Applied Energy 212 (2018) 527–551

Contents lists available at ScienceDirect

Applied Energy

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

A strategic analysis of tidal current energy conversion systems in the European Union

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HIGHLIGHTS

- A strategic analysis for offshore tidal energy conversion systems is provided.
- It covers political, economic, social, technological, environmental and legal aspects.
- Different strategies/recommendations to mitigate all risks are suggested.
- The presented analysis can be used to support future R&D and deployment.

ARTICLE INFO

Keywords:
Ocean energy
Tidal energy converters
Offshore renewable energy
PESTEL analysis
Risk identification
Risk mitigation

ABSTRACT

The exploitation of ocean energy is currently recognized as an abundant, geographically diverse and renewable energy source that could benefit European citizens by increasing energy independence, enhancing economic growth, creating jobs, allowing decarbonization or serving as a complement to other renewable sources within the global energy mix. Of the various types of ocean energy (wave, tidal, offshore wind, salinity gradient and thermal gradient), this paper is focused on technologies with which to harness the energy from ocean currents. This energy will have considerable possibilities in the future thanks to its high predictability and its enormous potential for the production of electricity. Most of the review papers concerning tidal energy systems are focused on engineering topics. However, there continues to be limited information as regards other aspects, such as those of an economical, social, political, legislative and environmental nature which, together with their inter-relationships, need to be dealt with as a whole in order to detect the key drivers that could affect the success or failure of making tidal energy technologies marketable. The objective of this review paper is to address this gap by providing a detailed strategic analysis based on the most up-to-date literature, reports and guidelines. The paper discusses the different disciplines of which the PESTEL analysis (political, economical, social, technological, environmental and legal) is composed and provides different strategies/recommendations through which to mitigate many of the risks identified in order to facilitate the successful development of these technologies and bring them onto the market. Finally, some recent advances in tidal technologies developed by our research group (GIT-ERM) are also highlighted in the technological part of this paper.

1. Introduction

Energy is a vital element in human life, and if modern societies are to be sustained then obtaining a secure, sufficient and accessible energy supply is fundamental. The demand for the provision of energy is rapidly increasing throughout the world and this trend is likely to continue in the future [1,2]. The growing recognition that global warming exists has led more governments, research centers and corporations to commit resources to the advancement of renewable energy technologies. The various nations within and bordering the region of the Oslo-Paris Commission (OSPAR) are all committed to significant reductions in carbon dioxide (CO_2) emissions in the short term. The European Union (EU) has set a target to reduce 20% of energy consumption and 20% of CO_2 emissions with the objective of 20% of the EU's final energy consumption will originate from renewable sources in 2020 [3]. Renewable energy generation could, in addition to provide a means to substantially reduce CO_2 emissions, help reduce national dependencies on imported energy, thus increasing energy security and

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https://doi.org/10.1016/j.apenergy.2017.12.045
Received 9 October 2017; Received in revised form 27 November 2017; Accepted 8 December 2017
0306-2619/

diminishing domestic supplies of fossil fuels [4–9]. One challenge as regards energy is to be able to move to a new low carbon economy in which energy demands can be met while the levels of CO_2 emitted are reduced. In order to meet this challenge, other forms of renewable energy that are currently less developed but which have a high potential, such as ocean energy (which has been indicated as being as one of the five key sectors for sustainable blue growth in the Blue Growth strategy of the EU[1] [10]) has become of incipient interest in the successful development of these technologies and in bringing them onto the market [11,12]. For example, since 2003 the European Commission has assigned more than 140 M€to ocean technology developments and more than 700 M€ to investment in industry, which has been translated into significant progress in this field in the last 8–10 years [13].

Global resources for ocean energy have been estimated to have a net potential greater than that of wind and solar energy (about 32,000 GW) and it has the potential to provide up to 7% of the global electricity demand [14–17]. Given its potential, the industry has established the target of 2020 for an installed capacity of ocean energy of 3.6 GW in the EU [18–20]. However, in the medium to long term, there are indications that ocean energy could make a much more significant contribution and become a major electricity source supply by 2050 [21–25]. The predicted installed capacity of 188 GW by 2050 shows the scale of development [24]. Of the various types of ocean energy (wave, tidal, offshore wind, salinity gradient and thermal gradient), this paper is focused on tidal current energy[2] which, although in its initial stage of development, will have considerable possibilities in the future thanks to its enormous potential for electricity production and its high predictability in comparison to offshore wind and wave energy [28–32].

