes	Active industry and knowledge institutes abroad, cross-cutting problem	Need to attract foreign personnel, educate home specialists abroad
	Poor grid access and capacity	National action for grid improvement	Cross-cutting problem	Cooperate on supra grid development
	Long and complex admin procedure	Simplification of the procedure	Selected other countries face similar problem but to a lesser extent	Need to simplify and align procedures to attract foreign companies
DK	Lack of home market	Market formation	Market in the UK and DE	Market formation less of a problem if access to neighbouring markets is possible
	Expected lack of trained personnel	Investments in training programmes	Cross-cutting problem	Need to cooperate to have access to wider set of resources

(national) TISs in Europe and it gives German industry sufficient competitive advantage to expand internationally and make use of the opportunity of earning extra benefits from international collaboration. Germany also faces what we call cross-cutting problems such as availability of trained personnel and grid quality (see Table 1). For these issues national policy makers cannot rely on potential contributions by innovation systems in other countries. However, given the already developed collaborations and interdependencies, and in view of the need for common electricity market, they might consider national grid improvements that would be compatible with the European network. That would further enhance the creation of a common European market. Collaboration is then more beneficial than proceeding solitarily.

Taking a more international perspective of the four countries demonstrates that the nation-specific obstacles identified based on the nationally delimited TISs analyses do not necessarily have to be very problematic in light of transnational linkages effects. The international orientation of national actors resolves already some of the weak parts of national offshore wind innovation systems. Table 1 summarises the nation-specific problems in the first column and the potential policy response in the second column. The third column shows how developments in neighbouring innovation systems may affect the nation-specific problems and the fourth column describes the potential impact on policies. The table shows that some of the national weaknesses may need less attention by national policy makers since the transnational linkages of the innovation systems may create effects that partly solve these issues.

5.2. International complementarities and policy implications

Our analysis shows that most of the institutional structures (in relation to market formation, legitimacy, guidance of the search) for offshore wind are strongly nation-specific but that business activities, entrepreneurs and knowledge easily move across borders (capital, actor, knowledge and technology linkages). Analytically we can separate two different policy strategies: (1) a strongly nationally oriented policy that is supportive of offshore wind and (2) an internationally coordinated policy strategy.

Strengthening of national TISs, especially in countries like the Netherlands where it is very weak, is not only important for the creation of national markets but also for the formation of the European offshore wind innovation system. It provides independence of other countries' decisions, keeps the financial returns on national investments within national borders (issue in the UK) and may be essential from an energy security perspective. It implies, however, the need to develop sufficient national capacity in all areas relevant for innovation in offshore wind, including knowledge, actors capacities and markets. Not all countries, as we have shown in Section 4, have sufficient predispositions to do that and these qualities are not easily obtainable because they are deeply rooted in historically conditioned institutions (they are e.g. manifested by a strong manufacturing culture of Germany or consultancy tradition in the UK). The financial returns argument is also tricky because in conditions of open markets and international mobility of corporations, profits captured in foreign markets usually return to the home country in the form of R&D funds fuelling national investments in technology development. This is, however, not the case for offshore wind in the UK: two of the 5 research centres of Vestas: Vestas Turbines R&D and Vestas Technology UK Ltd, are located in the UK. Strengthening of national TISs without collaboration may also mean less learning from other contexts and other practices.

As a think piece for the second strategy we refer to Fig. 5. This figure illustrates the functioning of all four offshore wind national innovation systems and it adds a virtual "North-Western European" offshore wind innovation system. This interrelated perspective on the innovation systems shows that there is a lot of potential through increased coordination. The countries together seem to have all necessary ingredients for well-functioning North-Western European TIS. Weaknesses in one country are compensated by strengths in other countries. While the Netherlands, for example, specialises primarily in the construction of wind farms with focus on foundations, Denmark in wind turbine manufacturing and heavy vessels, the UK in sub-sea cables installation. Germany is active in many areas of the value chain and has an attractive market. While the Netherlands has a strong research-oriented knowledge base, Germany is leading in engineering knowledge. Denmark covers the knowledge base most comprehensively but has lower market ambitions. The UK, despite its shortcoming in knowledge and domestic industry, has huge market potential and best climatic conditions for offshore wind parks. From this perspective it may thus make sense to develop a common or at least more closely coordinated North-Western European policy and action plan related to offshore wind. Such a collaborative effort is in a much better position to optimise the use of the various assets in the four countries analysed in this paper than when each country tries to focus solely on strengthening its domestic innovation system. Moreover, some shortcomings in national systems may be of a more persistent nature due to

