Oceanic Solutions – Tidal Power

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1. Introduction

This is the second in this series of posts on oceanic solutions to our climate change crisis. The first two are linked below:

Oceanic Solutions – Introduction and Offshore Wind:

https://energycentral.com/c/cp/oceanic-solutions-%E2%80%93-introduction-offshore-wind

This post is on Tidal Power, that is, hydroelectric power plants that use ocean tidal currents to generate power. This should not be confused with wave power. Although many support the latter, I believe it will, at best, be a limited niche-solution used to support remote facilities. Wave power has several major problems that limit its applicability, such as:

- Wave energy is highly distributed.
- Many wave power generators create a visual blight on very valuable real estate.
- Wave power generators may be destroyed by large storms.
- Like many other renewable energy sources (at least to some degree) the energy output from wave power generators is unpredictable.

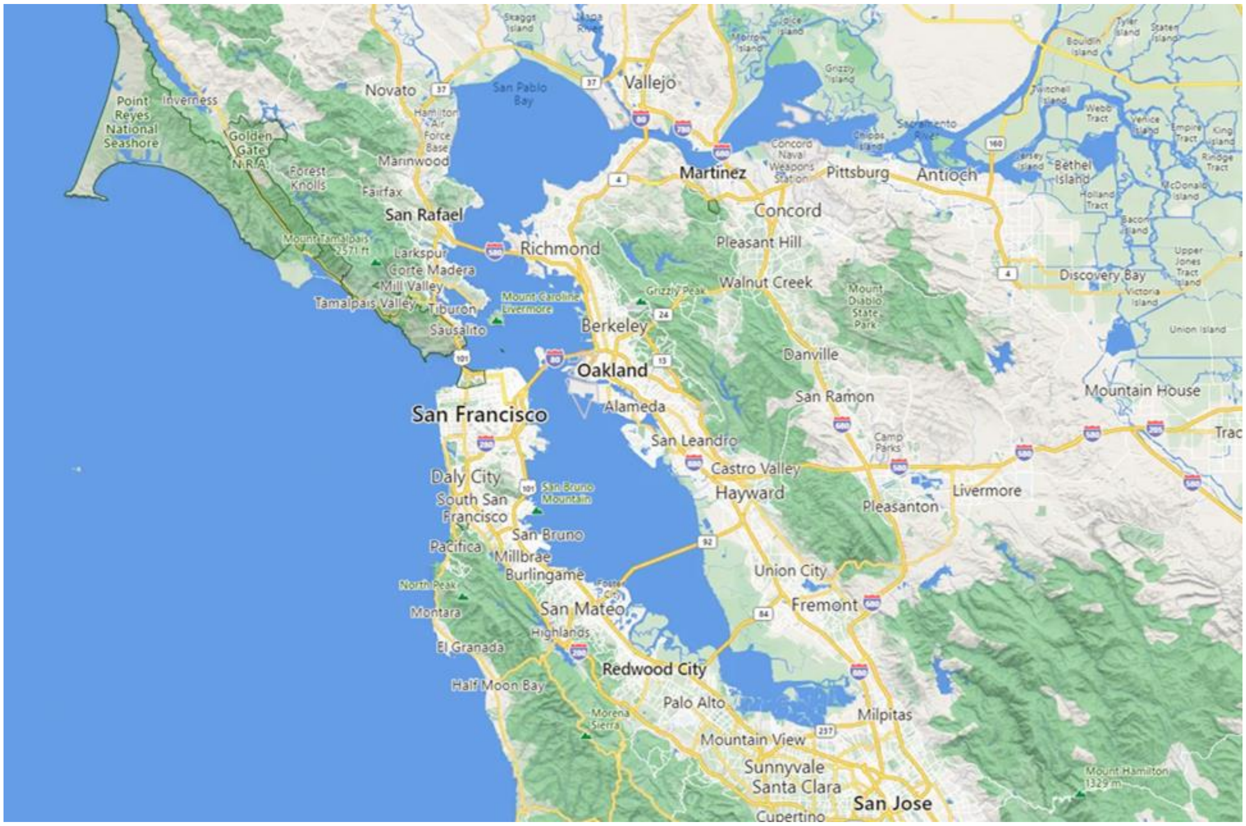
Most sources of tidal power tend to be fairly predictable. *The idea is simple, first, tides rise and fall predictably, relentlessly driven by the gravitational pull of the moon. Those traits combined make the tide an attractive proposition for powering the grid. "The sun doesn't always shine; the wind doesn't always blow;' notes Simon Forrest, the CEO of Scotland-based tidal-power producer Nova Innovation. But with tidal, he says, "we can tell you how much we will be generating two minutes past 3 in the morning a month from now, five years from now."*[1]

