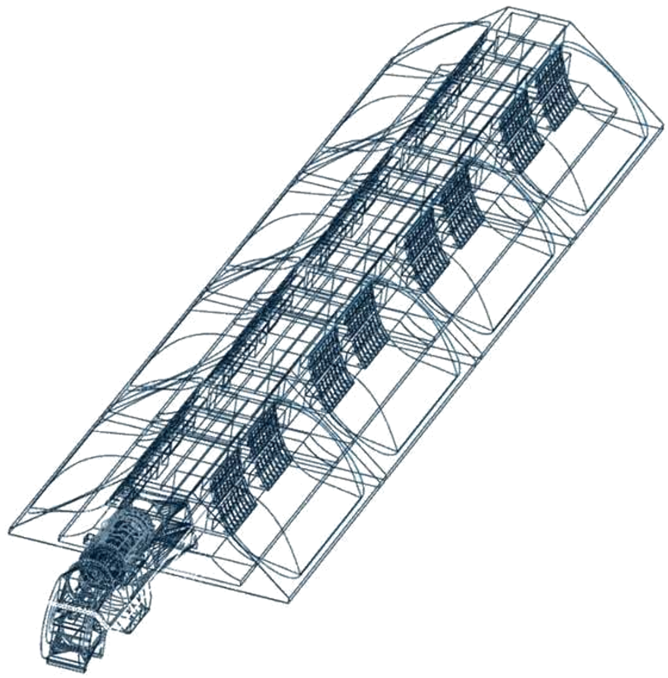
Bombora mWave



ENGM 2210: Technology Strategy

Section 02

Engineering Management Program

Vanderbilt University School of Engineering

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Bombora mWave

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Executive Summary

Bombora Wave power is a technology start-up company specializing in innovative solutions to the generation of clean and renewable energy. Bombora's strategy is focused on extracting energy from wave energy, a developing option within the renewable sector. Bombora's key differentiator is its patent-pending mWave technology, a novel method of capturing wave energy through a membrane that sits on the ocean floor. The device harnesses wave energy passing over an inflated rubber membrane pump that delivers air pressure to operate a turbine. This technology can greatly impact the renewable sector, providing an innovative and sustainable solution for many of the problems that exist with incumbent wave power technologies. Because the membrane lies on the ocean floor, it is not susceptible to harsh storms, and its simple design does not require complex maintenance repair and overhaul. The power generated by these farms would be most beneficial to utility companies and consumers operating in coastal locations, as the membranes must be deployed into oceanic environments.

Bombora has already raised its seed capital goal and has proven results of deliverable performance for small scale-wave farms. Bombora received funding from strategic investors and is working further to gain more funding for future deployments and research from other venture capitalists and additional sponsors. Shortly after Bombora's founding, the first full patent was lodged for the wave energy converter, protecting the technology contained in the mWave converter. Recently the company completed a feasibility study for a 60MW Portuguese wave farm, and is currently preparing for a full-scale wave farm deployment by the end of 2017. The technology has proven to be effective through the testing and trials, however there are still modifications and developments to be made for increased optimization and efficiency.

Currently, Bombora has a competitive advantage due to the immature state of the niche wave power market and the relatively innovative solution to the common problem of storms and shutdowns. Unlike the traditional buoy system, the mWave membrane does not disrupt the natural ecosystem of the ocean or the flow of sea vessels and fishing. Bombora currently does not have a share of the electric market, but there is high potential for Bombora to be able to scale up and cut down on operational costs.

The human population continues to grow while fossil fuels are depleting at a rapid rate, necessitating a transformation to the renewable sector. Households and utility companies are adapting new clean energy sources to provide electricity. Various governments are also developing policies to promote further renewable adoption. Wave power is a nascent field with opportunity for a large market share. If Bombora were to execute on its full capabilities, it could become a prospect for many utility sources to include in their energy portfolio. Bombora is still a small company and is likely to continue seeking new collaborators and refine their business strategy, creating a lot of opportunity to grow and emerge as a leader in the field of renewable energy.

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Macroeconomic/Societal Environment

Crisis identification

The human population remains critically dependent on non-renewable fossil fuels to produce energy. Coal and natural gas contribute to about 61% of electric power in the United States, with renewable energy contributing only 15% ***(Energy Information Administration, 2017)***. Country development and the improvement of living standards will continue to significantly drive global energy demand through 2040. Energy demand in Asia, including China and India which account for about half of the global consumption, is projected to grow by 83% ***(Doman, 2017)***. Population growth and an abundance of domestic resources is expected to cause energy consumption in the Middle East to also increase by 95%. While it is expected that the coal share of total electric generation declines from 40% in 2012 to 29% in 2040, the share of natural gas is predicted to increase from 22% in 2012 to 28% in 2040 ***(Energy Information Administration, 2017)***. Increased utilization of natural gas is particularly concerning as the United States is projected to have enough natural gas from recoverable reserves to last only about 86 years. Rapid depletion of limited resources should accelerate the adoption of new renewable energy technologies. The burning of fossil fuels creates heavy concentrations of pollutants into the air and water, and accounts for the 77% of greenhouse emissions ***(Energy Information Administration, 2017)***. With a near global consensus on the dire state of the environment, future policies should further boost support on promising clean sources of energy.

Identification of innovation enablers or inhibitors

The planet cannot sustain usage of the same levels of carbon emissions and expensive fossil fuels. It is necessary that companies and communities adopt an entirely new and relatively undiscovered form of energy. The conversion to hydropower does incur a number of operational and transitional costs, and it is required to realize the benefits of sustainable resources despite the original monetary costs. Another key enabler is the offshore wind, as motion of sea surface waves are principally determined by wind speed ***(Blackledge, Coyle, Kearney, McGuirk, & Norton, 2013)***. Even with these specific enablers, there do exist some inhibitors that may negatively impact adoption. Renewable energy and wave power membranes do not yet operate under an economy of scale, and only through increased usage would Bombora see the profitable benefits. Another inhibitor is the prospect of location for cities and countries that are landlocked and further from a source of water. Developments into electric grids would be required to transport the wave energy. High capacity batteries may help to further store and efficiently utilize generated electricity. The wave power market relies on a relatively undeveloped infrastructure, and manual implementation of dams for landlocked cities also drives up costs.

Timing

There are many limitations to the prospect of the wave power membrane, but only certain markets and cities are ready for the full utilization of this technology. Most coastal and developed cities are best primed for the technology, for they do not rely on extensive electric grids for driving electricity, and use this electricity on a daily basis. Most developing countries work and live without electricity. UNSE4ALL's goal of providing all people access to energy by 2030 shows insufficient progress ***(Deloitte Africa, 2014)***. Particular regions in Asia and Africa would require actions by the government or the industry to drive this reality. Therefore, some people would not need this form of generating the energy. Before the world can fully utilize and understand this new form of energy, it would require a better and more efficient form of energy transport, as well as energy storage. A transition to wave power could run independently, and it would be greatly beneficial to store the unused energy. While the world may not be able to completely rely on this technology immediately, there are many markets that are capable of working towards this transition.

Strategic implications

There are certain key strategic implications for Bombora mWave to succeed, one being the efficiency of the membrane to capture the full potential of the wave power. Ocean waves contain tremendous energy potential, and a critical condition for success is the efficient implementation to effectively capture all of this energy and store it properly. It is also crucial that Bombora ensures that their membrane technology can better capture this wave power over the buoy system. There still exists huge complexity in optimizing the design to best harness the wave power. Extensive research and development is required for a robust and reliable design, and the design should be reliable in all ocean settings. The vision for the innovation is clear, but it would take time to figure out some smaller details of design. Another strategic implication to be considered is the locations of implementation. While the best markets for the product exist in developed coastal countries, it is possible that the waves are weaker in the areas. It is important to consider these tradeoffs, and determine whether it is worth installing the technology in more powerful oceans with a less defined market.

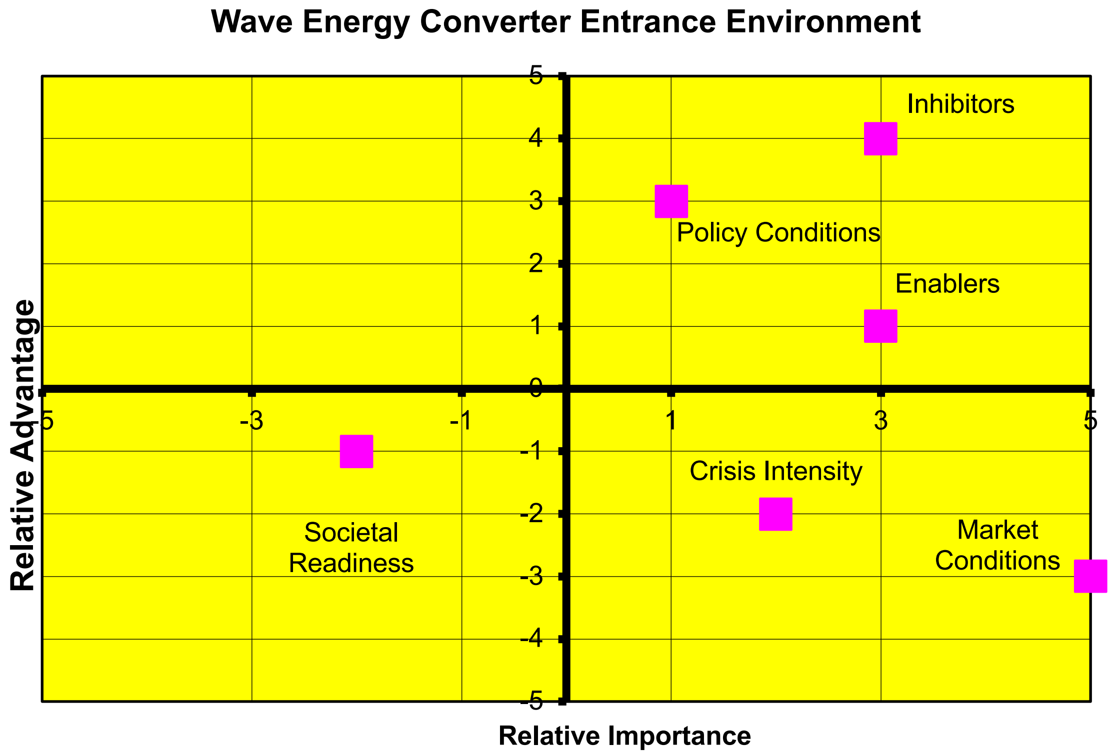

Figure 1. Importance-Advantage Matrix for Macro-Societal Innovation Success Factors

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Market/Demand Environment

Ideal market for your technology

Bombora would ideally sell wave farms to coastal energy suppliers and companies with access to the water. Higher revenue comes from complete openness to alternative fuels, as well as prioritization of environmental impact over costs. Increased tax credit incentives from the government, as applied to other renewable energy technologies further boosts market adoption. Bombora would focus on cities and countries with mandated renewable portfolio standards, requirements to supply a portion of their consumers from renewable resources, and a focus on utilizing clean energy. Many alternative energy companies do not rely on a singular source for generation of electricity, and could further benefit by diversifying their portfolio to wave power, especially if the company is located near the coast. Therefore, a company like Pacific Gas and Electric, which generates electricity from hydroelectric, nuclear, and fossil fuel sources, contracts independent power producers, and holds a significant hydropower market share of 19%, would likely act as the primary user of the mWave technology (IBISWorld, 2017). Bombora would be most profitable by independently operating the wave farms and leasing the energy to suppliers and creating contracts with companies that would pay for their utility. The ideal market could also include interest from independent consumers living on the cost that would purchase mWave modules to generate household electricity.

Candidate markets

One specific candidate market would be independent consumers living on the coast who want to generate their own power. This would likely rely on operations under an economy of scale, to cut prices and reduce overheads. Rather than going through a supplier, consumers could buy power directly from the membrane technology. This would provide them with clean and low-cost energy with no reliance on the intermediary to provide household electricity. Another candidate market could be wholesale third party distributor, to which Bombora could sell the rights to the membrane technology. Bombora could receive a royalty for each purchase, stimulating future income from the technology. A third potential market could operate under a business to business model by generating the electricity for the coastal energy suppliers. This would likely be the most lucrative path, for larger plants usually have far reaching residential grids that generate larger profits. Even if Bombora didn’t completely overtake reliance on natural resources, total electric company revenues from sales to ultimate customers equaled $381 billion (Edison Electric Institute, 2016). If Bombora captured just a portion of this total market, it could be a very profitable venture.