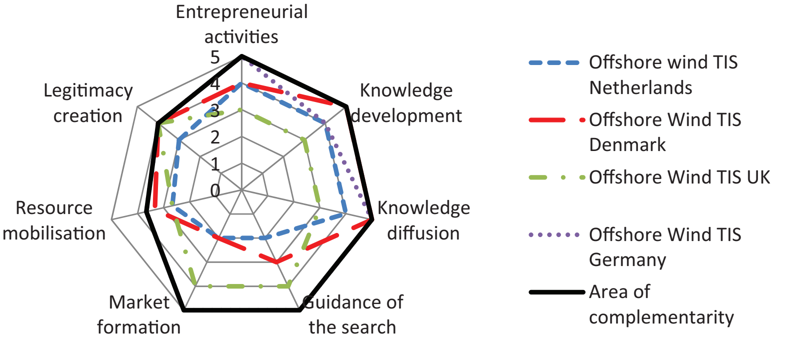

Fig. 5. System functions fulfilment in the four analysed countries in 2011 (Wieczorek et al., 2013).

place-based path-dependencies and institutional embeddedness (e.g. the Dutch preference for cost-efficient renewable energy policy, the UK's lack of domestic offshore industry or Denmark's relatively mature and saturated wind market). Solutions to these problems may not always be addressed effectively through national policy interventions as they need to 'work against the system' and are thus easily victim to *policy-failure*. In this light, stimulating or strengthening transnational linkages may offer a more conducive way to approach domestic problems in the innovation system. In Appendix C, we propose how this collaborative vision could be realised.

When coordinated policy is not possible or not aimed for by national policy makers, the linkages effects between innovation systems are still very relevant. We conclude, therefore, that explicit acknowledgement of the institutional embeddedness and transnational linkages of nationally delineated technological innovation systems has a substantial impact on the analysed strengths and weaknesses of an innovation system and the policy recommendations that follow from the analysis. Based on this empirical analysis we concur with the contribution by Coenen et al. (2012) who claim that analysts should be more explicit in taking the geographical context of a nationally delineated TIS into account.

We have also shown that coordinated policy efforts beyond national boundaries may be worthwhile exploring. In addition to the earlier described complementarities of the national offshore wind TIS there are other arguments why a coordinated policy effort is worthwhile exploring. The first is that in case of a coordinated effort, the locations for offshore wind farms are not related to national interests but to arguments of lowest construction costs and highest wind speeds.[7] Another argument is that in order to drive the costs down it is necessary to experiment with new turbine designs and foundations. A larger market makes it easier to invest in innovation and experimentation zones. Third, a homogeneous North-European market gives greater certainty, security and flexibility than in case of a sum of (varied) national markets since supranational policies are generally more stable than national policy plans. Fourth, a common market may help maximise the European competitive advantage before other regions do it cheaper since a European perspective can make optimal use of national strengths and thereby speed up knowledge development and innovation. Fifth, in the current decade North-Western European countries face a new energy investment cycle and the infrastructure built several decades ago is in need of replacement. Its gradual substitution with a European grid would make it easier for the Member States to manage variable electricity generation from many distributed sources and diminish the need for (expensive) storage facilities. It would also contribute to the reduction of even deeper dependence on the fossil resources.

[7] Realisation of this potential would imply the necessity to quit national and introduce a European subsidy scheme for offshore wind.