2. Tidal Energy Projects

The major downside of tidal power is that it requires a specific coastal feature to maximize the energy produced. I am very familiar with this because in late 1969 I was stationed on an Army Base (Nike Hercules Site) adjacent to one of these – the Golden Gate (see figure below, on the next page). The Golden Gate is the opening to the Pacific Ocean just north of San Francisco. Other than this one small opening, the San Francisco Bay (southeast of the Golden Gate) and the San Pablo Bay (northeast of the Golden Gate) is completely land-locked. These are also fed from the east by two large river systems, The Sacramento River and the San Joaquin River.

[1] Tom Vanderbilt, Time (hardcopy), July 4 / 11 Issue, Page 62, "A rising Tide Lifts all Grids." To order a copy of a Time issue, call 800-843-8463.

Although there is no tidal generation system at the Golder Gate (this is a challenging engineering problem because of the high tidal currents), such a system could harvest a huge amount of predictable, renewable power.



3. Past Projects

Major past projects are described in this section.

3.1. Rance Tidal Power Station

This is a tidal power station located on the estuary of the Rance River in Brittany, France.[2]

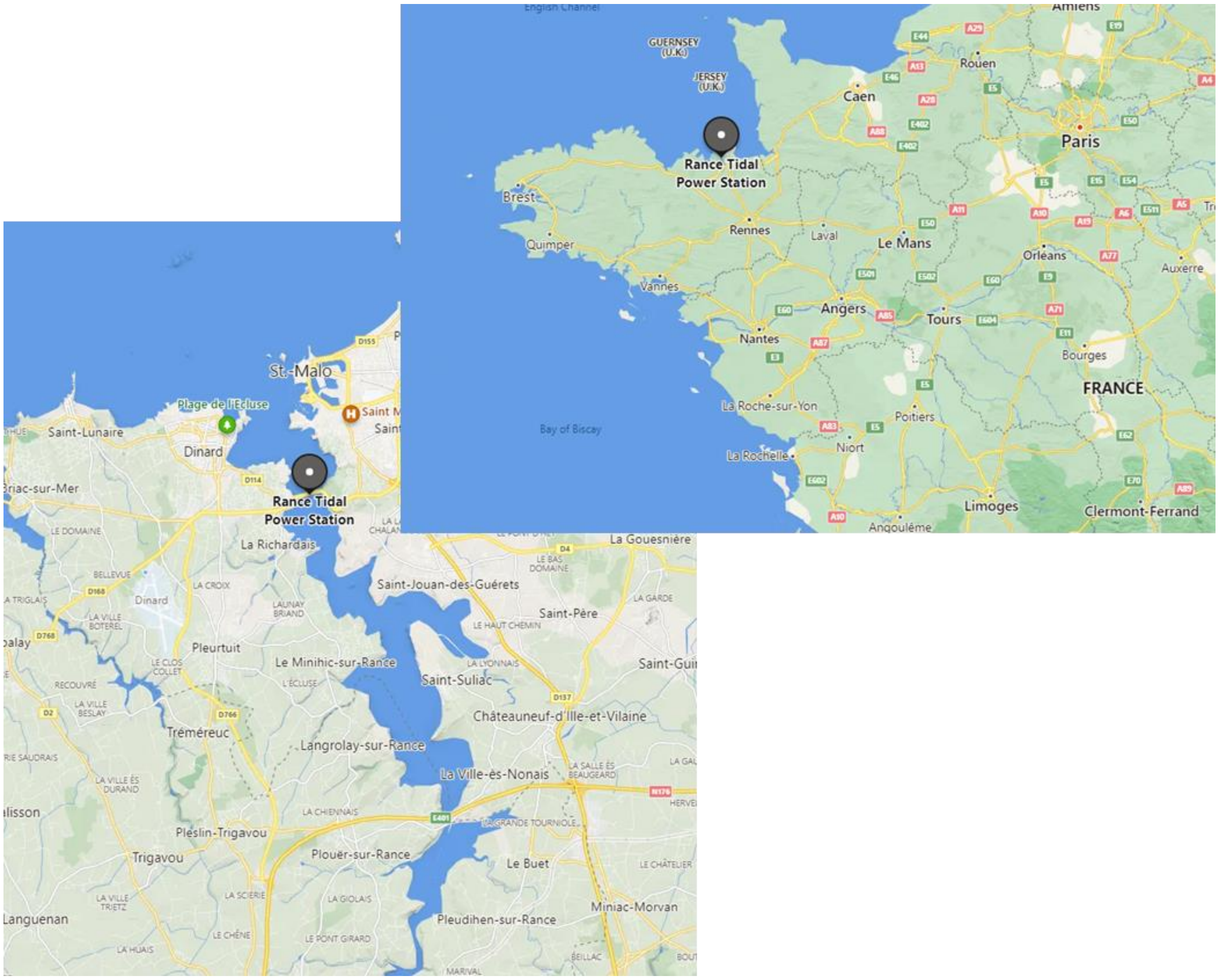
Opened in 1966 as the world's first major tidal power station, it is currently operated by Électricité de France and was for 45 years the largest tidal power station in the world by installed capacity until the South Korean Sihwa Lake Tidal Power Station surpassed it in 2011.

Its 24 turbines reach peak output at 240 megawatts (MW) and average 57 MW, a capacity factor of approximately 24%. At an annual output of approximately 500 GWh (491 GWh in 2009, 523 GWh in 2010), it supplies 0.12% of the power demand of France. The power density is of the order of 2.6 W/m^2. The cost of electricity production is estimated at €0.12/kWh.

[2] Wikipedia article on Rance Tidal Power Station, https://en.wikipedia.org/wiki/Rance_Tidal_Power_Station

The barrage (dam) is 750 m (2,461 ft) long, from Brebis point in the west to Briantais point in the east. The power plant portion of the dam is 332.5 m (1,091 ft) long and the tidal basin measures 22.5 km2 (9 sq mi).

See the maps below.