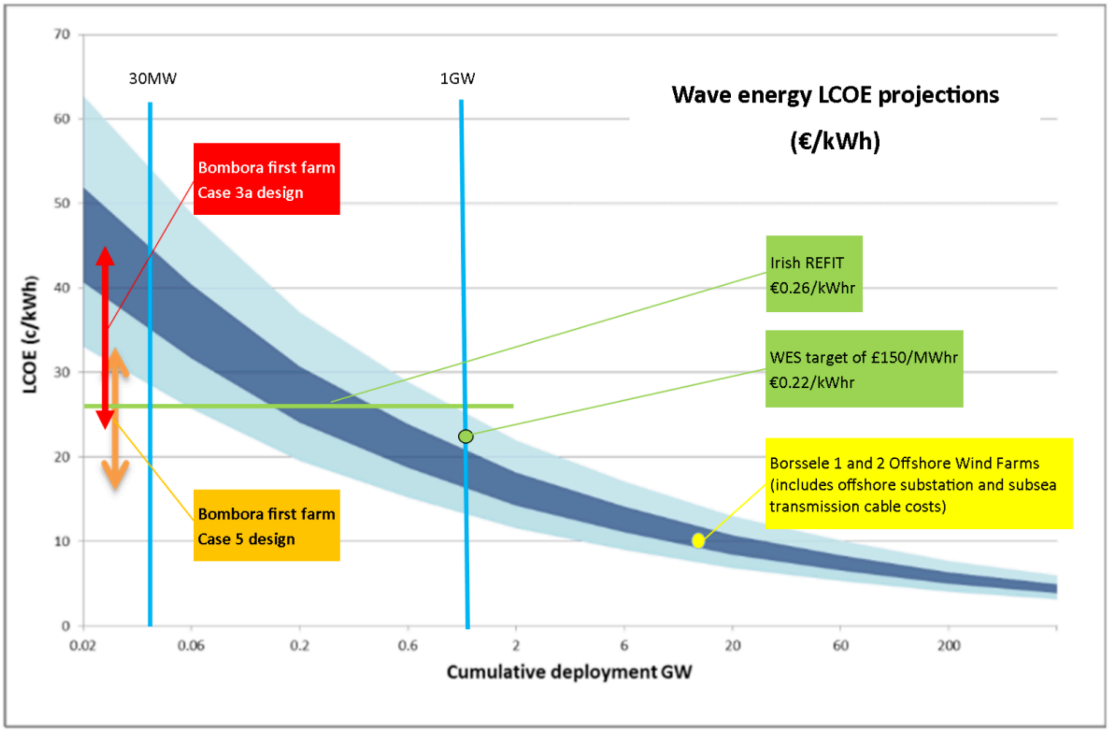

Figure 2. LCOE cost projection per cumulative deployment

Market size

Design Case	Case 3a	Case 5
Pessimistic (@14% discount rate)	AUD70.32c/kWhr (€0.47/kWhr)	AUD49.81c/kWhr (€0.33/kWhr)
Optimistic (@7% discount rate)	AUD34.77c/kWhr (€0.23/kWhr)	AUD25.33c/kWhr (€0.17/kWhr)

Figure 3. LCOE ranges for developing mWave models

Since Bombora would target coastal areas, the market for the product would be dependent on the electricity usage of populations living on the coast. With estimates of 39 percent of Americans living on the coast, with 100% access to technology, it can be assumed that approximately 90% of people in the United State use electricity on a daily basis (National Oceanic and Atmospheric Administration, 2017). If Bombora were to capture just 10% of the market primarily dependent on fossil fuels, this would result in an estimated 29 million Americans that would be using electricity generated by the mWave.

Plant Type	Range for Total System Levelized Costs (2016 $/MWh) Minimum	Non-weighted average	Capacity-weighted[2] average	Maximum	Range for Total System Levelized Costs with Tax Credits[1] (2016 $/MWh) Minimum	Non-weighted average	Capacity-weighted average	Maximum
Dispatchable Technologies								
Coal with 30% carbon sequestration[3]	128.9	140.0	NB	196.3	128.9	140.0	NB	196.3
Coal with 90% carbon sequestration[3]	102.7	123.2	NB	142.5	102.7	123.2	NB	142.5
Natural Gas-fired								
Conventional Combined Cycle	52.4	57.3	58.6	83.2	52.4	57.3	58.6	83.2
Advanced Combined Cycle	51.6	56.5	53.8	81.7	51.6	56.5	53.8	81.7
Advanced CC with CCS	63.1	82.4	NB	90.4	63.1	82.4	NB	90.4
Conventional Combustion Turbine	98.8	109.4	100.7	148.3	98.8	109.4	100.7	148.3
Advanced Combustion Turbine	85.9	94.7	87.1	129.8	85.9	94.7	87.1	129.8
Advanced Nuclear	95.9	99.1	96.2	104.3	95.9	99.1	96.2	104.3
Geothermal	42.8	46.5	44.0	53.4	40.0	43.3	41.1	49.3
Biomass	84.8	102.4	97.7	125.3	84.8	102.4	97.7	125.3
Non-Dispatchable Technologies								
Wind – Onshore	43.4	63.7	55.8	75.6	31.9	52.2	44.3	64.0
Wind – Offshore	136.6	157.4	NB	212.9	125.1	145.9	NB	201.4
Solar PV[4]	58.3	85.0	73.7	143.0	46.5	66.8	58.1	110.5
Solar Thermal	176.7	242.0	NB	372.8	134.6	184.4	NB	284.3
Hydroelectric[5]	57.4	66.2	63.9	69.8	57.4	66.2	63.9	69.8

Figure 4. Variation in levelized cost of electricity (LCOE) for new generation resources, 2022

Market's Needs/Expectations from the Technology

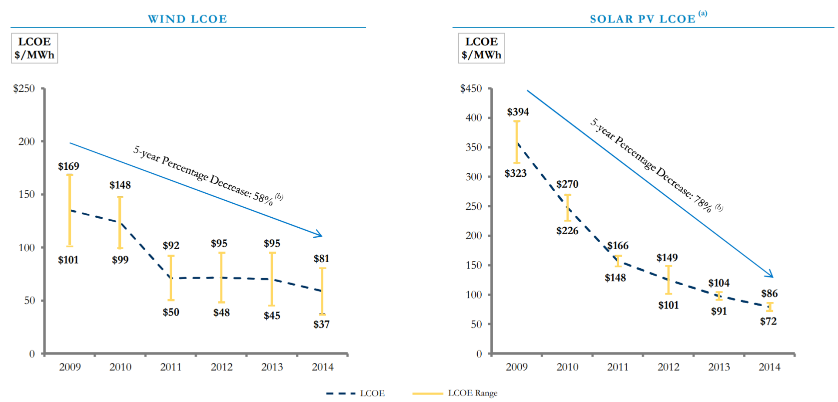

Figure 5. LCOE - Wind/Solar PV (Historical)

If Bombora were to sell directly to businesses, such as energy suppliers and utilities, the technology would provide a sustainable and reliable form of energy without the dependence on resource supply compared to energy generation via fossil fuels. Bombora would have to generate energy at an equal or better electric power unit/cost than current fossil fuels to ensure a consistent, reliable, and cost-efficient model. The market would specifically analyze trends in the leveled costs of electricity to determine whether the technology satisfies requirements related to cost of deployment. The market would expect little to no maintenance requirements from their part, as the water based technology could provide little hindrance to specific operations. Compared to wind power, wave power should be a more reliable form of energy "because waves travel across the ocean, their arrival time at the wave power facility may be more predictable than wind" (Renewable

Northwest Project, 2007). Of course, wave power is renewable and does not generate greenhouse gasses, which are detrimental to the environment. This would solve the huge problem of the limited fossil fuels and natural resources

Pricing – customer willingness to pay

Customers would primarily look towards the levelized costs of electricity (LCOE) to determine a reasonable price for deployment of our technology and a measurement of the maturity of the market. As displayed in figure 4, competitor costs for deployment per megawatt hour generated suggest that onshore wind and photovoltaic (PV) solar power requires only about six dollars per MWh produced. Examining figure 3, this value is observed to be significantly lower than the likely cost of about thirty dollars per MWh that is required by the current state of mWave technology. Historical data displayed in figure 5 has shown 58% and 78% decreases in LCOE of wind and solar PV deployments respectively over a five-year period from 2009 to 2014. There is high optimism that required costs for customers will reduce over time with additional developments. Demand will therefore increase with decreasing costs for the technology, also resulting in increased related market share.

Triggers and barriers to adopting this technology

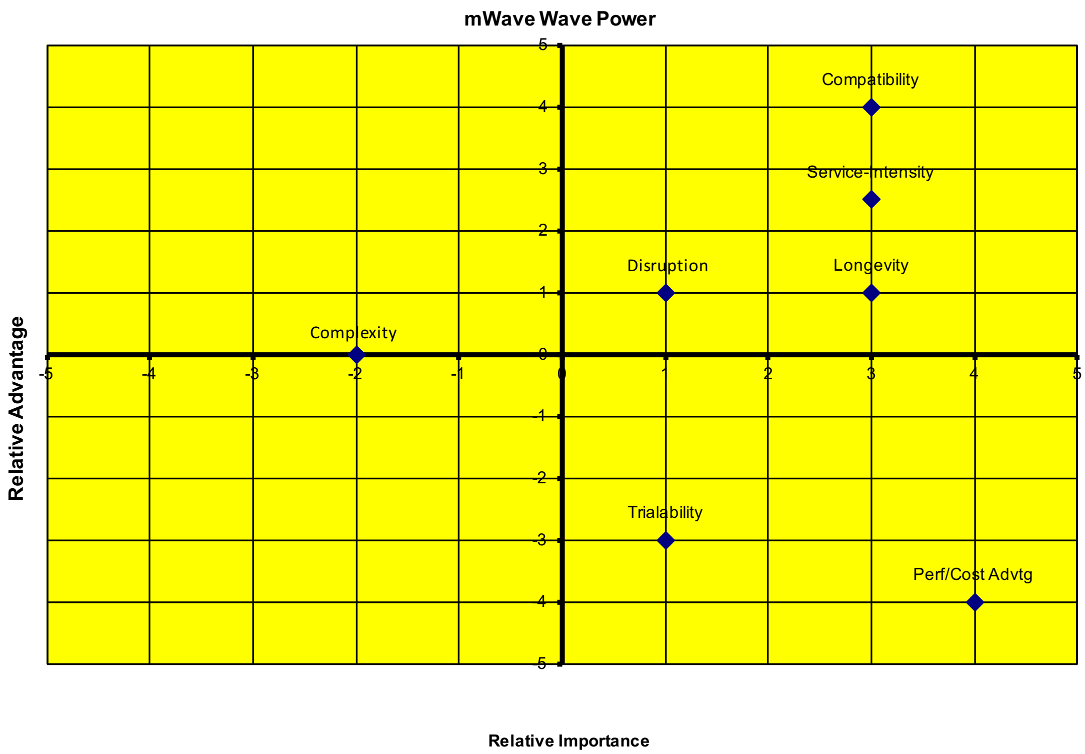

Figure 6. Importance Advantage Matrix

While wave power does seem like a viable option on both the economic and environmental front, there are multiple barriers that might inhibit easy access into the market. Right now, the mWave is a more expensive alternative to other forms of renewable energy, running at an average of around cents/kilowatt Hour. One advantage that our wave power would provide is much less maintenance. The mWave technology has no exposed moving parts, and the relatively simple design eliminates complexities that could streamline maintenance requirements (Bombora Wave Power Pty. Ltd, 2016). Bombora would likely be compatible with current trends and requirements, as it generates the same type of energy that should be compatible with the power grids and customer needs. Another barrier that could negatively impact the distribution of our technology are established trends in energy consumption and production. Consumers have been largely reliant on fossil fuels since the late 1800's, and many may not see the need to change to a new form of essentially the same energy. If an understanding of such environmental impacts does not exist, it may be hard to infiltrate an established market. One of the largest barriers for our technology is the trialability. While there is extensive testing on the energy generation, the installation is expensive and must be done in the ocean. Of course, there is no easy way to create a "trial period" for such products. Without proven results, energy suppliers and consumers may turn to other renewable sources or perhaps more established wave power producers. the mWave membrane connects directly to the electric grid through sea cables, which would require little external servicing for adoption of the product. Another barrier that could affect some would be the opposition against disruption of the natural ocean. Buoys and membranes may have certain undiscovered perverse effects on the ocean which may negatively impact sales.

Strategic implications

Currently, the relative performance compared to the cost of our product might be the greatest challenge to overcome. As seen on Figure 2 above, the goal for the mWave is currently sitting at around 306 USD per MWhr, while other forms of renewable energy are closer to 12 USD per MWhr. Of course, costs are often decreased with scalability and increased production, but without extensive trialability, it is difficult to get a gauge for the specific cost reductions. Additionally, the renewable energy market is already populated with a number of other energies, which makes it difficult to stand out with a relative advantage. Yet there is huge upside in Bombora's wave technology, especially since the sea cables are already integrated into the electric grid, which would add on no extra transition costs. Within the three tiers of the Stage-Gate model, the mWave definitely is feasible and has potential, but runs into some barriers within the second tier, namely in differentiation. All renewable energies are capable of generating electricity in some form or the other, but it is unclear whether there is one to focus on, or if diversification would be more sustainable. Wave power does have many advantages, as it does not take up land and can be installed in any coast, yet the electricity it produces cannot be easily differentiated from other competitors. Within this model, profits would likely suffer at this stage in development as costs have not yet been reduced to the goal. Trialability would be greatly beneficial to our strategy, as it would provide a way of testing the product in a commercial setting and analyzing what factors could be improved.

