

Memorandum

To: Alena Chercover
From: Alex Karges, Amber Rose, & Anim McCauley
Date: November 17, 2025
Re: Review of Tidal Energy

Summary

The next frontier of green energy development lies in the marine environment. Historically, ocean currents powered tidal mills, but their use declined after the Industrial Revolution. Interest in tidal energy revived in 2009 as researchers sought a consistent, reliable, and renewable power source. Marine energy falls into two main categories: tidal and wave. Each faces the challenge of capturing energy from tidal currents or ocean swells in harsh ocean conditions. Tidal energy faces several disadvantages, including high costs, environmental concerns, and the challenges of developing and maintaining turbines in the marine environment. Even so, research continues because tidal energy offers the promise of reliable, decentralized power that can support rural communities and is a less seasonal source of energy compared to solar or wind. Although this report focuses on in-stream platform tidal systems, which are turbines mounted near the water's surface to capture higher-speed currents, there are two other forms of tidal energy, along with a wide range of wave-energy technologies. Continued development is needed to address the challenges of marine energy capture, but recent milestones suggest strong potential with increased investment, further innovation, and lower installation and maintenance costs.

Overview

The focus of renewable energy development has been on wind and solar, which have proven to be capable of meeting our energy needs. However, both face limitations related to land use, proximity to urban areas, and seasonal availability, especially at higher latitudes where winter brings long periods of darkness.

The next frontier in renewable energy looks to the ocean for a more reliable and less seasonal power source. Ocean energy comes in two main forms: tidal and wave. Tidal systems use turbines driven by rising and falling tides, while wave systems capture energy from ocean swells. Their potential is substantial; wave energy could provide about 800 TWh per year, and tidal energy roughly 8,000 TWh per year (Chen, 2025). In this review, the focus will be on tidal energy capture.

While the promise of tidal energy capture is significant, how it is captured and how it is delivered to the electrical grid remains the main challenge. Tidal energy, put simply, comes from turbines being turned by the ocean currents as the water flows in and out of water basins. The electricity produced is then passed through large cables delivering the energy back to the shore, where it can be added to the power grid.

Tides shift roughly every six hours, creating two high and two low tides each day due to the gravitational pull of the sun and moon on the world's oceans, and tidal strength varies with basin

shape. Current technology is primarily limited to Northern Europe, Scotland, and eastern Canada due to the strong tides there, which are driven by their unique topography. However, many places, such as India, Western Canada, Spain, and Chile, have investigated tidal energy development (Bhui, K. et al., 2025; Mestres, M. et al., 2016; McVey, J. R. et al., 2025).

History

Tidal energy has a long history, once used to power flour mills such as the historic Woodbridge Tide Mill in Suffolk, England. Its decline followed the Industrial Revolution, when steam- and coal-powered mills replaced tidal systems (Free documentary, 2024). Modern tidal power did not re-emerge until 1966, when a tidal barrage was installed at the mouth of the Rance River in France (Free documentary, 2024).

Today, tidal energy systems fall into three main types, shown in Figure 2: barrages, bottom-mounted turbines, and surface platform turbines. Bottom and platform turbines have been deployed in locations such as the Bay of Fundy in Nova Scotia and the Bluemull Sound in the Shetland Islands (Nova Home, 2025).

Many companies and government agencies are working to optimize energy output and overcome the challenges posed by the harsh marine environment. Leading government groups include the European Marine Energy Centre in Orkney

and the Canadian Federal Task Force on Sustainable Tidal Energy Development in the Bay of Fundy. These organizations collaborate closely with industry partners. One key company, Nova Innovations, has pursued “clean, predictable, and cost-competitive electricity” since 2016 (Nova Tidal Energy, 2025). It installed the world’s first offshore tidal array in the Bluemull Sound in 2016 and later took over the Bay of Fundy tidal project originally launched in 2009 by the Fundy Ocean Research Center for Energy in 2018 seen in Figure 1 (Nova Tidal Energy, 2025; GoC, 2018; GoC, 2016).



Figure 1: Instream Tidal Platform in the Bay of Fundy (Coleman, N., 2022)

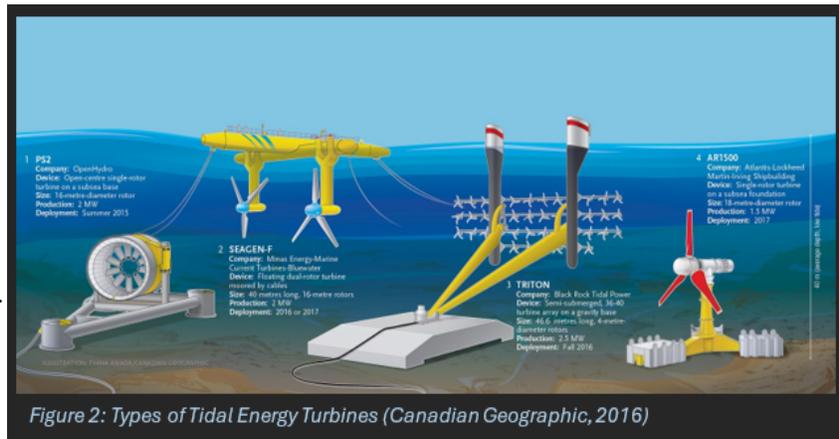
Although development is ongoing, tidal energy is beginning to show commercial promise. To be viable, it must reliably generate enough power to offset installation and maintenance costs. Since 2021, the UK has produced 2 MW of tidal power, marking early progress (Tidal Energy, 2025). A 2025 *Euronews* report highlights another major milestone: a Scottish turbine operating at a depth of 40 meters for six and a half years with no unplanned maintenance, producing enough electricity for up to 7,000 homes annually (Hughes, 2025). Achievements like this strengthen confidence in tidal energy’s commercial potential and help attract further investment.

