Systemic policy for offshore wind challenges in Europe

Anna J. Wieczorek
Robert Harmsen
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1 Innovation Studies, Copernicus Institute of Sustainable Development, Faculty of Geosciences, Utrecht University, Heidelberglaan 2, 3584 CS Utrecht, The Netherlands *Corresponding author. Email: A.J.Wieczorek@uu.nl, Phone: +31 30 253 1625, Fax: +31 30 253 2746

2 Institute for Environmental Studies, Vrije Universiteit Amsterdam, de Boelelaan 1085, 1087 HV Amsterdam, The Netherlands

Abstract

This paper discusses systemic problems hindering the large-scale European diffusion of offshore wind technology using the Technological Innovation System perspective. The most urgent identified problems include: cost of technology, lack of common vision on grid improvement, fragmented European electricity market, reliability and availability of technology, limited grid access and capacity as well as serious deficiency of high and middle level personnel. To address the problems the paper proposes a systemic policy package composed of such elements as: Innovation Zones, Expert Mobility Programme and Grid Initiative. The paper argues that a European coordinated action is beneficial not only for EU but also for its Member States.

Key words
Systemic problems, systemic policy framework, technological innovation system, systemic instruments, offshore wind

1. Introduction

A central finding in innovation studies is that innovation is not created in isolation but is a result of a cooperative process taking place within a context of an innovation system. The concept of the innovation system stresses that the flow of technology and information among people, firms and institutions is key to an innovative process. It stresses the interaction between actors who are needed to turn an idea into a successful process, product or service in the market. This changed view of innovation has shifted the policy attention away from problems of market failure towards the systemic problems that hinder the operation and the development of innovation systems (Klein-Woolthuis et al., 2005; Chaminade and Edquist, 2010; Jacobsson and Bergek 2011; Negro et al, 2012). To address the problems new forms of instruments became necessary that operate at the system level as opposed to traditional, predominantly financial policy tools that focus on R&D production and either support individual elements of the system or stimulate bilateral relations (Smits and Kuhlmann, 2004, Metcalfe, 1995). The new tools are called systemic instruments and are explicitly defined for specific innovation systems.
(Wieczorek and Hekkert, 2012). The instruments’ purpose is to create opportunities and conditions for system’s formation that would not emerge spontaneously. Of critical importance for the design of the most appropriate systemic instrument(s) is therefore a thorough system’s analysis and identification of problems that prevent the system from developing. As of now, there is no empirical evidence of existing systemic instruments that were designed based on systematic innovation system’s study. There are however examples of tools that have features of systemic instruments and are described as systemic instruments avant la lettre in the innovation literature (Smits and Kuhlman, 2004; Mierlo et al, 2010). In terms of a possible shape, systemic instruments can either take the form of programmes or be smart compositions of individual (traditional, e.g. financial, regulatory, participatory etc) tools that together reinforce each other and are able to address the systemic problems in an orchestrated way. Systemic innovation policy instruments are therefore policy mixes but explicitly designed to target the systemic problems of the innovation system.

Renewable energy receives increasing scientific and policy attention for its potential role within a portfolio of low-carbon and cost-competitive energy technologies competent of responding to the emerging major challenges of energy security, climate change, and access to energy. In Europe, in the next decades, renewable energy is expected to move to the centre of the energy mix. Offshore wind energy is an important element of the European commitment cutting greenhouse gas emissions by 80–95% below 1990 levels by 2050 (EU, 2011). Owing to the national support schemes and the commitment of the industry, offshore wind has developed quite remarkably over the recent years. While in the early 90’s 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 3294 MW providing Europe with 35,000 jobs (EWEA, 2011b). Offshore wind energy also has a great deployment potential, estimated by the European Wind Energy Association (EWEA) at the level of 40 GW in 2020, (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 allow meeting 5% of the EU’s total electricity demand (Capros et al., 2010). It would also provide significant employment opportunities (170,000 jobs in 2020) and help various countries diversify their energy sources (EWEA, 2011a).

Renewable technologies, however, are often described as hopeful monstrosities (Mokyr, 1990). They are crude and inefficient, far from optimised, badly adapted, with small advantage or none. The innovation systems around such technologies are incomplete and emergent and hence heavily dependent on various forms of public support. At the same time these immature systems are expected to compete with very efficient, well organised and optimised incumbent (fossil fuel-based) systems. Paradoxically, renewables frequently have to compete with each other. Offshore wind is no exception in that regard. Despite its recent rapid development it remains a relatively young and expensive technology, far from being competitive on the energy market and highly dependent on national subsidy schemes. Some of the specific problems that hinder its quick diffusion in Europe include a serious shortage of high and middle level technicians, non-aligned national regulatory frameworks and poor grid infrastructure (Wieczorek et al, 2012). Timely and systemic resolution of the problems is critical for the strengthening of the innovation system around this technology and setting it on the long-term path towards a
competitive system. It is believed that without this fastest growing (in EU projections) renewable energy option, achievement of the ambitious European goals will be very difficult (Capros et al., 2010).

In our earlier work we have in detail analysed the European offshore wind innovation system in 2011 (Wieczorek et al. 2012). In this paper we discuss what systemic problems the offshore wind system faces and, given the existing nationally oriented policies, what ideal policy package could be deployed at a European level to address the problems in an orchestrated manner. To discuss the problems and suggest systemic policy we make use of the Technological Innovation System (TIS) perspective (Hekkert et al., 2007) and in particular the systemic policy framework (Wieczorek and Hekkert, 2012).

Our European conclusions are purely based on the insights from four European countries that in 2011 had the largest online offshore wind capacity: the UK (1586MW), Denmark (854MW), the Netherlands (247MW) and Germany (195MW) (EWEA, 2011a). Each of these countries faces systemic challenges and a national systemic policy could be proposed to address them. Our ambition, however, is to draw conclusions for the European policy for a number of reasons. Firstly, a common European effort to meet the targets as described in the National Renewable Energy Action Plans (NREAPs) and EU documents (EU, 2008, 2011) implies lower transformation costs and lower risk in case some countries withdraw. Secondly, a common European energy market gives greater certainty, security and flexibility than in case of a sum of (varied) national markets. Thirdly, in the current decade European countries face a new energy investment cycle when infrastructure built several decades ago is in need of replacement. Its gradual substitution with a European smart grid would make it easier for the European countries 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 the risk of even deeper dependence on the fossil resources.