Technological Environment

History of the technology

Since the onset of the industrial revolution, coal, natural gas, and other fossil fuels have been the dominant form of energy generation and consumption. In 2016, around 4.08 trillion kilowatt hours of electricity were generated by large facilities, with around 65% from fossil fuels (Energy Information Administration, 2017). Until recently, society has relied on non-renewable fossil fuels for all energy needs, with supply continually depleting. Thus, new forms of sustainable energy have been explored, with no universally preferred source. U.S. renewable consumption by source has been fairly evenly distributed, with hydropower constituting 25%, biofuels 22%, and wind 19% (Institute for Energy Research, 2017).

Compared to fossil fuels, Bombora brings a new form of harnessing the renewable energy potential and turning it into a concentrated form. Compared to other forms of hydropower, our technology is much less reliant on large complex infrastructure such as dams. While wave power is dependent on water movement, wave utilization removes the requirements of water flow volume and change in elevation to determine sufficient energy yields. Our membrane is solely dependent on naturally occurring waves, and can be installed underwater discretely. This concealed portability reduces use of valuable land area and allows installations to be easily applied and removed. As many large cities are next to harbors and oceans, wave farms can be conveniently placed to utilize this source. Other forms of wave power implementations utilize a floating buoy component as the primary driver for generating energy (Bureau of Ocean Energy Management, n.d.). These systems are more susceptible to harsh storms and are likely to incur higher costs for maintenance.

Small scale tank testing and mid-scale sea trail tests are being used to better analyze the capturing power and efficiency of the mWave system. The technology still requires further development of more sophisticated computer modeling techniques and engagement with key supply chain partners to advance the technical capabilities of the mWave system. The first full-scale mWave wave energy converter deployment occurred in Portugal in 2016, following testing of a partial-scale trial in Perth, Western Australia (Bombora Wave Power, 2015). Final design work and vendor selection is underway for the construction of the first full-sized cell of the mWave technology (Bombora Wave Power, 2016). Refinements to the technical design and the accessibility of deployment locations requires further test deployments and government policy support. As shown in figure 7, investment in renewable sources have steadily been increasing in the last 10 years.

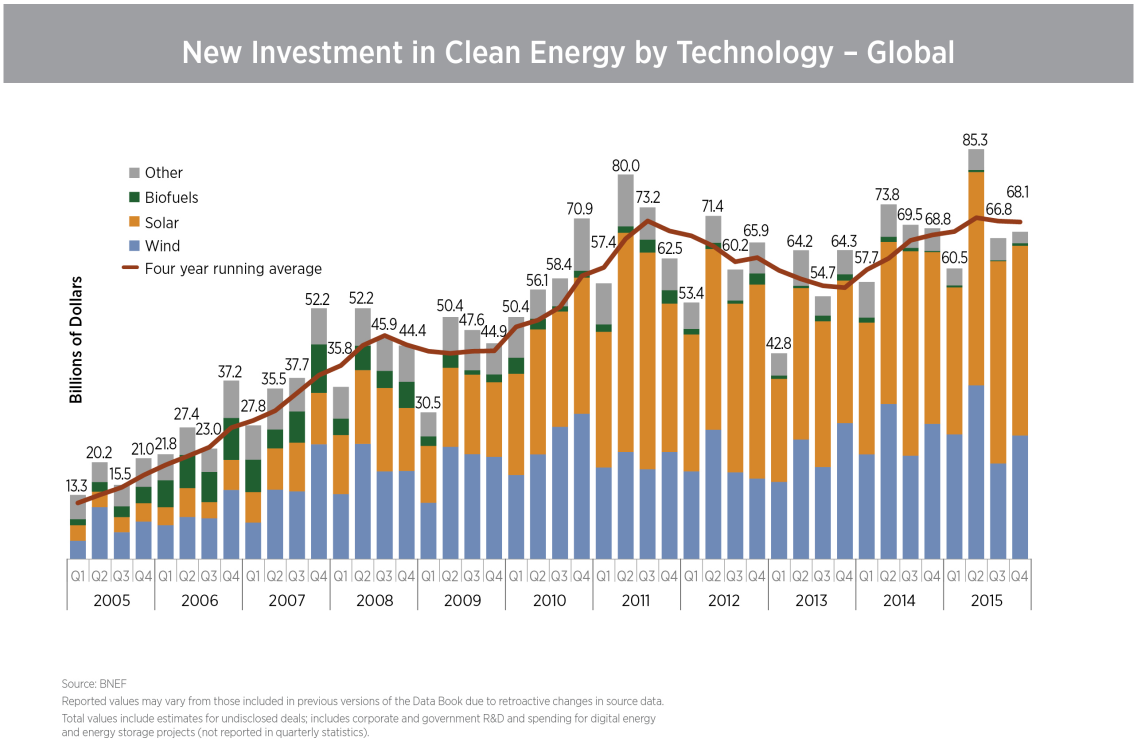

Figure 7. Historical chart of investments in clean energy

. While this is not limited to just wave power, it is clear that there is momentum and confidence in sustainable energy sources. Hydropower does constitute the largest percent of renewables, so it seems to be the most lucrative path for growth. With the continuation of this direction, commercial deployment of the mWave technology should take around 4 to 5 years.

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Physical architecture

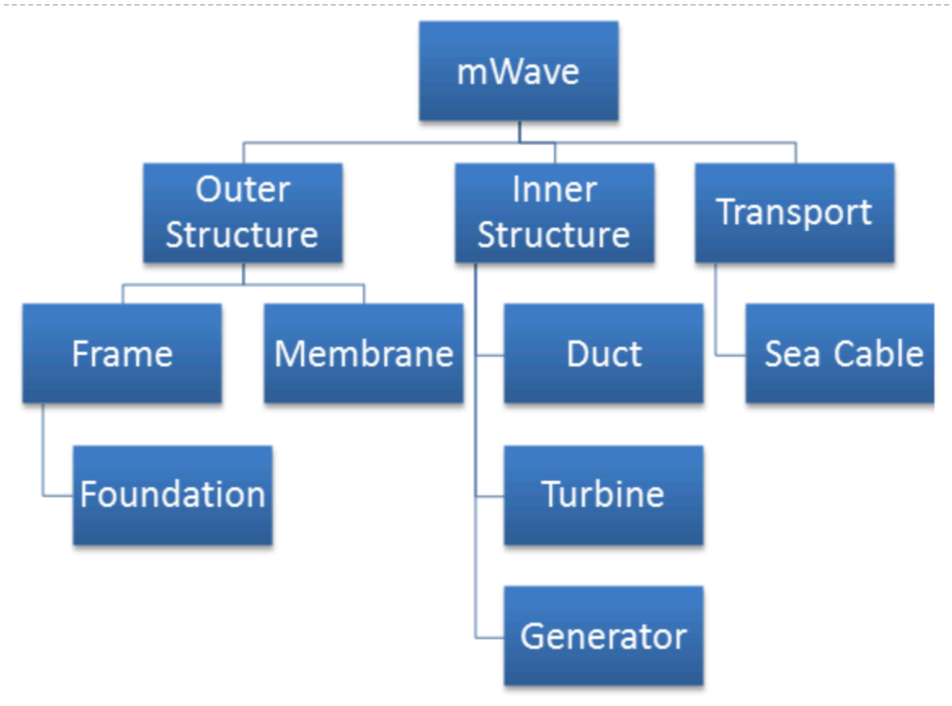


Figure 8. Topological organization of mWave technology

The mWave wave energy converter functions through a series of air-inflated rubber membranes, optimally angled towards the waves (Bombora Wave Power, 2017). As air passes over the membrane, the air inside is squeezed into a duct and through a turbine, which spins to generate electricity. The air is then recycled into the membranes for the next wave. The membranes are made of reinforced industrial grade rubber, ensuring good performance and durability.

The flow of the air from the membranes is controlled by check valves to guarantee unidirectional flow. This improves the efficiency of the extraction, and the air is directly converted into electricity with the variable speed generator. The electricity is then transferred to the shore via a sub-sea cable. This electricity can then be treated as any other electricity and delivered into the power grid.

Technical Specification

- mWave single cell units shall be rated at 1.5MW (megawatts) (Bombora Wave Power, 2016).
- mWave single cell units shall supply sustainable electricity to 500 households (Bombora Wave Power, 2016).
- mWave cells shall require little maintenance (Bombora Wave Power Pty. Ltd, 2016).

- mWave wave farms should not interfere with the aquatic ecosystem.
- mWave wave farms should allow recreational vessels to freely travel over.

- mWave infrastructure should not create excessive noise.
- mWave wave farms should not require beachfront infrastructure.

- mWave single cells will produce 172.6 megawatts of electricity per month.
- mWave cells will be able to withstand wave forces (Bombora Wave Power, 2017).
- mWave cell will be able to operate under storms and shut down in very extreme conditions (Bombora Wave Power, 2017).

Comparison with alternative technological approaches

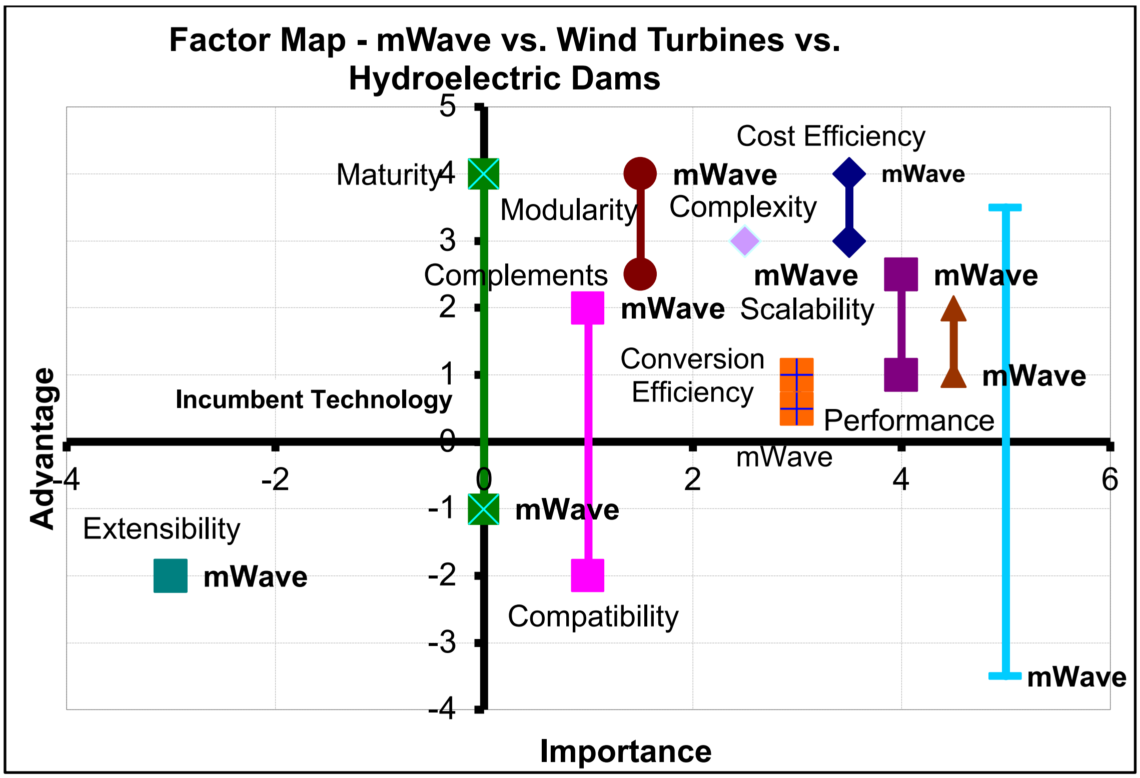


Figure 9. Factor map comparing qualities of mWave technology to wind turbines and hydroelectric dams

Bombora faces a few alternative technologies that are working towards the same goal in different, such as Dams and wind turbines. Dams are large man-made structures to generate hydroelectric power. With the use of turbines, the force of falling water pushing against its blades cause the turbine to spin, much like a windmill. The turbine is connected to a generator, which converts the mechanical energy into electric energy (Wisconsin Valley Improvement Company, 2017). Wind power operates in a similar manner, with the wind pushing propeller-like blades around a rotor, which is connected to the main shaft. The shaft spins a generator which creates the electricity.

Compared to these alternative technologies, there are certain success factors are deterministic in consideration. As for scalability, our mWave is extremely scalable, as it can be installed in essentially any body of water with waves. Dams are not scalable, as they require large scale infrastructure in reservoirs of water, which may require eviction for certain societies. Wind turbines are more scalable than most dams, but still have their limitations. They have no requirements on what land to be installed on, yet they usually do take up large fields. Further, wind turbines sometimes create "wind shadows" of slower air behind the blades, and larger scale wind farms may affect local and regional wind patterns (Science X, 2016).

Another key factor to examine is the maturity of the technology, which usually indicates stable and proven results. Our mWave technology and wave power in general is still fairly undiscovered with basic testing. It is still not well known the full capabilities of wave power and the most efficient and effective process of harnessing this energy, which creates difficulties in implementation. While the mWave has shown to capture the wave power in an efficient matter, it has not been deployed in a large scale commercial setting. Costs are still higher than market rates for electricity, mainly due to the "learning curve" as we reach a higher deployment capacity across the industry. Wind power and Dams both are more mature technologies, which has allowed us to discover the benefits and drawbacks of the respective technologies. Wind power has been used for over 50 years, and has proven to be a stable source of energy consumption. Like wave power, it is reliant on wind, which creates some fluctuations in energy generation. Dams have been around since ancient times, and have many useful functions. In addition to hydropower, dams also provide flood control, drinking water, and agricultural irrigation. Yet, dams have also shown to be extremely expensive and damaging to economies and certain marine life.