Tidal Lagoon Power Systems

Tidal lagoons are man-made enclosures along the coast or offshore that trap and release ocean water through turbines to generate electricity. Tidal lagoon systems produce renewable, demand-responsive power by combining tidal energy generation with pumped-storage capability. Enhanced tidal lagoons use electric pumps to move extra water into the lagoon at either high or low tide to increase the water level range, thus increasing the potential energy. This pumping technology can quadruple the net energy output from 3.3W/m² up to 14W/m² (Mackay, 2007). While tidal lagoon power stations are able to generate electricity from natural tidal flows, a pumped storage system is able to store excess energy to generate electricity on demand. This is done through a two-lagoon setup having one high pool and one low pool to allow continuous, steady and stable power output.

Tidal Barrage Technology

Tidal barrage technology uses a dam-like structure that is built across an estuary or bay that traps water in a basin at high tide and releases it through turbines at low tide to generate electricity. It is similar to a hydroelectric dam except it harnesses the potential energy created by the rise and



fall of ocean tides rather than river flow (Chang, 2008). The Bay of Fundy, located between Nova Scotia and New Brunswick on Canada's Atlantic coast, experiences the highest tides in the world. This tidal range provides immense potential for renewable energy development and has led to the establishment of Canada's first tidal energy plant, Annapolis Tidal Generating Station. Commissioned in 1984, this station was built at the mouth of the Annapolis River in Nova Scotia within the Bay of Fundy (Pacific Northwest National Laboratory, n.d.). The facility used a single Straflow turbine with a 20-megawatt capacity that produced 29 to 50 GWh of electricity each year, enough to power about 4,000 homes. After more than three decades of operation, the plant was decommissioned in 2019 due to equipment failures, rising maintenance costs, and growing environmental concern (Pacific Northwest National Laboratory, n.d.).

Advantages and Disadvantages

Tidal stream energy has a unique set of advantages and disadvantages that shape its potential. Not only is the seasonal variation of tidal minimal relative to wind and solar, but because water is approximately 800 times denser than air (Department of Energy, 2024; Ladislav et al., 2025), even small turbines such as the one in Figure 3 can generate enough power for 600 homes (NOVA, 2021). Potentially even more vital, tidal



can generate power for coastal communities that are unable to connect to the power grid or do not have the local potential for wind or solar.

The development of tidal stream technology has led to the alleviation of some disadvantages. Previously, submerged forms of tidal energy, such as tidal lagoons and barrages, created technological complications and ecological consequences. Technologically, submerged systems must contend with the salinity, weather, wave force, debris, and wildlife of marine environments without the aid of regular maintenance (Ladislav et al., 2025). Marine debris destroyed three turbines in the Bay of Fundy (CBC, 2016; Scott, 2022). Environmentally, channelling water through turbines alters the flow of sediment, changes salinity, and can be devastating for some marine species (Crawford, 2022), especially migratory ones (Perez, 2024). These impacts led to the end of a tidal barrage system in the Bay of Fundy and forced the transition to less impactful technologies (NOVA, 2021), such as tidal stream platforms similar to the second device depicted in Figure 2. In Orkney, Scotland, the SR200 tidal platform prototype finished its trial period in 2020 after generating 3 GWh each year (Crawford, 2022). It has been replaced by the O2 platform, which is projected to generate power for 2,000 homes (Crawford, 2022). Both platforms showed evidence of not impacting marine animals (NOVA, 2021; Weather Network, 2022). The O2 improved has turbines that can be raised above water for maintenance (NOVA, 2021). This is expected to decrease operational costs.

While the development of tidal stream technology mitigates many disadvantages, there are two remaining barriers to the widespread adoption of tidal: cost and geographic potential. On-shore solar and wind have seen remarkable reductions in cost, which have made them more competitive and widely adopted. Tidal has not gotten to this point; while 1 MWh from wind costs about \$20 as of 2025, 1 MWh of commercial-scale tidal costs \$130 - \$280 (Crawford, 2022). Part of the reason for the cost differential is that offshore technology requires the construction of strong foundations (or a platform) and laying cables to carry the power onshore (Ladislav et al., 2025). Moreover, the geographic distribution of that power source is uneven. The UK alone has an estimated 20% of that potential for tidal energy (Ladislav et al., 2025) and the Bay of Fundy was chosen as a research and development site because it has the largest tides in the world (CBC, 2016). The development of tidal stream platforms has the potential to reduce costs, improve tidal energy, and target tidal energy at the fastest point (the surface) as well as reduce ecological impacts (NOVA, 2024). However, it is still subject to the degree of tidal energy available, which is specific to the local environment and thus is far from universal.

Conclusion

It is not a matter of if tidal energy is effective; the SR200 and O2 platforms already prove that the technology works. The real questions are: how geographically widespread is its potential, and can it become cost-effective enough to be adopted in those areas of potential? If tidal energy can follow the trend set by onshore solar and wind by reducing the per-unit generation costs, it will likely become an increasingly popular technology. Even beyond that, it will still likely be adopted as a source of decentralized power for coastal, rural communities. In these areas, tidal energy will likely become exceptionally beneficial because of its reliability. The technology is here; it just has to reach the cost-effective threshold in order to take off.

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