The rest of the paper is constructed in the following way. In section 2 we present the systemic policy framework. In Section 3 we shortly summarise the current state of the European offshore wind TIS. In Section 4 we discuss problems that hinder this system functioning. In Section 5 we propose systemic policy to tackle the identified challenges. The paper closes with concluding remarks in Section 6.

2. TIS and the systemic innovation policy framework

Technological Innovation System (TIS) is a particular case of an innovation system built around specific technology. TIS is also a theoretical approach that helps to describe, analyse and understand the diffusion of particular technological innovations (Hekkert at al. 2007; Jacobsson and Bergek, 2012). The TIS approach has been translated into an analytical model - the 5-stage systemic policy framework (Wieczorek and Hekkert, 2012) that is used to identify barriers that hamper the development of the system and to arrive at policy recommendations that would help accelerate the diffusion and implementation of the new technologies (see Figure 1). The framework connects four innovation system concepts: structure, functions, problems and instruments (goals and design)¹ and is meant for research

¹ The concepts have been developed relatively separately from each other and for long used individually to inform innovation policy processes (see e.g. Klein-Woolthuis, 2005; Hekkert et al., 2007).
and policy that aim to understand and stimulate conditions for technological innovations (Wieczorek and Hekkert, 2012).

Figure 1. A systemic innovation policy framework (Wieczorek and Hekkert, 2012)

Stage 1 – structural analysis

Every innovation system is built of certain elements that are called structural elements or dimensions. They include: actors, institutions, infrastructure\(^2\) and interactions. Actors interact with each other in a specific institutional and infrastructural context. The elements’ presence or absence as well as capacity or capabilities (when we talk about actors) have impact on the system’s proper functioning. In the context of this framework therefore the structural analysis denotes: (i) mapping of the structural dimensions of the analysed system (are they present or missing?) and (ii) evaluating their capabilities (Can actors innovate? Are regulations supportive? Are interactions strong enough?).

Stage 2 – functional analysis

Systems can be built in a similar way but they may perform very differently. Structural analysis therefore needs to be complemented by an analysis that helps evaluate how the system functions – the so-called functional analysis. In this stage seven functions are assessed by policy makers and innovation experts: entrepreneurial activities (F1), knowledge development (F2), knowledge diffusion (F3), guidance of the search (F4), market formation (F5), resource mobilisation (F6) and legitimacy creation (F7) (as described by Hekkert et al., 2007). A set of diagnostic questions are developed for each of the functions that help assess whether e.g. entrepreneurial activities are strong or weak (see Appendix A). The functional

\(^2\) Infrastructure includes: physical (artifacts), knowledge (know-how) and financial (capital) elements.
analysis may also be carried out based on a longitudinal analysis of events specific to each of the functions (as in e.g. Negro and Hekkert, 2007).

**Stage 3 – systemic problems’ identification**

The functions signal problems but because they cannot be directly modified by policies they need to be studied through the perspective of the earlier mapped structural dimensions (e.g. are entrepreneurial activities weak because entrepreneurs are missing or because they have poor innovation capabilities?). This way the functional analysis complements the structural one by being a demonstration of the way in which an innovation system is organised. Relating functions to the structural dimensions is also critical for the identification of problems that hinder the development of the analysed system. Because problems within any system are caused by issues with the systems' elements or their properties, four types of systemic problems can be identified in innovation systems: actor problems, institutional problems, interaction problems and infrastructural problems. Each of the problems can be caused by the absence of the structural dimension, e.g. entrepreneurs are missing (presence aspect) or by its inappropriate attributes, e.g. institutions are too stringent or interactions are too weak (we call it a capacity/capability aspect of a problem).

**Stage 4 – systemic instruments’ goals**

Systemic problems call for systemic policy instruments. A systemic policy instrument is defined as an integrated coherent set of tools designed for a specific innovation system. Systemic instruments to be able to address all types of systemic problems, should focus on one or more of the eight goals that are strongly linked with the typology of the problems (see Table 1).

**Table 1. Goals of systemic instruments per (type of) systemic problem (Wieczorek and Hekkert, 2012)**

<table>
<thead>
<tr>
<th>Systemic problem</th>
<th>(Type of) systemic problem</th>
<th>Goals of systemic instrument</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actors problems</td>
<td>Presence?</td>
<td>1. Stimulate and organise the participation of relevant actors</td>
</tr>
<tr>
<td></td>
<td>Capabilities?</td>
<td>2. Create space for actors capability development</td>
</tr>
<tr>
<td>Interaction problems</td>
<td>Presence?</td>
<td>3. Stimulate occurrence of interactions</td>
</tr>
<tr>
<td></td>
<td>Intensity?</td>
<td>4. Prevent too strong and too weak ties</td>
</tr>
<tr>
<td>Institutional problems</td>
<td>Presence?</td>
<td>5. Secure presence of hard and soft institutions</td>
</tr>
<tr>
<td></td>
<td>Capacity?</td>
<td>6. Prevent too weak and too stringent institutions</td>
</tr>
<tr>
<td>Infrastructural problems</td>
<td>Presence?</td>
<td>7. Stimulate physical, financial and knowledge infrastructure</td>
</tr>
<tr>
<td></td>
<td>Quality?</td>
<td>8. Ensure adequate quality of the infrastructure</td>
</tr>
</tbody>
</table>

**Stage 5 – systemic instruments’ design**

In stage 5 systemic policy is designed based on a selection of individual policy tools that together can address the identified obstacles in an organised way. The proposed systemic instrument should be a mechanism that allows involved actors coordinate their activities and align their individual objectives with the goal of the system development. Since policy making should be a cyclic process, the effectiveness of the applied instrument can be evaluated (and adjusted if necessary) in another framework cycle (Wieczorek and Hekkert, 2012).
In this paper we first shortly summarise the current state of the European offshore wind TIS following stages 1-2 presented in our earlier work (Wieczorek et al, 2012). We then concentrate on discussing the systemic problems and most adequate policy response (following stages 3-5 of the systemic framework).