A third key factor that is critical to energy generation is harnessing efficiency. The mWave is capable of converting around 28% of waves to electrical energy, yet the technology itself is very efficient in converting the waves it does capture into energy. As shown in figure 10 below, most of the power that is missed is simply not collected. While a larger infrastructure could possibly collect more waves, this mWave is meant to be small enough for vessels to freely travel over. Only around 12% of the waves that are collected are lost within the technology itself, which is promising. Wind turbines convert around 45% of the wind passing through the blades into electricity, which seems to be more efficient than the wave power (NSW Government, 2010). Yet the power in wind and wave is very different, and the conversion rate may not accurately depict the true efficiency of the technology. Dams are very efficient and reliable for their specific functions of irrigation and domestic agricultural use. Dams are capable of storing around 60-90% of the water, which is very efficient comparatively (Wisconsin Valley Improvement Company, 2017).

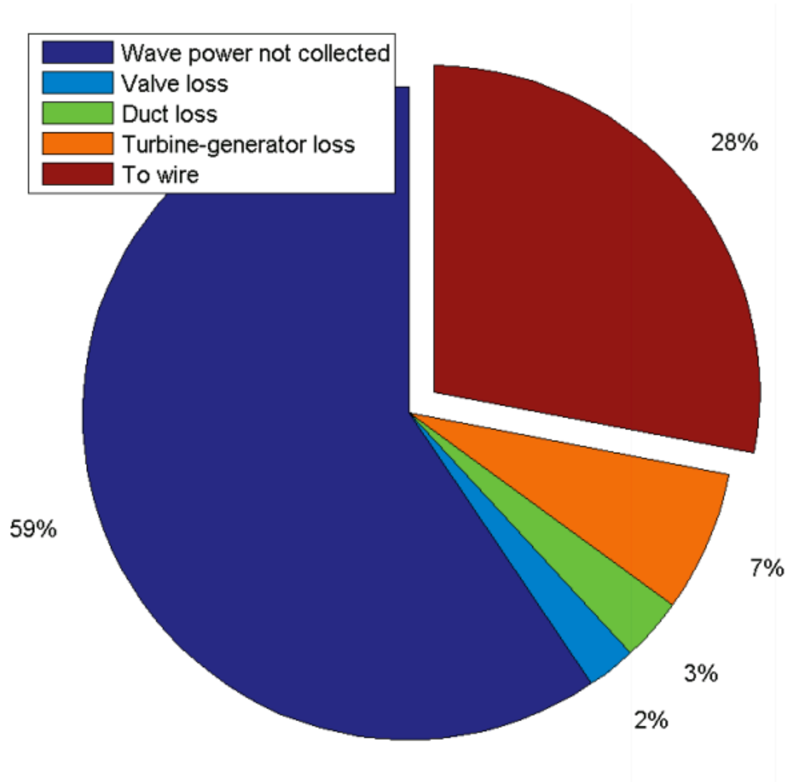


Figure 10. Proportion of Total Incident Wave Energy Conversion

Implications for your technology strategy

One key development challenge for wave power and the mWave particularly is the conversion efficiency. As shown in the above graphic, there is a huge percent of waves that are not captured or collected by the mWave, eliminating any potential for conversion. Bombora is still in the process of testing a number of different mWave prototypes, each made from different materials. The key structures they are working on are the primary structure type (Concrete or steel lattice), the foundation type (ballast or piles), and the installation technique (wet tow or Bombora barge). These small changes to the design are likely to have huge implications on the energy conversion, and it may be the case that certain designs are optimized for specific geographic locations. This requires extensive research and testing, and must be properly analyzed.

Competitive Environment

Top competitors and basis of competition

Bombora's direct competitor is Eco Wave Power, an Israeli based wave power company that generates power through hydraulic pumping and oscillating wave motion. As shown figure 11 below, Eco Wave Power utilizes floats that are attached to hydraulic cylinders, which harness the pressure from the rising and sinking motion of the floats on the waves ***(Bryce, 2016)***. This pressure is transmitted from the quay or jetty to a shore-located power station to spin a generator and produce electricity. Eco Wave Power is considered a threat because of the similar dependence on waves for energy, yet there are many factors that differentiate our technologies. Scalability is one critical issue for Eco Wave Power, as the technology must attach onto a man-made structure as a foundation. With many private land restrictions and unfavorable coastal conditions for installation, this model is limited in scope. Bombora is not confined by these requirements. Another defining factor is the process of generating electricity. The pressure captured by the machinery must be conveyed to an on-shore facility where this force is converted into electricity. Bombora's compact technology keeps the turbine within the mWave structure to harness air pressure and immediately generate electricity. One key success factor of Eco Wave is locating all technical equipment on land, improving the reliability and providing easy access for repair. The power stations are also centralized and located on-shore, so repairs would not have to be made underwater.

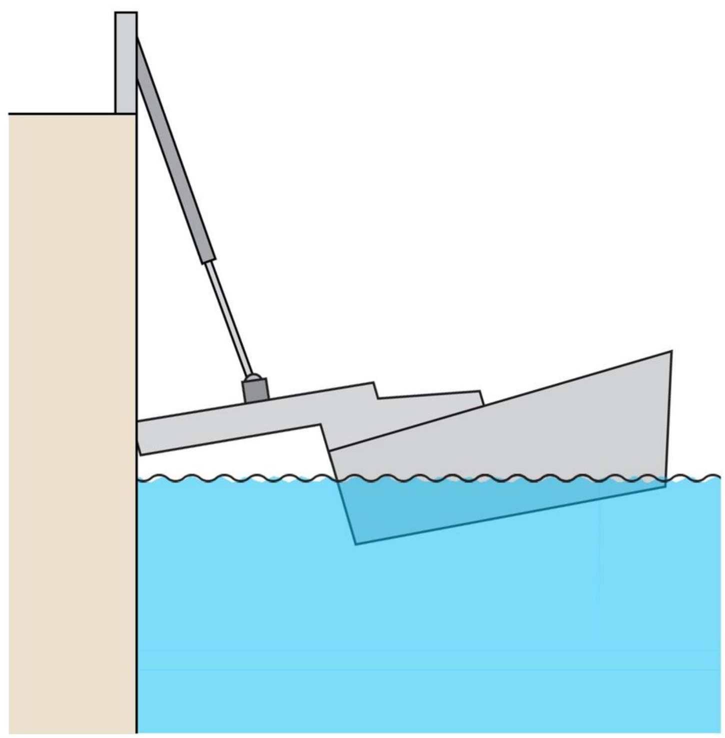


Figure 11. Simple illustration of Eco Wave Power Technology

Another primary competitor of Bombora is the wind turbine industry. One of the leading market-share companies in this industry is General Electric, a large-scale conglomerate that also focuses on power generation. GE has installed a number of renewable sources, including wind turbines, as shown in the figure 12 below.

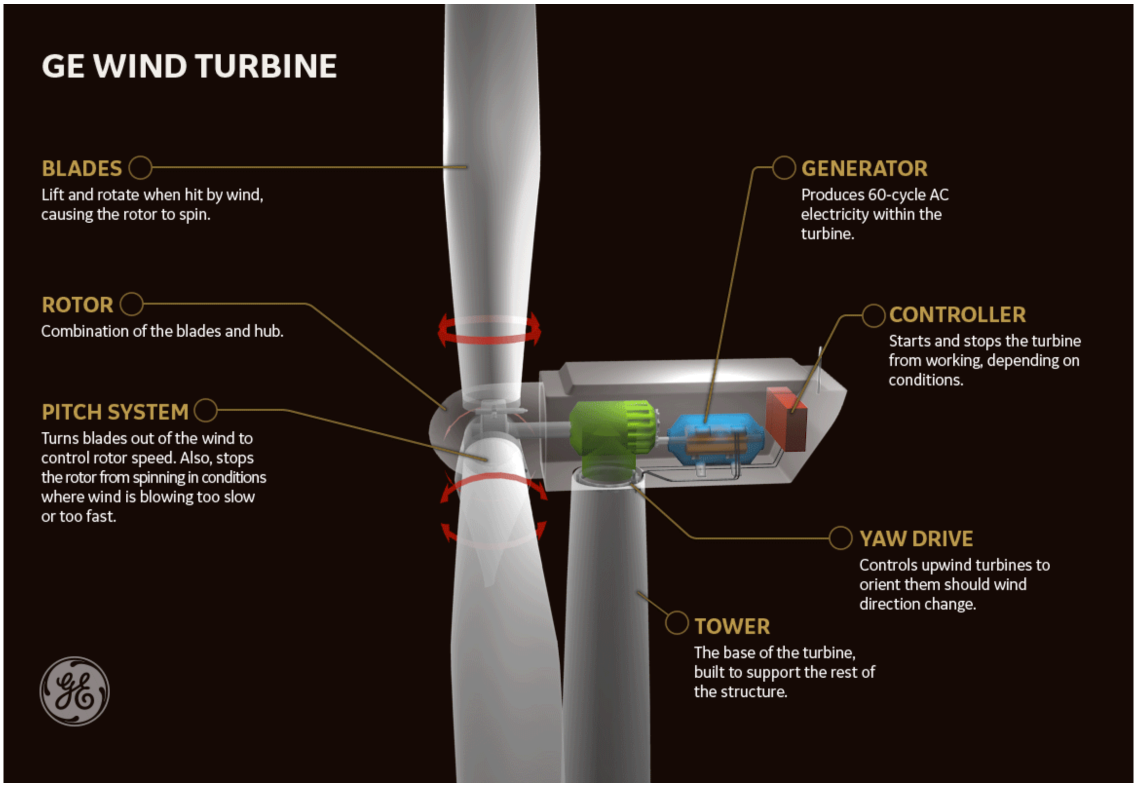


Figure 12. Basic Construction of GE Wind Turbine

GE's turbine operates under a simple principle in which propeller-like blades are rotated by wind energy, which cause the rotor to spin. This movement causes the internally spinning in the generator which produces electricity. The biggest differentiating factor between Bombora's mWave and GE's turbine is the reliance on wind rather than waves for the generation of electricity. While they are both renewable sources, wind turbines cannot harness the full potential of wind and has limited scalability. As shown in figure 13 and 14 below, there exists a much higher concentration of wind farms in the Midwestern land locked states, due to the vast lands and sparsely populated cities. On the other hand, many coastal cities are densely populated and often do not have capabilities to support such cumbersome infrastructure. Wind farms therefore cannot exploit the potential of wind on the coasts, reducing its potential power generation. One factor that separates Bombora from wind power is the limited scope that wind farms must operate under. Because wind turbines must be placed in more sparsely populated areas, this eliminates the prospect of many coastal regions. This restricts the potential of harnessing all of the energy that is naturally available. On the other hand, the mWave can be installed virtually anywhere in the ocean, and does not disturb sea travel or visual appearance of the ocean. Wind power does have an advantage in cost efficiency, as it operates under a large economy of scale, which has greatly reduced costs. In general, land-based utility-scale wind power only costs between 2-6 cents per kilowatt-hour, depending on the wind resource, compared to wave power's 26 cents per kilowatt-hour (Office of Energy Efficiency & Renewable Energy, 2017).