6. Conclusions

In this paper we aimed to address the myopic bias of the national focus of the TIS studies. We used offshore wind in North-Western Europe as empirical evidence of interconnectedness and interdependency of four offshore wind TISs in 2011: the UK, Denmark, Germany and the Netherlands.

At the conceptual level we showed that an explicit acknowledgement of the role of transnational linkages in the domestic TIS performance and a stronger appreciation of the territorially specific institutional embedding of a national TIS has implications for the type of conclusion that are drawn from the systemic analysis and the type of policy strategy. TIS studies should not underestimate the persistence of certain systemic problems due to path-dependencies and institutional embeddedness. Rather than a quick policy fix, addressing these problems may very well require gradual institutional change. Related to this, we also conclude that it is indeed useful to assess national TIS in relation to their wider international context and that studying several national TISs helps shed light on their interactions. In some cases, national system failures are effectively counteracted by the characteristics of the innovation systems in related countries. We propose that a focus on a limited number but carefully selected national TISs that are interconnected (by e.g. being part of the same value chain), may be more revealing and less complex than trying to get grips of the complete global TIS (for a similar reflection see Binz et al., 2014).

Related to the empirical case, we observe that according to the national analyses the countries face a number of nation-specific obstacles to the wider diffusion of offshore wind energy. Broadening of the analytical scale reveals, firstly, that the differences in the inclination to innovate in offshore wind and the related problems are conditioned by *deep* country-specific institutional circumstances. Out of the four analysed TISs, Germany is being characterised by the strongest support from the national institutions, while the Netherlands by the least. Because offshore wind as a technological field transcends national borders, actors in a nationally delineated TIS make use of strengths of other innovation systems. As a consequence, innovation systems may partly complement each other's deficiencies. These linkages effects make the countries mutually interdependent and may qualify the nation-specific obstacles to be less of a challenge for the overall TIS. Secondly, explicit inclusion of spatial sensitivity to the analysis of particular national TISs reveals that the countries face a set of common, non-idiosyncratic problems, which form a serious obstacle to innovation in offshore wind. National policies based on protection of national industry and markets are not able to address these problems in an effective and sustained way. We show that an internationally coordinated, systemic policy may be more effective in dealing with these problems and at the same time make it possible to fully exploit national synergies. Thus, selective cooperation between countries in technology development and aligned policy instruments could potentially be a very effective way to speed up technological transitions.[8]

By way of future outlook, it should be noted that in this paper we did four separate TISs analyses yet incorporated transnational linkages and institutional embeddedness explicitly in the analysis. For future research it would be recommended not to take national boundaries as a starting point but rather look at how the actors in the TIS define the system themselves following their value chains: where the market is, where knowledge is generated, which (territory-specific) institutions matter for the various actors; how the actors are influenced by certain institutions, how their investment decisions are influenced etc. and subsequently construct the system in a bottom-up way. This would also give analysts a chance to assess which institutions matter most, whether these institutions are related to market formation or to knowledge generation, directions of search, entrepreneurial experimentation, etc. This would also free the analysts from imposing institutions on actors.

[8] It should be noted that in spite of policy coordination, individual firms may very well chose to refrain from international collaboration or choose its collaborators selectively in light of competition aspects in an open market.

Appendix A.

Semi-structured interviews (ca 1 h each) during EWEA Conference, 29 November–1 December, 2011, Amsterdam, The Netherlands with representatives of:

4C Offshore, UK, Director Product Development
A2Sea, Denmark, Business Developer
Alstom, The Netherlands, Country Sales Director, Grid
DONG Energy, Denmark (Dong DK), Senior Manager Operations and O&M Management
DONG Renewable Energy, UK (Dong, UK), Offshore wind Project Development Manager
Ecofys, Wind Energy, The Netherlands, Unit Manager
Esbjerg Business Development Centre, Denmark, Business Consultant
EWEA, Brussels, Research Officer 1
EWEA, Brussels, Research Officer 2
EWEA, Brussels, Policy Lobbyist
Germanischer Lloyd Renewable Certification (GL), Germany, Head of Group Project Management
JDR Cable Systems LTD, UK, Sales Director
Jutlandia, Denmark, HSEQ Manager
KBR Power, UK, Senior Business Developer
KBR Power, UK, Technical Professional
Kema, Arnhem, The Netherlands, Consultant Wind Energy
MPI Workboats, UK, Operations Manager
Netherlands Wind Energy Association (NWEA), The Netherlands, Senior Advisor
Offshore Centre Denmark (OCD), Renewables Manager
PMSS, UK, Director
Rabobank, The Netherlands, Senior Associate
RenewableUK, UK, Offshore wind Development Manager
RWE; Germany, Executive Support Manager
Seas NVE, Denmark, Project Engineer
Seas NVE, Denmark, Project Manager
Siemens Wind Power A/S, Denmark, Strategic Recruiting Specialist
Technical University Delft, Professor of Future Energy Systems
Siemens Wind Power A/S Germany, Senior Sales and Marketing Manager
Typhoon Offshore, UK, Head of UK Operations
Van Oord Offshore Wind Projects BV, The Netherlands, Regional Manager
Volker Staal en Funderingen (VSF), The Netherlands, Director
Volker Staal en Funderingen (VSF), The Netherlands, Project Engineer

A working session (ca 8 h) on systemic policy for offshore wind in the Netherlands and Europe, 21 June 2012, Utrecht, The Netherlands with:

Van Oord, ECN, NWEA Manager Business Development
FLOW, Director
Offshore Monthly, Rotation Consultancy, Expert
Ampelmann TU Delft, Project manager, CEO, Nuon/Vattenfall, Manager Offshore New Developments
Out-Smart, Founder and CEO

Appendix B.

Diagnostic questions to determine the functioning of innovation systems

Key process/functions	Diagnostic question
Entrepreneurial activities	- Are there sufficient[a] and suitable types of actors contributing to entrepreneurial experimentation and up-scaling? - Are the amount and type of experiments of the actors sufficient? - How much technological up-scaling takes place?
Knowledge development	- Are there enough actors involved in knowledge development and are they competent? - Is the knowledge sufficiently developed and aligned with needs of actors in the innovation system?
Knowledge exchange	- Are there sufficient network connections between actors through which knowledge is exchanged?
Guidance of the search	- Do actors and institutions provide a sufficiently clear direction for the future development of the technology?
Market formation	- Is the size of the market sufficient to sustain innovation and entrepreneurial experimentation?
Resource mobilisation	- Is the availability of financial resources sufficient? - Are there sufficient competent actors/well trained employees? - Is the physical infrastructure sufficient?
Creation of legitimacy	- Do actors, formal and informal institutions sufficiently contribute to legitimacy? - How much resistance is present towards the technology, project set up or permit procedure?

[a] Since innovation does not recognise an optimum, it is impossible to judge whether there is *enough* of it. Our discussion on the *sufficiency* of innovative activity in the areas defined by the system functions is, therefore, based on the qualitative evaluation of the capacity of the four analysed systems to grow and accelerate. At the same time we refrain from any quantitative assessment in the context of reaching the European and national targets.

Appendix C.

Elements of collaboration-based European policy on offshore wind

C.1. Market Harmonisation Action

While the electricity market liberalisation process in Europe is underway, several countries lie behind and the level of integration of the national markets is low. The liberalisation process is also designed to support established large-scale conventional power generators with limited space to alternative providers (EWEA, 2012). The Market Harmonisation Action would be a mechanism, through which the regulatory framework behind the liberalisation process is redesigned to make space for renewable energy sources. It would also aim at developing a power-trading framework including harmonised market rules and support mechanisms (e.g. green certificates or tax exemptions). One of the important outcomes of the Action would be the creation of a European subsidy scheme and a level playing field for all power technologies by, among others, the removal of subsidies for fossil fuels and nuclear energy.

