IRENA
International Renewable Energy Agency

March 2017

UN Ocean Conference

Input to concept papers for Partnership Dialogues (5) and (6)

OCEAN ENERGY

The deployment of Renewable Energy technologies, and specially ocean energy, holds immense opportunity to make progress across SDG14 and other SDGs, in particular as regards economic and social development of SIDS and, by transitioning away from fossil fuels, achievement of the global climate goals. Against this background, this document provides insights on the ocean energy technologies, highlighting the technologies classifications and their deployments status. The document also presents the future deployments and further explains the main two technologies of ocean energy: tidal stream and wave energy, including highlights on the challenges and barriers to ocean energy technologies.

1. Key messages

For SIDS, implementing renewables is not just about saving the environment, it is about saving their communities, families, and homes for future generations. Many island nations have taken the first, second, or even third step towards the large-scale use of domestic renewable energy. With renewable energy sources now cost-competitive with oil-generated electricity, islands have an unprecedented opportunity to rethink their energy strategy, and by doing so create jobs, bring power to those currently without and deliver more reliable electricity services, all while combating climate change and preserving their way of life and oceans.

In the transition to a sustainable future, there is a need to explore all kind of forms of renewable energy to be well developed and operationalized in a sustainable way. Ocean energy is a significant form of renewable power which has been an integral part of human civilisation and development. Ocean energy is abundant and geographically diverse.

There are a variety of different technologies that could be deployed like using ocean surface waves, tidal steams and tidal range, and ocean currents to generate electricity. There is also the use of advanced liquid biofuels in the highly polluting shipping sector.

Rapid strides with technology and other innovations are being made, with many applications reaching a commercial stage. These will drive cost reductions and help expand markets. Ocean energy is poised to play an important role in the energy mix in a low carbon economy which could contribute to decarbonisation aims as well as to provide employment opportunities that can arise in the coastal areas, which normally suffer from high unemployment rates.

2. Technology overview

Ocean energy (marine renewable energy) is a term that contains all renewable energy sources found in the oceans, that uses kinetic, potential, chemical, or temperature of seawater. There are a variety of different technologies that could be deployed like using ocean surface waves, tidal steams and tidal range, and ocean currents to generate electricity. Ocean energy technologies are categorised based on the utilised resource to generate energy. The most common identified technologies are:

- Tidal energy
  - Tidal range

  - Tidal stream
  - Hybrid form
- Ocean current
- Wave energy
- Ocean thermal energy conversion
- Salinity gradient energy

Tidal energy

Tides are the result of the combination of the gravity of the sun, earth, and moon. The rise and fall of the tides in some cases is more than 12 meters (m) which creates potential energy. On the global scale, theoretically captured tidal energy resource from areas close to the coastal zones, is estimated by 1 terawatts (TW). There are three main types for tidal energy: (i) tidal range (barrage), (ii) tidal steam/current, and (iii) hybrid forms. It is worth noting that the potential for tidal stream energy is larger than for tidal range. Total tidal range deployment in 2012 was about 514 MW, and around 6MW for tidal current (of which 5 MW is deployed by UK, IORA's member dialogue partner). There are announcements for tidal range projects deployments in India (IORA's member country), Korea, the Philippines and Russia is leading by planning to install around 95 gigawatts (GW). Deployment projections for tidal stream are around 200 MW. The advantage of tidal energy is being predictable daily and even annually. Also, energy can be generated both during day and night. Furthermore, tidal range is hardly influenced by weather conditions.

Ocean current

Ocean currents are driven by latitudinal distributions of winds and thermohaline ocean circulation. Compared to tidal currents, ocean currents are unidirectional and slower but continuous. The currents operate most strongly close to the surface. Ocean current technologies are still in an early developmental stage, there is no full-scale prototype has been demonstrated yet.

Despite the fact of availability and distribute globally ocean currents, it is still unclear how many may prove feasibility of this projects and draw interest for project development. If technologies can be developed to capture the lower velocity currents, the projects scale could potentially be much larger given the large volumes of water and scale of oceanic currents in comparison to tidal streams.