### 3. European offshore wind TIS in 2011

#### Stage 1 – structural analysis

The structural analysis of the European offshore wind TIS shows that from an innovation perspective, offshore wind is a young but very dynamic system driven by the engineering knowledge developed by in-house R&D centres of the industry. The following table (Table 2) presents the summary of the results of the structural analysis.

**Table 2. Summary of the results of the structural analysis of the European offshore wind (based on Wieczorek et al 2012)**

<table>
<thead>
<tr>
<th>Structural dimension</th>
<th>Findings (related either with the presence or capacity of the structural dimensions)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Actors</strong></td>
<td></td>
</tr>
<tr>
<td>Governmental organisations</td>
<td>Whereas in Denmark the entire offshore wind process is administered by one agency, in the UK, the Netherlands and Germany many different ministries are responsible for different aspects of the offshore wind procedure</td>
</tr>
<tr>
<td>Knowledge institutes</td>
<td>Public research organisations lead in publishing on offshore wind, especially Risø (DK) and TU Delft (NL)</td>
</tr>
<tr>
<td></td>
<td>There are less Danish and Dutch knowledge institutes than German and the UK but they publish most internationally</td>
</tr>
<tr>
<td>Educational organisations</td>
<td>Offshore wind educational courses are few and recently developed</td>
</tr>
<tr>
<td></td>
<td>Denmark and the Netherlands are frontrunners in academic and polytechnic training in offshore wind. The UK is catching up in expectation of rapid market development</td>
</tr>
<tr>
<td></td>
<td>Vocational training is offered mainly by companies and often by those serving offshore industry</td>
</tr>
<tr>
<td></td>
<td>Countries in Europe cooperate on providing integrated trainings related to offshore wind such as the European Academy of Wind Energy and European Wind Energy Master</td>
</tr>
<tr>
<td>Industrial actors</td>
<td>Contrary to the UK, Dutch companies are very internationally oriented</td>
</tr>
<tr>
<td></td>
<td>The development, ownership, operation and management of wind farms is mostly performed by national companies</td>
</tr>
<tr>
<td></td>
<td>Large utilities dominate as owners, developers and operators particularly in the UK</td>
</tr>
<tr>
<td></td>
<td>Many established offshore firms are present in the UK, Danish, Dutch and German projects</td>
</tr>
<tr>
<td></td>
<td>The UK innovation system is most open to foreign actors of all four systems</td>
</tr>
<tr>
<td></td>
<td>Manufacturing of turbines and supply of substructures observe an increase of new entrants</td>
</tr>
<tr>
<td>Support organisations</td>
<td>There are few new entrants in the area of high voltage sub-sea cables</td>
</tr>
<tr>
<td>Networks</td>
<td></td>
</tr>
<tr>
<td>Knowledge networks</td>
<td>University-industry collaborations in journal publications are sparse and predominantly take place over short distances, with most co-authorship within the country</td>
</tr>
<tr>
<td></td>
<td>Industry does not publish in fear of their strategic knowledge being disseminated into the wrong hands</td>
</tr>
<tr>
<td>EU research projects</td>
<td>University-industry collaborations on EU research projects are more frequent than on journal articles</td>
</tr>
<tr>
<td></td>
<td>The informal industry-university networks in Denmark and Germany are tight</td>
</tr>
<tr>
<td>Lobby networks</td>
<td>There are a number of European and national political networks that lobby for offshore wind. Still oil and gas lobby is more powerful and better organised</td>
</tr>
<tr>
<td>Industrial networks</td>
<td>There are a number of strong industrial networks in Europe and at national levels</td>
</tr>
<tr>
<td>Institutions</td>
<td></td>
</tr>
<tr>
<td>Renewable energy targets and financial</td>
<td>There are considerable differences in regulations and financial incentives among the European countries. The process of institutional alignment is under way but incomplete</td>
</tr>
</tbody>
</table>
incentives
- All countries have binding renewable energy targets for 2020. The (indicative) role of offshore wind in meeting these targets is important but differs from country to country.

Infrastructural policies
- There is a lack of regulatory framework on electricity trade and grid development across Europe with few steps taken by Germany, the UK and the EU as a whole towards harmonised grid measures.

Expectations, social acceptance, routines and culture
- There are sporadic issues with public acceptability of the technology in some countries due to environmental and seascape impacts and lack of consultation with some stakeholders (e.g. fishermen in Scotland). However, social acceptance of offshore wind is hardly a topic of debate.
- Offshore wind has to compete with other renewables, especially in the eyes of politicians.
- Germany’s strong manufacturing culture results in strong engineering knowledge and manufacturing capacity. Strong academic culture in the Netherlands results in strong codified knowledge and an absence of a home market where the knowledge can be applied.

Infrastructure

Knowledge infrastructure
- Engineering knowledge developed at in-house R&D centres of firms drives the system development.
- Codified knowledge production on offshore wind takes place in public research organisations and is not directly connected to industry.
- Technological opportunities in offshore wind are not dependent on major scientific work at universities.
- Vestas and Siemens are in the top world companies patenting in the field of wind turbines and vessels.

Physical infrastructure
- There are large technical challenges for the design of turbines and tests are underway with 4-12 new turbines expected to enter the market later this decade; still further R&D is needed to make the technology cost-effective.
- If the offshore wind sector expands to meet the climate targets, availability of cables and vessels may become a serious constraint.
- Availability of substructures is good in Europe but requires constant innovation.
- Many of the Dutch, Danish, German and the UK harbours are suitable for large logistical offshore operations. Still serious adjustments are necessary to meet the needs of offshore wind industry.
- There is an emergence of strong offshore wind clusters around many European offshore harbours.
- Europe’s electricity grid is a sum of national grids and multiple markets. The amount of traded electricity is very low. Larger amounts of renewable electricity are challenging grid capacity.
- Early initiatives are underway to enhance the capacity and access to the grid.