3.2. Sihwa Lake Tidal Power Station

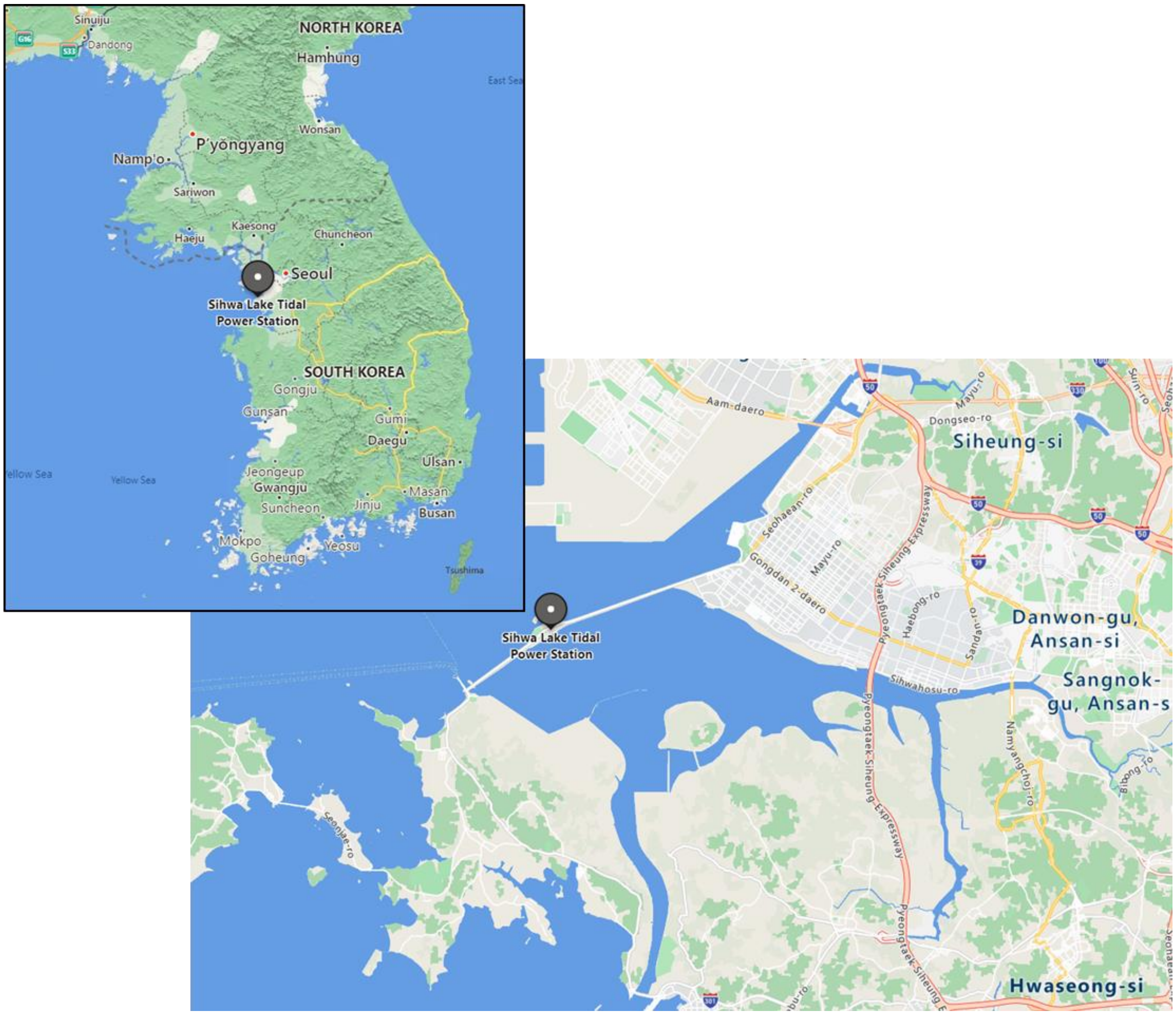
Sihwa Lake Tidal Power Station is the world's largest tidal power installation (by peak power only), with a total power output capacity of 254 MW. It is operated by the Korea Water Resources Corporation.[3]

The tidal barrage makes use of a seawall constructed in 1994 for flood mitigation and agricultural purposes. Ten 25.4 MW submerged bulb turbines are driven in an unpumped flood generation scheme; power is generated on tidal inflows only, and the outflow is sluiced away, i.e. as one-way power generation. This slightly unconventional and relatively inefficient approach has been chosen to balance a complex mix of existing land use, water use, conservation, environmental and power generation considerations.

[3] Wikipedia article on Sihwa Lake Tidal Power Station, https://en.wikipedia.org/wiki/Sihwa_Lake_Tidal_Power_Station

The station's mean operating tidal range is 5.6 m (18 ft), with a spring tidal range of 7.8 m (26 ft). The working basin area was originally intended to be 43 km^2 (17 sq mi) and has been reduced by land reclamation and freshwater dykes to 30 km^2 (12 sq mi), likely to be reduced further.

