Energy Policy 101 (2017) 52–64

Contents lists available at ScienceDirect

Energy Policy

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

The critical role of informed political direction for advancing technology: The case of Swedish marine energy

Johnn Andersson[a,*], Eugenia Perez Vico[b,c], Linus Hammar[d], Björn A. Sandén[a]

[a] Chalmers University of Technology, Division of Environmental Systems Analysis Department of Energy and Environment, Gothenburg, Sweden
[b] Lund University, Department of Business Administration, School of Economics and Management, Lund, Sweden
[c] Halmstad University, School of Business, Engineering and Science, Halmstad, Sweden
[d] The Swedish Agency for Marine and Water Management, Department of Marine Spatial Planning and Maritime Affairs, Gothenburg, Sweden

ARTICLE INFO

Keywords:
Technological innovation systems
Innovation policy
Ocean energy
Marine energy
Wave power
Tidal power

ABSTRACT

Marine energy technologies can contribute to meeting sustainability challenges, but they are still immature and dependent on public support. This paper employs the Technological Innovation Systems (TIS) framework to analyze the development and diffusion of Swedish marine energy up until 2014. While there were promising device developers, relevant industrial capabilities, and world-class research, the system suffered from weaknesses in several important innovation processes. Finally, the analysis identifies the lack of informed political direction as a critical blocking factor and highlights its connection to domestic market potential.

1. Introduction

Marine energy technologies[1] that produce power from ocean waves and tides can play a role in meeting the urgent climate challenge (IPCC, 2012, 2014; Stern, 2006), but they are immature and remain dependent on public support (OES, 2014a). Sweden is one of several countries that have promoted marine energy development through different policy measures (Corsatea, 2014; OES, 2014a). After an early start in the 1970s (Lindroth and Leijon, 2011; WERG, 1979) followed by decreased interest and activity during the 1990s, the last 15 years have seen the emergence of several device developers and substantial public investments in research, development, and demonstration (RD & D). Nevertheless, many stakeholders perceive policymakers as passive and misguided, which indicates a need for a deeper understanding of the factors that influence the sector's development (Andersson, 2013).

A number of studies address a broad set of policy challenges related to marine energy in countries such as the UK (Dalton and Ó Gallachóir, 2010; Jeffrey et al., 2013; Vantoch-Wood, 2012; Vantoch-Wood and Connor, 2013; Winskel et al., 2006; Winskel, 2007) and Portugal (Hamawi and Negro, 2012). Others focus on specific issues such as social acceptance and industry barriers (Kerr et al., 2014; Løvdal and Neumann, 2011), and some include 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).[2] While the existing evidence highlights many interesting aspects by comparing several European countries, it provides a rather limited understanding of the Swedish case for two reasons. Firstly, it mainly draws on data from 2011, which was not a representative year for Swedish developments.[3] In addition, it mainly relies on quantitative data and therefore fails to capture some of the factors that hinder the field's development.

The purpose of this paper is therefore to identify factors that block the development and diffusion of Swedish marine energy and to discuss related policy issues. As a case of the role of policy intervention in early development stages, it also contributes to more general discussions on technology policy. The study covers developments up until 2014 and applies the Technological Innovation Systems (TIS) framework (Bergek et al., 2008a, 2008b; Hekkert et al., 2007), which has proved useful for

Abbreviations: NGO, non-governmental organization; R & D, research & development; RD & D, research, development, and demonstration; SwAM, Swedish Agency for Marine and Water Management; TIS, Technological Innovation Systems

* Corresponding author.
E-mail address: johnn.andersson@chalmers.se (J. Andersson).

[1] There is no commonly agreed-upon definition of marine energy. In the present paper, however, marine energy refers to energy harnessed from ocean waves and tides, with the latter including both 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 the concept.

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

[3] In 2010 and 2011, public and private investments were exceptional compared to the years before and after (Section 5.3).

http://dx.doi.org/10.1016/j.enpol.2016.11.032
Received 25 December 2015; Received in revised form 17 November 2016; Accepted 20 November 2016
0301-4215/

identifying blocking factors in a wide range of technology areas (Bergek, 2012) including marine energy (Corsatea, 2014; Hamawi and Negro, 2012; Vantoch-Wood, 2012). The analysis focuses on the Swedish marine energy innovation system but includes influential developments in other sectorial or geographical contexts.