Financial infrastructure
- The availability of funds for capital costs is problematic and increasing number of actors (utilities, banks, insurers) need to be involved to make projects bankable.

Stage 2 – functional analysis

The functional pattern of the offshore wind innovation TIS in the UK, Denmark, the Netherlands and Germany in 2011 (Figure 2) was determined based on interviews with over 30 stakeholders (Appendix B), using a set of diagnostic questions (Appendix A) as well as the desk top research (Wieczorek et al, 2012). Figure 2 shows that entrepreneurial activities score relatively strong in all four countries but are strongest in Germany. In knowledge creation it is Denmark that excels while the UK scores relatively low. Germany is strong in engineering knowledge production while the Netherlands produces high level scientific knowledge. Knowledge diffusion is strongest in Germany and Denmark but weak in the UK. Guidance of the search is by far the strongest in Germany, strong in the UK but very weak, almost absent in the Netherlands. In Denmark the guidance is not strong but is on a rise due to new green government established in fall 2011. Market formation processes are the most advanced in Germany and in the UK, but very weak, almost non-existent in the Netherlands and Denmark. Resource mobilisation is equally weak in all four analysed TISs, while legitimacy creation scores on average slightly higher than the previous function, but is evenly weak in all four cases.
Figure 2. System functions fulfilment in the four analysed countries in 2011 (Wieczorek et al., 2012)

The two analyses summarised above preliminarily indicate that the individual, nationally delimited TISs do not function to their best and are hampered on various dimensions. Together, however, they seem to complement each other and we can witness the emergence of a strong European offshore wind TIS. In particular, we can observe that despite the immaturity of the technology and its costs, entrepreneurs are active, knowledge is being developed and shared, markets are (selectively) formed and expectations grow. What seems problematic from the European perspective are legitimacy creation processes (F7) and resource mobilisation (F6). Furthermore, except for the fact that these two are equally weak in all four countries, there is quite a large distribution of strengths and weaknesses in the remaining five functions but especially in the market formation (F5) and guidance of the search (F4). To verify and to understand why this is the case, in the following section, we examine which of the structural elements or their properties cause the problems. While demonstrating and discussing issues that are at play at national level in the four countries, we focus on identifying most severe systemic problems that block the European diffusion of the offshore wind technology.

4. What hinders the development of the European offshore wind TIS?

Stage 3 – systemic problems’ identification

The entrepreneurial activities (F1) are quite strong in all four countries: the value chains, especially in Germany, the Netherlands and Denmark consist of a number of strong incumbents (who contribute most to entrepreneurial activities) and a growing number of new entrants (EWEA, 2011a; RWE, A2Sea, OCD, Van Oord, 2011). There is also quite a degree of competition in the system (Jutlandia, Esbjerg, PMSS, Typhoon Offshore, VSF, Rabobank, JDR, 2011). This is seen as a positive factor stimulating the
development of an immature offshore wind technology (Jutlandia, Seas NVE, 2011). The UK, due to lack of national manufacturing capacity and dominance of conservative fossil fuel based industries and power plants (KBR, 2011), is particularly open to foreign companies. At the national, UK level, this may raise legitimacy issues but from the European perspective, this openness of the UK system is beneficial to the formation of the European system and allows for increased European collaboration. Mainly, the Dutch construction companies, in conditions of a limited home offshore wind market, make good use of this opportunity (Ecofys, VSF, Van Oord, 2011). This fosters European cooperation along the value chain and is a sign of strong specialisation of the Netherlands in the construction business. At the national, Dutch level, entrepreneurial activities suffer from the lack of political support. The changing renewable policy of consecutive cabinets results in a changing regulatory regime and ineffective support programmes that fail to assist in achieving the ambitious goals (Ecofys, VSF, Rabobank, 2011). Denmark had a low rate of increase in installed capacity in 2011 (EWEA, 2011a) and limited entrepreneurial activity. However, since autumn 2011, Denmark has a new greener government, which raises hopes among entrepreneurs for new pro-renewables politics (Dong DK, Seas NVE, Jutlandia, OCD, 2011). In Germany, where the government is committed and the feed-in tariff does its job, entrepreneurial activities are not hindered by any specific factor (RWE, 2011). We conclude therefore that from a European perspective the entrepreneurial activities are somewhat hindered by the absence of a common European market and a lack of unified regulatory schemes but this does not stop companies from operating internationally. Especially the strong incumbent companies have sufficient resilience and resources to operate in these rather unfavourable conditions.

Even though offshore wind is an emerging field, there seems to be enough knowledge produced (F2) not to create a serious barrier for the system development in Europe (RWE, Siemens, Seas NVE, Jutlandia, Esbjerg, OCD, NWEA, A2Sea, JDR, 2011). The number of knowledge institutes doing research on offshore wind is large and increasing. In the Netherlands ECN and TU Delft are the world experts in codified knowledge on offshore wind. However, limited governmental commitment results in a poor domestic market, and creates rather unfavourable R&D conditions. Germany excels in the engineering knowledge production as observed in the high level of patents by Siemens (Eize de Vries, 2012, RWE, Siemens, 2011). Codified knowledge in Germany is produced in a great number of institutes and it is difficult to assess whether this dispersed model hinders or stimulates the knowledge development. It may possibly have negative implications for creation of critical mass and for stimulation of education that is close to research (Staffan Jacobsson, 2012). On the other hand, however, this may also be an indication that offshore wind is a popular research area. In the UK the knowledge base on offshore wind does not have a long tradition and is only now being organised (KBR, 2011). In 2011 it was quite fragmented (large number of institutes with 1 article per institute). As a result the UK does not specialise in any of the offshore wind areas (yet) and is quite dependent on knowledge produced elsewhere. This may have a negative impact on the education of skilled offshore wind labour in the UK but is not perceived by the stakeholders as a factor that hinders the European system development (KBR, Dong UK, 2011). In Denmark the knowledge base, both codified and engineering is in a good shape (TUD and Risø with good publication records and patents by Vestas) (Seas NVE, Jutlandia, Siemens, OCD, 2011), but what creates uncertainty for companies who plan R&D investments in Denmark is that the R&D programmes are negotiated annually as part of the government’s fiscal budget and not on a longer term perspective. We
conclude therefore that from a European perspective, knowledge development on offshore wind is not significantly hindered. On contrary, countries seem to complement each other in the various types of knowledge.

