The importance of informed political direction: An analysis of the Swedish marine energy innovation system

Johnn Andersson*[a], Eugenia Perez Vico[b], and Linus Hammar[b]

[a] Chalmers University of Technology
Division of Environmental Systems Analysis
Department of Energy and Environment
Gothenburg, Sweden

[b] SP Technical Research institute of Sweden
Division of Systems Analysis
Gothenburg, Sweden

[c] The Swedish Agency for Marine and Water Management
Department of Marine Spatial Planning and Maritime Affairs
Gothenburg, Sweden

*Corresponding author: johnn.andersson@chalmers.se, +46 (0) 70 3363747

Author biographies

Johnn Andersson, Chalmers University of Technology

Johnn Andersson is a PhD Candidate at the Department of Energy and Environment at Chalmers University of Technology in Gothenburg, Sweden. His main interest is trying to understand how global socio-technical transitions towards sustainability unfold, and how they can be promoted by different actors in society. Johnn's research explores how small countries, such as Sweden, can contribute to global energy transitions and renew domestic industry, by developing technologies that have a limited home market but a substantial global potential. Through case studies of solar and marine energy, he develops knowledge about key innovation processes and identifies implications for public policy.

Eugenia Perez Vico, SP Technical Research Institute of Sweden

Dr. Eugenia Perez Vico conducts research in the field of research and innovation policy, focusing on how research is made socially useful. She focuses on developing methodologies for capturing and explaining multidimensional and long-term utilities stemming from academic R&D, as well as academic collaboration with society. Her work builds on the innovation system approach and the empirical domains are primarily nanotechnology, energy and environmental research. The purpose of her work is to contribute to an informed view on the utility of academic research. Eugenia also works as a policy analyst and researcher at SP Technical Research Institute of Sweden.

Linus Hammar, Chalmers University of Technology

Dr. Linus Hammar has worked with environmental impacts of tidal energy and offshore wind power at Chalmers University of Technology, Department of Energy and Environment. In 2014 he completed his PhD with the thesis "Power from the Brave New Ocean – Marine Renewable Energy and Ecological Risks". Currently he is working with marine spatial planning, shipping and marine renewables at the Swedish Agency of Marine and Water Management.

Abstract

While marine energy technologies can contribute to meeting sustainability challenges, they are still immature and dependent on public support. This paper employs the Technological Innovation Systems (TIS) framework to describe and analyze the Swedish marine energy innovation system. In conclusion, there are promising device developers, relevant industrial capabilities and world-class research, but the system suffers from an uncertain domestic market potential and lack of clear political direction, which has hindered policy coordination and collaboration among actors. These issues need to be addressed by policy if Sweden wants to contribute to, and benefit from, an accelerated deployment of marine energy technologies.

1. Introduction

To prevent catastrophic climate change, greenhouse gas emissions have to be radically reduced by 2050, which requires a massive deployment of low-carbon energy technologies (IPCC, 2014; Stern, 2006). Marine energy[1] is a renewable energy source that can play an important role in meeting this challenge (IPCC, 2011). While the global resource potential is small compared to solar and wind energy,[2] it is quite substantial in certain regions, such as the UK (The Crown Estate, 2012), and may allow for balancing other renewables (Hammar et al., 2012; Kim et al., 2012).

However, marine energy technologies are immature and their development is still dependent on public support (OES, 2014). Sweden is one of many countries that have identified the technology field as a potential low-carbon energy source and driver of economic development (Magagna & Uihlein, 2015; Muller, Brown, & Ölz, 2011), and therefore promote its development through different policy measures (Corsatea, 2014; OES, 2014). After an early start in the in the 1970's (Lindroth & Leijon, 2011; WERG, 1979), followed by a decline in interest and activity during the 1990's, the last 15 years have seen the emergence of several promising device developers and substantial public investments in research, development and demonstration (RD&D). Nevertheless, the domestic market potential is uncertain and there are indications that policy for promoting marine energy have been somewhat uninformed and lacked coordination (Andersson, 2013). A better understanding of how the technology field develops in the Swedish context is therefore needed to enable the design and implementation of appropriate policy measures.

A number of studies have attempted to inform policy makers about challenges relating to marine energy by analyzing its development from a broad perspective. The majority focuses on policy and innovation in the UK (Dalton & Ó

[1] Marine energy refers to energy harnessed from waves, tidal streams and ocean currents. Accordingly, technologies such as offshore wind power, tidal barrage technology, ocean thermal energy conversion, salt gradient energy conversion, and current power from inland rivers, are excluded from this paper.

[2] The global physical potential has been estimated at about 70 000 TWh per year. However, technical, social, environmental and economic constraints introduce major uncertainties and reduce the estimated socio-economic potential to a few hundred TWh per year. (Sandén et al., 2014)

Gallachóir, 2010; Jeffrey et al., 2013; Vantoch-Wood, 2012; Vantoch-Wood & Connor, 2013; Winskel et al., 2006; Winskel, 2007), while one study concerns the Portuguese context (Hamawi & Negro, 2012). Others focus on cross-country issues such as social acceptance and industry barriers (Kerr et al., 2014; Løvdal & Neumann, 2011). In addition, several studies have included marine energy in studies encompassing a wide range of renewables (Foxon et al., 2005; Negro et al., 2012; Winskel et al., 2014). However, only one study covers the development of marine energy technology in Sweden (Corsatea, 2014)[3]. Even though this study highlights many interesting aspects by comparing several European countries, it gives a rather limited understanding of the Swedish case, since it mainly draws on quantitative data from 2011. Accordingly, there is a need for further insights into the Swedish case that can underpin policy recommendations.

The purpose of this paper is therefore to contribute to these insights by describing and analyzing the Swedish marine energy innovation system, in order to identify factors that block the system's development and that may be used to raise and discuss policy issues. The study employs the Technological Innovation Systems (TIS) framework, which is suitable for describing and analyzing the emergence of new technologies in order to identify barriers to their development and deployment (Bergek et al., 2008a; Bergek et al., 2008b). The TIS framework has proved to be useful for studying innovation systems in many technology areas (Bergek, 2012), including marine energy (Corsatea, 2014; Hamawi & Negro, 2012; Vantoch-Wood, 2012).

[3] There are also relevant reports from industry networks and public agencies, see for example (Andersson, 2013; VINNOVA, 2009).

2. Analytical framework and methodology

Markard and Truffer (2008, p. 611) define a TIS as "... a set of networks of actors and institutions that jointly interact in a specific technological field and contribute to the generation, diffusion and utilization of variants of a new technology and/or new product". It follows that a TIS consists of four structural components: technology, including both artifacts and knowledge; actors, such as companies, research institutions, government agencies and NGOs; networks, which can be formal or informal to their character; and institutions, consisting of laws and regulations as well as norms, beliefs and expectations. When a new technology field, such as marine energy, emerges, few of these structural components are in place (Bergek et al., 2008b). Thus, for the technology to develop and diffuse, the TIS structure needs to be strengthened gradually through the accumulation of artifacts and knowledge, the entry of actors, the formation of networks and the alignment of institutions (Bergek et al., 2008b; Hekkert & Negro, 2009). To better understand this strengthening process, TISs are commonly analyzed by looking at a subset of processes referred to as functions. These influence the build up of system structures and accordingly have a direct impact on the development, diffusion and use of new technologies (Bergek et al., 2008a; Bergek et al., 2008b; Hillman & Sandén, 2008). By analyzing the functions of a TIS, rather than just looking at its structure, it is possible to gain a better understanding of what actually happens in the system (Bergek et al., 2008a). This involves describing and assessing strengths and weaknesses in individual functions as well as mapping the interaction between them (Hekkert & Negro, 2009). Table 1 lists the seven functions that are used in this paper.[4]

[4] The functions can be defined, grouped, divided and aggregated in many different ways (Bergek et al., 2008a; Markard & Truffer, 2008). This paper follows Bergek et al. (2008a), with additions from Jacobsson and Karltorp (2013). It does, however, omit the function *development of positive externalities*, which is here viewed as a descriptor of functional dynamics rather than a function in itself, and adds the function *development of social capital*, in order to capture aspects such as levels of trust and mutual understanding, which are particularly important for TISs in early development phases (Perez Vico, 2013).

Table 1. Functions of innovation systems (Bergek et al., 2008a; Jacobsson & Karltorp, 2013; Perez Vico, 2013).

The function…	*is the process of strengthening…*
Knowledge development and diffusion	The breadth and depth of the knowledge base, and how it is developed, diffused and combined in the system.
Entrepreneurial experimentation	The testing of new technologies, applications and markets whereby new opportunities are created and a learning process unfolds.
Resource mobilization	The extent to which actors are able to mobilize human and financial capital as well as complementary assets such as infrastructure.
Development of social capital	The creation and maintenance of social relations, including trust, dependence, mutual recognition, authority and shared norms.
Legitimation	The social acceptance of the technology and its compliance with relevant institutions.
Influence on the direction of search	The incentives and/or pressures for organizations to enter the technological field, as well as the guidance within the field.
Market formation	The factors driving market formation, such as articulation of demand from customers, institutional change and changes in price/performance.

Analyzing the functions of a TIS enables identifying factors that block the system's development (Bergek et al., 2008a). These factors may then be used to raise policy issues and to design policy measures for reducing their negative impact (Bergek et al., 2008a). This paper will largely follow the methodology suggested by Bergek et al. (2008a). First, in Section 3, the system boundaries of the TIS are specified and the structural components are identified and described. Second, in Section 4, the functions are analyzed in terms of strengths and weaknesses in their performance as well as the interaction between them[5], and a set of blocking factors is identified. Finally, in Section 5, policy issues derived from the blocking factors are discussed.

Empirically, the paper is based on 25 semi-structured interviews, six short e-mail communications, and direct observations during three multi-stakeholder

[5] The analysis of functions will not result in a summarizing valuation of each function's performance, since several functions exhibit clear strengths and weaknesses that are hard to weigh against each other.

workshops.[6] The interviewees were chosen to represent different stakeholder perspectives, including device developers, research institutions, large and small suppliers, multinational utilities, interest organizations, and public actors on local, regional and national levels. Data was also obtained through a mapping of Swedish public RD&D funding to the technology field[7], a patent search[8], a mapping of the number of bills and motions concerning marine energy from Swedish government and parliament[9], and a media search[10]. In addition, the study builds on reports from interest organizations, official documents from public agencies, actors' websites, and academic literature.