Wave energy

Wave energy converters (WECs) harvests the energy contained in ocean waves to generate electricity. There are many wave energy technologies. Each technology uses different technique to capture energy from waves. Technologies differ based on the water depth and on the location whether it is shoreline, or off shore or even near to shore. In 2014, there was no commercial WEC arrays in operation in the world. Wave energy aims for an initial deployment of demonstrating WECs in small arrays of 10 MW, which could be located close to the shore.

Ocean thermal energy conversion

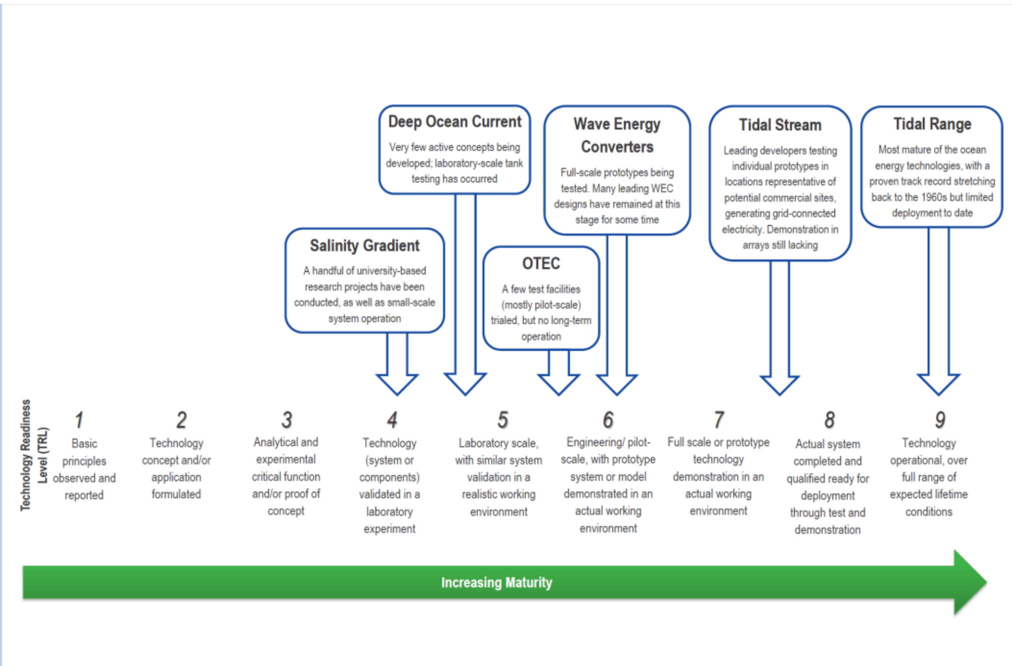
Ocean thermal energy conversion (OTEC) has the highest potential in comparison with all ocean energy technologies. There are around 98 nations and territories have identified that they have viable OTEC resources in their exclusive economic zones. OTEC technologies operates based on the temperature difference between the surface of the ocean (warm seawater), and a deep sea water (cold seawater) which is commonly at between 800–1,000 m depth to produce electricity. The warm seawater is used to produce a vapour which is the working fluid would drive turbines. The cold water is used to condense the vapour and ensure the vapour pressure difference drives the turbine. OTEC technologies are distinguished by the working fluids that can be used. The working fluid in the open cycle uses seawater. But closed cycle, the working fluid is mostly ammonia.

Only OTEC plants up to 1 MW have been deployed due to the technical challenges and barriers such as the size of the water pipes that should be deployed in a large scale OTEC plants. For example, a 100 MW OTEC plant needs cold water pipes of 10 m diameter or more and a length reaches up to 1,000 m.

Salinity gradient energy

Salinity gradient energy occurs from the difference in salt concentration between two different fluids, commonly happen between salt and fresh water, e.g. when a river flows into the sea. The energy can be harnessed by two main concepts: (i) Pressure Retarded Osmosis (PRO) which uses a membrane to separate the concentrated salt solution like sea water from freshwater, and (ii) Reversed Electro Dialysis (RED), which captures the chemical potential between the freshwater and seawater where the flow through a semipermeable membrane. It is still the conceptual and early research sage technology.