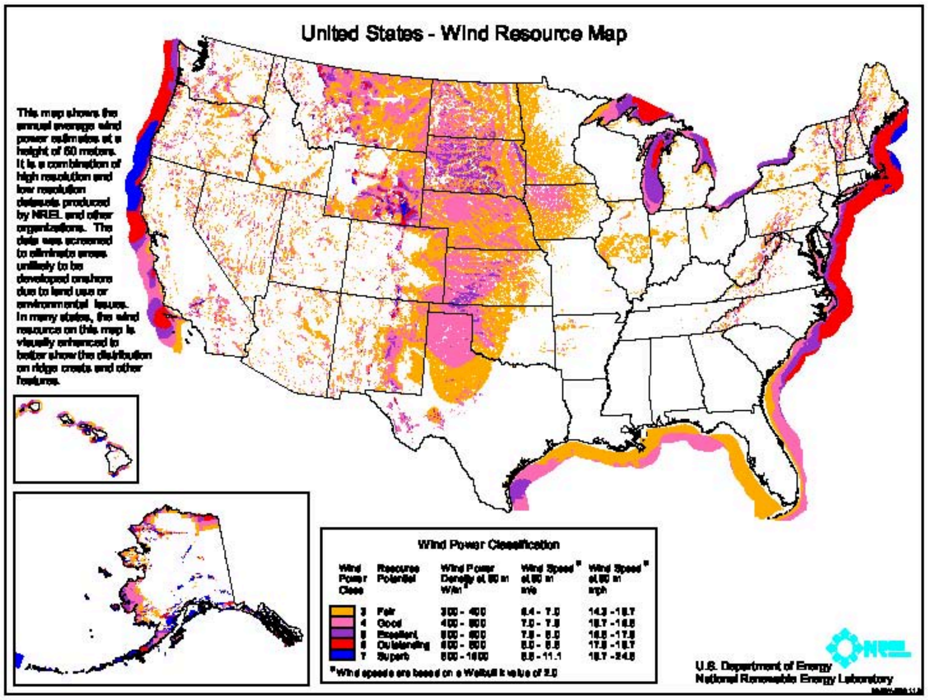


Figure 13. Wind Resource Map

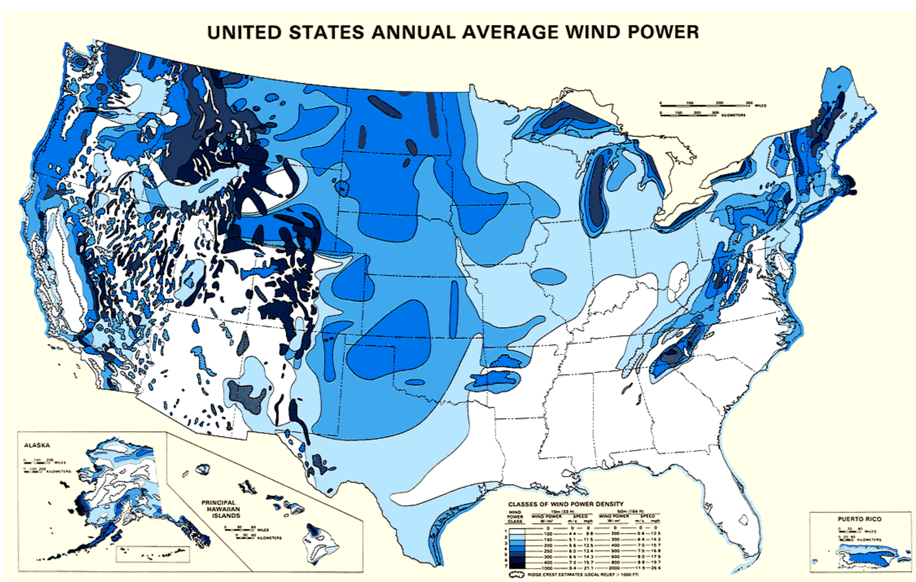


Figure 14. Wind Turbine Power Density

Competitive Landscape

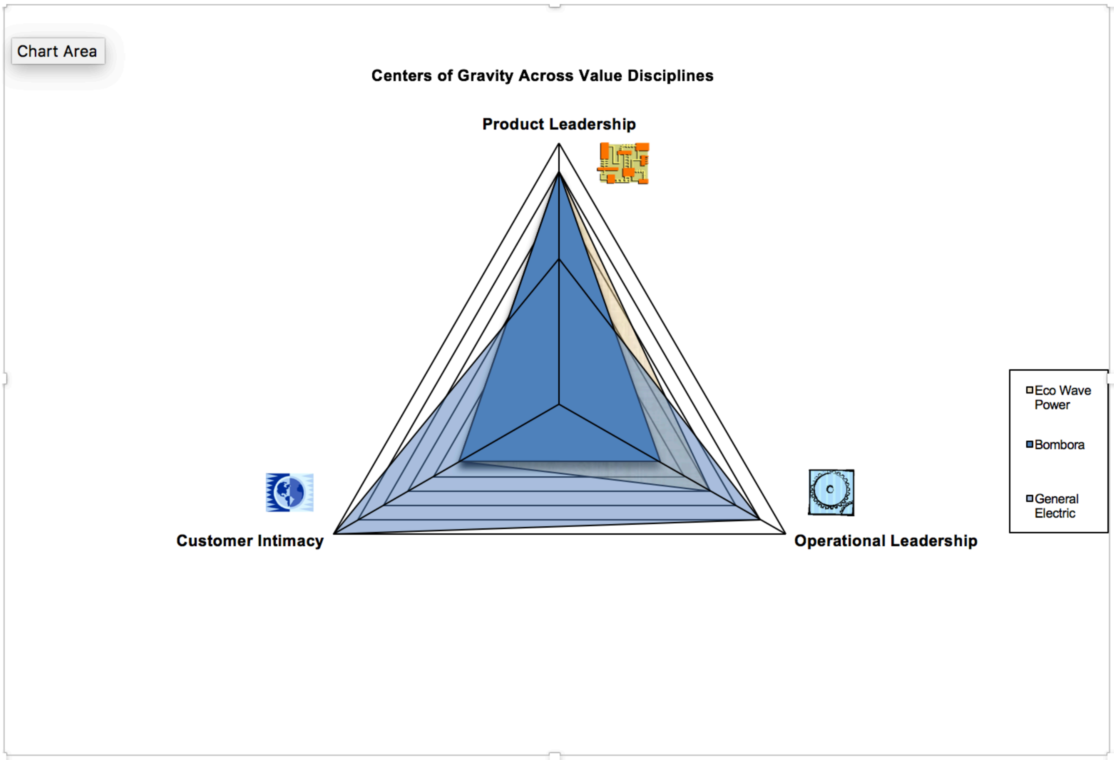


Figure 15. Value Discipline Overview

To succeed in the marketplace, it is critical that Bombora evaluate the drivers of the competitive landscape to better understand and analyze a particular product line. One key factor in this landscape is product leadership, or the ability to bring a greater knowledge and superior product to the customer base. On this front, Bombora and Eco Wave Power seem to have the competitive advantage, with an exclusive focus on wave powered energy and generation. By targeting such a niche market, all energy is spent on domain specific innovation, which creates efficiency and effectiveness. On the other hand, GE operates under a large-scale conglomerate, which can create some inefficiencies in certain sectors. GE has branches within many segments, including transportation, aviation, energy generation healthcare, and lighting, which can easily create asymmetry in resource allocation and focus. Focus may drift away from specific domains including the renewable energy domain, which does not guarantee a consistent model of superiority. Of course, GE does have more experience with their product line and can evaluate the success of their past products, yet by operating through so many industries it is difficult for them to be superior within each industry.

Another critical component of this competitive strategy is operational leadership, or the ability to harness a technology's core components that can meet the needs of the global market. On this front, Bombora and Eco struggle more than GE, primarily due to their inexperience within the industry. Cost leadership and strong leadership often lead to operational excellence, and GE's ability to operate under such an economy of scale allows their costs to be reduce and provide services at a lower cost. GE is at a stage where they can streamline their processes and eliminate inefficiencies, which does require time and experience experimenting within a domain. Bombora is still very new to the market, and has relatively high operational costs and new leadership. While Bombora has a clear plan as to how to harness and generate power through wave farms, it has not been tested within the established market and does not have the same base that GE has created for itself. It will take time for Bombora to integrate into the market and efficiently harness the energy from the mWave, and create a standardized procedure of implementation and distribution into the market.

The third key discipline that must be considered is customer intimacy, or the development of a personalized strategy to adhere to the needs and wants of different customer needs. Compared to the other competitive strategies, customer intimacy is less of a focus due to the industry that Bombora operates in. Currently, Bombora does not have extensive customer relations with any power or utility company, as they have not deployed their product in the commercial market. Thus, they have not established a connection with any customers or companies that they will work with. As Bombora proves establishes itself as an efficient source of energy, they will likely gain consumer confidence and a greater customer intimacy. Eco Wave Power likely operates under the same intimacy with customers, as they have not yet been fully deployed into the commercial market and will need time to establish a base for their energy generation. On the other hand, GE has a much higher customer intimacy, with a wide range of products and services meeting the many varying needs of their customer base. By achieving operational excellence in processes that support the customer, they are able to maintain a strong customer intimacy. As long as GE can continue proving and operating its services at a low cost and maintain the same quality, customers will expect and receive the same quality of products. GE has been operating since the late 1800's, and has effectively refined its processes to adapt to the changing tastes of the market. Once Bombora and Eco Wave Power establish a base in the market and create efficient maintenance protocols, they will be able to better operate within the needs of the energy sector.

Customer Value Proposition

For energy suppliers who want to supply renewable energy, the Bombora mWave is a wave energy converter that provides a consistent, scalable source of energy. Unlike current renewable energy technologies, the mWave is located on the ocean floor, keeping it out of sight, and connects directly to the pre-existing energy grid.

Projected market share

As seen in figure 16 below, there does seem to be projected growth in the renewable energy sector, yet the hydroelectric industry is projected to level off around 2020 (Energy Information Administration, 2017). This creates some difficulty for Bombora's mWave, as it is a hydroelectric source and depends on this market to succeed. While the hydroelectric sector does not indicate much growth, it is possible that the mWave technology does prove superior to other hydroelectric forms of energy and take a portion of this sector. This growth and potential market share relies on efficiency in harnessing such power and operating within an economy of scale.

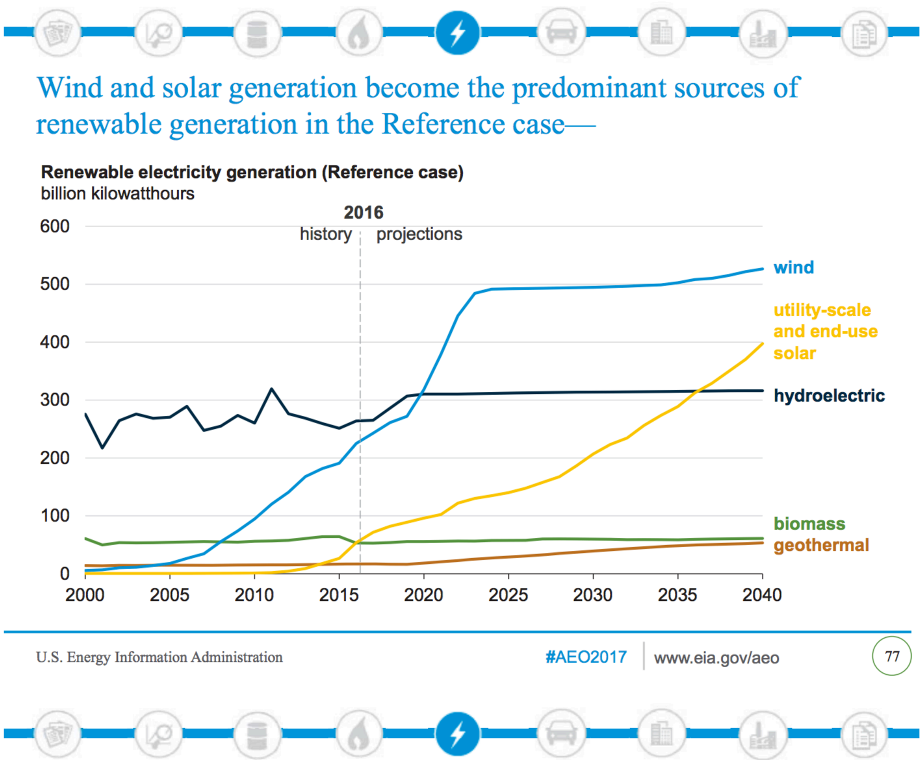


Figure 16. Projected Renewable Energy Growth

Host Company Identification and Assessment

Capabilities required

Companies capable of hosting mWave technology must have stable operations within the renewable energy market to accommodate the specific requirements set by the innovation. Further development is required in order to lower the levelized cost of electricity (LCOE) to competitive levels. Companies that practice heavier investments into research and development are preferable in order to accelerate the technology's cost viability in the market. Financial stability allows the company to take risks towards improving the technical specification of mWave over a long-term timeline. The $135 million cost evaluation for the 60MW wave farm further necessitates high financial resource availability. Once the technology becomes more viable, the company must be able to provide resources to drive scalability. The company's current involvements in renewable energy, particularly hydropower, allows maximum compatibility within the supply chain, mindset, and general operations. Established relations with hydropower supply industries (turbine, heavy infrastructure, and transmission line manufacturing) and demand industries (electric power transmission) minimizes the work required to construct an efficient pipeline. Other preferred capabilities include accessibility to coastal locations and significant operations in countries with policy-based incentives.