[6] Interviews were made with five device developers, three research institutions (six interviews in total), one utility, five industry suppliers, two interest organizations and six public actors. Moreover, the study was conducted in parallel to Swedish policy processes (e.g. the development of a funding program for research and development by the Swedish Energy Agency), which enabled the researchers to make direct observations during three multi-stakeholder workshops (referred to as 'Meeting Notes'). In addition, material from these parallel processes, as well as databases originating from earlier industry activities (see e.g. Andersson, 2013), supported the process of mapping actors.

[7] The mapping of public investments included funds from the following agencies: the Swedish Energy Agency, the Swedish Innovation Agency, the Swedish Agency for Economic and Regional Growth, the Swedish Research Council, and Region Västra Götaland. The mapping drew on information from actors' websites, searches in project databases using multiple key words (marine energy, wave energy, tidal energy etc.), and other documentation. Note that some beneficiaries may not appear due to some methodological limitations of the mapping. The mapping only included main project owners, thus project partners in collaborative projects do not appear. In addition, general-purpose projects, such as those including both offshore wind and marine energy, and minor support to start-up companies, are left out.

[8] The patent data search was performed 2014-04-03 on the European Patent Office's international database (http://worldwide.espacenet.com), and included Swedish applicants in the patent classes Y02E10/28 (tidal stream or damless hydropower) or Y02E10/38 (wave energy or tidal swell).

[9] The search for bills and motions was performed 2014-04-22, using multiple key words (marine energy, wave energy, tidal energy etc.) in the Swedish Parliament's archive (www.riksdagen.se).

[10] The media search was performed 2014-05-08, using multiple key words (marine energy, wave energy, tidal energy etc.) in the database Retriever Business (www.business.retriever.se).

3. Structural components in the Swedish marine energy innovation system

Since this paper concerns marine energy innovation in Sweden, a national system boundary is adopted for the TIS. In terms of technology, the focus is on the development and diffusion of devices for producing electric power from waves, tidal streams and currents in the ocean, while up- and downstream value chain activities, such as raw materials and manufacturing technology as well as power distribution and consumption, fall outside the system boundaries.[11] Moreover, the analysis focuses on the last 15 years and includes developments up until 2014. Below, the TIS is described in terms of its structural components: technology, actors, networks and institutions.

3.1. Technology

Marine energy is in an early development phase, characterized by technological diversity, concept development and small-scale sea trials (IPCC, 2011; Magagna & Uihlein, 2015). Only a handful of technology concepts have undergone full-scale sea trials and there are very few power-producing installations worldwide (Magagna & Uihlein, 2015; OES, 2014). Tidal power is considered to be closest to a commercial break-through, followed by wave power close behind, while current power is in an earlier phase (Ingmarsson, 2014; IPCC, 2011; SI Ocean, 2014). There are hundreds of technology concepts that are being developed through RD&D activities (EMEC, 2014). These concepts fall into a number of broad categories, depending on the way in which they harness the kinetic energy and convert it to electric power (Magagna & Uihlein, 2015). The activities of Swedish device developers and researchers fall under several of these categories.

[11] Although these parts of the value chain are excluded from the TIS, they are still highly relevant for the analysis. For example, actors, such as utilities, have relevant capabilities (and accordingly constitute potential entrants) and technological systems, such as the power grid, constitute important infrastructure.

Since marine energy technologies depend on the availability of exploitable waves, tidal streams and currents, the resource potential is a key aspect. In Sweden, the resource potential is fairly limited relative to other European countries. For wave power, the technical resource potential has been estimated at 10–30 TWh per year for the entire Swedish coastline (Claesson et al., 1987; Interview E; WERG, 1979), and at 8 TWh per year for the Swedish parts of the Baltic Sea (Bernhoff et al., 2006). However, these estimates do not take environmental, social and economic constraints into account. In particular, they do not account for the fact that Swedish waters are characterized by small waves with less energy content, which some consider to significantly reduce cost-efficiency (Interview B; Interview J; Interview L). For tidal power, the available resource is considered negligible, while current power may have some potential (Grahn, 2011; Interview B; Interview N). It should be noted, however, that although the Swedish resource potential is limited, and perhaps insufficient for commercial deployment, domestic waters are considered well suited for test activities (Claesson et al., 1987; Ingmarsson, 2014; Interview B).

3.2. Actors

Actors in the TIS consist of device developers, suppliers of sub-systems, components and services, power utilities, research institutions, public actors and NGOs. The value chain is undeveloped and its future structure is uncertain: suppliers may diversify into device development and production; device developers may license or sell their technologies, or supply turnkey power plants; and power utilities may own and operate power plants, or focus on buying and distributing power.

Ten Swedish device developers are identified in this study (see Table 2). These are predominantly small start-up companies. Some are university spin-offs and others are based on ideas from individual inventors or established industry actors (CorPower Ocean, 2012; Current Power, 2014; Minesto, 2013; Seabased, 2013). Several of the device developers aim to become suppliers of turnkey marine energy systems (Interview F; Interview Q). Seabased, a spin-off from Uppsala University, has come the furthest in its development. The company started building a demonstration plant on the Swedish west coast in 2013, which is meant to become the world's largest wave power array with 420 devices and a capacity of 10 MW (Fortum, 2011; Interview F).[12] Minesto has also come relatively far in its development, with quarter-scale test activities in Northern Ireland (Interview N; Minesto, 2013).[13] The rest of the device developers have limited activities with few employees and focus mainly on early-stage concept development, modeling and tank testing.

Table 2. An overview of Swedish device developers.[14]

Name	*Technology*	*Employees*	*Phase*	*Location*
CorPower Ocean	Wave	5–10	Lab/tank tests	Stockholm
Current Power	Tidal	<5	Full scale river trials	Uppsala
Exim Strömturbiner	Tidal	<5	Small scale river trials	Stockholm
Minesto	Tidal	20–30	Small scale sea trials	Gothenburg
Ocean Dynamic Power	Tidal	<5	Full scale river trials	Stockholm
Ocean Harvesting Technologies	Wave	<5	Lab/tank tests	Karlskrona
Seabased	Wave	60-70	Full scale sea trials	Uppsala/Lysekil
Vigor Wave Energy	Wave	5–10	Lab/tank tests	Gothenburg
Waves4Power	Wave	<5	Full scale sea trials	Gothenburg
WaveTube	Wave	<5	Lab/tank tests	Gothenburg

Suppliers and utilities with relevant capabilities, knowledge and access to investment capital are considered essential for accelerating the development of marine energy technology (Interview D; Interview J; Interview O). However, these established actors have been passive in Sweden. About 20 companies in the power electronics, manufacturing and offshore sectors have supplier relationships with device developers, ranging from joint development of customized solutions to supply of standard components and informal knowledge exchanges (Interview D; Interview O; Interview Q).[15] The multinational bearings

[12] Since the study was made, Seabased has initiated a collaboration with a utility in Ghana with the ambition to deploy a 14 MW wave power array (Seabased, 2015).

[13] Since the study was made, Minesto has received EU funding for deploying a 10 MW array in Wales (Minesto, 2015).

[14] Current Power, Ocean Dynamic Power and Exim Strömturbiner have performed their tests mainly in inland rivers, but their concepts can potentially be applied in both ocean and inland river environments (Interview E; Ocean Dynamic Power, 2014; Pettersson, 2014). Moreover, "tidal" technologies can potentially be used for producing power from ocean currents as well.

[15] Only one company, the mooring supplier Seaflex Energy Systems, is entirely specialized on marine energy (Interview K).

company SKF has had several collaborations with Swedish device developers and also holds a number of patents in the area (Interview D), while the multinational power electronics company ABB is more oriented towards supplying standard components (Interview B). As regards utilities, the Finnish company Fortum has by far invested the most in Sweden through its engagement in Seabased's demonstration plant (Fortum, 2011). Other utilities, such as Vattenfall, E.ON and Göteborg Energi, have only had minor collaborations with Swedish device developers (Interview I; Interview O; Vattenfall, 2011; Waves4Power, n.d.). Instead, the large suppliers and utilities in Sweden have focused their attention on markets with more promising resource potentials and stronger public support systems (Interview C; Vattenfall, 2011). On these markets, they have employed specialized staff (Interview C) and invested in device developers (Interview B). The main motivation, however, seems to be to strategically monitor the development, rather than generating financial short-term returns (Interview B; Interview C; Interview I; Vattenfall, 2011).

The most engaged research institutions are Uppsala University, Chalmers University of Technology (Chalmers) and SP Technical Research Institute of Sweden (SP). Uppsala University's research is considered world leading (Nordgren et al, 2011), with about 50 researchers and two test sites related to marine energy (Interview E; Uppsala University, 2013a, 2013b). The university focuses on applied and multi-disciplinary research related to two specific technology concepts for wave and current power (Uppsala University, 2011), and collaborates closely with the spin-off companies Seabased and Current Power (Billquist & Södahl, 2012; Interview E). Chalmers conducted wave power research during the 1970's and 1980's, which included sea trials in collaboration with industry actors (Interview L; Waves4Power, n.d.; WERG, 1979), and hosted the collaboration platform Ocean Energy Centre between 2011 and 2014 (Andersson, 2013; Interview M). Recently, however, Chalmers' activities have been limited to 3–4 PhD Students working with marine energy.[16] SP has been involved in a number of research and development (R&D) initiatives and

[16] Chalmers has also played a role in fostering the device developers Minesto and WaveTube through its business incubator Encubator and School of Entrepreneurship (Encubator, 2012; Interview N).

participates in the European trade association Ocean Energy Europe (Interview A; Interview T). In addition, limited activities are found at Blekinge Institute of Technology and KTH Royal Institute of Technology, both of which collaborate with individual device developers (Ingmarsson, 2014; Interview O). Limited activities are also found at the research institute SSPA, whose facility for tank testing and related competence have been used by several device developers (Interview T; Interview Y).

The public actors consist of government ministries and agencies, regional administrations, and municipalities, which are involved in supporting RD&D or in the consenting process for sea installations. Among the ministries, mainly the former[17] Ministry of Enterprise, Energy and Communication has been involved in marine energy related activities, mostly through strategic undertakings on European and national levels as well as by governing funding agencies, such as the Swedish Energy Agency and the Swedish Innovation Agency (Ingmarsson, 2014; Interview U; Interview W; Interview X; Meeting Notes, 2014c; Swedish Government, 2014). The Swedish Agency for Marine and Water Management (SwAM) is the most prominent actor in the consenting process, though many other public actors on national, regional and local levels participate. However, these activities are limited since the number of sea installations is very small (Interview S; Interview W). SwAM also coordinates the development of offshore marine spatial plans, which are expected to become important for marine energy deployment (SwAM, 2014a). Region Västra Götaland, a regional administration in Western Sweden, has identified marine energy as a potential driver of regional economic development and provided R&D funding (Interview G; Wenblad et al., 2012). Moreover, several municipalities, mainly in Western Sweden, support device developers, facilitate sea installations, and develop coastal marine spatial plans (Ingmarsson, 2014; Interview H; Rantakokko, 2014).