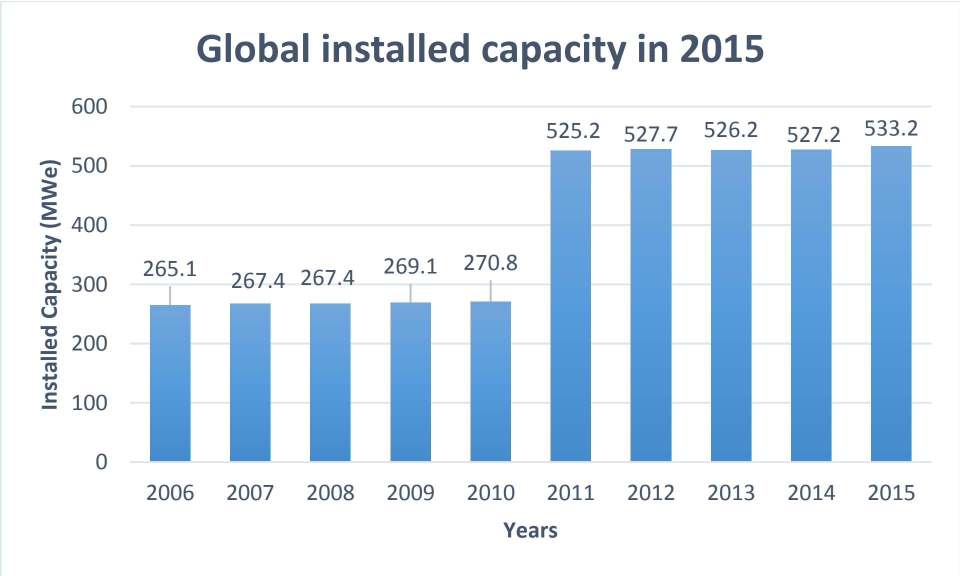
Figure 1: Ocean energy technologies maturity level



3. Technology Development and Deployment Status

In 2015, the global installed capacity of ocean energy technologies was 533.2 MW (IRENA, 2015) with most of this capacity is to the La Rance in France and Sihwa in South Korea tidal range plants. Figure 1 shows the latest deployments up to 2015, it is obvious that the jump between 2010 and 2011 was due the operation of the tidal range plant of Sihwa (South Korea). It is worth noting that this is the only tidal range deployed project in the 21 century with a capacity of 254 MW. Tidal and wave energy dominate the market share of the ocean energy technologies and are largely viewed to have the highest potential for significant commercial applications in the near future due to the market share and number of project deployments and the global interest in comparison to other technologies.

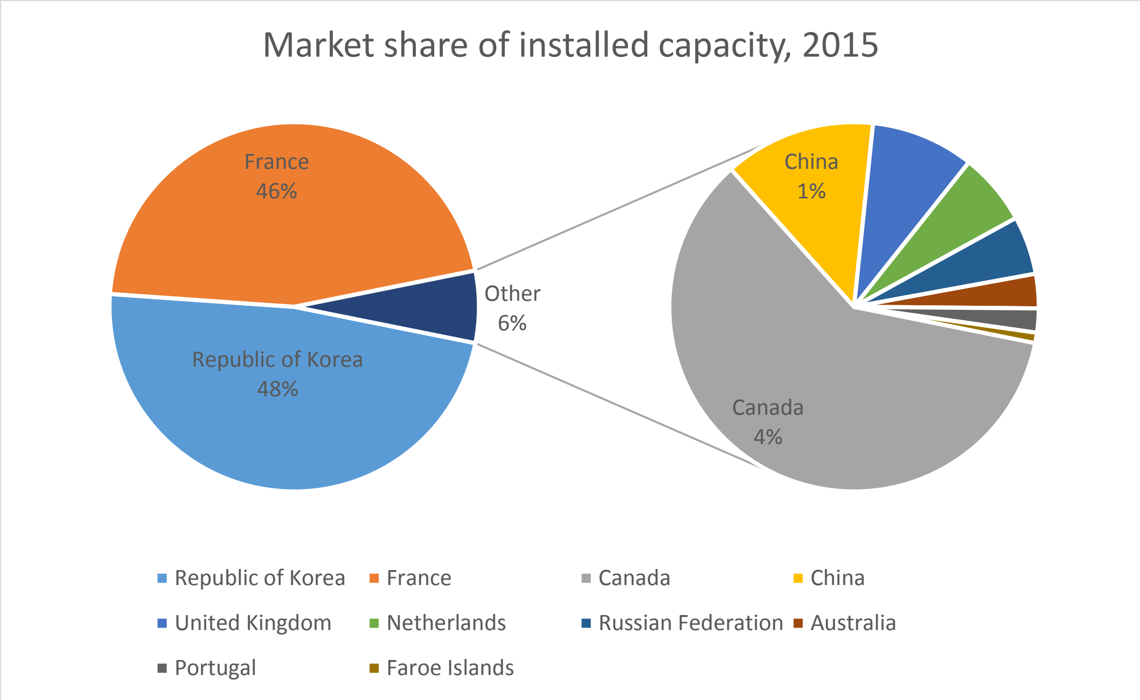
Figure 2: Global installed capacity of ocean energy technologies, 2015