C.2. EU Grid Initiative

In the first period of its operation, the Initiative would provide a platform for discussing the future European electricity transmission network. The aim would be to align the varying visions and expectations but also provide space for national diversity and a step-wise, organic, grid reinforcement. Such an organic model would be more receptive to on-going natural developments and would allow countries to benefit from each other. Other outcomes of the Initiative would be the establishment of a clear legal framework for pan-European transmission management including binding guidelines and network codes. Such framework is considered indispensable for the North Sea states' ability to set and maintain the development of a shared transmission network in a mutually beneficial way (Woolley, 2013). The Initiative would build upon and bring together or cooperate with other current initiatives by various parties such as by OffshoreGrid,[9] TEN-E Programme[10] or ENTSO-E.[11]

C.3. R&D and Demo Programme

The objectives of this programme are: the development of low-cost technologies, optimisation of the value chain and improving the economics of offshore wind by setting the green value of kWh, the most efficient manner to trade it within Europe, evaluation of the effectiveness of the various support schemes (FIT, subsidies) and the strategies for their potential timely phase out. The programme would particularly encourage university–industry collaboration and would have two modules. By default, it would support projects that are *feasible*. However, it would also have substantial budget available to making projects *profitable*. Proponents of the latter, to be eligible for funds, would need to demonstrate the outcomes of their work in the Innovation Zones (described below).

C.4. Innovation Zones

Innovation Zones are test fields: dedicated spaces at sea or parts of existing wind farms that expedite first generation of projects and technologies before their commercial scale-up. The data and experiences (including failures) gathered in the Innovation Zones would be fed into a monitoring evaluation programme, an open database, with the aim to facilitate better-informed decisions on second generation projects.

C.5. Expert Mobility Programme

Expert Mobility Programme is part of the R&D and Demo Programme and aims to support offshore wind researchers in gaining practical experience by spending 1–2 years in the industry or in Innovation Zones. Such a programme would facilitate skills development, knowledge diffusion and reduction of training costs. It would also encourage greater collaboration between business and academia and support the process of trust building and network expansion.

C.6. European Technology Platform

A European Technology Platform (TPWind) and a SET Plan (incl. EERA Wind) already exist and fulfil their function of fora for the crystallisation of policy and technology research and development pathways for the wind energy sector. It also provides an opportunity for informal collaboration among Member States. Support to such programmes or their successors should continue. Such initiatives support network formation, confidence building and setting of the R&D priorities.

C.7. European Offshore Wind Academy

Europe already has a European Academy of Wind Energy, which focuses on training experts in both onshore and offshore wind energy. We suggest, given the severe deficiency of high and middle level offshore wind technicians, to establish a European Offshore Wind Academy dedicated to emerging and urgent issues of the offshore wind system. The Academy would provide a variety of vocational and academic training and take a form of cooperation between the leading knowledge institutes and industrial partners. The Academy would complement the national educational efforts by e.g. stimulating international collaboration on PhD projects.

---

[9] www.offshoregrid.eu (accessed on April 2012).

[10] www.ec.europa.eu/energyinfrastructure/tent_e/tent_e_en.htm (accessed on April 2012).

[11] www.entsoe.eu (accessed on April 2012).

References

Alok, J., 2008. UK Overtakes Denmark as World's Biggest Offshore Wind Generator. The Guardian (London), 21.11.08.

Amin, A., Cohendet, P., 2004. Architectures of Knowledge. Firms, Communities and Competencies. Oxford University Press, Oxford.

Asheim, B.T., Coenen, L., 2005. Knowledge bases and regional innovation systems: comparing nordic clusters. Res. Policy 34, 1173–1190.

Bergek, A., Jacobsson, S., Carlsson, B., Lindmark, S., Rickne, A., 2008. Analyzing the functional dynamics of technological innovation systems: a scheme of analysis. Res. Policy 37, 407–429.

Berkhout, F., Wieczorek, A.J., Raven, R., 2011. Avoiding environmental convergence: a possible role for sustainability experiments in latecomer countries? Int. J. Inst. Econ. 3 (2), 367–385.