See the figure below.



3.3. Annapolis Royal Generating Station

Only one significant tidal energy project has been built in North America, and it is no longer operating.

The Annapolis Royal Generating Station was a tidal power generating station in the Bay of Fundy in Nova Scotia, Canada. When operational, it was the only tidal generating station in North America and was one of the few in the world. Located upstream of Annapolis Royal, Nova Scotia, it generated about 30 million kilowatt hours per year, enough for 4500 houses. Peak output was 20 megawatts.[4]

[4] Wikipedia article on Annapolis Royal Generating Station. https://en.wikipedia.org/wiki/Annapolis_Royal_Generating_Station

The station was shut down in April 2019, after the Canadian Science Advisory Secretariat found substantial fish mortality caused by the turbine, and a crucial component failed within the generating system. For example, research from the 1980s showed almost one quarter of the American shad passing through were killed. The station operated 34 years, mostly with minimal regulatory scrutiny.

A causeway on the Annapolis River created a reservoir which powered a water turbine. Sluice gates in the causeway allowed the reservoir to be refilled by the incoming tide, and retain the water in the reservoir when the tide recedes. Power was only generated when the tide was out, for about five hours, twice a day.

Construction began in 1980, and it opened in 1984. It was constructed by Nova Scotia Power, at the time a provincial crown corporation.

4. Modern Technology

Buoyed by successful demonstration projects and a new interest in renewable energy bolstered even further by Europe's anticipated turning off of Russian taps, tidal energy is moving increasingly into the mainstream. While the number of megawatts produced annually by ~ tidal is still small, notes Donagh Cagney, policy director for the advocacy group Ocean Energy Europe, "the increase is exponential." For example, by 2050, tidal energy is expected to account for 11% of the U.K’s electricity, compared with just 3% today.[1]

But in remote coastal Scotland, some residents are already getting a taste of that future. Scotland has become to tidal energy what Saudi Arabia is to fossil fuels. Cagney chalks this up to several factors, ranging from its geography-the country is blessed with some of the world's fastest-moving tidal sounds-to its experience in working with offshore oil extraction. For those reasons, it has for almost two decades hosted the world's biggest grid-connected test bed for tidal energy, the European Marine Energy Centre (EMEC). Founded in 2003, it's headquartered in the Orkney Islands, off Scotland's northern coast. Neil Kermode, the center's director since 2005, has seen some 35 tidal energy projects tested, by startups that have come and gone-some shuttered for lack of capitalization or nonviable technology, some absorbed by larger companies like GE.

