

Tidal Energy and Japan

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April 25, 2016

Introduction

In the past ten years, the global concerns regarding our use of non-renewable energy sources and their effect on the environment have become much more serious. The year 2015 was the hottest recorded year in Earth's history, beating the record set by the previous year [1]. The stress on finding new alternatives to sustain our ever growing energy needs is at an all time high. One energy alternative that has arisen in recent years is tidal energy, the details of which will be explained later in this paper. As implied in the name, tidal energy requires tides (i.e. the ocean), so in this paper we will be examining the feasibility of tidal energy for a country that is completely surrounded by the ocean – Japan. Japan is a major consumer of electricity, especially from non renewable (see section 2.1), so they will be a good model to look at in terms of the feasibility of tidal energy as a large scale energy alternative.

1. Tidal Energy – A Brief Introduction

1.1 What is Tidal Energy?

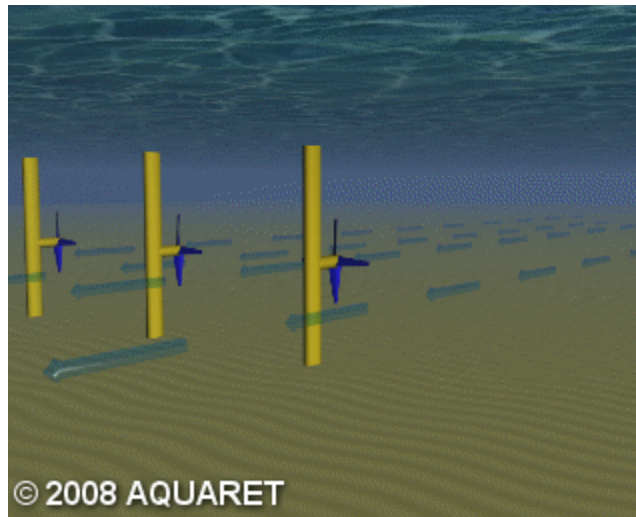
As the name states, tidal energy is the energy that comes from tides. More specifically, tidal energy is the form of hydropower that utilizes tidal motion created by the moon and the sun to produce electricity [2]. In the most basic sense, tidal energy functions much like wind energy in that it uses a medium (in this case water) to turn some sort of turbine in order to produce electricity. This may sound similar to how a coal power plant produces electricity, and it is. However, the key difference that sets tidal energy, and wind energy for that matter apart from coal and natural gas, is that tidal energy is renewable. The Earth is about 70 percent water [3], so we won't be running out of tides anytime soon. We will explore many of these differences in later sections. For now, let's look at the different methods in which we can harness tidal energy.

1.2 How Do We Harness Tidal Energy?

There are several ways that tidal energy is harvested, but there are really only six main methods are actually utilized in tidal energy harvested at the coast. You may be wondering, "Why do we care if they are near the coast?", and the reasons for that will become clear soon.

The first method of tidal energy collection is the horizontal axis turbine (see figure 1). The horizontal axis turbine functions similarly to your typical wind turbine, using the water flow from the tides to turn a rotor about a horizontal axis in order to generate electricity [4]. This energy can then be transferred to shore.

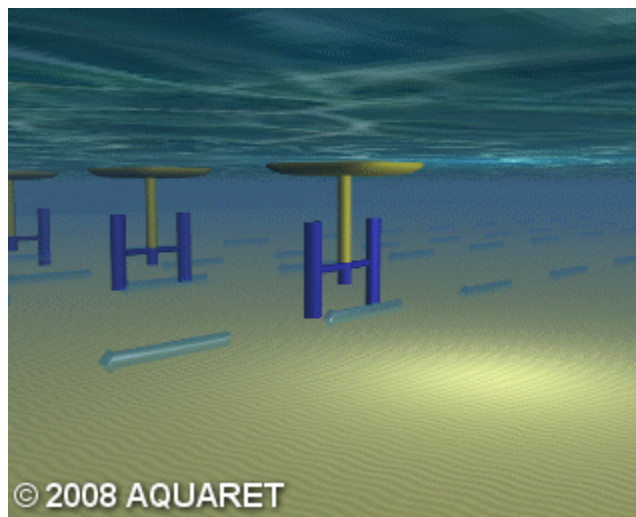
Figure 1. Horizontal Axis Turbine.