Source: (IRENA REsource, 2015)

There have not yet been any demonstrations of ocean current and salinity gradient energy projects of large- scale, and new large-scale OTEC prototypes since 2000. Nevertheless, OTEC is growing with a few of pilot plants over the previous three decades such as in the USA, Republic of Nauru, India, and Japan. Recently, there has been some announcements on OTEC plants to be launched in the future. On top of them is China (10 MW), India (IORA's member state) (20 MW), United Kingdom (IORA's dialogue partner member) (4 MW). Figure 3 illustrates how the ocean energy installed capacity share look like. It is obvious that it is dominated by France and South Korea, followed by Canada and China.

Figure 3: Market share of top 10 countries on ocean energy deployments up to 2015



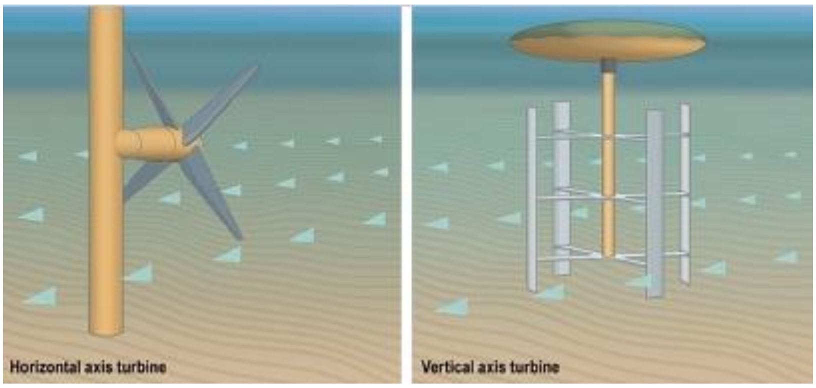
Source: Author elaboration based on IRENA REsource, 2015

a. Tidal

The tidal energy is the result of the interaction of gravitational forces of the sun, earth and moon. Tidal energy technologies are not newly developed. There has been reported in the past since the Roman times about utilized tidal mills around year 700. From 1960 to 2012, only five projects have been commercially deployed. There are three different types of tidal energy technologies. The first one is tidal range technology which depends on use of a barrage (dam) to harvest the generated power from the height difference between high and low tide. The electricity is generated by tidal turbines most of them come from hydropower design. These turbines are well established and commercially feasible since their operation in the first established plants of France (240 MW), Canada (20 MW), China (5 MW) and Russia (0.4 MW) in period of1960s to 1970s. There are also other new technologies have been developed for tidal range such as tidal 'lagoons', tidal 'reefs', and tidal 'fences', and low-head tidal barrages.

The second type of tidal technology is tidal stream or tidal current. From 2006 to 2013, there are 40 new devices are introduced. The major difference is the used turbine, which can be vertical or horizontal axis as illustrated in Figure 5.