4.1. Surface Turbine

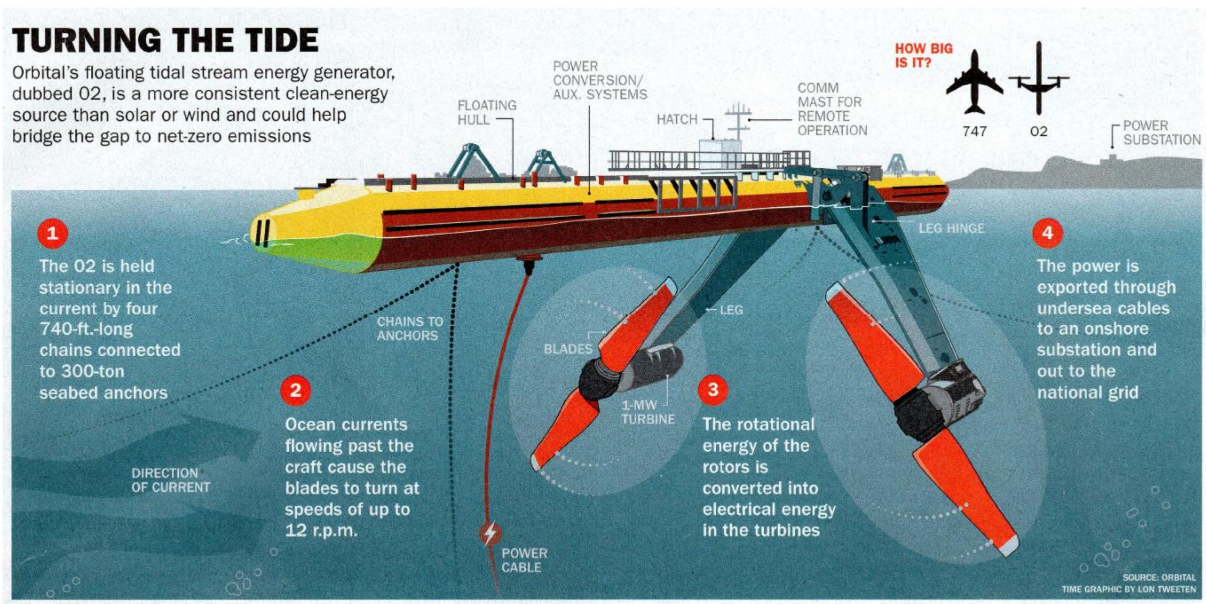
The biggest project ever run at EMEC is still there, providing power for 1 in 12 Orcadian households. The O2, as it's dubbed, created by the Scottish company Orbital Marine, weighs some 680 tons, is longer than a Boeing 747, and skims the top of the water like the world's largest rowing scull. "It looks like, well, a yellow submarine," says Kermode. "When you see it, and the tide is roaring past, it's really hard to realize it's stationary. There's a real optical illusion-you think this I thing is being towed through the water." But the O2 is chained to the seabed, via four cables, each capable of lifting some 50 double-decker buses off the ground. Only the water is moving, pushing two 10 m.-long turbines with some 100 metric tons of pressure.

Orbital Marine Power’s O2, the world’s most powerful tidal turbine, has commenced grid connected power generation at the European Marine Energy Centre (EMEC) in Orkney.

The innovative, floating turbine is anchored in the Fall of Warness where a subsea cable connects the 2MW offshore unit to the local onshore electricity network.[5]

Manufactured and launched in Dundee earlier in the year before being towed up to Orkney, the O2 is Orbital's first commercial turbine and represents the culmination of more than 15 years of world leading product development in the UK. The 74m long turbine is expected to operate in the waters off Orkney for the next 15 years with the capacity to meet the annual electricity demand of around 2,000 UK homes with clean, predictable power from the fast-flowing waters. In a further ground-breaking element of the project, the O2 is to provide power to EMEC's onshore electrolyzer to generate green hydrogen that will be used to demonstrate decarbonization of wider energy requirements.

See the figure below, Source, Orbital Marine via Time (Ref 1), graphic Lon Tweeter:



Orbital CEO, Andrew Scott, said: "This is a major milestone for the O2 and I would like to commend the whole team at Orbital and our supply chain for delivering this pioneering renewable energy project safely and successfully. Our vision is that this project is the trigger to the harnessing of tidal stream resources around the world to play a role in tackling climate change whilst creating a new, low-carbon industrial sector."

The construction of the O2 turbine was enabled by public lenders through the ethical investment platform, Abundance Investment, as well as being supported by the Scottish Government by the Saltire Tidal Energy Challenge Fund. The O2 project has been supported through funding from the European Union's Horizon 2020 research and innovation program under the FloTEC project and the European Regional Development Fund through the Interreg North West Europe Program under the ITEG project.

Commenting on the news Cabinet Secretary for Net Zero and Energy Michael Matheson of Scottish Government said: "With our abundant natural resources, expertise and ambition, Scotland is ideally-placed to harness the enormous global market for marine

[5] Orbital Marine. Power, "World's most powerful tidal turbine, the O2, starts exporting clean power," https://orbitalmarine.com/o2-power-generation/

energy whilst helping deliver a net-zero economy. That's why the Scottish Government has consistently supported the marine energy sector for over 10 years, including through the Saltire Tidal Energy Challenge fund, which provided £3.4m for this project.

