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Current developments and future prospects of offshore wind and ocean energy

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ABSTRACT

The year 2008 saw the emergence of the first generation of commercial ocean energy devices, with the first units being installed in the UK and Portugal. This means that there are currently four ways of obtaining energy from sea areas, namely from wind, tides, waves and thermal differences between deep and shallow sea water. This paper focuses on current developments in offshore wind and ocean energy, highlighting the efforts currently underway in a variety of countries, principally some of the projects typically less talked about such as those in the Asian-Pacific countries. Finally, the growth potential of these industries will be assessed, using as a basis the historical trends in the offshore wind industry and extrapolating it to compute future growth potentials. Using this as a basis, the percentage of the world's electricity that could be produced from ocean based devices is estimated to be around 7% by 2050, and this would employ a significant amount of people by this time, possibly around 1 million, mostly in the maintenance of existing installations. The paper will also evaluate the likely cost of production per kW of ocean energy technologies using a variety of learning factors.

1. Introduction

Much of the debate on and investment in technological solutions to climate change has so far centred on a range of technologies such as carbon capture and storage (CCS) or geo-sequestration, ocean fertilisation, the so called new generation of nuclear technologies and biofuels. Most of these technologies, however, have been associated with some type of environmental problems. It is still not completely clear if CCS is viable, or whether it can represent a long-term solution. The environmental impacts of large-scale biofuels have also been called into question by a number of authors (see Gasparatos et al. [1] for a critical assessment of the tradeoffs). With regards to nuclear power, independent of its potential and any benefits that it may have, the long-term contamination, suffering and world-wide emotional response the Fukushima nuclear reactor has caused makes it unlikely that democratic countries will have an easy time building new installations of this type.

However, it is imperative that new ways of producing energy are found to satisfy the world's growing appetite for energy. The year 2008 saw the introduction of the first generation of commercial ocean energy devices, with the first units being installed in the UK and Portugal (SeaGen and the Pelamis respectively). With them there are currently three types of energy mechanisms in sea areas from which energy can be generated in a commercial way (i.e. wind, tides and waves). These sets of technologies are not only clean (in terms that they produce no greenhouse gas emissions) but they also have an almost negligible visual impact, especially compared to other renewable sources such as hydropower or onshore wind (provided of course that offshore turbines are located at a sufficiently long distance from the coastline, according to Landenburg [2]).

The ocean energy sector has the potential to make an important contribution to the supply of energy to countries and communities located close to the sea, though this considerable source of renewable energy has so far not been utilised on a significant scale [3]. The 1992 United Nations Framework Convention on Climate Change (UNFCCC) recognises the important role the development, application and diffusion of new technologies will play in reducing greenhouse gas emissions. More recently the United Nations Intergovernmental Panel on Climate Change (IPCC) in its Fourth Assessment Report has highlighted the important role that technology will play in addressing climate change. In fact, large penetrations of various combinations of renewable power could theoretically power entire countries, such as Portugal [4] or even Japan [5].

The objective of the current work is to assess what could be expected from ocean-based renewable energy technologies in the middle to long term. Generally offshore wind and ocean energy systems are not included in the same analysis, and in the present papers the authors argue that as they share the same environment and a number of common characteristics, and hence energy scenario projections should include both sectors together. To develop

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these scenarios the authors have carried out a review of the history and potential of ocean energy installations, and have built a database of all cutting-edge research and applications of ocean and offshore wind energy. A general outline of the state of this sector will be presented in parts 2 and 3 of this paper. In part 4, this information was then fed into a model based on the development of the offshore wind industry to attempt to predict the future development of ocean energy for a variety of scenarios. A prediction was then made of around which date ocean energy is likely to become competitive with other forms of electricity production and the approximate size of the sector in terms of jobs. Part 5 will then compare the results obtained to those of other studies, and this will then be followed by a discussion on the obstacles facing such a large development in ocean-based renewable energy.

2. Description and potential of ocean energy

Ocean energy defines a wide range of engineering technologies that are able to obtain energy from the ocean using a variety of conversion mechanisms. It is an emerging industry, with the first commercial units coming online in 2008 and 2009. It is important to remember that there are technical limits to its application, since although it has been reported that the theoretical global potential for the various types of ocean energy is between 20,000 and 92,000 TWh/year, compared to the world consumption of electricity of around 16,000 TWh/year, it is unlikely that this technology by itself will be able to solve the energy needs of the planet [6]. For instance, although there is estimated to be around 3000 GW worldwide of tidal energy, less than 3% is located in areas suitable for power generation (World Offshore Renewable Energy Report [7]). Wave energy on the other hand has an estimated potential of around 1000–10,000 GW, which is in the same order of magnitude as world electrical energy consumption. However, one advantage of tidal currents over waves (or wind) is its predictability, as tides can be accurately predicted weeks or even years in advance.