Figure 4: Vertical and horizontal turbines of tidal stream energy



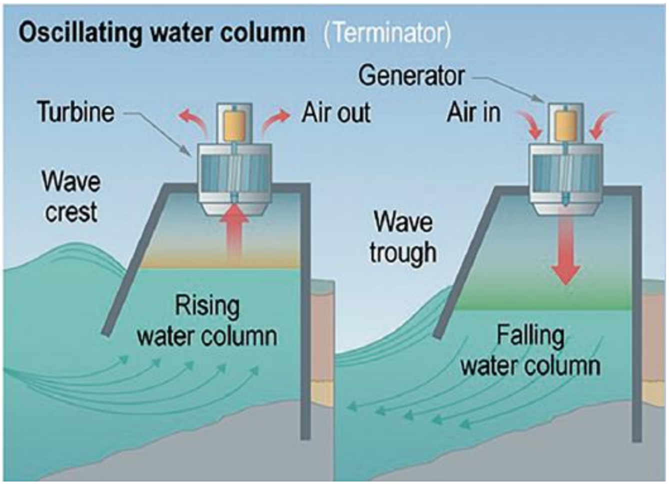
The third type is hybrid form of tidal range technologies that have significant potential in case of combining the design and deployment with the planning and design of a new infrastructure for coastal zones. For example, there are some deployed projects are existing in Canada, China, the kingdom of Netherlands and the UK (IORA's dialogue partner). In addition, there are plans for a hybrid form of tidal range and current power generation called 'dynamic tidal power' but there is no full-scale prototype has been yet.

The important driver for tidal energy technologies is that can generate renewable electricity close to urban centres, without causing any destructions and noise or even harmful environmental impact. Additionally, tidal range technologies installation can have a minimal effect on the environment. However, there is some barriers that should be overcome. The main barrier is technological progress for tidal range which is to increase the efficiency and improve the performance of the turbines. However, for tidal current technologies, the basic fundamental technology is developed but there are still technical challenges continue to arise.

b. Wave Energy

Wave energy converters (WECs) harnesses the energy from the ocean waves to generate electricity. Wave energy technologies consist of a several components but the three main elements are: i) the prime mover, 2) the power take-off (PTO) system which converts the wave energy mechanical into electrical energy, and 3) the control system that is to optimize and improve operational performance. The European Marine Energy Centre (EMEC) has identified nine categories for the WECs. However, here is a three WECs have been identified which are: (i) oscillating water columns (OWCs), (ii) oscillating body converters and (iii) overtopping converters.

Figure 5: Oscillating water columns system (OWCs)



Source: (IRENA, 2014a)

First type is OWC. Figure 6 illustrates how OWCs functions, they are conversion devices combined with a semi-submerged chamber, where keeping a stuck air pocket above a column of water. With movement of waves, the column acts like a piston, then moving up and down and thereby pushing the air out of this chamber. This mechanism, thus returns the stream of high-velocity air, which is channelled through rotor blades driving an air turbine-generator. This system is simple and reliable.

Second type is Oscillating Body Converters which could be either floating or submerged. They target the more powerful wave that normally are located at high depths where it is more than 40 m. The oscillating body converters are mostly floating devise, so they are quite flexible.

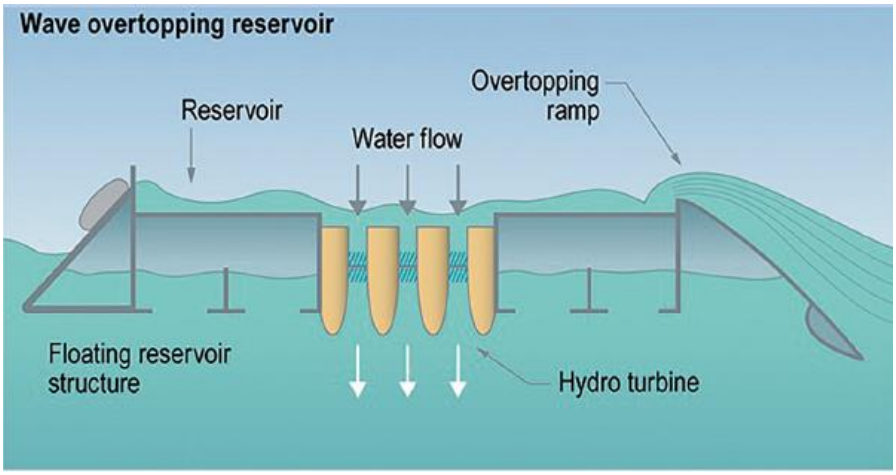


Figure 6: an example of wave energy technology: overtopping converters

Figure 7 shows the third technology of wave energy which is overtopping converters that consist of a floating or bottom fixed water reservoir structure, which ensure that whenever waves passes by, they capture it at the top of the structure and are remained in the reservoir of the system. There is a hydro turbine that transform the remained and collected water into electricity.