Finally, there are no marine energy specific NGOs or trade associations in Sweden. However, certain lobby activities have been undertaken within R&D

[17] Since the Swedish general election in 2014, a number of government ministries and agencies have changed names and responsibilities.

oriented initiatives, such as proposals for a joint strategic innovation agenda for the industry (Andersson, 2013; Andersson et al., 2013).

3.3. Networks

The most prominent network in the TIS, hereafter referred to as the Uppsala Network, revolves around Uppsala University and its spin-off companies. It is characterized by extensive person mobility, enabled by double employments and positions of trust, as well as by joint R&D projects (Billquist & Södahl, 2012; Interview F). There is a strong focus on the technologies that are being commercialized by the spin-off companies, and the network is therefore perceived as closed by other actors (Billquist & Södahl, 2012; Interview L). Another network has evolved from the Ocean Energy Centre, hereafter referred to as the OEC Network, and includes device developers and research institutions outside the Uppsala Network. These actors have an informal and loose collaboration, which does not focus on a specific technology. Although the OEC Network has shown significantly less interaction and collaboration than the Uppsala Network, it has played an important role for initiating collaborative R&D projects as well as for developing a joint strategic innovation agenda that involved a large number of Swedish actors (Andersson, 2013; Interview M). Although the Ocean Energy Centre is formaly inactive since the beginning of 2014, the network has lived on in other initiatives, often led by SP (Meeting Notes, 2014a, 2014b, 2014c).

The Uppsala Network and the OEC Network have had very limited mutual collaboration and the contacts between Uppsala University and Chalmers are weak, with few examples of joint research activities (Meeting Notes, 2014a, 2014b, 2014c). However, the interaction between the two networks has recently been enhanced through various initiatives, most notably in the preparation process for a Swedish Energy Agency funding program (Interview I; Interview N; Meeting Notes, 2014c).

Furthermore, firm-specific networks are emerging around device developers. These consist of relationships with suppliers, which sometimes include joint development efforts (Interview N; Interview O; Interview Q), individual research collaborations (Interview L; Interview N), and involvement in trade associations (Interview N; Interview O; Interview Q). The firm-specific networks are often international, with a strong focus on the UK. However, the device developers have limited interaction with large suppliers and utilities (Interview D; Interview I; Interview M).

Finally, networks between public agencies, most notably the Swedish Energy Agency and the Swedish Innovation Agency, are weak and characterized by a lack of dialogue and coordination (Interview J; Interview W; Meeting Notes, 2014c).

3.4. Institutions

Marine energy is affected by policies for promoting renewable energy technologies. One relevant policy is the Swedish green certificates system, which includes wave power but excludes tidal and current power (Swedish Government, 2003). However, the system only gives a very small effective price subsidy for wave power compared to other countries (see Section 4.3). Public funding has instead reached the technology field through substantial RD&D investments, with about 250 MSEK allocated between 2003 and 2014 (see Section 4.3). Despite this, marine energy is not perceived as politically prioritized by experts on Swedish energy policy (Interview U; Interview V). The lack of politically endorsed goals, strategies and planning frameworks confirm this view (SwAM, 2014a).

There are no marine energy specific laws and regulations, but all sea installations, both for testing and commercial purposes, have to undergo a consenting process based on the Swedish Environmental Code and get permission from Land and Environmental Courts (The Swedish Energy Agency, 2012). The consenting process includes concerns trade-offs between conflicting interests among actors, such as the Swedish Armed Forces and the fishing industry, and between negative local environmental impacts and positive global climate benefits.

Regarding norms, beliefs and expectations, it is clear that public attitudes to marine energy are very positive, and there is no organized lobby against the technology field (Hedberg, 2011; Interview E; Interview I; Interview L; Interview N). There have been tensions between the Uppsala Network and actors with an interest in space allocation at sea, such as the Swedish Armed Forces and the fishing industry, but these have been largely resolved with more positive attitudes as a result (Interview H). However, expectations on the Swedish market potential differ widely due to uncertainties regarding the available resource potential, as discussed in Section 3.1. This mainly applies to wave power, which has some technical potential, while there seems to be stronger agreement on the marginal market potential of tidal and current power. Some actors have a strong belief in the potential for deploying wave power technologies in Sweden, whereas others discard the resource as insufficient and propose a focus on export markets (Interview B; Interview E; Interview J; Interview L).

4. Analysis of functions and identification of blocking factors

In this section, the TISs functions are analyzed in terms of their strengths and weaknesses. Also, six blocking factors that contribute to the observed weaknesses are identified and labeled B1–B6. These will be further discussed in Section 5.

4.1. Knowledge development and diffusion

Uppsala University's extensive, broad and prominent research (Billquist & Södahl, 2012; Nordgren et al., 2011), historical and current activities at Chalmers (Interview L; WERG, 1979), and the advancement of several internationally recognized device developers indicate strength in knowledge development. A patent search identifies 102 Swedish patents within marine energy (see Figure 1). It reveals that patenting has been concentrated to the last 15 years, largely driven by Seabased that holds about a third of all granted patents during this period. This indicates that knowledge development intensified around the turn of the century and that the Uppsala Network has played a key role, although RD&D has been on going since the 1970's with many other actors involved (Lindroth & Leijon, 2011; WERG, 1979).

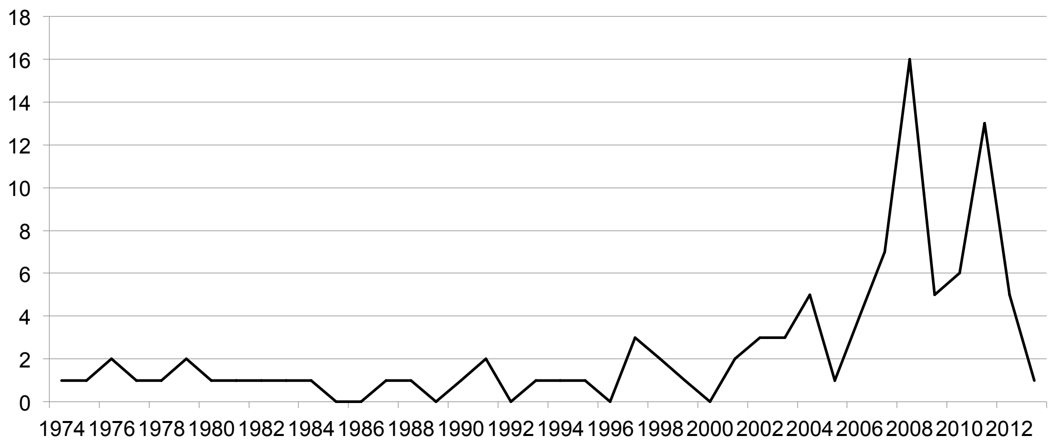

Figure 1. Swedish patenting within marine energy over time.

However, knowledge diffusion is poor and constitutes an important weakness in the function. Recent public investments in RD&D have focused heavily on Seabased's technology (see Section 4.3) and accordingly led to a concentration of knowledge development to the Uppsala Network. But due to limited collaboration and person mobility between the Uppsala Network and other universities and device developers (Interview E), knowledge has not disseminated to the rest of the system, a part from through graduate training at Uppsala University and a certain mobility of PhDs to other actors in the system (Interview E; Interview J). Outside the Uppsala Network, there is also limited collaboration across different technology concepts[18,19] and between research institutions and private actors (Interview B; Interview L; Interview M; Interview N; Interview Q; Meeting Notes, 2014b, 2014c). In addition, the links between early research activities at Chalmers and contemporary knowledge development are also perceived as weak (Interview B; Interview L; Interview M; Interview N; Interview Q; Meeting Notes, 2014b, 2014c). The poor knowledge diffusion is mainly due to weaknesses in the development of social capital (see Section 4.5), which have led to low levels of trust and limited collaboration among actors in the system.

Furthermore, the passivity of large suppliers and utilities, with Fortum's collaboration with Seabased as a notable exception, has limited the access to capabilities and knowledge that could potentially accelerate knowledge development. This is a result of weaknesses in influence on the direction of search (see Section 4.6), which have made established actors hesitant to enter the system (Ingmarsson, 2014; Interview B; Interview D; Interview I; Interview M; Interview N).

4.2. Entrepreneurial experimentation

Both historical and more recent RD&D activities indicate strength in entrepreneurial experimentation. In the 1970's, Chalmers together with industry actors performed several sea trials of wave power in Western Sweden. More

---

[18] Evidence from the development of marine energy in the UK suggests that lack of collaboration can slow down the development of the technology area as a whole (Winskel, 2007). Increased collaboration, on the other hand, can potentially lead to joint knowledge development and achieve the critical mass required to mobilize specialized suppliers, which in turn can create economies of scale that lead to customized and more cost effective solutions.

[19] There is one recent initiative that gathers three device developers in an effort to develop a shared concept, building on the core technologies and solutions from each developer. However, this initiative does not involve actors from the Uppsala Network (Interview T).

recently, the Uppsala Network has dominated experimentation in Sweden through extensive test and demonstration activities of Seabased's and Current Power's technologies. However, device developers, such as Minesto and Waves4Power, have also performed repeated sea trials, and several others express high ambitions for continued experimentation in Sweden and abroad (Interview N; Interview Q; Interview T). In addition, there is on-going experimentation with less mature technologies, ranging from conceptual modeling to lab and tank tests.