Some researchers such as Scruggs and Jacob [8] and Cornett [9] recently noted how the potential for ocean energy is promising, and across Europe, the technically achievable resource has been estimated to be at least 280 TWh per year [8]. In 2003, the US Electric Power Research Institute (EPRI) estimated the viable resource in the United States at 255 TWh per year (6% of demand), comparable to the energy currently generated in the United States by conventional hydropower [8]. Ocean energy can be converted into electricity in four main ways, namely the energy present in the waves, currents, thermal or osmotic energy [6].

3. Current developments in ocean energy

3.1. Tidal barrages

Tidal barrages were built as early as 1966, when the plant at La Rance (France) came into operation, and is still in operation today. China also started to build a number of barrages around this time, as part of policies from 1958 that emphasised energy independence as a key route to poverty alleviation [10]. One of the four stations built, at Shashan, stopped operating in 1984 when the local area was connected to the national grid, due to the high cost of operating the plant [11]. Elsewhere, Canada also built a barrage at Annapolis, which began service in 1984.

More recently, there has been some renewed interest in these schemes, and in late 2004 the Chinese government planned once more to build a tidal power station near the mouth of the Yalu River [10]. Also, Russia is in the process of constructing its first plant. In the UK, tidal barrages, such as the one proposed for the River Severn, are currently being re-appraised. The Severn Barrage is currently around half way through a Feasibility Study Consultation process, although Owen [12] notes how opposition from the Environment Agency and other groups appear to make it unlikely that the project will ever reach construction. The environmental impacts of these structures have generally hindered their wide-scale application, and they have been known to have some impacts on marine biodiversity [13]. At present the only country which is seriously undertaking efforts to construct tidal barrages is South Korea, which is scheduled to complete a 254 MW tidal barrage at Sihwa-ho Lake. Another plant almost three times the size is under planning for Ganghwa. The South Korean government claims that the project will make a profit, as it puts the cost of the project at 355bn won (USD 382 million) [11]. In other countries it is not clear that these plants are economically viable, due to the massive infrastructure investments they require and the fact that often the environmental damage outweighs the benefits of the structure. These traditional, or ''old'' types of ocean energy are thus not without their problems, though modern ocean energy technology is far more environmentally benign [13].

3.2. Modern ocean energy developments

The modern ocean energy industry is currently moving from the prototype stage to installation of the first showcase commercial farms. The first of these have just recently come into operation, with the Pelamis project (in Portugal) and SeaGen (in Northern Ireland) having completed installation at the end of the summer of 2008 [14]. Many devices that use hydrokinetic conversion systems that take advantage of the flow in tidal or river streams are currently under development (over 60 different schemes are reported by Khan et al. [15]), and a number of devices using other technologies have already completed prototype testing, such as the WaveDragon. Also, there are currently a number of other projects and prototypes undergoing full scale testing (for example at the European Marine Energy Centre (EMEC), which has four grid connected births for wave and five for tidal devices, all of which are either in use or booked [16] or awaiting for support installations to be constructed (such as the WaveHub).

However, although a great deal of research and investment has been carried out in Europe, there have also been a number of significant developments in other continents. For example in Australia there are at least three companies involved in the research, development and pre-commercial testing of wave energy devices. These include the Western Australian based company Carnegie Corporation, developers of the CETO [17] wave power converter which has a commercial scale demonstration at Freemantle. Construction of a commercial scale plant is due to commence by 2010 with completion and connection to the grid due by 2013 [17]. Also in Australia, Oceanlinx re-deployed in February 2009 its pilot plant device at Port Kembla on the New South Wales coast south of Sydney [18]. This oscillating power column technology had been under development since it was first deployed in Port Kembla in 2005, and though one of the prototype units sank in 2010 research into the unit continues [18].

Another type of ocean energy technology that is reaching maturity is that referred to as Ocean Thermal Energy Conversion (OTEC), which has significant potential for countries located in tropical regions. These plants must be located in an environment where the warm surface seawater must differ about 20 °C from the cold deep water that is no more than about 1000 m below the surface, and the shore must be located within 25 km of the ocean region where the temperature difference occurs. This is normally found in areas between latitudes 20° North and South of the Equator, as shown in Fig. 1 [19]. India, for example has considerable potential for the development of OTEC energy, and some trial plants have already built in this country, such as a 1 MW OTEC and a 100t/d of fresh