What seems problematic about knowledge but only in selected countries is its diffusion (F3). Our analysis reveals that the offshore wind innovation system is driven by the engineering (tacit) type of knowledge, which is difficult to disseminate (VSF, Van Oord, RWE, Siemens, MPI, Kema, 2011). Companies are not very eager to share their know-how in fear of losing their competitive advantage (VSF, Dong DK, Dong UK, Rabobank, A2Sea, MPI, 2011; Eize de Vries, 2012). Also the transfer of university knowledge to a specific context of application is challenging, particularly in the Netherlands. The Dutch knowledge institutes have a high publication record and they claim to work closely with industry, but the industry does not patent (VSF, Kema, 2011), and knowledge produced at universities (e.g. on rotor techniques) does not translate into a national manufacturing capacity. The small domestic market additionally does not allow for an immediate feedback from the industry to university. In Germany and Denmark the situation is different: there are large and informal industry-university networks and both countries have a good record of effective university-industry collaboration (Jutlandia, OCD, Dong DK, Seas NVE, Siemens, RWE, 2011). Hence diffusion of knowledge in both countries is much stronger than in the Netherlands. The UK has not yet developed any significant expertise that can be diffused to other countries. At the European level the presence of strong lobby networks such as EWEA and its national associates positively influences knowledge diffusion. Stakeholders also feel that when necessary, parties can easily find each other (MPI, JDR, RenewableUK, 4COffshore, KBR, PMSS, Typhoon Offshore, 2011). We conclude therefore that issues related to knowledge diffusion are country specific and can therefore be addressed in the national context. From the European perspective knowledge diffusion is not significantly hindered.

Guidance of the search (F4) is in all four countries driven by a strong expectation of large market and extensive employment possibilities (Kema, RWE, Dong UK, KBR, RWE, 2011). It is, however, hindered by the uncertainty around wind turbine technology, availability of specialised vessels and cables supply (especially HV cables) and increasing costs per kWh (all interviewees confirm that). Furthermore, despite the Memorandum of Understanding for EU offshore super-grid\(^3\), there is still a lack of clear grid strategy (EWEA, 2011c; Ecofys, Seas NVE, Esbjerg, OCD, NWEA, A2Sea, RenewableUK, 4C Offshore, KBR, 2011) and of a truly European market which, to some extent, hinders guidance of the search. Also, since offshore wind is a young technology it strongly depends on political support (Rabobank, GL, Kema, EWEA, 2011. The national governments, however, are not always stable in their commitments (JDR, 2011). Particularly in the Netherlands, the unfavourable policy for renewables, and absence of a suitable support scheme, have negative impact on the guidance of the search (Ecofys, NWEA, Rabobank, Alstom, RWE, 2011; Verdong and Wetzels, 2012). The Green Deal, negotiated by the Dutch offshore wind industry in October 2011 is a sign of its determination, but is criticised for being a camouflage for the government’s lack of vision and determination to act and take its earlier renewable energy commitments and obligations seriously (Eize de Vries, 2012). In Denmark, guidance of the search was in

2011 also hindered by the lack of strong governmental commitment but is improving ever since a new green cabinet took over in October 2011\(^4\) and released the New Danish Energy Agreement (Dong DK, Seas NVE, Jutlandia, OCD, A2Sea, 2011). In the UK the guidance of the search seems strong (RenewableUK, Dong UK, KBR, PMSS, 2011, BWEA, 2011, The Crown Estate, 2011; Department of Energy and Climate Change, 2011), but administrative barriers, such as a great number of authorities involved in the authorisation procedure and a slow approval rate, have a negative impact on this function (RenewableUK, KBR, 2011). Also, according to the report by the Committee on Climate Change, the UK’s offshore wind ambitions for 2020 can be reduced if lower-cost alternatives can be found (Windpower Monthly, 2011). In Germany, who has a committed government that recently made the decision to phase out nuclear power from the country and that believes in the power of mass deployment to reduce the costs (Windpower Monthly 2011), this function is not visibly hindered (RWE, Siemens, GL, 2011). In that view we reckon that weak guidance of the search at the European level and in particular the varied levels of political support are a derivative of the low legitimacy of the technology caused by its costs (institutional problem), reliability and availability (physical infrastructure problem). Problematic are also grid access and capacity (physical infrastructure problem), lack of common strategy on grid improvement and the fragmented European electricity market (institutional problems).

Market formation (F5) in Europe is strongly driven by the expectation of big returns, long-term commitments of the German\(^5\) (RWE, 2011) and the UK (Dong UK, KBR, 2011) governments\(^6\) and the determination of the Dutch industry (Van Oord, 2011). At the same time, however, market formation in Europe is currently and in the future stalled by a number of barriers. First are issues related with grid connection and feeding-in of the growing amount of offshore wind power into the existing network (Rabobank, NWEA, Ecofys, Alstom, Seas NVE, Siemens, OCD, 2011), as well as the availability of cables and specialised vessels that can work on deeper waters far offshore (VSF, Van Oord, Siemens, RenewableUK, 2011). These are technical barriers caused by the high cost of the technology, which make offshore wind still fully dependent on the support of subsidy schemes (Rabobank, 2011). Second challenging issue is the increasingly hampered access to funds that can help cover capital costs of wind farms construction (Ecofys, Van Oord, RWE, Siemens, Dong UK, Rabobank, Jutlandia, Esbjerg, A2Sea, PMSS, Typhoon Offshore, 2011). Financial crisis and the related increased perception of risk cause that banks reduce their renewable energy projects funds, hence more financial organisations and more insurers are needed before the project is made bankable (EWEA, 2012; Wind directions, 2012; Guillet, 2011; KPMG, 2010; Van Oord, Rabobank, 2011). Third barrier is the serious shortage of human capital (mainly engineers) (RenewableUK, 2011a; Kema, Dong UK, JDR, RenewableUK, 4C Offshore, KBR, GL, Seas NVE, Siemens, OCD, Typhoon Offshore, PMSS, VSF, Van Oord, 2011, INTPOW, 2011, Jacobsson and Kaltrop, 2012)). Fourth obstacles to market formation are the non-aligned institutions, especially