<http://www.emec.org.uk/marine-energy/tidal-devices/>

The next major form of harnessing tidal energy is the vertical axis turbine (see figure 2). This is essentially the same as the previous method, but this time the rotor is mounted parallel to the ocean floor and rotates about a vertical axis [4].

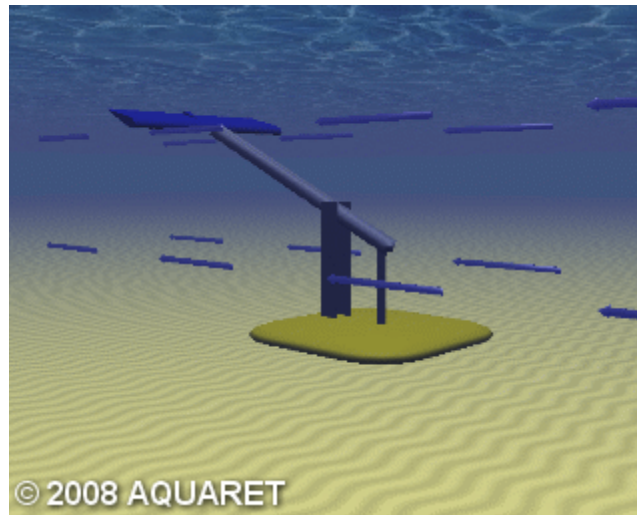
Figure 2. Vertical Axis Turbine



<http://www.emec.org.uk/marine-energy/tidal-devices/>

The oscillating hydrofoil (see figure 3), which is the method of harnessing tidal energy that will be the focus in this paper is a way of harnessing tidal energy that uses a hydrofoil (basically a fan) attached to an arm to oscillate the arm. This pumps a hydraulic fluid system causing electricity to be generated [4].

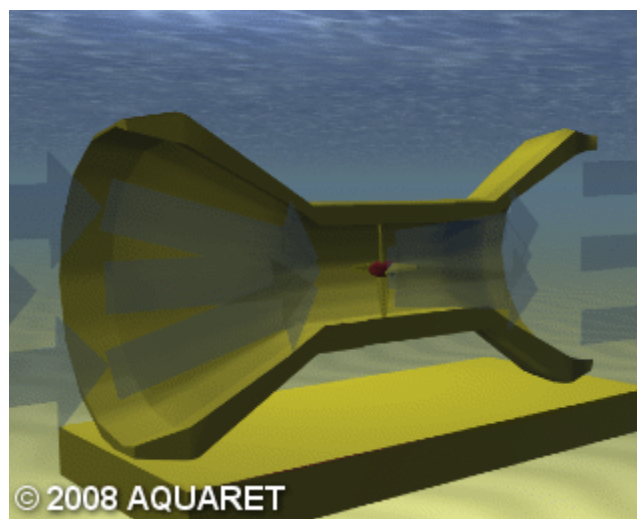
Figure 3. The Oscillating Hydrofoil.



<http://www.emec.org.uk/marine-energy/tidal-devices/>

The next device uses what is called the Venturi Effect – a change in pressure that results in fluid flow through a constricted section of a pipe [5]. These Venturi devices, often called enclosed tips (see figure 4) function much the same as horizontal axis turbines, except they have the enclosed pipe and try to get the turbine to turn without requiring an active tide to function [4].

Figure 4. Enclosed Tip.