Candidate host companies

Capabilities	Importance (1-5)	Bombora Wave Power	General Electric	Innergex
Financial Stability	5	1	5	4
Market Understanding	4	2	3	4
Dedication to Renewable Energy (Hydropower)	4	5	3	5
Coastal Access	2	5	4	4
Scalability	4	1	3	3
Total Score		47	69	76

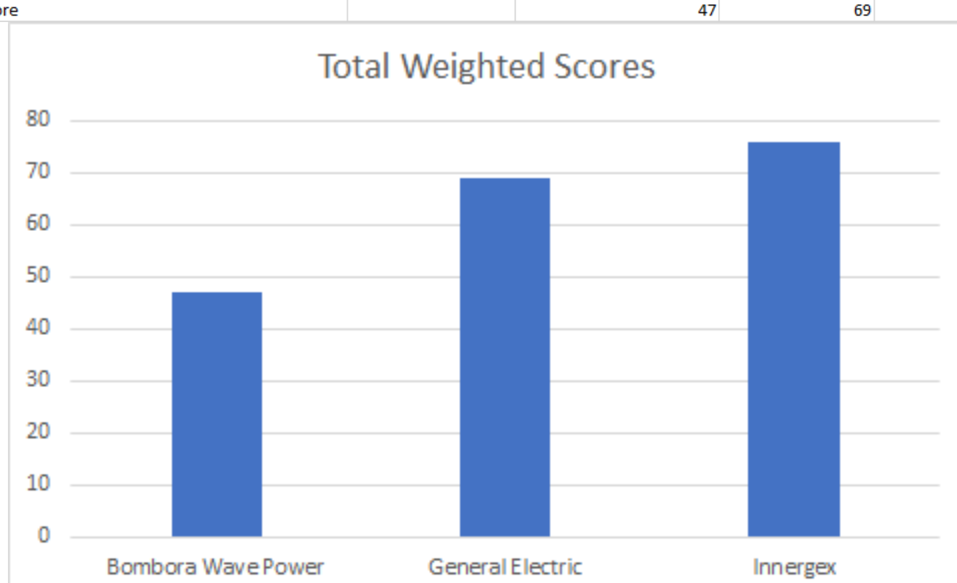


Figure 17. Results of Host Company Matrix

Bombora mWave

Sachit Bhat, Gabriel Hoppock, and William Ju

Three companies able to fulfill the criteria of financial stability, direction, and industry experience include General Electric Company, Innergex Renewable Energy Inc, and Bombora Wave Power Ltd. The primary company of choice is Innergex Renewable Energy. Innergex demonstrates solid assets and growth. Innergex had a year over year growth percentage of 2% in 2015, 19% in 2016, and as of September 11, 2017, an expected 41% growth for 2017 (Innergex, 2017). Innergex also holds 3.6 billion in total assets with annual sales of 292 million (Dun & Bradstreet, Inc., 2017). The financial stability should allow the company to invest into mWave to further develop and deploy the technology. Bombora's financial sales of 612 thousand and total reliance on partnering company resources to fund development suggests the company is too unstable to refine and deploy the mWave on a larger scale (Dun & Bradstreet, Inc., 2017). General Electric's Alstom Renewable subsidiary also produces a lower revenue to reinvest with sales reaching only 150 million (Dun & Bradstreet, Inc., 2017). Innergex and Bombora both share a heavy focus on renewable energy as both companies' products utilize renewable energy infrastructure as the primary source of revenue. The size of General Electric causes the company to act as a conglomerate with a wide range of diverse interests outside the energy industry. General Electric Oil & Gas also introduces conflicting concentrations in non-renewable resources and suggests less commitment will be received by the company. Innergex has deployed 31 hydropower sites out of 51 sites in operation (Innergex, 2017). While Innergex sites operate with reservoir and run-of-river models, similar technologies such as turbine engines, electric transmission lines, and heavy infrastructure are used by the mWave to convert the kinetic energy into electricity for transmission (Innergex, 2017). By building relations with hydropower suppliers and demand industries, Innergex can efficiently integrate mWave wave farms into its energy pipeline and further refine its deployment. Installations of this many hydropower plants also suggests that Innergex is experienced with infrastructure scalability. Innergex is also expanding its offices into San Diego, providing coastal access in the United States.

Company's business, key customers or markets.

Innergex's mission is to increase production of renewable energy by developing and operating high quality facilities while respecting the environment and balancing the best interests of host communities, partners, and investors. The company has a pure-play focus on renewable power with a clear focus on infrastructure for renewable technologies. The company's primary source of revenue is generated from electricity and therefore has a focused market towards energy distributers and direct household consumers. They showed an 18.6% revenue increase and an operating profitability improvement of 108.9% in 2016 compared to the previous year, proving that the company is currently successful and growing. Of the 51 sites that Innergex currently holds, 31 are hydropower based, proving there to be opportunity and space for Bombora's mWave (Merer, 2017). In terms of revenue, hydroelectric generation has consistently accounted for over 65% of the total segment (wind, solar, and solar), with production equaling 72.4% in 2016 (Dun & Bradstreet, Inc, 2017). According to in-house research, global cumulative hydro installed capacity is estimated to grow at a rate of 2.8% from 1.21 million MW in 2016 to 1.76 million MW by 2030, indicating a positive outlook for Bombora's wave power core. Innergex's Hydro power division currently works through a generating station that uses a dam to create an artificial lake, in which water would be collected seasonally. Water is constantly flowing, and Innergex works to convert this mechanical energy into clean electricity.

Analysts' views of company's strengths, weaknesses, and future prospects.

The Innergex's strengths are in growth revenue, potential, and yield. The company holds a large project portfolio. They currently have 51 renewable energy generation sites with a net operating capacity of 1,063 MW and have 3 sites under construction (Merer, 2017). This diversification of resources and extensive portfolio enable it to meet the future needs for electricity. However, due to high expectations of the company's potential the price to earnings ratio and earnings per share revisions are low. In addition, the company's debt is a looming concern over the next few years (4-traders, 2017). As shown in Figure 18, debt has been growing with the expansion of sites, which could negatively impact the operational performance and efficiency of the company. This debt could impact other strategic opportunities that could be profitable in the long run and prevent Innergex from pursuing other strategic opportunities that could be profitable. Earnings per share is expected to decrease as current investments improve the company's sustainability and execute its potential. Innergex has continued to make larger acquisitions of power projects, notably in wind power, as it acquired 69.55% interest in Yonne Wind Farm in Northern France in addition to a 69.55% interest in two wind power projects in Nouvelle-Aquitaine, Paris, France (GlobalData Ltd., 2017). Recent investments suggest the company is looking to expand and invest into other renewable energy technologies, with hopes to become a major player in the renewable energy industry. Innergex has steadily been increasing in revenue and holds an expansive portfolio of development sites, creating a stable base and positive outlook for the future

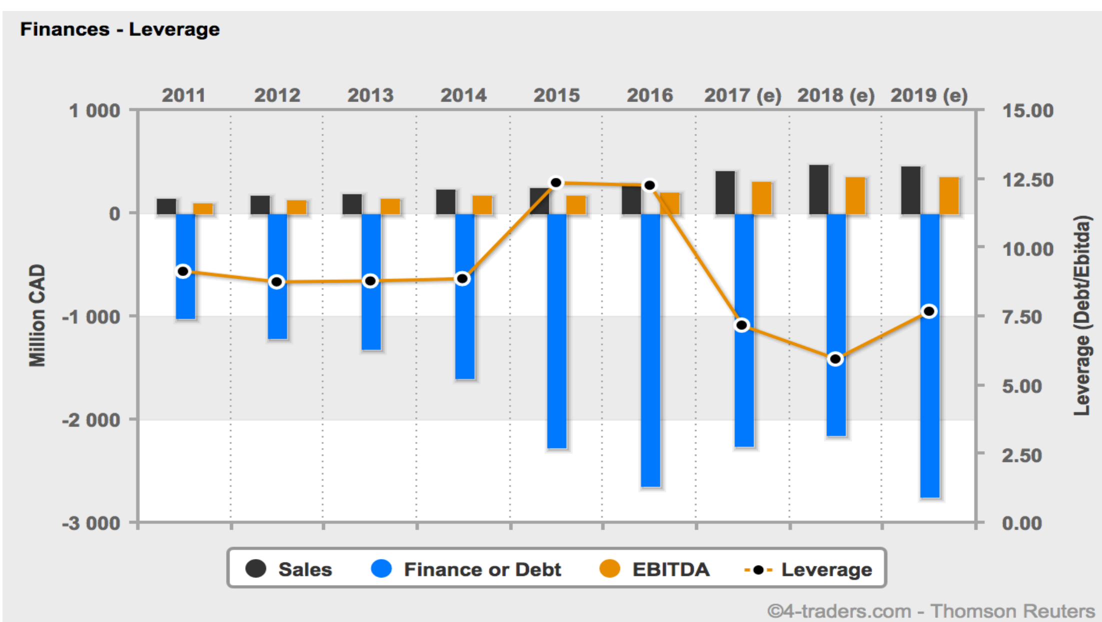
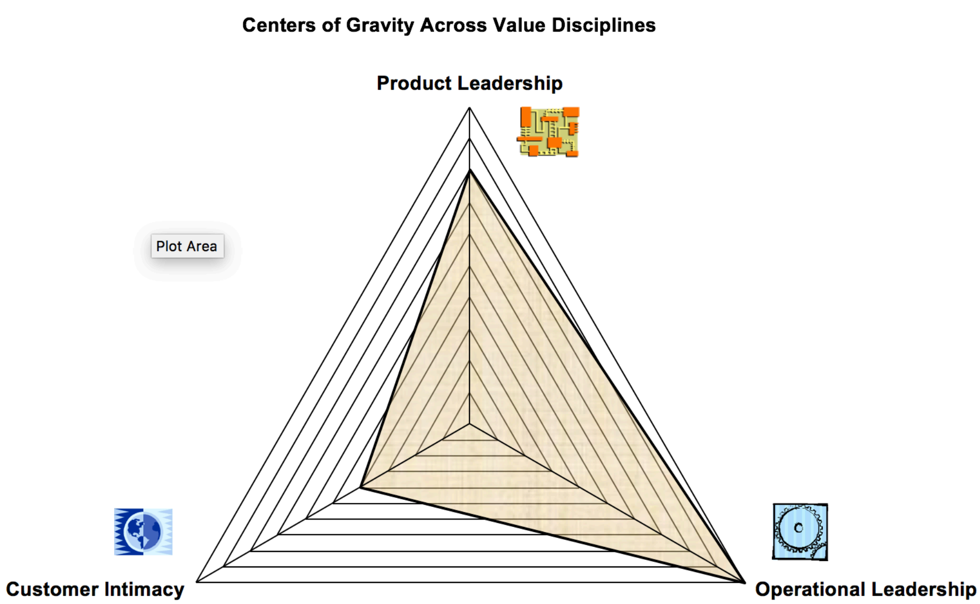


Figure 18. Finances and Debt of Innergex

Company's technical strengths

The company's key technical strengths are in their operations and infrastructure, as well as resource management. Innergex operates at 51 different sites across the world which generate over 817 MW of electricity (Merer, 2017). The facilities are diversified across a number of different renewable sectors, which allows them to allocate resources as they see most fit and efficient. While the generation of electricity will eventually be used by millions of customers, there is little room for customer intimacy as they work through an electric provider middleman. Product leadership is quite stable for Innergex, as they have established a consistent product base capable of generating energy, as well as sustained management over a number of substantial run-of-river hydropower projects. The executive team is quite established and experienced, and led by a CEO who worked directly with the development and operation of several run-of-river hydroelectric projects prior to Innergex. The company seems to focus on a particular technology and utilize different assets to acquire interests to ultimately expand their operations. Innergex's mission statement is develop and operate high quality facilities that can propel growth and provide a consistent means of energy production, and their current sites have shown to effectively do so.



Value Discipline	**You**
Product Leadership	4
Operational Leadership	5
Customer Intimacy	2

Figure 19. Center of Gravity Across Value Disciplines

Bombora mWave

Sachit Bhat, Gabriel Hoppock, and William Ju

Strategic implications

Innergex has established itself as a stable electricity generator, with a diverse set of power plants across the world. There is great opportunity within the renewable energy industry, yet there are also many other competitors, working to achieve the same goal. Innergex sets itself apart through its vast diversity of projects and commitment to providing 100% energy through renewable sources. Hydroelectricity has shown to be the most promising source of energy, primarily due to the large number of Canadian lakes and rivers where the company is headquartered. One major challenge that Innergex could face with the mWave would be lack of understanding and operational strategy for the new technology. Innergex has mainly focused on run-of-river hydropower technology, which could create a difficult transition in managing and scaling the new membrane technology. Another potential weakness is the debt that Innergex is facing, which could impact their focus on future development of the mWave. Initial capital costs and maintenance of the new technology could prove to be expensive, and this debt could likely hinder expansion into new forms of hydropower. If Innergex is unable to cut their operational costs, customers will have to pay the higher energy bills, which already are higher than those from traditional, non-renewable forms of electricity. Further, mWave still does require development to optimize growth and efficiency, and Innergex would have to turn some efforts into building this relatively new form of energy generation. Innergex seems to work more with the deployment of facilities and energy sources rather than the initial developments, which could be challenging for the viability for such a new and relatively un-tested mWave technology.

Technology/Business Intelligence

Priority issues for intelligence collection

1) Success in long run: Predictions show that hydropower is expected to level out in next few years, must identify the key differentiating factors that will make technology succeed in long run. Does Bombora have the flexibility to adapt and make a viable product?
2) Strategy for growth: Understanding how Bombora is planning to continue developing such technology and product. Wind and solar power are more developed and have lower cost curve.
3) mWave harnessing capabilities. According to Figure 10, only 28% of the total wave power is transferred to the wire. This seems low for such an abundant resource.
4) Understanding wave power in terms of the efficiency of hydropower. Would like to learn more about the overall efficiency of hydropower and whether certain techniques can be translated into wave power – perhaps could lead to design improvements.
5) Viability for Power Supply companies: Many of the renewable sources, especially Bombora are relatively undiscovered and untested technologies. Are energy suppliers willing to invest in this technology and if so how they plan to incorporate it.

Interview questions

1) We've seen some graphs and market predictors showing that hydropower does not have substantial growth projections in the coming years. How do you see mWave being successful and sustainable in this non-moving market?
2) Research and development for such an integrated technology is likely costly and difficult to implement. What is the strategy for growing this technology and overcoming these initial costs? How do you compete with energies such as wind and solar energies with such low costs?
3) Our research has showed that only about 28% of the wave power is being sent to the wire, which does seem a bit low. Is there a goal that you and working towards, and what are the steps you are taking to get there?
4) How can improvements and efficiencies of hydropower be translated into specifics of wave power? Rather than focusing on such a niche field, is it possible to draw conclusions from the hydropower market and apply it to wave power in particular? What similarities do you see?
5) What are the greatest concerns in adopting such a new technology? How do you plan on incorporating the new source of energy into the grid and how might this impact future operations? How do you plan on making this transition and what could be the benefits of this adoption?