However, commercial installations are still lacking and there are few test and demonstration activities at sea, which mirrors the fairly slow international development (Vantoch-Wood, 2012). This indicates weaknesses in entrepreneurial experimentation owing to several causes. First, experiences from wind power show that it is considerably more expensive to perform test activities at sea than on land (DNV GL, n.d.; Jeffrey et al., 2013), which has led to persistent uncertainties and knowledge gaps (Hammar, 2014; Interview E; Interview T; Meeting Notes, 2014a, 2014c). Second, device developers consider the access to appropriate and reasonably priced test facilities in Sweden to be limited (Ingmarsson, 2014), even though Swedish waters are considered well suited for test activities (Claesson et al., 1987; Ingmarsson, 2014). This has resulted in discussions on how to increase collaboration around existing and future infrastructure (Backman, 2014; Interview T). The limited access to test facilities has also led some developers to experiment abroad[20], thereby gaining access to both infrastructure and knowledge (EIT, 2013; Interview N). Third, the consenting process is considered time and resouce demanding (Ingmarsson, 2014). This is mainly due to the fact that device developers have to show that the direct environmental impacts of their appliations are either marginal or surpassed by their common good (The Land and Environmental Court, 2014). Thus, results from extensive environmental studies, building on data that is hard to obtain wihtout having performed sea trials, are required in early stages, which implies an obvious risk for ”catch-22” situations. These have already arisen for

[20] The activities of Swedish device developers abroad are generally considered to increase the risk of these companies leaving Sweden and weakening the development of the domestic value chain (Interview I). However, experimentation abroad can also give important knowledge about future export markets.

both Swedish and international device developers, and are expected to be a major problem for the deployment of full-scale installations (Meeting Notes, 2014a).[21] Moreover, SwAM lacks both knowledge and internal coordination around marine energy (Interview W), which further complicates the consenting process. The process may, however, be simplified by an ongoing national marine spatial planning initiative, which public actors perceive to be an important tool for dealing with the mentioned trade-offs (Interview F; Interview H; Interview Q; Interview R; Interview S). To summarize, test and demonstration activities are very resource demanding, which is identified as a blocking factor (B1). This, in combination with weaknesses in resource mobilization (see Section 4.3) as well as limited collaboration among actors and passivity of established actors (see Section 4.1), inhibits entrepreneurial experimentation (Ingmarsson, 2014; Interview I), which is confirmed by experiences in other countries (Vantoch-Wood, 2012).

4.3. Resource mobilization

Resource mobilization comprises access to public and private capital, relevant infrastructure, human capital and sea sites. There are indications of both strengths and weaknesses across these aspects of the function.

The mobilization of public capital to RD&D indicates certain strength. A national funding program allocated over 1.5 MEUR[22] to wave power R&D between 1976 and 1986. The support then subsided during the 1990's, while the last ten years have seen a substantial increase in public funding. An analysis of grants to marine energy RD&D projects reveal that 27.6 MEUR has been allocated between 2003 and 2014 (see Table 3).[23] The Swedish Energy Agency is the main contributor, with close to 90 % of total funding, while the Swedish Research Council, Region Västra Götaland and the Swedish Innovation Agency contribute with a few percent. Actors within the Uppsala Network have received over 90 %

---

[21] Actors from the Uppsala Network have, however, successfully managed the consenting process by initiating thorough environmental studies in an early stage (SwAM, 2014b).

[22] This figure is not expressed in current prices.

[23] The analysis only includes marine energy specific funding and does not cover general research activities, which may relate to marine energy.

of public funding during the period (see Table 4). Seabased's demonstration plant alone accounts for more than 50 %. This largely explains the spike in public funding in 2010 and 2011, which is when the main part of the funds to Seabased was granted (see Figure 1).

Table 3. Public funding to marine energy RD&D in Sweden, granted between January 2003 and April 2014 – per funding agency

Funding agency	*Amount (MEUR)*	*Percentage*
The Swedish Energy Agency	24.7	89.4 %
The Swedish Research Council	1.5	5.6 %
Region Västra Götaland	0.7	2.4 %
The Swedish Innovation Agency	0.6	2,3 %
The Swedish Agency for Economic and Regional Growth	0.1	0.3 %
Total	27.6	100 %

Table 4. Public funding to marine energy RD&D in Sweden, granted between January 2003 and April 2014 – per beneficiary

Beneficiary	*Amount (MEUR)*	*Percentage*
Seabased AB	17.6	63.8 %
Uppsala University	7.3	26,4 %
Chalmers University of Technology	1.1	4,0 %
Corpower Ocean AB	0.8	2,9 %
Minesto AB	0.6	2,2 %
Others	0.2	0,7 %
Total	27.6	100 %

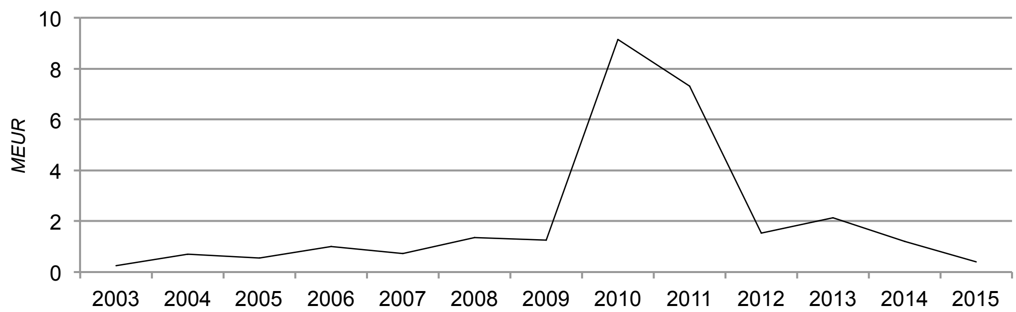

Figure 2. Public funding to marine energy RD&D in Sweden, granted between January 2003 and April 2014 – over time[24]

[24] The pubic funding is allocated to different years according to the funding agencies' approval decisions.

Although the magnitude of public funding can be considiered quite substantial (Corsatea, 2014), a common view among actors is that its allocation has been uninformed and lacked overview, coordination and transparency (Andersson, 2013; Billquist & Södahl, 2012; Ingmarsson, 2014; Interview E; Interview J; Interview L; Interview N; Interview T; Interview V; Interview X). This has led to a partly unintentional focus by funding agencies on the Uppsala Network and in particular on Seabased's technology concept. By attracting funds in a relatively early stage, these actors have managed to attain a position that has made it easier to motivate further funding by pointing to previous achievements. This has in turn resulted in a crowding-out effect towards other technology concepts as well as blocked the development and diffusion of generic knowledge, since the Uppsala Network focuses on specific technology concepts and has limited collaboration with other actors in the system (Billquist & Södahl, 2012; Ingmarsson, 2014; Interview E; Interview L; Interview N; Interview T). Moreover, the allocation process has by some actors been perceived as unfair (Ingmarsson, 2014; Interview L; Interview N; Interview T). An important blocking factor is therefore the lack of knowledge and coordination among public actors (B2), in particluar funding agenices such as the Swedish Energy Agency and VINNOVA (Ingmarsson, 2014; Interview H; Interview I; Interview T; Interview W; Meeting Notes, 2014b).

There are also some indications of strength regarding the mobilization of private capital. Fortum's investment in Seabased's demonstration plant is extensive, and the other device developers attract smaller but significant funds (Ingmarsson, 2014; Interview N; Interview O). Nevertheless, most actors consider the access to private capital in Sweden to be very limited and several express concerns about having to move abroad as a consequence (Fröberg, 2013; Interview F; Interview N; Johnsson, 2013; Magnusson et al., 2014). Large suppliers and utilities that are active in Sweden have invested in marine energy, but primarily abroad and to a decreasing extent over time. These actors and other private investors remain passive, since the relatively low technological maturity brings high costs, financial risk and long pay-back times (Ingmarsson, 2014), which is partly due to the resource demanding test and demonstration activities (B1) that was identified as a blocking factor in Section 4.2. This clearly indicates important weaknesses in the function, which are common with many other renewable energy technologies (Bloomberg New Energy Finance, 2014). However, it also suggests that established actors question the market potential of marine energy (see Section 4.6).

As regards relevant infrastructure, marine energy is relatively compatible with the one in place, which strengthens the function. The technologies are compatible with the existing land-based power grid in Sweden (Interview E), even though the geographical range of the grid may have to be extended (Ingmarsson, 2014; Magagna & Uihlein, 2015) and offshore power grids need to be developed and deployed (Interview J; Magagna & Uihlein, 2015). There is also suitable infrastructure for operations and maintenance, although a large-scale diffusion may require increased capacity among docks and service vessels (Interview E; Interview P). Moreover, marine energy could benefit from the developing infrastructure for offshore wind power (Interview N; Interview V; Jeffrey et al., 2013), but some actors believe these opportunities to be exaggerated (Interview Q).

Concerning the availability of human capital, it is considered to be in line with current needs, which also indicates strength in the function. Uppsala University has extensive educational activities and there is also relevant and transferable competence in other industries (Interview B; Interview D; Interview E; Interview F).

Finally, access to suitable sea sites is expected to become a challenge if large-scale deployment becomes reality (Interview H; Meeting Notes, 2014c), which indicates a potential weakness in the function. So far, conflicts of interest have been rare[25] since there are few installations, but considerate marine spatial planning will be needed in order to manage competition for sea sites in the future (SwAM, 2014a). The coming maritime strategy and offshore marine spatial plans will deal with this issue, but it remains to be seen if the outcome of

[25] Earlier consenting processes have brought conflicts of interest between renewable offshore energy, fishing, shipping and environmental conservation, although these conflicts have largely been resolved successfully (Interview E; Interview F; Interview R; Interview S; Interview W).

these processes will facilitate the access to sea sites for marine energy (Ingmarsson, 2014; Interview U; Interview W; Meeting Notes, 2014c).

4.4. Development of social capital

The high levels of trust and extensive collaboration within the Uppsala Network, and to some extent within the OEC Network, indicate certain strength in the development of social capital. This is, however, contrasted by several indications of important weaknesses.

First, the trust and collaboration between the Uppsala Network and the OEC network is very weak[26]. This seems to be partly due to diverse attitudes to collaboration, based on different perceptions of the best strategy for technology development. The Uppsala Network proposes a strong focus on the most developed technology concept and acts rather closed, while many others see an urgent need to unite the industry in order to share risks and enable joint learning around common challenges (Interview E; Interview F; Interview M; Interview O; Interview T; Meeting Notes, 2014b). Second, the collaboration between research institutions and commercial actors is perceived as weak, except for within the Uppsala Network. There is a lack of understanding when it comes to differences in roles, drivers and needs; commercial actors call for more applied research that can benefit their immediate development efforts, while researchers request stronger capabilities for research collaboration and knowledge transfer among commercial actors as well as longer time perspectives (Interview B; Interview M; Interview N; Meeting Notes, 2014b, 2014c). Third, established actors remain passive and there is a lack of coordination among public actors, indicating a lack of trust and commitment (Ingmarsson, 2014; Interview C; Interview I; Interview W; Meeting Notes, 2014b). To sum up, the development of social capital is limited by a general lack of collaboration among actors, which is identified as a blocking factor (B3).

In addition, the function is affected by the lack of knowledge and coordination among public actors that was identified as a blocking factor (B2) in Section 4.3.