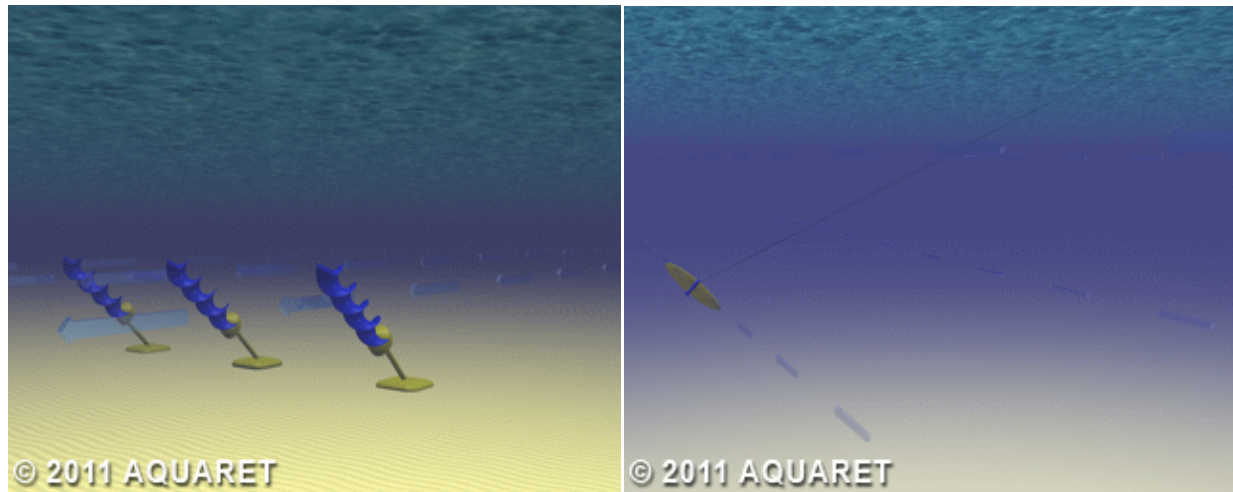


<http://www.emec.org.uk/marine-energy/tidal-devices/>

The last two methods are used far less often than the previous four. They are the Archimedes screw (figure 5, left) and the tidal kite (figure 5, right). The Archimedes screw is shaped as it sounds, like a screw. The helical shape is spiraled upward by the

passing tide, causing the shaft to turn and generate electricity. The tidal kite on the other hand, carries a turbine below a wing. This tidal kite is mounted to the seabed and flies around the water in a figure eight to maximize energy generation [4].

Figure 5. The Archimedes Screw and the Tidal Kite



<http://www.emec.org.uk/marine-energy/tidal-devices/>

These are just a few of the many ways to collect tidal energy. There are many other ways such as overflow generators and attenuators, but those aren't used as often as the ones above and are often used in the deeper ocean. Now that we have these let's look at the pros and cons of this renewable resource.

1.3 Pros and Cons of Tidal Energy

As with any form of energy, there are pros and cons to its use and this is no exception with tidal energy. Tidal energy has many pros and several cons as we are about to explore.

Let's begin with the pros of tidal energy. To start, tidal energy is a renewable energy source. As mentioned earlier, we are in desperate need of alternative, renewable sources of energy. Tidal energy is one such resource, utilizing the never ending tide that is produced from our very own sun and moon. The next major pro of this renewable resource is that there are no emissions from using tidal energy as a way to produce electricity (this excludes the initial emissions used in construction of tidal energy devices and plants). Harmful emissions are a major concern and tidal energy has none of them, giving it a great advantage over other forms of energy. Furthermore, tidal energy is predictable. Unlike the wind, or the appearance of random clouds in the sky, we know the patterns of the tides (for the most part) and can thus set up tidal devices in places where we know the tides will provide the most energy. In addition to being more predictable than wind, tidal energy harnessing devices are more effective than wind energy devices. Due to the fact that water is 1000 times denser than air [6], the

turbines, or hydrofoils on a tidal energy device do not need as much speed to be activated and thus, will have more operation time than wind energy devices. The final pro of tidal energy has a bit of a prerequisite to be true. Tidal energy is relatively long lasting if it is near the coast. Recall, that the methods we looked at in the previous section were all for near shore underwater harnessing, so for the purpose of this paper, we can count this last advantage of tidal energy [7].

Tidal energy also has its cons. One major concern is its effect on wildlife. Much like wind power and birds. Tidal energy has the concern of harming wildlife and their ecosystems. However, this is mostly for the harnessing methods that involve rotors. Since this paper will be focusing on the oscillating hydrofoil method, we basically can eliminate the concern for wildlife (but we can't ignore the harm construction has on the ecosystem of marine life). The next con of tidal energy is that it must be close to land. It is very difficult to collect the energy produced by tidal energy, especially if it is in the deep ocean. Additionally, once tidal energy is no longer close to shore maintenance and durability become a problem. However, for this essay we have restricted the tidal energy we are analyzing to close-to-shore tidal energy [7].

You may be asking, "Why do we impose these restrictions on ourselves to eliminate cons from the picture?" The reason is that in doing so, we can put all our focus on the largest con keeping tidal energy back – its expensiveness. Tidal energy is extremely expensive, especially for the amount of energy produced per plant in comparison to other popular methods of producing energy [7]. These details will be explored in the next section.