Binz, C., Truffer, B., Coenen, L., 2014. Why space matters in technological innovation systems – mapping the global knowledge dynamics of membrane bioreactor technology. Res. Policy 43 (1), 138–155.

Binz, C., Truffer, B., Li, L., Shi, Y., Lu, Y., 2012. Conceptualizing leapfrogging with spatially coupled innovation systems: The case of onsite wastewater treatment in China. Technol. Forecast. Soc. 79, 155–171.

Binz, C., Truffer, B., 2012. Conceptualizing leapfrogging with spatially coupled innovation systems: the case of onsite wastewater treatment in China. Technol. Forecast. Soc. 79 (1), 155–171.

Capros, P., Mantzos, L., DeVita, N., Tasios, A., Kouvaritakis N., 2010. Trends to 2030-Update 009, European Commission-Directorate General for Energy in Collaboration with Climate Action DG and Mobility and Transport DG. Office for official publications of the European Communities, Luxembourg, ISBN 978-92-79-16191-9.

Carlsson, B. (Ed.), 1997. Technological Systems and Industrial Dynamics. Kluwer Academic Publishers, Boston, Dordrecht, London.

Carlsson, B., Stankiewicz, R., 1991. On the nature, function, and composition of technological systems. J. Evol. Econ. 1, 93–118.

Carlsson, B., 2006. Internationalization of innovation systems: a survey of the literature. Res. policy 35 (1), 56–67.

Chesbrough, H.W., 2003. Open Innovation: The New Imperative for Creating and Profiting from Technology. Harvard Business Press.

Coenen, L., Benneworth, P., Truffer, B., 2012. Towards a spatial perspective on sustainability transitions. Res. Policy 41, 968–979.

Coenen, L., Diaz-Lopez, F., 2010. Comparing systems approaches to innovation and technological change for sustainable and competitive economies: an explorative study into conceptual commonalities, differences and complementarities. J. Clean. Prod. 18 (2), 1149–1160.

Coenen, L., Raven, R., Verbong, G., 2010. Local niche experimentation in energy transitions: a theoretical and empirical exploration of proximity advantages and disadvantages. Technol. Soc. 32, 295–302.

Coenen, L., Truffer, B., 2012. Places and spaces of sustainability transitions: geographical contributions to an emerging research and policy field. Eur. Plan. Stud. 20 (3), 367–374.

Cooke, P., 2001. Regional innovation systems, clusters and the knowledge economy. Ind. Corp. Change 10 (4), 945–974.

Cooke, P., Morgan, K., 1993. The network paradigm: new departures in corporate and regional development. Environ. Plan. D 11, 543–564.

Corbett, A., (unpublished Ph.D. thesis) 2002. Ideas, Institutions and Policy Entrepreneurship in European Community Higher Education, 1955–95. University of London.

De Jager, D., Klessman, C., Stricker, E., Winkel, T., de Visser, E., Koper, M., Ragwitz, M., Held, A., Resch, G., Busch, S., Panzer, C., Gazzo, A., Roulleau, T., Gousseland, P., Henriet, M., Bouille, A., 2010. Financing Renewable Energy in the European Energy Market, Project No. PECPNL084659. Ecofys, European Commission, DG Energy, Belgium.

De Vries, E., 2012. Rotation Consultancy, WindpowerMonthly, Personal communication, April.

Deutsche Bank Climate Change Advisors, 2011. UK Offshore Wind: Opportunity, Cost and Financing.

Dewald, U., Truffer, B., 2011. Market formation in technological innovation systems—diffusion of photovoltaic applications in Germany. Ind. Innov. 3 (18), 285–300.

Douglas-Westwood, 2010. Offshore Wind: Building an Industry. Analysis and scenarios for industrial development, www.renewable-uk.com

Dunning, J.H., Lundan, S.M., 2009. The MNE as a creator, fashioner and respondent to institutional change. In: Collinson, S., Morgan, G. (Eds.), The Multinational Firm. Blackwell Publishers, Oxford.

Edquist, C. (Ed.), 1997. Systems of Innovation: Technologies, Institutions and Organizations. Pinter Publishers, London.