2. Analytical framework, scope and methodology

Based on Bergek et al. (2008b), we define a TIS as the socio-technical system that enables the development and diffusion of a new technology, where 'technology' can be more or less broadly defined. A TIS accordingly consists of four structural component types: actors such as companies, research institutions, government agencies, and non-governmental organizations (NGOs); networks, which can be formal or informal; institutions, consisting of laws and regulations, as well as norms, beliefs, and expectations; and technology including artifacts and knowledge. Few of these components are in place when a new technology field such as marine energy emerges (Bergek et al., 2008b). Thus, the TIS structure must be gradually developed through technology accumulation, actor entry, network formation, and institutional alignment (Bergek et al., 2008b; Hekkert and Negro, 2009).

TISs are commonly analyzed by describing a set of sub-processes that build system structures, referred to as functions (Bergek et al., 2008a, 2008b; Hillman and Sandén, 2008; Markard and Truffer, 2008). These emanate from the combined effect of agency, internal system structure, and influences from the system's geographical and sectorial context (Bergek et al., 2008b; Hillman and Sandén, 2008). The latter include stimuli and obstructions from less technology-specific structures such as established industries and political, educational, and financial systems; spillovers from technological development in other geographical areas; and competition and coevolution with related emerging technologies (Bergek et al., 2015; Sandén and Hillman, 2011). Analyzing strengths and weaknesses in TIS functions, and identifying how they interact in sequences of cumulative causation that either stimulate or obstruct system development, provides a dynamic understanding of the system (Suurs and Hekkert, 2009). This in turn enables the identification of factors that block development and could be targeted by policy (Bergek et al., 2008a). Table 1 lists the seven functions used in this paper.[4]

This study concerns the Swedish marine energy innovation system and thus focuses on the development and diffusion of devices for producing electric power from ocean waves and tides. Less technology-specific activities downstream (e.g., electric power transmission and consumption) and upstream (e.g., production of raw materials and manufacturing technology) of the value chain fall outside the system boundary.[5] The analysis covers activities in the Swedish marine energy innovation system up until 2014, as well as influential developments in other geographical or sectorial contexts. It largely follows the methodology suggested by Bergek et al. (2008a). First, the global context for marine energy technology is reviewed (Section 3). Then, the structural components in the Swedish marine energy innovation system are identified (Section 4). The functions are subsequently analyzed,[6] and a set of blocking factors is identified (Section 5). Finally, policy issues derived from the blocking factors are discussed (Section 6).

[4] The functions can be defined, grouped, divided, and aggregated in many different ways (Bergek et al., 2008a; Markard and Truffer, 2008). This paper follows Bergek et al. (2008a), with additions from Jacobsson and Karltorp (2013) and Perez Vico (2014).

[5] Although these parts of the value chain are placed outside of the TIS, they are still highly relevant for the analysis. It should also be noted that some actors whose main activities fall outside the system boundary are still included because they engage with device developers and have relevant capabilities (and accordingly constitute potential entrants). Moreover, technological systems such as the power grid constitute important infrastructure and are therefore discussed in the analysis.

[6] 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.

Table 1
Functions of innovation systems (Bergek et al., 2008a; Jacobsson and Karltorp, 2013; Perez Vico, 2014).

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 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.

Empirically, the paper is based on 25 semi-structured interviews (Table 2), 6 short e-mail communications, and direct observations during 3 multi-stakeholder workshops.[7] Data were also obtained through a mapping of Swedish public RD & D funding,[8] patent search,[9] mapping of the number of bills and motions concerning marine energy from the Swedish government and parliament,[10] and media search.[11] In addition, the study builds on industry reports, official documents from public agencies, actors' websites, and academic literature.

3. The global context for marine energy technology

Marine energy technologies have a large physical resource potential estimated at about 90 000 TWh per year (Sandén et al., 2014).[12] It is clear, however, that only a minor part of the physical potential can realistically be exploited due to technical, economic, social, and ecological constraints. For example, marine energy power plants moored to the seafloor exclude large parts of the global potential due to insurmountable depths, sites far offshore will be more expensive to exploit due to infrastructure requirements, some areas may be reserved for other activities such as fishing, and local environmental impacts must be weighed against global benefits. Although the socioeconomic potential (i.e., the realistically expected level of deployment) is dynamic and dependent on how constraints are developed and perceived (IPCC, 2012),[13] it has been estimated at a few hundred (Sandén et al., 2014) or thousand (The Carbon Trust, 2012) TWh per year. While the global potential is not very impressive compared to solar and wind energy, it

Table 2
Distribution of interviews among actor categories and reference codes.

Stakeholder perspective	*Number of interviews*	*Ref. code*
Device developers	5	D1–D5
Suppliers and utilities	6	F1–F6
Industry associations	2	I1–I2
Universities and research institutes	5	R1–R5
Policy experts	2	E1–E2
Public actors	5	P1–P5