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\(^6\) [http://www.thecrownestate.co.uk/media/229356/owdf_04_01_finance_group_paper.pdf](http://www.thecrownestate.co.uk/media/229356/owdf_04_01_finance_group_paper.pdf) accessed April 2012
regarding the grid and trade of electricity in Europe. In particular, the current market rules and institutional frameworks do not facilitate the integration of any renewable technology including offshore wind (JDR, PMSS, RWE, 2011). EWEA (2012) reports a lack of level playing field caused by low level of liberalisation of European electricity markets. In the result large incumbents and huge subsidies to fossil fuels and nuclear energy dominate and create additional risks and costs to offshore wind and other renewables (A2Sea, 2011). Finally, some countries such as the UK are in serious need of adjusting their harbours’ infrastructure and organising the incentives for the development of clusters around the ports. This issue is urgent for the UK’s market formation (KBR, 2011). From the European perspective it will become pressing when the offshore wind system expands (EWEA, 2011a). Again that background we can summarise that market formation in Europe is hindered mainly by the shortage of resources: human (actors problem), and financial (financial infrastructure problem), all caused by the low legitimacy and as underlying reason – the high costs of the technology (institutional problem). Insufficient grid infrastructure (physical infrastructure problem), lack of common strategy on its renewal and fragmented electricity market (institutional problems), are other serious factors blocking the European market formation processes.

Resource mobilisation (F6) is, on the one hand, driven by a certain financial situation in some countries due to long-term commitments (UK and Germany), a growing number of educational courses in all four countries and intensifying EU collaboration on education (European Academy of Wind Energy and European Wind Energy Master). On the other hand, however, despite the efforts, all analysed countries still experience a deficiency of skilled labour (all interviewees; INTPOW, 2011, Jacobsson and Kaltrop, 2012), while Denmark additionally faces a generation gap expecting many current professionals to retire (OCD, Alstom, JDR, 2011). Among other issues that hinder resource mobilisation are: availability of finance for growing capital costs of wind farm construction, the grid access and capacity, and availability of cables (Siemens, RenewableUK, 2011). The lack of European regulations and a common vision on possible grid reinforcements make any coordinated action at a European level difficult. In the Netherlands the perception of the technology as being very expensive, compared to natural gas, create a lack of urgency and a significant slowdown of resource mobilisation. So does the strong and well organised oil and gas lobby. In summary, the resource mobilisation process in Europe is blocked by deficiency of high skill labour (actors’ problem), difficult access to finances (financial infrastructure problem), grid access and capacity (physical infrastructure problem) and what causes it, lack of common vision on grid refurbishment, common electricity market (institutional problems) and reduced legitimacy caused by the high costs of the technology (institutional problem).

There are a number of factors that positively influence legitimacy creation (F7) in Europe: the EU Roadmap to 2050 (EU, 2011), 20/20/20 goals (EU, 2008), NREAPs; furthermore the perception of offshore wind as fastest growing renewable, a lack of significant societal resistance, good support programmes in Germany and the UK, and the industrial lobby in the Netherlands. However, legitimacy creation is a serious problem for the European offshore wind innovation system and has impacts on other functions: guidance of the search and resource mobilisation. The major reason is the cost, availability and reliability of technology. Offshore wind is just one of the alternatives to the (strongly subsidised) fossil fuels and so it has to face competition from other renewables in gathering attention
and financial resources (Jacobsson and Karltorp, 2012; A2Sea, 2011). Uncertainties around grid connection and lack of common vision on its renewal also have negative impact on legitimacy creation. Although the societal acceptance of the technology is currently good (VSF, Van Oord, RWE, Siemens, MPI, Kema, Dong DK, Seas NVE, Jutlandia, OCD, NWEA, JDR, Alstom, Dong DK, JDR, EWEA 2011) and the presence of large utilities as owners and operators of national projects necessary for this early stage of system development (A2Sea, 2011), in the long term, their dominance needs attention. In particular the incumbents need to be well balanced by new entrants of SME character (KBR, 2011). According to Markard and Petersen (2010) the social acceptance of the technology applied in projects is partially based on access to public finance by smaller parties. If the funds are continually streamlined to the large utilities this may raise issues regarding the legitimacy of the system. In the UK this holds an extra risk of reduced legitimacy in which case not only large but also foreign companies benefit most from national efforts. Overall there are also high expectations with regards to robustness of the technology which might develop into a hindering factor if not fulfilled after the testing period (which for wind turbines is about 10-15 years). We conclude therefore that legitimacy issues are caused mainly by the cost and reliability of technology (institutional and infrastructural problem) and to some extent by high-strung expectations (institutional problem).

The following table presents the overview of problems behind the seven functions.

**Table 3. Problems causing weakness or absence of the functions in the EU offshore wind innovation system**

<table>
<thead>
<tr>
<th>Function</th>
<th>Type of problem</th>
<th>Problems</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1 Entrepreneurial activities</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>F2 Knowledge development</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>F3 Knowledge diffusion</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
| F4 Guidance of the search | Institutional | • Cost of technology  
• Lack of common vision on grid improvement  
• Fragmented European electricity market |
| | Infrastructural | • Reliability and availability of technology (cables, vessels, turbines)  
• Grid access and capacity |
| F5 Market formation | Actors | • Deficiency of engineers |
| | Institutional | • Lack of common vision on grid improvement  
• Fragmented European electricity market |
| | Infrastructural | • Reliability and availability of technology (cables, vessels, turbines)  
• Grid access and capacity  
• Availability of finance |
| F6 Resource mobilisation | Actors | • Deficiency of engineers |
| | Institutional | • Cost of technology  
• Lack of common vision on grid improvement  
• Fragmented European electricity market |
| | Infrastructural | • Reliability and availability of technology (cables, vessels, turbines)  
• Grid access and capacity |
| F7 Creation of legitimacy | Institutional | • Cost of technology  
• Overheated expectations |
| | Infrastructural | • Reliability and availability of technology (cables, vessels, turbines) |
Based on this analysis we conclude that legitimacy creation (F7) is the critical factor in the formation of the European offshore wind innovation system and has strong impact on the other innovation system processes, in particular the resource mobilisation (F6). Both functions F6 and F7 effect market formation (F5) and in some countries guidance of the search (F4). Even though the entrepreneurial activities (F1) as well as knowledge creation and diffusion (F2 and F3) are currently strong in Europe, in the long run, they may get negatively affected by the increased deficiency of resources (F6), the uneven market formation (F5) and what causes it, the reduced legitimacy of the technology (F7). We therefore suggest that addressing of the legitimacy problems (F7) and simultaneously improving resource mobilisation processes (F6) are key to improving the performance of the remaining system processes due to the feedback loops that exists between the functions. In practice, improvement of the two processes implies tackling of three types of problems that cause them:

1. Institutional problems:
   - Cost of technology (F4, F6, F7)
   - Lack of common vision on grid improvement (F4, F5, F6)
   - Fragmented European electricity market (F4, F5, F6)
2. Infrastructural problems:
   - Reliability and availability of technology (especially cables, vessels, turbines) (F4, F5, F6, F7)
   - Grid access and capacity (F4, F5, F6)
3. Actors problem
   - Serious deficiency of personnel (F5, F6)

We consider the above problems systemic because they negatively impact almost all European offshore wind innovation system processes (as indicated above in the brackets) and effectively block the build-up of the system.

5. Systemic policy for the European offshore wind innovation system

Stage 4 - goals of the systemic policy

If the offshore wind innovation system is expected to contribute to the European goals of climate change reduction and stimulation of green growth, the systemic problems identified in the earlier section require a systemic, coordinated policy effort at a European level. Following step 4 of the systemic policy framework we suggest four broad goals of policy in support of this system:

1. Fast reduction of costs and increase of reliability of the technology to support the large scale diffusion of offshore wind technology and tackle the legitimacy issues.
2. Development of common grid to support market formation processes.
3. Integration of a European electricity market, to stimulate employment, contribute to the increased national turnovers and level up the unbalanced national markets.
4. Creation of space for education of the high and middle level engineers to address the problem of human resource deficiency, support market formation and increase of legitimacy.
In the next stage we suggest how to achieve these goals in a coordinated manner.

**Stage 5 - systemic policy proposal**

Policy design is not a practice of research but of the governmental organisations. It is always about making choices from the possibilities offered by the given historical situation and cultural context (Howlett, 2011). Furthermore, the scope of this paper does not allow for a complete analysis of current offshore wind policy and instruments. We therefore do not pretend to be in a position to suggest the best design of policy that would tackle the above identified problems in line with the suggested policy goals. We also do not pretend to be complete in our suggestions. However, based on our analysis we would like to make proposition as to some elements that could possibly be taken into account by the European policy makers dealing with the offshore wind system obstacles. They are shortly described below.

**R&D and Demo Programme**

The main objectives of the R&D and Demo programme would be the development of low cost technologies, in particular turbines, specialised vessels, cables, foundations and substations and optimalisation of the entire value chain. Second focus would be the economics of offshore wind: setting of the green value of kWh, the most efficient manner to trade it within Europe as well as the evaluation of the effectiveness of the various support schemes and the strategies for their timely phase out. The programme would particularly encourage university-industry collaboration and would oblige the proponents to demonstrate the outcomes of their work in the Innovation Zones (described below). All research results should have an open character and data as well as empirical statistics fed into an open database.

**Innovation Zones**

Innovation Zones could form a part of the R&D and Demo Programme. Practically, Innovation Zones are test fields: dedicated spaces at sea where new innovations and techniques can be developed and tested before application in the commercial wind farms. Given the tendency of offshore wind farms to go further offshore and towards harsher conditions, areas in which such tests are necessary include: wind turbines, foundations, connection to grid, installation techniques, management and logistics, farm maintenance, transport etc. The data and experiences (including failures) gathered in the Innovation Zones would be brought together in a database and by obligation made publically available.

**Expert Mobility Programme**

Expert Mobility Programme is also part of the above mentioned R&D and Demo Programme and aims to support offshore wind researchers who wish to gain practical experience by spending one to two years in the industry. Such a programme would facilitate skills development and knowledge diffusion. It would also encourage greater collaboration between business and academia and would support the process of trust building and network formation.
European Technology Platform

A European Technology Platform (TPWind) already exists and fulfils its function of a forum for the crystallisation of policy and technology research and development pathways for the wind energy sector, as well as an opportunity for informal collaboration among Member States. Support to the programme or its successor should continue beyond its official end date of 2014. Such support serves well network formation, confidence building and setting of the R&D priorities.

European Offshore Wind Academy

Europe does already have 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. It would take a form of cooperation between the leading knowledge institutes and industrial partners with international steering board deciding on the curriculum and its periodical adjustment. The curriculum itself should be both theoretical as well as practical with the obligation imposed on participants to spend a significant number of hours at the (demonstration) wind farms or in the Innovation Zones. It is also suggested that the academy is mobile i.e. the countries (either knowledge institutes or industries) take turns in hosting the Academy in their premises with the aim to train local experts. The Academy should complement the national educational efforts.

Grid Initiative

Within the Grid Initiative a number of interrelated issues would be tackled. The Initiative would provide a platform for discussing the future European electricity transmission network. The aim would be to align the various visions and expectations on the one hand but provide space for national diversity and step wise grid reinforcement, on the other. Specific tools that can be used to facilitate such process are foresight, backcasting and visioning. Other outcomes of the Grid Initiative would be the establishment of a clear legal framework for pan-European transmission management including binding guidelines and network codes. The Grid Initiative would build upon and bring together all current initiatives by various parties such as by OffshoreGrid7, TEN-E Programme8 or ENTSO-E9. Another outcome of the Grid Initiative could be the establishment of an internationally owned and managed offshore Transmission System Operator.