The EU is characterized by an abundance of ocean energy sources in its coastal waters that could provide opportunities and benefits, some of which are energy independence, job creation, decarbonization or being a complement to other renewable sources within the global energy mix. However, as tidal energy harnessing is still in its infancy, and only some marine current energy conversion systems are being implemented at the prototype and pre-commercial demonstration stage at sea, there are numerous areas of uncertainty which need to be explored if the future of the industry is to be insured. In order to bridge these gaps in data, and based on the most up-to-date literature, reports and guidelines, in this research we have performed a strategic analysis (*PESTEL*) of the ocean energy industry as a whole, and with a more particular focus on tidal current energy. The PESTEL analysis provides a comprehensive list of influences on the possible success or failure of particular strategies and is a framework that is already accepted by industry as a method with which to determine the state of a particular industry or market [33–36]. The PESTEL framework (see Fig. 1) stands for political, economic, social, technological, environmental and legal analysis for this industry/market and also identifies the principal stakeholders involved in each of these disciplines. *Political factors* usually include how and to what degree governments intervene in the economy, *economic factors* have a meaningful impact on how organizations do business and also how profitable they are, *social factors* are the areas that involve the population's shared belief and attitudes, *legal factors* embrace legislative constraints or changes and, *environmental factors* represent green issues. The identification of the key drivers for change will help managers to focus on the most important PESTEL factors that are of the highest priority. Without a clear sense of the key drivers for change, managers will not be able to make the decisions that will enable effective action to be taken. Research has also suggested different strategies/recommendations with which to mitigate many of the risks identified that, when working in this way, could even turn project risks into benefits. The remainder of the paper is organized as follows: Sections 2–6 deal with the different disciplines of which the PESTEL analysis is composed through the process of making tidal current energy technologies marketable, and finally, Section 7 is dedicated to the conclusions of the work.

Fig. 1. PESTEL framework.

2. Political and legal analysis

The political and legal analysis is devoted to the assessment of government regulations and legal factors in terms of their ability to affect the business environment and trade markets. Tidal energy projects (or ocean energy projects in general) are viewed by governments as a renewable energy source with a high potential that could decisively supply a substantial amount of electricity to the grid in the near future and make a significant contribution to the future energy mix [12,32]. However, despite the importance of the political and legal framework, and keeping in mind the rapid evolution of this sector, there is a scarcity of literature that is directly related to ocean energy, and this could lead to important obstacles in the future development of these technologies [37,38]. In fact, the political and legal frameworks may be the most significant non-technical barrier for this renewable energy sector [39,40]. Some of the reasons for this are the following [41,42]:

- The technologies used in ocean energy (wave, tidal, offshore wind, salinity gradient and thermal gradient) have completely different characteristics and have reached different degrees of maturity.
- There is sometimes an absence of dedicated legal frameworks with which to support ocean energy (in the case of wave and tidal energy, procedures designed for other energy sectors such as oil and gas or offshore wind tend to be used instead, thus leading to inappropriate legal procedures and delays in consent).
- In addition to the aforementioned lack of clarity in the consenting processes, we must also include the fragmentation of the consenting authority throughout multiple consenting agencies, which can cause important delays. This evidences the limited experience related to ocean energy, with one coordinating authority or a *one-stop shop* approach. This has led to environmental impact assessment (*EIA*)

[1] The other four are: biotechnology, coastal and marine tourism, seabed mining and aquaculture.

[2] Other tidal technologies are tidal range power plants (or dam-based power plants) that use the difference in the sea level between high and low tides to create power [26]. They use the same principles as conventional hydropower, and require a barrier to impound a large body of water, which then drives turbines and generates electricity. This method has been effectively utilized in France (La Rance), South Korea (Lake Sihwa), Russia (Kislaya Guba) and China (Jiangxia), among others [27].