1.4 Cost, Size and Energy Generation

Now that we have laid out the pros and cons of tidal energy, we can look at the actual numbers associated with creating the necessary pieces to produce tidal energy and the energy generated by harnessing tidal energy. By doing so, we will complete the foundation we need to analyze how tidal energy would fit into Japan's energy needs.

A typical tidal energy plant (plant and tidal energy harnessing devices) takes up about half a square mile in space [8]. In comparison to coal power plants, which average about one square miles in size [9], this is two times the size of a tidal energy plant.

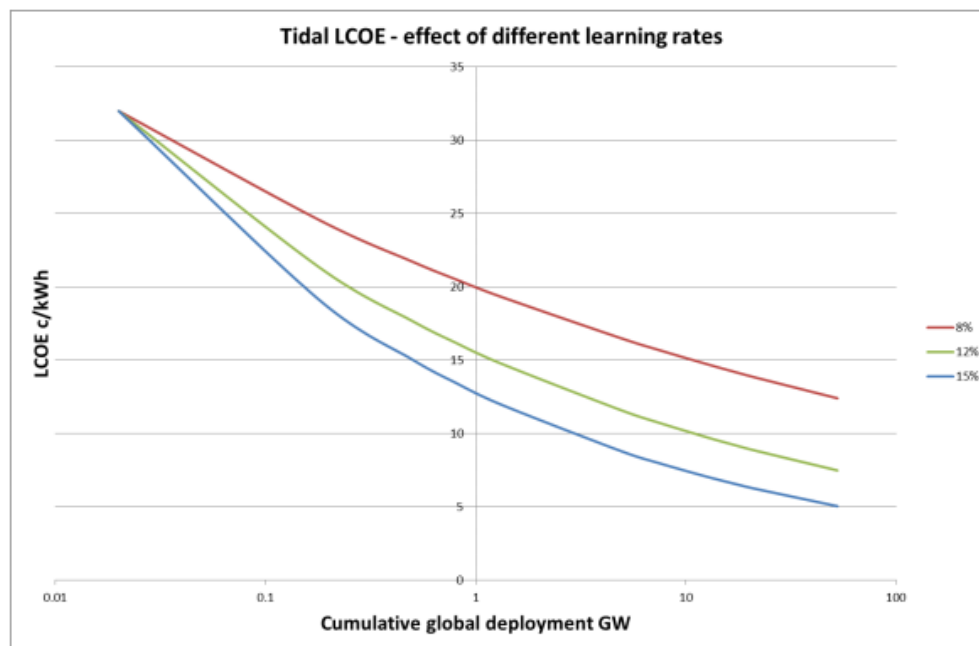
A standard tidal energy plant also differs greatly in comparison to coal with regards to the amount of energy that can be generated per plant per year. Tidal energy plants can produce an average of 275 GWh of energy per year [10] whereas a coal power plant produces about 1200 GWh of energy per year [11].

But how does your average tidal energy power plant compare in price to your typical coal power plant? The average tidal energy plant costs about 1.2 billion dollars to

construct [12]. That is about 190 percent the price of a coal power plant [13]. This extreme difference in price is due to the fact that tidal energy is a relatively new form of energy production and thus, the technology is not advanced enough to where it can cheaply be constructed. However as you can see in figure 6, the price of production will drop if we continue on the current track of development that we know have.

You may be asking if tidal energy is inferior to coal power plants in almost every way, why even consider it at all? As stated above we need a renewable resource for energy and a clean one at that. That is where tidal energy has coal and all other non-renewable energy sources beat. A tidal energy plant saves about 3.5 million tons in CO₂ production [14] . If there is a 220 dollar per ton cost for CO₂ production, then this means tidal energy plants save about 770 million dollars in unnecessary expenses [15]. Additionally, we must remember the numbers above are current. Tidal energy is getting much cheaper and more efficient (see figure 7). Not to mention we can fit twice as many tidal energy power plants into the same area as a coal power plant, so we can produce the same energy per square mile with tidal energy as a coal power plant.

Figure 7. Levelized Cost Projections of Tidal Energy for Different Learning Rates¹



http://www.si-ocean.eu/en/upload/docs/WP3/CoE%20report%203_2%20final.pdf

Now that we know some of the current numbers associated with the size, energy production and cost of tidal energy, keeping in mind that these numbers are improving, we can get into looking how this energy source fits into Japan's economy.