[26] However, recent initiatives, such as the Swedish Energy Agency's funding program, seem to bring these networks and other actors closer (Meeting Notes, 2014a).

Not only is the poor coordination among public actors an indication of weak social capital in itself; the lack of knowledge and coordination has also resulted in what many perceive to be an unfair allocation process (see Section 4.3). The outcome of the process has in turn contributed to the lack of trust and collaboration (Ingmarsson, 2014; Interview L; Interview N; Interview T).

4.5. Legitimation

There are very positive public attitudes to marine energy, which indicates strong legitimation. A generally positive outlook towards renewable energy drives these attitudes, together with perceived visual and noise benefits in comparison to wind power (Esteban & Leary, 2012; Interview H; Interview L; Interview N; Meeting Notes, 2014a). Public actors have developed a positive attitude based on research results on the environmental impact of offshore installations (Interview R; Interview W). In addition, the resolution of conflicts around sea installations has led to an increased openness for future installations (Interview E; Interview F). Nevertheless, positive attitudes may change if a large-scale deployment takes place (Interview J), or if installations are placed in areas that bring new conflicts of interest (Interview R). Also, experiences from the UK show that marine energy deployment can give rise to concerns about environmental impacts and the realization of benefits to the local community, even though the general attitudes are positive (Corsatea, 2014).

Furthermore, the last ten years' increased focus on sustainability has led to renewed and intensified political interest, which also indicates strength in the function. Figure 2 shows the number of bills and motions from the Swedish government and parliament that mention marine energy over time. The figure clearly indicates an increased interest since the turn of the century. Individual members of parliament have also expressed support for the technology area in media (Lundgren, 2011; Tiger, 2009). At the regional level, several municipalities show political interest, for example by including marine energy installations in their spatial planning (Interview H). These actors have high expectations that future deployment will create growth opportunities for local businesses (Henricson, 2012; Ingmarsson, 2014; Interview G; Interview H; Wangel, 2009).

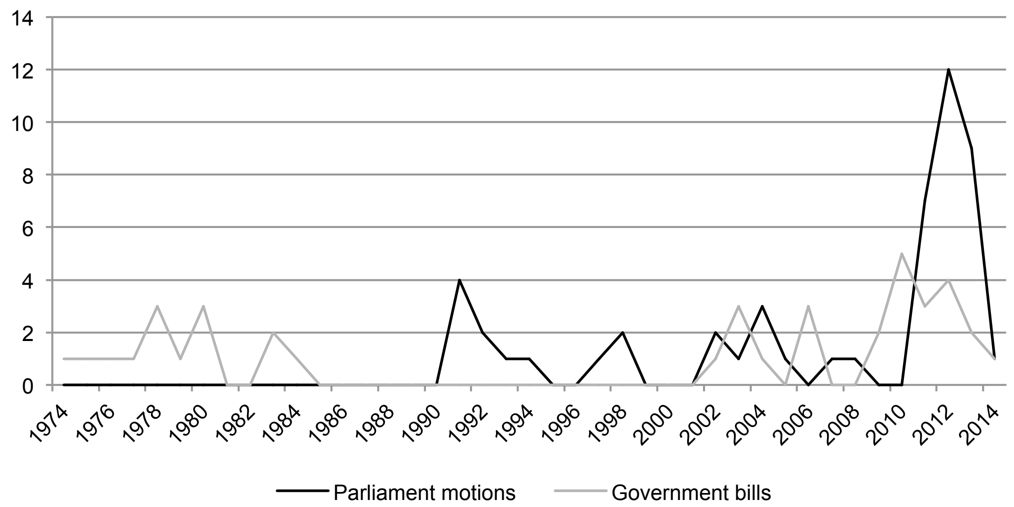

Figure 3. Number of bills and motions from the Swedish government and parliament mentioning marine energy.

Another indication of strong legitimation is that Swedish device developers have been gaining international recognition and media attention for their concepts, which has increased the legitimacy for the whole industry (Corneliusson, 2013; Ehn & Nordin, 2013; Johnsson, 2013; Sievers, 2010; Zerpe, 2008).

However, political lobbying for marine energy is poor. Some actors have experienced opposition from wind and nuclear power advocates, and claim that marine energy has been marginalized by wind power as a result of weak lobbying efforts (Interview E; Interview L; Interview Q). The political interest described above has not led to prioritization of marine energy in terms of political actions, and some political actors hold passive or skeptical attitudes (Interview U; Interview V; Levin, 2012; Södermanlands Nyheter, 2012). This is partly due to the lack of collaboration among actors (B3), which makes it difficult to gather the industry around joint lobbying initiatives, and partly due to uncertainties regarding the Swedish resource potential (see Section 4.6)

Finally, actors state that attitudes towards marine energy have suffered from technical failures, a lack of long-term test results, safety concerns around sea trials, and a lack of standards for technology evaluation that facilitates the emergence of unserious actors (Ingmarsson, 2014; Interview E; Interview Q; Interview R; Interview S; Meeting Notes, 2014b). These aspects makes more mature technologies, such as offshore wind power, seem more attractive, which is partly a result of the blocking factor resource demanding test and demonstration activities (B1), which was identified in Section 4.2.

4.6. Influence on the direction of search

The fairly strong mobilization of public capital to RD&D, together with an interest and belief in the potential of marine energy among many actors, has drawn entrepreneurs and researchers to the technology field. This indicates significant strength in influence on the direction of search.

However, the passivity of large suppliers and utilities indicate important weaknesses. These are mainly due to the high financial risks that result from large uncertainties related to technology, resource availability and political direction (de Jager et al., 2011).

Technical uncertainties concern the insufficiently demonstrated reliability and affordability of marine energy devices, which discourage actors to engage and invest. Also, dominant designs[27] have not yet emerged, which potentially obstructs guidance within the system, increases the complexity of investment decisions and constitutes a barrier for entering the system. Moreover, RD&D projects abroad have been too optimistic about technological maturity and expected results (Jeffrey et al., 2013). This has led to a backlash where important suppliers and utilities have withdrawn from the technology field (Vantoch-Wood, 2012), and so have some Swedish actors (Meeting Notes, 2014c). Reducing the technical uncertainties requires extensive experimentation, and oftentimes resources and competence from established actors. This shows the mutual dependence of the functions influence on the direction of search and entrepreneurial experimentation, which are both affected by the blocking factor resource demanding test and demonstration activities (B1) identified in Section 4.2.

[27] However, several technology concepts might exist in parallel as the area matures, adapted for different resource and site conditions. Technical diversity can also be a strength in innovation systems that are characterized by large uncertainties (Jacobsson et al, 2004). But in this case, there are indications that the lack of dominant designs and collaboration has limited the technological development.

Uncertainties regarding resource availability revolve around the relatively small and uncertain Swedish market potential for marine energy technology. Although the Swedish technical potential has been estimated at 10–30 TWh, a majority of the actors consider the market potential to be marginal, dismissing Swedish waters as suitable for anything except testing (Ingmarsson, 2014; Interview B; Interview J; Interview K; Interview P; Interview U). At the same time, some actors believe that commercial domestic deployments are realistic, but to a small extent and in a longer time perspective (Andersson, 2013; Ingmarsson, 2014; Interview E; Interview O). These uncertainties drive the political uncertainties and make actors focus on other markets. The uncertain Swedish market potential is therefore identified as a blocking factor (B4)

Hence, political uncertainties are partly a consequence of the uncertain market potential that places marine energy in an unclear position in the future national energy system. There is no political vision for the development of the technology field and no strategies or roadmaps (Andersson, 2013; Interview E; Interview Q; Meeting Notes, 2014b). Consequently, the rationale for policy initiatives has so far been unclear. Two rationales may be adopted; deployment of technologies in Sweden or creation of an industry that can supply the global market. These hold different implications as regards the role of a domestic market in the development of the technology field. Thus, the unclear rationale spurs the market uncertainty. In addition, the absence of strategies or roadmaps has contributed to the poor coordination among public actors, and is also reflected in the lack of clear instructions to public actors that are involved in the consenting process for sea installations (Interview E; Interview S; Interview W). Taken together, these features make up a lack of political direction, which is identified as a blocking factor (B5).

4.7. Market formation

Marine energy technology is expensive (see Figure 4) and both Swedish and international markets are still pre-commercial. It will likely take decades before the technologies can fully compete with other renewables (Esteban & Leary, 2012). This indicates significant weaknesses in market formation.

However, leading Swedish device developers aim for markets with higher energy prices, such as Africa and the Middle East, as faster routes to commercialization (Hammar, 2014; Meeting Notes, 2014a). Also, niche applications, such as desalination plants, oil platforms and fish farming could pave the way to commercial markets, as may integration with other offshore renewables (Ingmarsson, 2014; Interview K; Interview Q; Meeting Notes, 2014b, 2014c).

Although device developers focus on international markets, domestic market development is considered important for enabling test and demonstration activities and fostering a local industry (Lewis & Wiser, 2007). The green certificates system is the only demand-side policy instrument in Sweden that aims to stimulate domestic market formation.[28] However, the scheme is designed for stimulating market deployment for reaching national renewable energy targets, rather than early-stage test and demonstration activities. Wave power technology is less mature than other renewables[29] included in the scheme and still in a test and demonstration phase. Therefore, the scheme is ineffective in driving market formation given current technology maturity. The discrepancy between the technology maturity and the design of the Swedish green certificate system becomes obvious when the estimated cost of energy for wave power is compared to the Swedish electricity price including the green certificate subsidy, as illustrated in Figure 4.

[28] Only wave power is included in the scheme since the potential for tidal and ocean current power is considered marginal.

[29] The cost of energy is uncertain since the technologies are still immature. Available estimates include: Bloomberg New Energy Finance (2014) at 0.19 EUR per kWh; OECD (2010) at 0.14 EUR per kWh; and SI OCEAN (n.d.) at 0.30–0.59 EUR per kWh (estimate includes experiences from real installations).