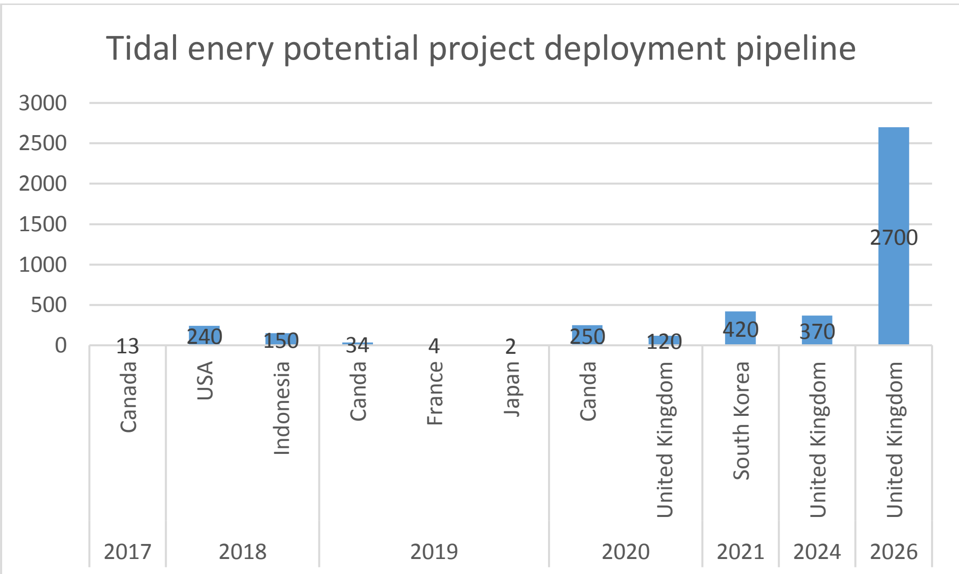
4. Future Deployment

The tidal and wave technologies have been the most deployed technologies and have gathered a commercial interest. This interest is increasing by time and moving forward as can be seen from the market outlook for future deployments of wave and tidal projects over the upcoming five to ten years. The projections of upcoming projects are announced and presented here in Figure 4.

There are no large deployments from the Indian Ocean Rim Association member state countries yet, but recently India (IORA's member country) announced a deployment of a two plants in Andaman and Nicobar Islands, an OCET (20 MW) and a wave energy plant (30 MW). In addition, United Kingdom (Scotland) is leading the deployments of the

Figure 4 consider announcements of key project developers and development activity in each of the listed countries on Tidal energy technologies. The pipeline of announced projects is most likely greater than what can be expected to be deployed in the allocated time. The United Kingdom (IORA's dialogue partner) is leading by example with projects announcements for future deployments on tidal barrage projects with a total capacity of 2700 MW to be operationalized by 2026. There is a relation between cost declinations and technologies deployment rates, the more deployments of ocean energy technologies, the more cost reduction which result in deploying much more ocean energy technologies.

Figure 7: Announced tidal energy projects deployment pipeline



Source: Author elaboration based on Global Data, 2016

5. Economics

Levelised cost of electricity (LCOE) from ocean energy technologies is currently higher than for conventional energy generation technologies. However, for a suit of technologies is early stages of development as ocean energy, a LCOE calculation is highly uncertain. The empirical cost data is limited, different designs lead to different cost profiles, and how to determine the capacity factor and the technology lifetime are aspects yet to be fully understood. Estimates published as part of the European Strategic Initiative for Ocean Energy suggest a mid-level case range of EUR 0.320 to 0.371 per kWh for the first tidal stream demonstration arrays, compared with approximately EUR 0.407 to 0.52 per kWh for the first wave demonstration arrays.

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