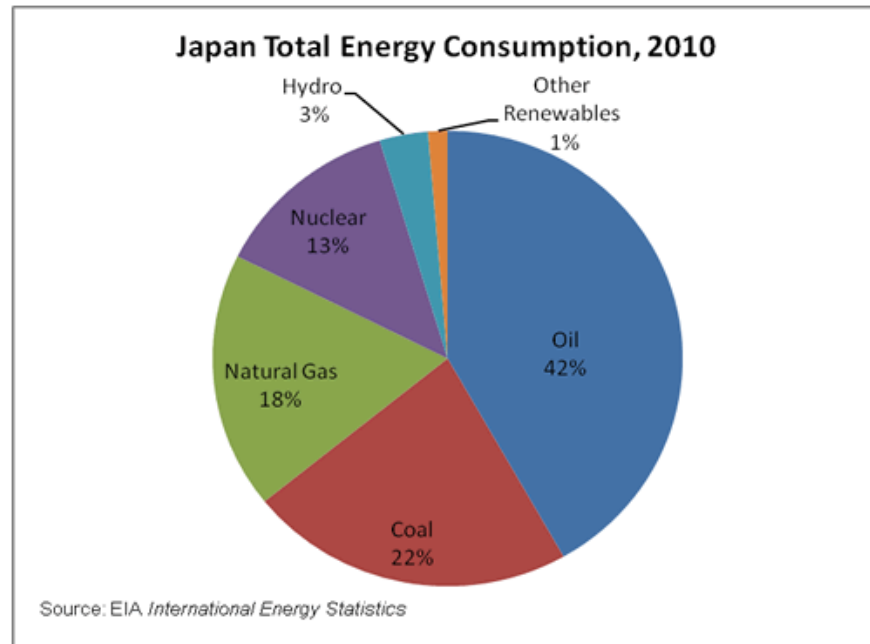
¹ Learning rate – the rate at which we are improving the efficiency of the tidal energy technology

2. Japan and Tidal Energy

2.1 Japan's Current Energy Situation

Before we begin to examine the future of tidal energy in Japan, we must understand their current energy situation. In figure 7, we can see that Japan uses about 6 different forms of energy including nuclear, natural gas, oil, coal and hydroelectric.

Figure 7. Japan Energy Consumption.



http://www.eoearth.org/files/229301_229400/229397/japan-total-energy-consumption--2010.gif

Japan is the third largest energy consumer in the world, consuming about 5,300 TWh of energy per year [16], 3 percent of which comes from hydroelectric power [17]. However, more surprising than that is the fact that about 82 percent of their energy consumption is from oil, natural gas, and coal [17]. Japan clearly has a large need for renewable energy, so our next section will explore the numbers that would be associated with Japan implementing more tidal energy.

2.2 Japan and Tidal Energy – The numbers

Japan has about 18,500 miles of coastline [18]. This means that they could fit 9250 tidal energy power plants if they utilized 25 percent of their coastline and produce 2543 TWh of energy (that's almost % of their total energy consumption. However, this many power plants would cost 11.1 trillion dollars.

Let's look instead at if Japan utilized a more realistic 10 percent of their coastline. They would produce 1018 TWh in clean energy (relieving almost all of the energy need from coal). This 10 percent usage would cost the country 4.44 trillion dollars which is over twice their annual budget [19].

3. Conclusions

3.1 Japan Needs to Wait

Based on the fact that Japan would have to spend twice times their annual budget in order to produce only 22 percent of energy needs, implementing tidal energy to alleviate nonrenewable energy sources is just not feasible at this time. The technology is not at the point where it will be a good decision for the country to implement despite its status as a renewable, clean energy source.

3.2 What to Do in the Meantime?

So what should Japan do in the meantime? They should invest in research on tidal energy and how to make it cheaper in more efficient. Tidal energy has so many great advantages as a renewable resource that just requires some technological improvements to make feasible. If tidal energy can be developed to the point where it is as cheap as coal power plants (or slightly more) and can become 50 percent more efficient, then Japan can utilize 5 percent of their coastline and produce 15 percent of their energy needs for half of their annual budget. This is may be still too expensive, but is much more reasonable. The point is, that as technology is improved and the cost continues to fall, this form energy will be a good future energy source in conjunction with other renewable energy sources. So for now, Japan should stick to other forms of clean energy, but they should invest in tidal energy and keep it in their minds as the future of their power needs because tidal energy does have great promise.

Word Count [2,340]

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