Potential interview sources

1) Dylan Heath (Project Engineer)

2) Shawn Ryan (Project and Exec Director)
3) Dylan Heath (Project Engineer)
4) Eugene LeBoeuf (Professor of Civil & Environmental Engineering, Vanderbilt), Malcolm Spaulding (Department of Ocean Engineering, Rhode Island)
5) PG&E energy company (Roy Kuga, Barry Anderson, Fong Wan), Covanta (Paul Stauder, Derek Wveenhof)

1.1 Summary of Strengths, Weaknesses Opportunities, and Threats

The strengths of the wave energy converter technology primarily lie within the scope of product development. Bombora is focused on research and development and is concerned with pioneering a novel effective design. This concentration would result in a scalable and modular design with high compatibility with the current electricity market. Issues arise in the execution of the technology and the current state of the renewable market. Bombora has little experience with customer relations or manufacturing and deployment operations. In addition, the cost to performance ratio is significantly higher than most technologies. Measuring by potential these deficits can be improved, however the maturing renewable market demands that cost effectiveness be compared with available solutions such as wind and solar. This severely limits the technology's successful trial entry into the market as investors continue to safely fund improvements in more mature and competitive designs. The accelerating adoption of renewables by major governments does suggest there is a possibility of gaining financial assistance to further develop and deploy the technology through subsidization.

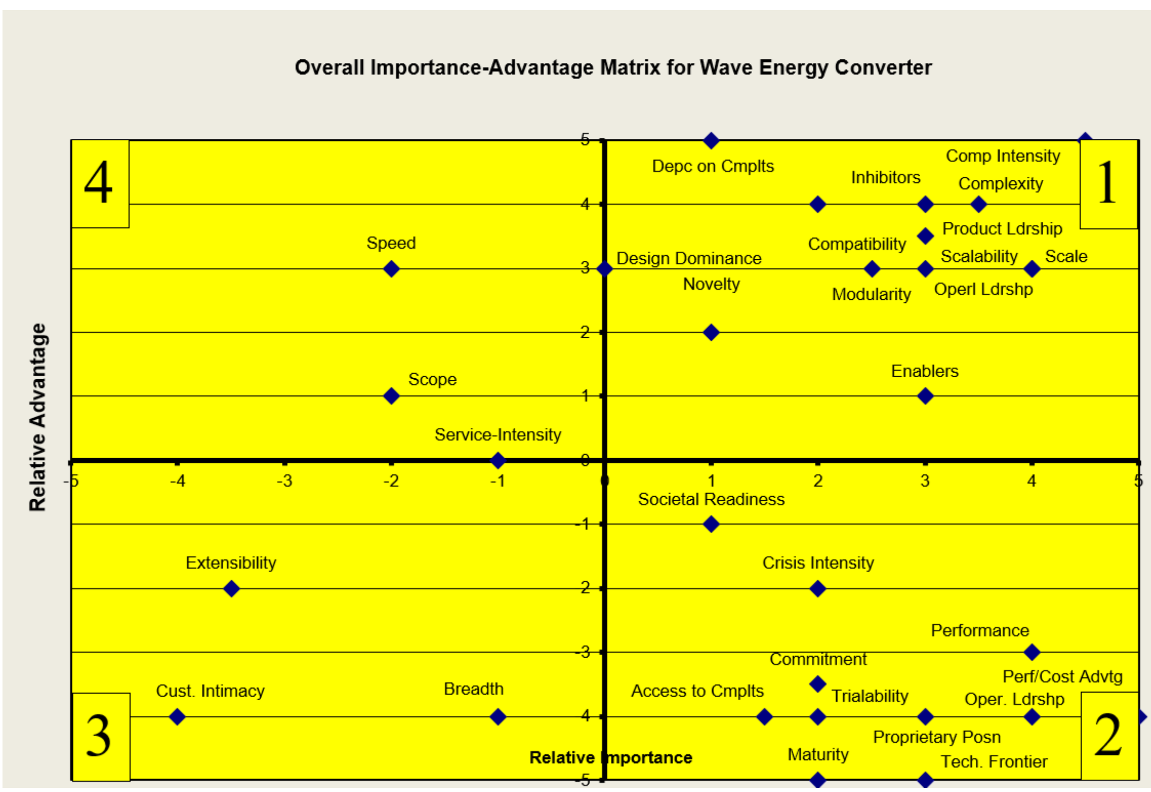


Figure 20. Summary of Importance-Advantage Factors of the mWave

Intellectual Property Strategy

Patent strategy

Bombora Wave Power Property Limited has applied a patent related to the wave energy converter, the mWave component composed of an inclined face structure that utilizes flexible membranes to convert the kinetic energy of the wave to fluid pressure within the wave energy converter cell (Australia Patent No. WO 2017143399 A1, 2017). Additional components involved with the operation of the mWave primarily deal with the conversion of fluid pressure into electrical energy via turbines. The primary differentiator of the design from those of conventional wave power converters is the use of a flexible membrane over common buoy systems. The primary patentable element of the system is the membrane construction which has been particularly designed to capture an optimal amount of energy from underwater wave movements. The design requires significant consideration to formulate due to the complexities involved with maximizing energy collection, an effort which is ongoing. Multiple prototypes of the device have been constructed and deployed by Bombora, and these prototypes have been the subject of independent studies to determine the financial viability. The design itself is relatively weak in marketability and profitability due to high cost of about 3.375 million USD per system deployed and levelized cost of electricity inefficiencies. In addition, the existence of the buoy dominant design will make entry with the new design difficult. However, there is also a potential to drive a new dominant design and lead the proprietary market through early control. A provisional patent would have been appropriate to allow additional time to develop the system while reducing costs and testing the market. Early control will also allow complete profitability from use royalties. As Bombora is acting as the primary developer for membrane-based wave energy converters, a patent is required to regulate implementations of this novel concept. However, the company’s minimal patent portfolio will make legal defense of the patent difficult as the company is not experienced with patent enforcement and retains a weak proprietary position in the market.

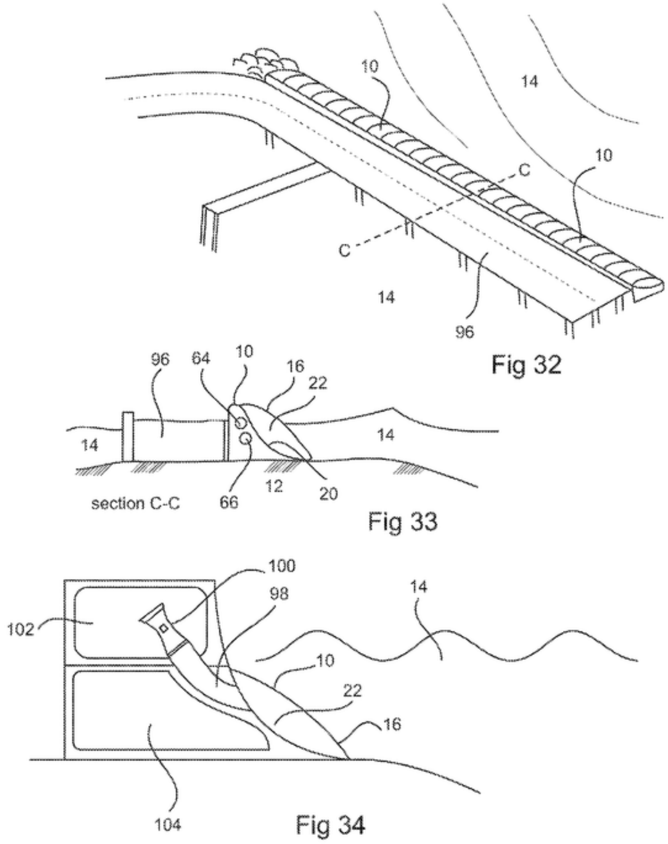


Figure 21. Wave Energy Converter Patent Membrane Cell Overview

Other strategies for building your proprietary position

The dominant design of the wave power market utilizes buoys to capture kinetic energy from wave surface movement. These designs are found from the products of other wave power competitors such as Eco Wave Power and Wave Hub Limited (BryceEmma, 2016). The primary challenge in building a position in the wave power market requires significant efforts to shift the dominant design over to similar membrane based constructions. Bombora's early developments and refinements in this technological space would allow it to capture a substantial portion of a shifted wave power market. In addition, royalties collected from the proliferation of the design further strengthens the product's financial viability while further solidifying the membrane device as a component of the dominant design. To maintain a foothold in the market and build on our proprietary position, Bombora's key defining separator is its utilization of the wave floor, allowing the product to be non-intrusive and to utilize the abundant underwater space. While the wave power and pressure differ greatly at different depths, temperatures, and locations, Bombora's membrane does not require a direct connection to land and runs through sea cables. In terms of the market, this is preferable to any energy harnesser that sits on the top layer of the ocean. This disrupts the natural beauty that should be inherent to oceans, and could be a great differentiator.

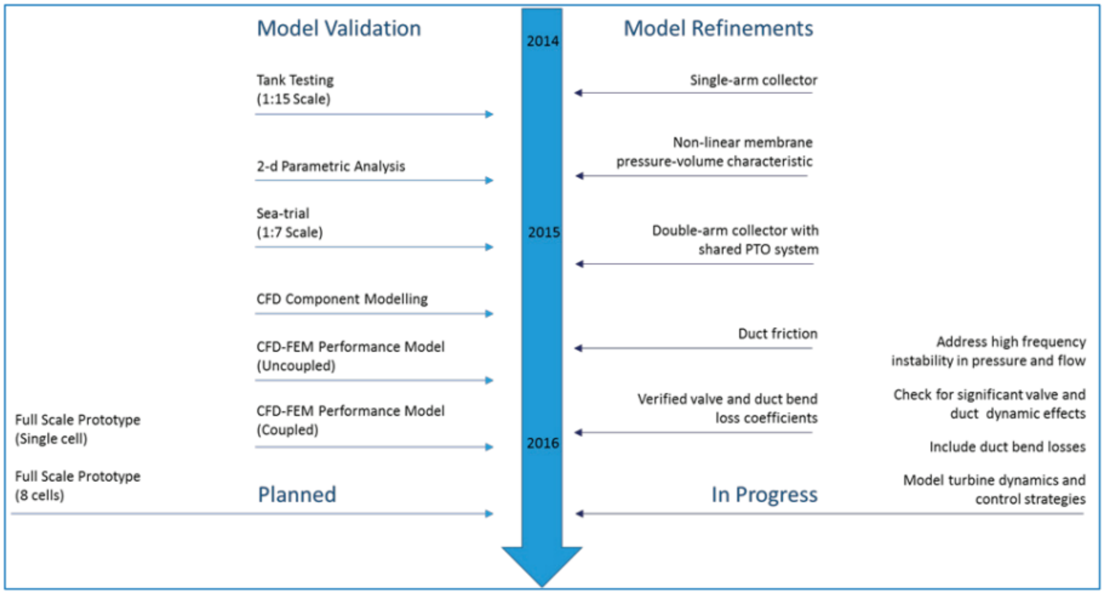


Figure 22. Design Refinements Timeline

The continuous building of our proprietary position will also be dependent on the improved efficiencies of the product. Research developments have been focused proposing multiple case designs to minimize manufacturing and deployment costs while also maximizing wave energy collection and translation into electrical energy. Figure 10 outlines the current weaknesses of the current iteration of the membrane cell system as over fifty percent of wave power is not collected. This value affects the levelized cost of electricity projections, causing it to be higher than mature renewable sources of energy (Bombora Wave Power Pty. Ltd, 2016). Model adjustments have lowered calculated LCOE values to meet minimum targets but retain significant room for improvement. As Bombora is the sole facilitator of membrane-based wave energy converters, accumulated research into these improvements will make it difficult for competitors to match the performance of the company's case designs without an expensive investment towards product imitation. Increased efficiency will also make the product more competitive to overtake current buoy implementations as the dominant design, capturing a chunk of the wave power market in the process.

Product Strategy

Product-market scope

Bombora's mWave technology is likely still in the product development stage of commercialization, with a novel technology that is being integrated into a fairly saturated market. While there exists a number of hydropower and wave power converters, most work with and utilize water in very different ways. Bombora is unique in that it lies on the ocean floor, and captures the energy of the water near the bottom. Many other companies have technologies that work on the surface, either through buoys, water columns, and other floating designs. While the wave power market is a relatively undiscovered field of clean energy generation, it still must compete with the larger renewable market that includes wind energy, solar power, and biomass. Bombora has a hold within the more niche wave power market specifically, but it must compete with and integrate into the larger and more established field of renewable energy. Because most utility companies have not explored the full capabilities of wave power, there does exist potential for Bombora to fill this gap and steal a considerable share of this open market. While the energy grid is already quite established, Bombora is a complement to this grid by allowing diversification of the energy core.