Edquist, C., Lundvall, B.A., 1993. Comparing the Danish and Swedish systems of innovation. Nat. Innov. Syst., 265–298.

EEA, 2009. Europe's Onshore and Offshore Wind Energy Potential. Technical Report No. 6/2009.

EU, 2011. European Union Roadmap for Moving to a Competitive Low Carbon Economy in 2050, vol. 112. COM, Brussels, EU.

EWEA, 2011a. Wind in Our Sails – The Coming of Europe's Offshore Wind Energy Industry. The European Wind Energy Association, 11/2011.

EWEA, 2011b. Pure Power, Wind energy targets for 2020 and 2030.

EWEA, 2012. Creating internal energy market in Europe, September.

Freeman, C., 1987. Technology Policy and Economic Performance. Pinter Publishers, London.

Gee, S., McMeekin, A., 2011. Eco-innovation systems and problem sequences: the contrasting cases of US and Brazilian biofuels. Ind. Innov. 18 (3), 301–315.

Gertler, M.S., 2004. Manufacturing Culture: The Institutional Geography of Industrial Practice. Oxford University Press, Oxford and New York.

Hall, P.A., Soskice, D., 2001. An introduction to varieties of capitalism. In: Hall, P.A., Soskice, D. (Eds.), Varieties of Capitalism: The Institutional Foundations of Comparative Advantage. Oxford University Press, Oxford, pp. 1–70.

Hekkert, M., Suurs, R., Negro, S., Kuhlmann, S., Smits, R., 2007. Functions of innovation systems: a new approach for analysing technological change. Technol. Forecast. Soc. 74, 413–432.

Heptonstall, P.R., Greenacre, G.P., Cockerill, T., 2012. The cost of offshore wind: understanding the past and projecting the future. Energy Policy 41, 815–821.

