Chapter 22. Other Marine-Based Energy Industries

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1. Marine Renewable Energy Resources: Background

This chapter concerns ocean processes that are viable sources of renewable energy in various forms, such as offshore wind, waves, tides, ocean currents, marine biomass, and energy from ocean thermal differences among different layers (Appiott et al., 2014). Most of these energy forms are maintained by the incoming heat from the sun, so they represent indirect solar energy. Tidal energy is an exception, driven by the varying gravitational forces that the moon and sun exert on both the earth and its oceans (Butikov 2002). Marine renewable

1.2 Ocean Wave Energy: Background

As the wind flows over the ocean, air-sea interface processes transfer some of the wind energy to the water, forming waves which store this energy as potential energy and kinetic energy (Special Report on Renewable Energy Sources and Climate Change, 2011). The immense power of waves can be observed at the coast, where this energy can have considerable impacts on coastal landscapes, shoreline topography, and infrastructure. Efforts are now underway to tap this resource for electric generation using wave energy conversion (WEC) devices. WECs transform mechanical energy from the surface motion of ocean waves or from velocity fluctuations below the surface into electrical current. a

nutrients much more rapidly and efficiently than terrestrial ecosystems.

cost of transmission cabling further offshore, and due to the technical and economic challenges of installing turbines in deeper waters.

Figure 1. Photo credit: Principle Power. The WindFloat Prototype (WF1) floating wind turbine, deployed by Principle Power in 2011, 5km off the coast of Aguçadoura, Portugal. The WF1 is outfitted with a Vestas v80 2.0 MW offshore wind turbine. As of December 2015, the system has produced in excess of 16 GWh of renewable energy delivered to the local grid.

2.2 Wave Energy Capacity

The global exploitable wave energy resource is estimated at around 3,700 GWa (Mørk et al., 2010), which is large enough to meet the average

Figure 2. Waves4power OWC plant in operation offshore Sweden (Reprinted with permission from Waves4power AB).

2.3 Tidal Energy Capacity

The global tidal energy resource is estimated to be 3,000 GWa by the World Offshore Renewable Energy Report 2004-2008 (UK DTI, 2004), however, less than 3 per cent of this energy is located in areas suitable for power generation. Tidal energy is feasible only where strong tidal flows are amplified by factors such as funneling in estuaries, making it highly site-specific (UK DTI, 2004). Traditionally, tidal energy has been harnessed using large barrages in areas of high tidal ranges. Many countries, such as Canada, China, France, Republic of Korea, Russian Federation and the United Kingdom have sites with large tidal ranges that are viable for tidal energy capture facilities. The Sihwa Lake Tidal Power Station in the Republic of Korea, which has been operational since August 2011, is the world's largest tidal power barrage with a capacity of 254 MW, surpassing the 240 MW Rance Tidal Power Station in France, which has been generating power since 1967. Numerous projects have also been proposed in other areas, including in the Severn 05 Terrngbrudiy, Unile

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2.4 Ocean Current Energy Capacity

There are no commercial grid-

3. Environmental Benefits and Impacts from Offshore Renewable Energy Development

Marine renewable energy installation and generation invariably has environmental impacts, both positive and negative. These impacts depend on the installation size and footprint, location, and the use of specific technology. A major positive impact of ocean renewable energy is the provision of low-carbon electricity. Analysis suggests that the carbon intensity of offshore wind and marine determining factors in the magnitude of stressors and receptors. Within this framework, we discuss various ecological impacts in the following sections.

Potential negative impacts on flora and fauna including marine mammals, birds, and benthic organisms, as well as impacts on the larger ecosystem may occur from offshore renewable energy (OREI) development. Some of these impacts are limited to the construction phase, while other impacts span operation and decommissioning phases (Linley et. al., 2009). Potential impacts include habitat loss or degradation at various stages of a project life cycle; injurious noise and displacement of marine mammals from pile driving of wind and tidal-stream generators. Tide power turbines may also induce local seabed scouring and/or changes to the current regime, with unintended consequences for biota. Turbine construction may induce mortality due to physical collision with the OREI structures; effects of operational noise; and electromagnetic field (EMF) impacts from submerged cables (U.S. Department of Interior, 2011).

Noise created during pile-driving operations involves sound pressure levels that are high enough to impair hearing in marine mammals and disrupt their behaviour at a considerable distance from the construction site (Thomsen et. al., 2006). During pile driving for the Horns Rev II offshore wind project in Denmark, a negative effect was detected out to a distance of 17.8 km (Brandt et. al, 2011). Although it has been observed that marine mammals temporarily abandon the construction area, they tend to return once pile driving operations cease. Acoustic impact on marine mammals is a major concern and an important topic of assessment and mitigation strategies in many States. More information is required almost everywhere to understand impacts on and responses by marine organisms to such stresses.

Fixed and moving parts of Ocean Renewable Energy (ORE) devices can lead to fatal strikes or collisions with birds and aquatic fauna. Blades used in marine turbines, such as those in ocean current or tidal energy devices, are relatively slow-moving and therefore not considered to pose a significant threat to wildlife (Scott and Downie, 2003). However the speed of the tip of some horizontal axis rotors could be an issue for cetaceans, fish, or diving strike birds (Boehlert and Gill, 2010). Operation of the SeaGen tidal energy device in Strangford Lough, United Kingdom, considered the presence of seals and porpoises and the potential threat of blade strikes; to minimize strike risk, the turbine was shut down when the presence of seals was observed within 30 meters (Copping et al., 2013). Similarly, investigation of long-tailed geese and ducks in and around the Nysted offshore wind project in Denmark suggests that flocks employ an avoidance strategy. Research suggests that the percentage of flocks entering the wind project area decreased significantly from pre-

Submerged cables carrying electricity from ORE devices to onshore substations emit low-frequency Electric and Magnetic Fields (EMF). Marine and avian species are sensitive and responsive to naturally occurring magnetic fields; these are commonly used for direction-finding using the Earth's geomagnetic field. Anthropogenic

Socioeconomic impacts cover a range of issues, including access to the ocean, visual recommendations on how to mark different types of offshore renewable energy installations so that they are conspicuous under different meteorological conditions. This, along with proper charting of installations and associated cables, can limit navigational risks (Detweiler, 2011).

Planning, construction, and maintenance of offshore

To achieve a commercial break-through such that ocean renewable energy becomes cost-competitive, many governments have funded Research and Development (R&D) projects and provided financial support for technological developments and demonstrations within this sector. Traditional commercial funding sources are often insufficient to achieve this goal in the long-term, so innovative strategies are required. In addition, higher education courses on ocean renewable energies must be promoted, and research to understand and mitigate potential environmental and socio-economic impacts of these new technologies must be conducted. Given its immense potential, offshore renewable energy is well positioned to be part of a carbon-constrained energy future.

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