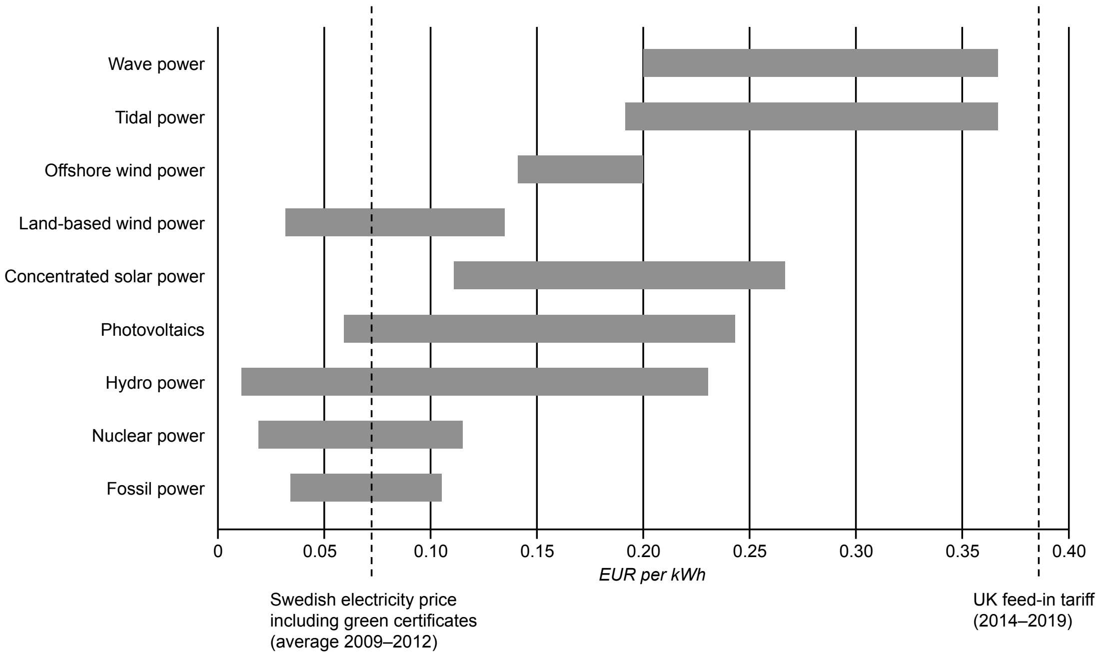

Figure 4. Estimated cost of energy for different energy sources, the Swedish electricity price (with subsidy from the Green Certificate system) and the UK feed-in tariff (Bloomberg New Energy Finance, 2014; DECC, 2013; SEA, 2014).

In comparison, most European countries with technical potential for marine energy have stronger support schemes such as investment support, tax incentives and feed-in tariffs (de Jager et al., 2011). For example, Figure 4 illustrates that the UK feed-in tariff for wave power is about five times higher per kWh than the Swedish electricity price including the green certificate subsidy.

However, the appropriateness of market formation policies will depend on the rationale for supporting marine energy in Sweden. If the rationale is to create an industry that can export technology suitable for harnessing the global potential, then strong domestic market incentives could potentially guide actors in the wrong direction. Technologies that perform well in Swedish conditions are not necessarily the ones that will be demanded globally. On the other hand, if the rationale is to deploy marine technologies in Sweden, then strong domestic market incentives are vital. Market formation is therefore strongly connected to the uncertain market potential (B4) and to the lack of political direction (B5). Nonetheless, the lack of sufficient market incentives that can stimulate test and demonstration activities is identified as a blocking factor (B6).

5. Discussion on blocking factors and policy issues

So far, this paper has identified and described the structural components of the Swedish marine energy innovation system, analyzed its functions, and identified six blocking factors. In this section, the focus turns to the policy implications that follow from these findings. It begins with an overview of the identified blocking factors (see Table 5) and then discusses the key policy issues that emerge.

Table 5. An overview of the identified blocking factors and their main impacts on the system.

Blocking factor	*Main impacts*
B1. Resource demanding test and demonstration activities	Limited experimentation and persistent technical uncertainties, which have made established actors passive, reduced private investments and affected attitudes negatively.
B2. Lack of knowledge and coordination among public actors	An uninformed, unbalanced and non-transparent allocation of public funding, which has led to concentrated knowledge development and contributed to low levels of trust and limited collaboration among actors.
B3. Lack of collaboration among actors	Limited knowledge diffusion, few joint RD&D projects (which enable resource-pooling and risk sharing), and poor political lobbying.
B4. Uncertain domestic market potential	Passive established actors and hindered development of political direction.
B5. Lack of political direction	A lack of clear instructions to and coordination among public actors, passive established actors, and uncertainties regarding the domestic market potential.
B6. Insufficient market incentives	A lack of market incentives for test and demonstration activities, which has made established actors passive.

The analysis reveals that the blocking factors are closely related and interdependent, and have had multiple impacts on the system. To shortly summarize the dynamics, the analysis indicates that the uncertain domestic market potential (B4) has hindered the development of political direction (B5), particularly around the crucial issue of whether policy interventions should aim for deploying marine energy technologies in Sweden or for creating an industry that can supply the global market. At the same time, the absence of political direction (B5) has likely added to uncertainty regarding the domestic market potential (B4), since policy has not taken an active role in shaping expectations.

The uncertainties created by these interlinked blocking factors (B4 and B5) have had a number of impacts on the system, which may be summarized in three sequences. First, they have contributed to a lack of knowledge and coordination among public actors (B2), which has led to an uninformed, unbalanced and non-transparent allocation of RD&D funds. Knowledge development has been concentrated to the Uppsala Network, with poor knowledge diffusion and a somewhat unintentional focus on a single technology concept as a result. This has reduced trust in the system and limited the collaboration among actors (B3) outside of this network.[30] In turn, the limited collaboration has resulted in few collaborative RD&D projects, which sequentially reduce the possibilities to pool resources and share risk when carrying-out resource demanding test and demonstration activities (B1). Another consequence of the poor collaboration among actors (B3) is that political lobbying for the technology field, which could potentially have resolved uncertainties by stimulating the development of political direction (B5), has been poor. Second, the uncertain domestic market potential (B4) and the lack of political direction (B5) have made established actors, with much needed capabilities and resources, passive and reluctant to enter the system. This hampers the development, since test and demonstration activities are very resource demanding (B1). The result is persistent technical uncertainties, which further add to the passivity of established actors. Finally, the unclear role of the domestic market, induced by the uncertain domestic market potential (B4) and lack of political direction (B5), has contributed to the lack of sufficient market incentives (B6), which further hinder test and demonstration activities and adds to the passivity of established actors.

It follows that the key policy issues revolve around the uncertain domestic market potential (B4) and the lack of political direction (B5). However, in order to successfully address these blocking factors, the overarching policy rationales for promoting marine energy technology have to be taken into account. Public support to RD&D and deployment of renewable energy technologies is normally motivated by their potential for: supplying low-carbon power to the Swedish

[30] Although uninformed and uncoordinated policy actions have induced the poor collaboration among actors, this is obviously not the only factor that influences the actions of the actors.

energy system, in order to achieve ecological sustainability, ensure competitiveness of Swedish industry and maintain security of supply; and for driving domestic economic development and create new jobs, by forming the basis for a new export industry (Swedish Government, 2009, 2012). An additional rationale is the potential contribution to global sustainable development by supporting technologies that can be deployed abroad, especially in developing countries where needs for renewable energy are pressing.

The degree of policy engagement in marine energy technology should correspond to the potential benefits that derive from the rationales described above. Although there are great difficulties with assessing the potential benefits, it is possible to explore the feasibility of different policy rationales. A central aspect, and possibly a necessary first step for any policy development, is to assess the domestic market potential. If domestic deployment turns out to be unfeasible, the potential for creating an industry that primarily caters to the international market should be explored. The rationale for public support would then rest on arguments for driving domestic economic development rather than supplying low-carbon power to the Swedish energy system. However, creating an export industry without access to a domestic market may turn out to be difficult. Experiences from solar power in Germany highlight that policy interventions aiming to promote a technology field may unintentionally lead to industry growth and economic benefits that mainly arise abroad (Binz et al., 2014; Pegels & Lütkenhorst, 2014). In these cases, public support may still make important contributions on a global level by reducing the cost of renewable energy technology. However, it is questionable if this outcome is in line with the policy rationale that motivated the investments.

After assessing the domestic market potential, a political direction needs to be established. This includes exploring whether the technology field should be politically prioritized. If policy perceives that marine energy merits priority, a vision that provides clear goals and clarifies the role of the domestic market needs to be in place. Moreover, the vision needs to be operationalized on a tactical level in strategies and roadmaps that can create balance, predictability and transparency in support systems. This is likely to facilitate coordination among public actors in different policy areas, such as research, innovation, energy and environment. If the political direction involves domestic deployment, it will also guide public actors in balancing global climate benefits against local environmental impacts when allocating space at sea. In addition, a clear political direction can potentially build trust and stimulate collaboration as well as attract established actors with important capabilities and resources. This would likely accelerate the reduction of technical uncertainties, by stimulating knowledge diffusion and enabling resource demanding test and demonstration activities focused on verifying reliability and affordability. It should be stressed, however, that the ultimate decision to invest, engage and collaborate lies with the actors, even though policy has an important role in creating the right conditions.

Conclusively, the appropriate design of support systems obviously depends on the political direction. If the ambition is to achieve commercial deployment of marine energy technologies in Sweden, allocation of RD&D funding should promote technology concepts that can harness Swedish wave, tidal stream and current resources. In addition, domestic deployment would require market incentives that are adapted for the technologies' early development stage. Relying on existing market support systems for renewable energy (i.e. the Green Certificate System) is not enough to stimulate deployment, since marine energy is still far less mature than other renewables. On the other hand, if the ambition is to create an export industry that primarily caters to international markets, the allocation of RD&D funding should promote technology concepts that can harness the global resource. A key challenge given this scenario is to ensure that industrial development and job creation takes place in Sweden, since this is what then primarily motivates public support. One possible strategy is to introduce support systems that stimulate a domestic niche market for testing and demonstration, which can possibly help retain parts of the value chain in Sweden even though the focus is on export markets. However, this may unintentionally lead to the promotion of technologies adapted for Swedish conditions, which are not necessarily the ones suitable for harnessing the global potential. Independently of which of these scenarios that the political direction points to, it is quite clear that public support is required to reduce technical uncertainties and verify the reliability and affordability of marine energy technologies. In addition, an overarching issue bears repeating, namely the degree of political attention that marine energy merits. This issue underlines the importance of establishing an informed political direction that clearly link public investments to environmental, social and economic benefits.