"The deployment of Orbital Marine Power's O2, the world's most powerful tidal turbine, is a proud moment for Scotland and a significant milestone in our journey to net zero. I congratulate Orbital Marine, the European Marine Energy Centre and everyone who has made this achievement possible," Matheson continued…

From the video on the Orbital Marine Home page (https://orbitalmarine.com/) it looks like the water turbines move pretty slowly. This would probably greatly reduce predation of ocean-life. This is a good video, and you are interested in the subject of this post, I would recommend it.

4.2. Bottom Turbine

There are basically three ways to generate tidal power:

(1) Dam the flow and force it to go through turbines, but this is almost guaranteed to decimate marine life (see subsection 3.3 above).

(2) Use a surface-floating turbine tethered to the sea-floor as described in the prior subsection.

(3) Use a bottom mounted turbine. See below.

You need what is basically the equivalent of a wind turbine, placed underwater (either moored to the seabed or attached to the underside of some floating structure), which drives a generator. And luckily, water is denser than air, by some 500 times. "You tend to get a more compact, powerful source of energy;' says Forrest.[6] "Our turbines are a lot smaller than wind turbines, but produce a lot more bang for the buck." Nova, in particular, has other advantages: where the 02 floats, Nova's turbines lie beneath the ocean surface. "Our technologies are unaffected by storms," says Forrest.[1]

There's no visual impact, he says-aesthetics have been a reason many people have objected to wind turbines in the past-and do not create hazards for shipping or other marine operations. Nova billed its initial deployment, in Scotland's Shetland Islands in 2016, as the "world's first offshore tidal array." There are now six turbines in Shetland's Bluemull Sound, powering homes and, thanks to a collaboration with Tesla, electric vehicle charge points as well. After the success of that project, authorities granted Nova a license to build a 50-MW array, which will provide up to one third of Shetland's power.

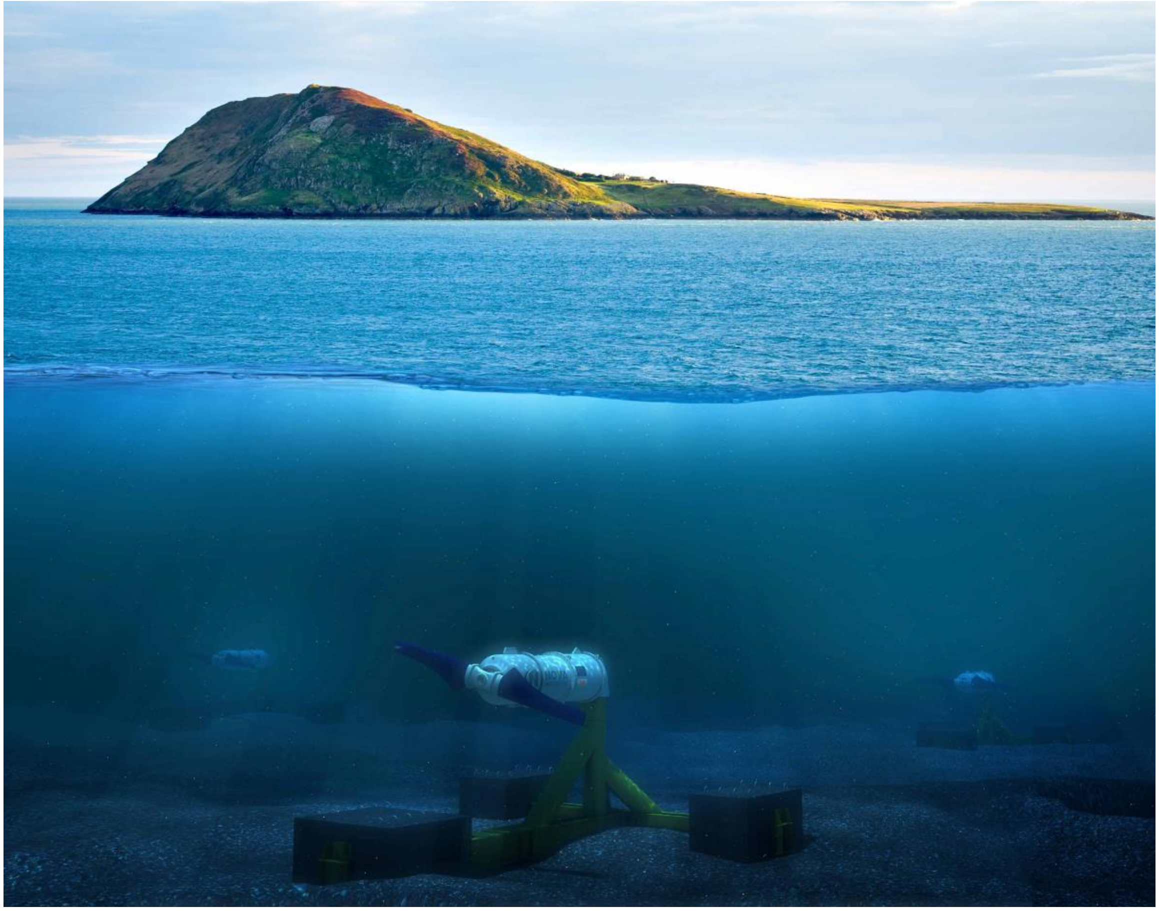
"We've been producing clean, predictable power for six years in Shetland;' says Forrest. "And you don't see it." Another thing that consumers on Shetland-or Orkney-do not see is the true price of their energy use on their monthly bills, thanks to government subsidies. For the technology to grow and spread globally, tidal-energy companies will need to reduce costs through scale and technology-driven efficiency improvements. It's not a fantasy; for example, in the U.S., the price of wind power has fallen 70% over the past decade.