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

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7 www.offshoregrid.eu, accessed April 2012
9 www.entsoe.eu, accessed April 2012
regulatory framework behind the liberalisation process could be revaluated and 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 (such as green certificates or tax exemptions). One of the important outcomes of the Action would be the creation of a level playing field for all power technologies by, among others, the removal of subsidies for fossil fuels and nuclear energy.

All above suggested mechanisms should be interlinked and coordinated by an EU organisation. We expect their impact is not only confined to addressing of the individual identified problems, but that it is much broader and helps deal with numerous barriers at the same time (see Table 5). Furthermore, being designed for the European level, the policy package addresses not only European systemic problems but it also facilitates solution of national systemic problems. If successful, the package can significantly improve the level playing field for other renewables.

Table 5. Summary of the systemic problems in the EU offshore TIS and the expected area of impact of proposed systemic policy elements

<table>
<thead>
<tr>
<th>Type of systemic problem</th>
<th>Systemic problems in the EU offshore wind TIS</th>
<th>Function blocked</th>
<th>Systemic instrument elements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actors’ problems</td>
<td>Deficiency of human capital (engineers)</td>
<td>F5, F6</td>
<td>European Offshore Wind Academy Expert Mobility Programme R&amp;D and Demo Programme Innovation Zones</td>
</tr>
<tr>
<td>Institutional problems</td>
<td>Cost of technology</td>
<td>F4, F6, F7</td>
<td>Innovation Zones R&amp;D and Demo Programme Market Harmonisation Action</td>
</tr>
<tr>
<td></td>
<td>Lack of coordinated vision on grid improvement</td>
<td>F4, F5, F6</td>
<td>Grid Initiative R&amp;D and Demo Programme European Technology Platform</td>
</tr>
<tr>
<td></td>
<td>Fragmented market</td>
<td>F4, F5, F6</td>
<td>Market Harmonisation Action R&amp;D and Demo Programme European Technology Platform</td>
</tr>
<tr>
<td>Infrastructural problems</td>
<td>Reliability and availability of technology</td>
<td>F4, F5, F6, F7</td>
<td>Innovation Zones R&amp;D and Demo Programme European Technology Platform</td>
</tr>
<tr>
<td></td>
<td>Grid access and capacity</td>
<td>F4, F5, F6</td>
<td>Grid Initiative Innovation Zones R&amp;D and Demo Programme European Technology Platform</td>
</tr>
</tbody>
</table>

6. Conclusions

Offshore wind belongs to the portfolio of low-carbon energy technologies competent of responding to the emerging challenges of energy security, climate change and access to energy\(^\text{10}\) (Wieczorek et al., 2012). Like other renewables, however, offshore wind is a *hopeful monstrosity*, which has to compete with an established fossil fuel based energy system in circumstances of a missing level playing field. European policy next to stimulating equal opportunities may also create conditions that strengthen and trigger the development of an innovation system around this technology.

In this paper we discuss the most urgent problems that hinder the diffusion of the European offshore wind technology using the TIS perspective and in particular the systemic policy framework. The identified obstacles include: cost, reliability and availability of technology; grid access and capacity; lack of common vision on grid improvement; fragmented European electricity market as well as deficiency of engineers. We conclude that the identified problems have a systemic nature because they hinder the functioning for the entire system. In particular they block two system functions: legitimacy (F7) and resource mobilisation (F6), which, through the feedback within the system, negatively influence the remaining functions F1-F5. We therefore suggest that addressing the obstacles that deter the two system functions F6 and F7 is key to improve the performance of the entire offshore wind TIS in Europe.

Our conclusions on European level are purely based on insights from the four studied countries that in 2011 had the highest online offshore wind capacity: Denmark, the UK, Germany and the Netherlands. In the paper we show that despite that each of the countries face a number of problems that hinder national offshore wind TISs, together however, the countries complement each other in terms of knowledge development, value chain specialisation as well as markets; and the emergence of a strong European offshore wind TIS can be observed. We argue therefore that problems that manifest themselves at national levels such as slow consenting procedure (UK) or poor cooperation between university and industry (NL) can effectively be addressed by the countries themselves. Problems that manifest themselves at the European level require a coordinated European action and collaboration.

Using the systemic policy framework we propose goals and elements of such a systemic innovation policy. We recommend that the European policy package in support of the offshore wind system includes following elements: European Offshore Wind Academy, Expert Mobility Programme, R&D and Demo Programme, Innovation Zones, Market Harmonisation Action, European Technology Platform, Grid Initiative. We expect that these elements reinforce and complement each other and are not confined to address individual problems but have an impact that is much broader and helps deal with numerous barriers at the same time. We also anticipate that solving European problems will facilitate solution of issues within particular Member States at lower costs and with less risk.

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### Appendix A

Diagnostic questions to determine the functioning of innovation systems

<table>
<thead>
<tr>
<th>Key process</th>
<th>Diagnostic question</th>
</tr>
</thead>
</table>
| Entrepreneurial activities | - Are there sufficient\(^{11}\) and suitable types of actors contributing to entrepreneurial experimentation and upscaling?  
                          - 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? |

\(^{11}\) 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 B

Personal communications during EWEA Conference, 29 November-1 December, 2011, Amsterdam, The Netherlands with representatives of:

4C Offshore, UK
A2Sea, Denmark
Alstom, The Netherlands
DONG Energy, Denmark (Dong DK)
DONG Renewable Energy, UK (Dong, UK)
Ecofys, Wind Energy, The Netherlands
Esbjerg Business Development Center, Denmark
EWEA, Brussels
Germanischer Lloyd Renewable Certification (GL), Germany
JDR Cable Systems LTD, UK
Jutlandia, Denmark
KBR, UK
Kema, Arnhem, The Netherlands
MPI Workboats, UK
Netherlands Wind Energy Association (NWEA), The Netherlands
Offshore Center Denmark (OCD)
PMSS, UK
Rabobank, The Netherlands
RenewableUK, UK
RWE; Germany
Seas NVE, Denmark
Siemens Wind Power A/S, Denmark and Germany
Typhoon Offshore, UK
Van Oord Offshore Wind Projects BV
Volker Staal en Funderingen (VSF), The Netherlands