6. Conclusions

The purpose of this paper is to describe and analyze the Swedish marine energy innovation system. It reveals that the system is characterized by: immature and expensive technologies, with substantial global but limited domestic resource potential; promising device developers and world-class research, but passive established actors; strong local networks, but weak linkages between them; and, substantial public funding and quite positive attitudes, but lack of vision, strategies, laws and regulations. Moreover, the functions show a number of significant weaknesses. Knowledge development is highly concentrated and poorly diffused throughout the system. Entrepreneurial experimentation activities have not successfully reduced technical uncertainties. The mobilization of private capital is weak and the allocation of public RD&D funding is questionable. Social capital is characterized by lack of trust and limited collaboration among actors. Strong legitimacy among the general public has not led to political prioritization. Weak influence on the direction of search has made established actors passive. Finally, market incentives are insufficient for stimulating testing, demonstration and deployment. By identifying six blocking factors that contribute to these weaknesses, and exploring the connection between these, this paper highlights key policy issues that revolve around the uncertain domestic market potential and lack of political direction. Uncertainties stemming from these two blocking factors have contributed to others, such as a lack of knowledge and coordination among public actors as well as limited collaboration among actors. Moreover, they have hindered resource demanding test and demonstration activities as well as contributed to insufficient market incentives.

The analysis concludes that a necessary first step for any policy development is to assess the Swedish market potential and establish an informed political direction. This step should clarify whether the technology field is politically prioritized and, if so, outline a vision, provide clear goals and clarify the role of the domestic market: is it a first step towards large-scale deployment or a stepping-stone towards creating an export industry? Reducing political uncertainties may facilitate the coordination among public actors, build trust and stimulate collaboration in the system as a whole, and attract established actors with important capabilities and resources. Finally, based on the political direction and depending on policy's propensity to promote the development of the technology field, balanced, predictable and transparent support systems need to be in place. This is likely to involve both extensive RD&D funding and appropriate market incentives.

These findings are largely in line with previous studies of marine energy innovation systems in other national contexts. For example, Hamawi and Negro (2012) highlight the need for a clear vision and more collaboration in Portugal, while Vantoch-Wood (2012) emphasizes the need for coherent and transparent innovation support in the UK. However, this paper paints a slightly different picture of the Swedish marine energy innovation system than Corsatea (2014), which highlights Sweden as a country with very high private and public investments relative to many other European countries. This is largely because it draws heavily on data from 2011, which was an exceptional year in terms of resource mobilization in Sweden (see Section 4.3). Moreover, by focusing on quantitative data, Corsatea (2014) fails to highlight uncertainties regarding resource availability and political direction, weak networks and poor collaboration, and passivity of established actors, which are key for the findings presented in this paper.

The study presented in this paper is a first attempt at performing a thorough analysis of the Swedish marine energy innovation system, and the scope for expanding the analysis, in terms of both breadth and depth, is significant. In addition, the findings highlight an important area for future research, namely the policy challenges associated with promoting a technology field where the domestic market potential is highly limited, but where there are promising device developers, relevant industrial capabilities and world-class research. There is a need for a deeper understanding of the characteristics of the innovation systems related to such technology fields, the global and national benefits they may bring, and how policy can act to stimulate their development, if public support is considered motivated. As this paper shows, marine energy in

Sweden is a very interesting case, but fully analyzing this particular aspect has been beyond the scope of this study. This would involve a more thorough analysis of certain functions and the system's global context, and possibly a scenario approach where implications of different political directions are analyzed separately. A study of this kind could potentially lead to more robust policy recommendations as well as to theoretical contributions about how to balance national and global perspectives when analyzing innovation using the TIS framework.

References

Andersson, J. (2013). Blå energi – En strategisk innovationsagenda för marin energi. Chalmers University of Technology. Gothenburg, Sweden.

Andersson, J., et al. (2013). Fiska jobb och energi ur havet. NyTeknik, June 5, p. 29.

Backman, M. (2014). Vind, vågor & bioenergi. Göteborgs-Posten, February 2, pp. 64–66.

Bergek, A. (2012). Ambiguities and challenges in the functions approach to TIS analysis: a critical literature review. In International Conference on Sustainability Transitions. Copenhagen, Denmark.

Bergek, A., et al. (2008a). Analyzing the functional dynamics of technological innovation systems: A scheme of analysis. Research Policy, 37(3), 407–429.

Bergek, A., et al. (2008b). "Legitimation" and "development of positive externalities": two key processes in the formation phase of technological innovation systems. Technology Analysis & Strategic Management, 20(5), 575–592.

Bernhoff, H., Sjöstedt, E., & Leijon, M. (2006). Wave energy resources in sheltered sea areas: A case study of the Baltic Sea. Renewable Energy, 31(13), 2164–2170.

Billquist, K., & Södahl, B. (2012). Utvärdering av CFE II 2011. Report to the Swedish Energy Agency.

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

Bloomberg New Energy Finance. (2014). Global Trends in Renewable Energy Investment 2014. Frankfurt, Germany.

Claesson, L., et al. (1987). Energi från havets vågor. Stockholm, Sweden: Energiforskningsnämnden.

Corneliusson, M. (2013). Centerpartister besökte Seabased. Bohusläningen, January 22, p. 11.

CorPower Ocean. (2012). CorPower Ocean. Retrieved April 15, 2014, from http://www.corpowerocean.com

Corsatea, T. D. (2014). Increasing synergies between institutions and technology developers: Lessons from marine energy. Energy Policy, 1–16.

Current Power. (2014). Current Power. Retrieved April 10, 2014, from http://www.currentpower.eu

Dalton, G., & Ó Gallachóir, B. P. (2010). Building a wave energy policy focusing on innovation, manufacturing and deployment. Renewable and Sustainable Energy Reviews, 14(8), 2339–2358.

de Jager, D., et al. (2011). Financing Renewable Energy in the European Energy Market. Retrieved March 15, 2014, from http://ec.europa.eu/energy/renewables/studies/doc/renewables/2011_financing_renewable.pdf

DNV GL. (n.d.). Offshroe Wind 10 Years 10 Lessons – Reflections on a decade of experience. Retrieved March 10, 2014, from http://www.gl-group.com/assets/technical/10years_10_lessons_GL_GH.pdf

Ehn, T., & Nordin, L. (2013). Framtidens energi finns i Bohuslän. Bohusläningen, October 16, p. 23.

EIT. (2013). KIC InnoEnergy: CorPower Ocean – Getting Closer to the Sea. European Institute of Innovation & Technology. Retrieved April 22, 2014, from http://eit.europa.eu/newsroom/kic-innoenergy-corpower-ocean-–-getting-closer-sea

EMEC. (2014). European Marine Energy Centre. Retrieved March 15, 2014, from www.emec.org.uk

Encubator. (2012). Encubator. Retrieved April 25, 2014, from http://www.encubator.com

Esteban, M., & Leary, D. (2012). Current developments and future prospects of offshore wind and ocean energy. Applied Energy, 90(1), 128–136.

Fortum. (2011). Fortum and Seabased AB to start construction of a wave power park in Sweden. Press Release. Retrieved April 4, 2014, from http://www.fortum.com/en/mediaroom/Pages/fortum-and-seabased-ab-to-start-construction-of-a-wave-power-park-in-sweden.aspx

Foxon, T. J., Gross, R., Chase, a., Howes, J., Arnall, a., & Anderson, D. (2005). UK innovation systems for new and renewable energy technologies: Drivers, barriers and systems failures. Energy Policy, 33(16), 2123–2137.

Fröberg, J. (2013). Sex heta miljöteknikbolag blev sex iskalla. Svenska Dagbladet, July 5, p. 4.

Grahn, D. (2011). Utredning av möjligheterna till marin förnybar energi i Öresund. Master's Thesis. Lund Institute of Technology. Lund, Sweden.

Hamawi, S., & Negro, S. O. (2012). Wave Energy in Portugal The paths towards a successful implementation. Proceedings to International Conference on Ocean

Energy 2012. Retrieved from http://www.icoe2012dublin.com/icoe_2012/downloads/papers/day2/1.6 International Roadmaps/Soraya Hamawi - Wave Energy Centre.pdf

Hammar, L. (2014). Power from the Brave New Ocean - Marine Renewable Energy and Ecological Risks. Doctoral Thesis. Chalmers University of Technology. Gothenburg, Sweden.

Hammar, L., et al. (2012). Renewable ocean energy in the Western Indian Ocean. Renewable and Sustainable Energy Reviews, 16(7), 4938–4950.

Hedberg, P. (2011). Färre vill satsa mer på vindkraft. In Holmberg, S., Weibull, L. & Oscarsson, H. (red) Lycksalighetens ö. SOM Institute, Gothenburg University. Gothenburg, Sweden.

Hekkert, M. P., & Negro, S. O. (2009). Functions of innovation systems as a framework to understand sustainable technological change: Empirical evidence for earlier claims. Technological Forecasting and Social Change, 76(4), 584–594.

Henricson, L. (2012). Alliansförslag skapar irritation. Göteborgs-Posten, May 30, p. 11.

Hillman, K. M., & Sandén, B. A. (2008). Exploring technology paths: The development of alternative transport fuels in Sweden 2007–2020. Technological Forecasting and Social Change, 75(8), 1279–1302.

Ingmarsson, P. (2014). Förstudie om havsenergibranschens forsknings och utvecklingsbehov Innehållsförteckning. Report to the Swedish Energy Agency. SP Technical Research Institute of Sweden and ÅF-Infrastructure AB.

Interview A–Y. (2014). Anonymous stakeholder interviews. Performed by the authors during 2014.

IPCC. (2011). IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation. Prepared by Working Group III of the Intergovernmental Panel on Climate Change [O. Edenhofer, R. Pichs-Madruga, Y. Sokona, K. Seyboth, P. Matschoss, S. Kadner, T. Zwickel, P. E.]. IPCC. Geneva, Switzerland.

IPCC. (2014). Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC. Geneva, Switzerland.

Jacobsson, S., & Karltorp, K. (2013). Mechanisms blocking the dynamics of the European offshore wind energy innovation system – Challenges for policy intervention. Energy Policy, 63(June 2010), 1182–1195.

Jacobsson, S., Sandén, B., & Bångens, L. (2004). Transforming the Energy System—the Evolution of the German Technological System for Solar Cells. Technology Analysis & Strategic Management, 16(1), 3–30.

Jeffrey, H., Jay, B., & Winskel, M. (2013). Accelerating the development of marine energy: Exploring the prospects, benefits and challenges. Technological Forecasting and Social Change, 80(7), 1306–1316.

Johnsson, L. (2013). Aktier ska förverkliga Seabaseds nya fabrik. Bohusläningen, June 27, p. 17.

Kerr, S., et al. (2014). Establishing an agenda for social studies research in marine renewable energy. Energy Policy, 67, 694–702.

Kim, C.-K., et al. (2012). Catching the right wave: evaluating wave energy resources and potential compatibility with existing marine and coastal uses. PloS One, 7(11), e47598.