There is the question of how mass deployment of tidal turbines might impact the seas. "If you are putting something in the ocean that is extracting energy, [you] are perturbing the

[6] Simon Forrest, the CEO of Scotland-based tidal-power producer Nova Innovation

ocean;' says Michela de Dominicis, a senior scientist with the U.K.'s National Oceanographic Centre. "This can have cascading effects like disrupting the nutrient mix of ocean ecosystems as well as raising water temperatures. Her research suggests, however, that any disturbances may well be worth it. "In one of my papers I was showing that even if I'm putting like 20,000 turbines at sea and I'm perturbing the environment; this effect is one order of magnitude less than what can happen with climate~ change."

The figure below shows how the Nova Innovation turbines are deployed. This is from the Nova Innovations Products Page (https://www.novainnovation.com/products/). The text below that is also from this page.



Key Benefits:

Rapid deployment - our plug and play system enables our turbines to be containerized, transported and installed anywhere in the world using locally available infrastructure.

No visual impact - our subsea turbines are invisible with no impact on the landscape, shipping or navigation.

High reliability - our direct drive technology, robust design and blue-chip partners ensure high quality and low maintenance.

High performance - years of operational experience have ensured our systems are highly efficient, ensuring optimum return on investment even in lower tidal flows.

Environmentally friendly - our years of operating tidal turbines have demonstrated that our technology is eco-friendly - there are no dams, no barriers, and they work in harmony with wildlife and the environment.

Each Nova Innovation Turbine produces 100 kW. Additional specifications and close ups of these turbines can be seen on the above linked web page.

4.3. Back to Golden Gate

If I were to select a design that might be viable for this tidal energy site (see section 2), it would probably be the Nova Innovation turbines. They seem to tick all of the boxes to enable a sustainable and cost-effective deployment here.

Also, a deployment in this location would have one other major advantage. There are major load centers south (City of San Francisco) and North (Marin County with a population of over a quarter million people, most of these concentrated near the Golden Gate, see the map below). Thus these could be served by the turbines using sub-transmission circuits.