Hillman, K., Suurs, R., Hekkert, M., Sanden, B., 2008. Cumulative causation in biofuels development: a critical comparison of the Netherlands and Sweden. Technol. Anal. Strat. Manag. 20, 592–612.
Jacobsson, S., Bergek, A., 2011. Innovation system analyses and sustainability transitions: contributions and suggestions for research. Environ. Innov. Soc. Trans. 1 (1), 41–57.
Jacobsson, S., Karltorp, K., 2013. Mechanisms blocking the dynamics of the European offshore wind energy innovation system – challenges for policy intervention. Energy Policy 63 (12), 1182–1195.
Jacobsson, S., Karltorp, K., 2012. Formation of competencies to realize the potential of offshore wind power in the European Union. Energy Policy 44, 374–384.
Jacobsson, S., Lauber, V., 2006. The politics and policy of energy system transformation – explaining the German diffusion of renewable energy technology. Energy Policy 34, 256–276.
Jensen, M.B., Johnson, B., Lorenz, E., Lundvall, B.Å., 2007. Forms of knowledge and modes of innovation. Res. policy 36 (5), 680–693.
Karnøe, P., Garud, G., 2003. Bricolage versus breakthrough: distributed and embedded agency in technology entrepreneurship. Res. Policy 32 (2), 277–300.
Klein-Woolthuis, R., Lankhuizen, M., Gilsing, V., 2005. A system failure framework for innovation policy design. Technovation 25, 609–619.
KPMG, 2010. Offshore Wind in Europe. 2010 Market Report.
Laranja, M., Uyarra, E., Flanagan, K., 2008. Policies for science, technology and innovation: translating rationales into regional policies in a multi-level setting. Res. Policy 37 (5), 823–835.
Lundvall, B.Å. (Ed.), 1992. National Systems of Innovation – Toward a Theory of Innovation and Interactive Learning. Pinter Publishers, London.
Lundvall, B.Å., Maskell, P., 2000. Nation states and economic development–from national systems of production to national systems of knowledge creation and learning. In: Clark, G.L., Feldman, M.P., Gertler, M.S. (Eds.), The Oxford Handbook of Economic Geography. Oxford University Press, Oxford, pp. 353–372.
Makridis, C., 2013. Offshore wind power resource availability and prospects: a global approach. Environ. Sci Policy 33, 28–40.
Malerba, F., 2002. Sectoral systems of innovation and production. Res. Policy 31, 247–264.
Markard, J., Petersen, R., 2009. The offshore trend: structural changes in the wind power sector. Energy Policy 37 (9), 3545–3556.
Markard, J., Raven, R., Truffer, B., 2012. Sustainability transitions: an emerging field of research and its prospects. Research Policy 41 (6), 955–967.
Metcalfe, S., Ramlogan, R., 2008. Innovation systems and the competitive process in developing economies. Q. Rev. Econ. Finance 48 (2), 433–446.
Negro, S., Hekkert, M., 2008. Explaining the success of emerging technologies by innovation system functioning: the case of biomass digestion in Germany. Technol. Anal. Strat. Manag. 20, 465–482.
Negro, S., Hekkert, M., Smits, R., 2007. Explaining the failure of the Dutch innovation system for biomass digestion – a functional analysis. Energy Policy 35, 925–938.
Nelson, R.R. (Ed.), 1993. National Systems of Innovation. A Comparative Analysis. Oxford University Press, Oxford.
Nooteboom, B., 2000. Learning and Innovation in Organizations and Economies. Oxford University Press.
Patel, P., Pavitt, K., 2000. National systems of innovation under strain: the internationalisation of corporate R&D. In: Productivity Innovation and Economic Performance. Cambridge University Press, pp. 217–235, ISBN 521780314.
Raven, R., Schot, J., Berkhout, F., 2012. Space and scale in socio-technical transitions. Environ. Innov. Soc. Transit. 10 (4), 63–78.
Rodríguez-Pose, A., 2013. Do institutions matter for regional development? Reg. Stud. 47 (7), 1034–1047.
Saxenian, A.L., 2005. From Brain Drain to Brain Circulation: Transnational Communities and Regional Upgrading in India and China, Studies in Comparative International Development.
SER, 2013. Energieakkoord voor duurzame groei.
Smith, K., 2000. Innovation as a systemic phenomenon: rethinking the role of policy. Enterp. Innov. Manag. Stud. 1, 73–102.
Späth, P., Rohracher, H., 2012. Local demonstrations for global transitions—dynamics across governance levels fostering socio-technical regime change towards sustainability. Eur. Plan. Stud. 20 (3), 461–479.
Storper, M., 1997. The Regional World: Territorial Development in a Global Economy. Guilford Press.
The Crown Estate, 2011. Report from the Financing Sub-group to the Offshore Wind Developers Forum, 21 June, 2011.
Truffer, B., Coenen, L., 2012. Environmental innovation and sustainability transitions in regional studies. Reg. Stud. 46 (1), 1–21.
Vogel, D., 1997. Trading up and governing across: transnational governance and environmental protection. J. Eur. Public Policy 4 (4), 556–571.
Wieczorek, A.J., Hekkert, M., 2012. Systemic instruments for systemic innovation problems: a framework for policy makers and innovation scholars. Sci. Public Policy 39, 74–87.
Wieczorek, A.J., Negro, S.O., Harmsen, R., Heimeriks, G.J., Hekkert, M.P., 2013. A review of the Western European offshore wind innovation system. Renew. Sustain. Energy Rev. 26, 294–306.
Wieczorek, A.J., Raven, R., Berkhout, F., 2014. Transnational linkages in sustainability experiments. The case of solar PV in India. Environ. Innov. Soc. Transit. (submitted for publication), paper presented at IST conference Zurich in June 2013.
Woolley, O., 2013. Governing a North Sea grid development: the need for a regional framework treaty. Compet. Regul. Netw. Ind. 14 (1), 73–97.
Zimmerman, M.A., Zeitz, G.J., 2002. Beyond survival: achieving new venture growth by building legitimacy. Acad. Manag. Rev. 27 (3), 414–431.