Levin, D. (2012). Politiker avvaktar satsningar. Dagens Nyheter, October 1, p. 9.

Lewis, J. I., & Wiser, R. H. (2007). Fostering a renewable energy technology industry: An international comparison of wind industry policy support mechanisms. Energy Policy, 35(3), 1844–1857.

Lindroth, S., & Leijon, M. (2011). Offshore wave power measurements - A review. Renewable and Sustainable Energy Reviews, 15(9), 4274–4285.

Løvdal, N., & Neumann, F. (2011). Internationalization as a strategy to overcome industry barriers-An assessment of the marine energy industry. Energy Policy, 39(3), 1093–1100.

Lundgren, A. (2011). Vågkraften har potential i Sverige. GT, January 31, p. 19.

Magagna, D., & Uihlein, A. (2015). 2014 JRC Ocean Energy Status Report. Retrieved May 10, 2014, from https://setis.ec.europa.eu/system/files/2014 JRC Ocean Energy Status Report.pdf

Magnusson, M., Lindner, G., & Edlund, M. (2014). Statliga fonder agerar som kortsiktiga riskkapitalister. Dagens Nyheter, March 28 (web Edition). Retrieved from http://www.dn.se/debatt/statliga-fonder-agerar-som-kortsiktiga-riskkapitalister/

Markard, J., & Truffer, B. (2008). Technological innovation systems and the multi-level perspective: Towards an integrated framework. Research Policy, 37(4), 596–615.

Meeting Notes. (2014a). Notes form workshop on business, environment and renewable energy in Western Sweden, organized by The Swedish Federation of

Business Owners, Fouriertransform and Sotenäs Municipality, June 26, 2014. Smögen, Sweden.

Meeting Notes. (2014b). Notes from workshop on the future of the Ocean Energy Centre, organized by Chalmers University of Technology, May 21, 2014. Gothenburg, Sweden.

Meeting Notes. (2014c). Notes from workshop organized by SP Technical Research Institute of Sweden within the Swedish Energy Agency's preparation for a marine energy funding program, April 11, 2014. Gothenburg, Sweden.

Minesto. (2013). Minesto. Retrieved March 16, 2014, from http://www.minesto.com

Minesto. (2015). Welsh Government invests 13 million euros of EU funds in marine energy leader Minesto to start the commercial roll out of marine power plants in Wales. Retrieved July 1, 2015, from http://minesto.com/welsh-government-invests-13-million-euros-of-eu-funds-in-marine-energy-leader-minesto-to-start-the-commercial-roll-out-of-marine-power-plants-in-wales/

Muller, S., Brown, A., & Ölz, S. (2011). Renewable Energy: Policy Considerations for Deploying Renewables. Retrieved May 20, 2014, from https://www.iea.org/publications/freepublications/publication/Renew_Policies.pdf

Negro, S. O., Alkemade, F., & Hekkert, M. P. (2012). Why does renewable energy diffuse so slowly? A review of innovation system problems. Renewable and Sustainable Energy Reviews, 16(6), 3836–3846.

Nordgren, J., et al. (2011). Quality and Renewal 2011 An overall evaluation of research at Uppsala University 2010/2011 (Vol. 2011). Retrieved February 11, 2014, from http://www.teknat.uu.se/digitalAssets/385/385022_3quality-renewal.pdf

Ocean Dynamic Power. (2014). We're here to change things. Retrieved May 20, 2014, from http://odp-group.com/about-odp/

OECD. (2010). Projected Costs of Generating Electricity. Atomic Energy (Vol. 118 Suppl). Paris and Issy-les-Moulineaux, France: OECD International Energy Agency and OECD Nuclear Energy Agency. Retrieved May 5, 2015, from http://www.oecd-ilibrary.org/oecd/content/book/9789264008274-en\nhttp://www.oecd-ilibrary.org/energy/projected-costs-of-generating-electricity-2010_9789264084315 en\nhttp://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:Projected+Costs+of+Generati

OES. (2014). Annual Report: Implementing Agreement on Ocean Energy Systems. Retrieved March 23, 2015, from http://report2014.ocean-energy-systems.org/documents/OES-Annual-Report-2014/

Pegels, A., & Lütkenhorst, W. (2014). Is Germany's energy transition a case of successful green industrial policy? Contrasting wind and solar PV. Energy Policy, 74, 522–534.

Perez Vico, E. (2013). The Impact of Academia on the Dynamics of Innovation Systems: Capturing and explaining utilities from academic R&D. Doctoral Thesis. Chalmers University of Technology. Gothenburg, Sweden.

Pettersson, I. (2014). Short e-mail communication with the authors during 2014.

Rantakokko, E. (2014). De ska enas om havets villkor. Bohusläningen, January 28, p. 11.

Sandén, B., Hammar, L., & Hedenus, F. (2014). Are renewable energy resources large enough to replace non-renewable energy? In Sandén, B. (Ed.), Systems Perspectives on Renewable Power. Chalmers University of Technology. Gothenburg, Sweden: Chalmers University of Technology. Retrieved August 24, 2014, from http://www.chalmers.se/en/areas-of-advance/energy/cei/Pages/Systems-Perspectives-on-Renewable-Power.aspx

Seabased. (2013). Seabased. Retrieved March 20, 2014, from http://www.seabased.com

Seabased. (2015). Newsroom. Retrieved July 1, 2015, from http://www.seabased.com/en/newsroom

SI OCEAN. (n.d.). Ocean Energy : State of the Art. Retrieved March 26, 2014, from http://si-ocean.eu/en/upload/docs/WP3/Technology Status Report_FV.pdf

SI Ocean. (2014). Wave and Tidal Energy Strategic Technology Agenda. Retrieved March 26, 2014, from http://www.oceanenergy-europe.eu/images/OEF/140215_SI_Ocean_-_Srategic_Technology_Agenda.pdf

Sievers, J. (2010). Uppfinning från LiU hyllas. Norrköpings Tidningar, December 6, p. 14.

Södermanlands Nyheter. (2012). Nej till vågkraft i Oxelösund. Södermanlands Nyheter, October 12, p. 6.

Stern, N. (2006). The economics of climate change – the Stern review. Cambridge University Press. Cambridge.

SwAM. (2014a). Marine spatial planning - Current status 2014. The Swedish Agency for Marine and Water Management. Gothenburg, Sweden.

SwAM. (2014b). Yttrande: Ansökan om tillstånd enligt 11 kap miljöbalken till projektområde för forskning och utveckling inom vågkraft, Dnr. 2236-14. Gothenburg, Sweden: The Swedish Agency for Marine and Water Management.

Swedish Government. (2003). Regeringens proposition 2003/04:42 Torv och elcertifikat. Stockholm, Sweden.

Swedish Government. (2009). Regeringens proposition 2008/09:163 En sammanhållen klimat- och energipolitik – Energi. Stockholm, Sweden.

Swedish Government. (2012). Regeringens proposition 2012/13:21 Forskning och innovation för ett långsiktigt hållbart energisystem. Stockholm, Sweden.

Swedish Government. (2014). Den maritima strategin växer fram. Retrieved July 10, 2014, from http://www.regeringen.se/sb/d/18185

The Crown Estate. (2012). UK Wave and Tidal Key Resource Areas Project - Summary Report. Retrieved March 15, 2014, from http://www.thecrownestate.co.uk/media/5476/uk-wave-and-tidal-key-resource-areas-project.pdf

The Land and Environmental Court. (2014). Ansökan om tillstånd för uppförande och drivande av vindkraftverk i Kattegatt, Falkenberg kommun (Mål nr M 2036-12). Vänersborg, Sweden: The Land and Environmental Court.

The Swedish Energy Agency. (2012). Utvecklingen av tillståndsprocesser för anläggningar som producerar förnybar el och för kraftnät. Retrieved July 15, 2015, from http://www.energimyndigheten.se/Global/Press/Pressmeddelanden/Redovisning_av_uppdrag_10_i_Regleringsbrevet_för_Energimyndigheten_20120831.pdf

Tiger, A. (2009). Potentiellt utbyte inom vågkraft. Kristdemokraten, September 4.

Uppsala University. (2011). CFE - Centrum för förnybar elomvandling. Retrieved May 10, 2014, from http://www.el.angstrom.uu.se/CFE/CFE_se.htm

Uppsala University. (2013a). Lysekilsprojektet – forskning och utveckling av vågkraft. Retrieved August 26, 2014, from http://www.el.angstrom.uu.se/forskningsprojekt/WavePower/Lysekilsprojektet.html

Uppsala University. (2013b). Pågående forskningsprojekt Marin Strömkraft. Retrieved August 26, 2014, from http://www.el.angstrom.uu.se/forskningsprojekt/Marin Stromkraft.html

Vantoch-Wood, A. (2012). Developments within the UK Wave Energy Sector. Proceedings for BIEE 9th Academic Conference.

Vantoch-Wood, A., & Connor, P. M. (2013). Using network analysis to understand public policy for wave energy. Energy Policy, 62, 676–685.

Vattenfall. (2011). Ocean Energy Development Programme Annual Report 2011. Retrieved April 20, 2014, from http://corporate.vattenfall.com/Global/corporate/news_and_media/doc/Ocean_Energy_Annual_Report_2011_20781072.pdf

VINNOVA. (2009). Var ligger horisonten? Stor potential men stora utmaningar för vågkraften. The Swedish Innovation Agency. Stockholm, Sweden.

Wangel, U. (2009). Vågkraftsvisioner för Skurups kommun. Ystads Allehanda, June 1, p. 16.

Waves4Power. (n.d.). Den Historiska bakgrunden till W4P WAVES4POWER AB Åren 1974 till 2013.

Wenblad, A., Lindegarth, S., & Hanning, A. (2012). Maritime Clusters in Västra Götaland. Gothenburg and Tjärnö, Sweden.

WERG. (1979). Vågenergi i Sverige. Report by the Wave Energy Research Group, commissioned by the Swedish committee for energy production research.

Winskel, M. (2007). Marine energy innovation in the UK energy system: financial capital, social capital and interactive learning. International Journal of Global Energy Issues, 27(4), 472.

Winskel, M., et al. (2006). Energy policy and institutional context: marine energy innovation systems. Science and Public Policy, 33(5), 365–376.

Winskel, M., et al. (2014). Remaking the UK's energy technology innovation system: From the margins to the mainstream. Energy Policy, 68, 591–602.

Zerpe, H. K. (2008). Länsföretag på ambassadörs lista för framtiden. Norrbottens-Kuriren, December 29, p. 36.