Product family

Currently, Bombora operates primarily in coastal markets near oceans and large bodies of water with their patent pending membrane technology, limiting the scope of the product. The membrane technology is quite unique from some of the incumbent technologies, and there is potential for the membrane design to be applied in many different cases that might not be ocean based. One application that has not been fully explored is the use of the membrane in rivers and smaller bodies of water. While the mWave has been tested along the coast, rivers run through many cities in most countries and there could be an optimized product to capture the energy of water in these smaller streams. This would require slight modifications to the original mWave, which is optimized for the ocean, such as reduction of the size of the membrane and turbine. There are also possibilities for Bombora to create a membrane that can capture wind energy. Currently, most wind converters are large and obstruct natural views, and require a vast and open area. Because the membranes are relatively flat, there is an opportunity to attach them to the top of buildings and other elevated infrastructure. This would greatly increase the scalability potential for the product, with the only limitation being certain regulations and agreements with targeted companies and buildings. Bombora's host company, Innergex, primarily works on the application of the specific technologies within the renewable sector, and seem to have experience with optimizing potential of different technologies. If Bombora was able to make modifications to their original design and create a product family with alternate capabilities and features, Innergex would be used in finding the right space for application and installation. Even if Bombora does not have the full capabilities to create a membrane that could capture wind energy, it could be mutually beneficial to collaborate with a company with more expertise in the wind energy field. It is necessary to learn the specificities of the wind market, and would require some external resources to figure out ways that the membrane could be modified to capture such energy.

Product specifications

- mWave single cell units shall supply sustainable electricity to 500 households (Bombora Wave Power, 2016).
- mWave's technology shall properly integrate into the existing grid without modifications or external maintenance.
- mWave should not significantly alter the current cost of provided electricity.
- mWave single cells will produce 172.6 megawatts of electricity per month.
- mWave cells will be able to withstand wave forces (Bombora Wave Power, 2017).

Potential lead users and minimum viable product

Bombora's lead users have been established as coastal energy suppliers who are either looking to diversify or expand on their current portfolio of energy supply. Because the mWave currently operates on coastal waters and oceans, these would be nearby suppliers and would be easiest to integrate and connect with. There are certain key pieces of information that would be necessary in identifying the minimum viable product in the market, the first being the performance of the technology in different environments. The mWave will be operating in many different bodies of water and must adapt to the pressure and depth changes that come with this. To capture this performance, it would be necessary to save and maintain state within each of the membranes, and accurately assess which wave farms generate the most energy per unit. Another key requirement would be assessing the durability of the membranes, and how they withstand the changing conditions of the ocean. To assess this, it would require Bombora to understand which wave farms require the most maintenance and how that relates to the environmental conditions affecting them. Bombora also must be able identify the effects of the technology on the surrounding environment, both within the water and for the larger community. That is, they would need to identify whether the wave farm is causing any disturbances that could be impactful. To do this, it would require responses from the public community, both suppliers Bombora connects to as well as those who interact directly with the waters we operate within, such as fishermen and beachgoers. To gauge this, we would likely need to understand the density of fish in a certain area within the ocean, and compare the previous density with that after the wave farms have been installed and running. Lastly, Bombora would need to realize how the adoption of the new technology impacts the energy suppliers. Because they are the direct customer that we are selling to, it is necessary that we adapt to their needs and wants. If the energy generation does not meet the standards that the company sets out, it is clear that Bombora would need to modify its design or find a more cost-efficient implementation. Bombora would need to adhere to their specifications because they supply the broader customer base, so we would build our core product around their requirements.

Product-market penetration path

Logical application extensions would include using the technology to monitor natural force magnitudes. This information would primarily be used by researchers to detect changes in the environment as measured by wind or water movement. The membrane technology can also be extended to act as a filtering component by utilizing the natural permeability of the material. Logical market extensions would include river-based power generation and then to wind-based power generation, both of whom convert natural force into electric outputs. These possibilities are shown below in figure 22.

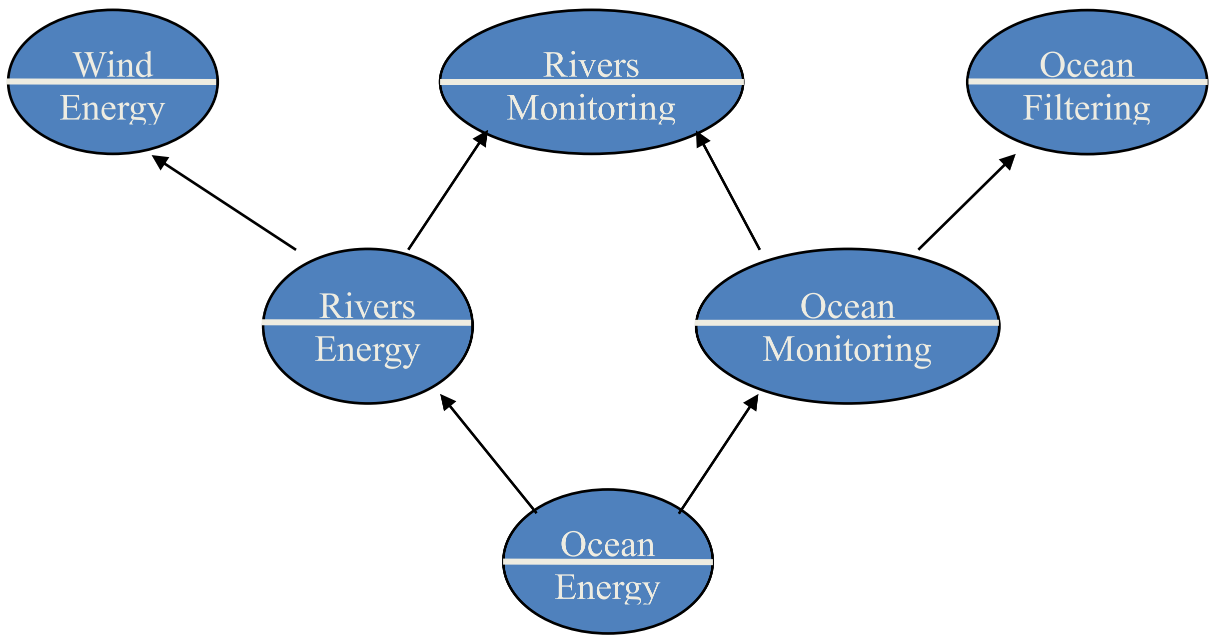


Figure 23. Bowling Pin Model for Membrane Technology

Operational Strategy

Operational Architecture of the Business

0. Research and Development within Bombora
1. Working with Partner Companies for Product Manufacturing
2. Deployment and Installation
3. Marketing and Distribution
4. Maintenance

Key Processes

Working with Partner Companies for Product Manufacturing

Suppliers	***Input***	***Processes***	***Output***	***Customers***	***Requirements***
Raw material suppliers	Raw materials	Manufacturing	mWave farms	Bombora	95% functioning units
Manufacturing company (location + labor pool)	Manufacturing plants				6 units per week
	Labor				
	Blueprints, designs				
	Necessary machines				
	Holding facility				

1. Transportation of materials to manufacturing plant	2. Processing of materials	3. Construction of mWave	4. Quality/function testing	5. Transfer functional units to holding facility

Figure 24. SIPOC diagram outlines the manufacturing process of mWave cells

The two main suppliers for manufacturing are the raw material suppliers and the manufacturing company. The manufacturing company will provide a location, machines necessary to the manufacturing process, and labor, which are all necessary inputs. The first step of the process would be the transportation of the raw materials from the suppliers to the manufacturing plant, where they would then be processed for quality. After the materials have been processed, the construction of the mWave could begin. The manufactured mWaves would then be tested for quality and proper function before the functional units are then shipped to a holding facility. Requirements of 6 mWave units per week and a 95% functioning ratio help keep production steady and prevent prices from rising because of money wasted the production on non-functioning units.

Deployment and Installation

Suppliers	***Input***	***Processes***	***Output***	***Customers***	***Requirements***
Energy suppliers	Access to energy grid	**Deployment and installation**	Installed mWave	Energy Supplier	Proper functionality: supply 172.6 MW of electricity per cell
Manufacturer	Viable ocean space		Energy supplied by mWave		Cooperation with zoning regulations
Land supplier	Manufactured mWave				
	Deployment laborers				
	Sea cable connection to grid				

1. Transportation of materials	2. Preparation of target location	3. Installation of device at location on ocean floor	4. Connection to power grid	5. Verify functionality & make adjustments

Figure 25. SIPOC diagram outlines the deployment and installation process of mWave cells

Deployment and installation of the mWave is a critical part of its commercialization, and must go through certain steps to achieve functionality. For Bombora to operate in an ocean, it must first have some contact with the local energy supplier, as well as the land supplier that may have property rights to the ocean. Bombora must establish a secure connection to the energy grid through its proprietary sea cables, and enough ocean space to deploy its full wave farm. This does require adequate planning, for they must clear the targeted land of boats, and other environmental issues that may hinder a safe installation onto the ocean floor. If the installation and deployment of the mWave is not done properly and safely, it could harm the environment and cause for costly maintenance issues in the future.

Market and Distribution

Suppliers	***Input***	***Processes***	***Output***	***Customers***	***Requirements***
Marketing consultants	Performance research information	**Marketing and Distribution**	Greater understanding of technology from market base	Energy suppliers	Accurate data collection
Marketing promotional designers	Cost information		Increase in customer base	Local households	Viable cost to energy efficiency from technology
	Optimal market location data		Expanded entry into wave power market		Understanding of local market needs and wants
	Testing data and analysis				
	Environmental agenda				

1. Contact with marketing company	2. Understanding of local market choice, analysis of market data	3. Determine optimal target markets for deployment and profitability	4. Strategic advertising trials	5. Full advertising process and optimization

Figure 26. SIPOC diagram outlines the marketing and distribution process of membrane-based wave power collection systems (mWave)

The first step in figuring out our marketing plan and distribution is connecting with marketing consultants that might have interest or understanding of the renewable sector. Bombora would use this resource to collect valuable data on the structure and size of the local market, and understand their choice in products and electricity suppliers. This could potentially give key insights into the viability of the technology in a certain market and how it could adapt to the incumbent. From the customer perspective, Bombora would use its advertising capabilities to expand to a greater number of utility companies and customers, and present the many benefits of switching to a sustainable and relatively hidden source of energy. This marketing plan would hopefully increase the number of customers aware of and interested in our services, which would likely drive up demand and eventual profits. In order for this marketing plan to be successful, it requires that Bombora can find a price point that is affordable, viable, and profitable. In addition, Bombora must be able to analyze the market data to make informed decisions on optimal markets to target.

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Sourcing

Bombora's primary strengths lie in research and development along with system design. The company can therefore source out wave force and related geographic data collected for mWave designs to other research facilities. Bombora is one of the only wave power companies that operate on the ocean floor, and could work with other marine researchers to monitor force magnitude, pressure, or other deep-water conditions. Additional services beyond energy generation, such as ocean life surveillance and water filtering, may be added to the mWave to be sourced out. Bombora is still a small and relatively new company, so the large-scale manufacturing will likely need to be outsourced to experienced players like Innergex, who have experience in large project deployments in the hydropower market. Installation and maintenance could also be outsourced to manufacturers who can provide workers to be trained by Bombora to specialize in mWave repairs and upgrades. The marketing and distribution will be primarily handled by a marketing agency or consultant, with Bombora providing relevant information about the mWave technology and making high level decisions for marketing strategies.

Technology Commercialization/Collaboration Strategy

Capabilities sought

Deployment into any coastal location requires much planning and understanding of the environment, and Bombora does not have the adequate resources to assess local conditions and regulations. Thus, one capability sought in a collaborator would be both figuring out the policies that define certain coastal regions and working to create a standardized protocol for deployment across the individual ventures. While certain regions might have higher tax rates or stricter zonal laws, Bombora needs to work with these policies and perhaps adapt them to optimize our internal efficiency. Another key capability is the supply of manufactured raw materials used to construct the mWave. While we may be able to construct the membrane itself, it is necessary that we work directly with the supplier companies to ensure that their raw product is most efficient. Another capability that Bombora will require in a collaborator is ability of deployment and maintenance of the wave farms, likely in the form of labor. The small size of Bombora would require manpower to be sourced from a company experienced with project deployments with training applied directly from Bombora. Other capabilities likely to bolster our technology are abilities to formulate useful solutions and improvements for research and development. While Bombora focuses on the technology itself, it would be beneficial to learn more about specific wave conditions in different regions, depth of certain waters, and optimal deployment strategies. Bombora is capable of working in any ocean around the US, and requires external strategies and partnerships to understand local conditions. We would likely seek this information both before and after deployment, first to gain insight into external conditions and later to see how to improve on installed units. Marketing is another critical component for the business, and Bombora would need the capabilities of a marketing firm to distribute the knowledge and benefits of the mWave. There are many existing sources of renewable energy, and Bombora must find a way into energy suppliers' portfolio. Of course, the success of Bombora is entirely dependent on the existing energy grid, and it must be able to efficiently integrate into this grid.

Prospective collaborators

One of Bombora's key collaborators would be the utility companies that distribute the electricity across the grid. Bombora's primary consumer would be the energy suppliers and they would likely rely on the supplier to create aggregated data of the demand and wants of the end user. This insight would allow Bombora to determine deployment capabilities and optimal size of the wave farm. This information would allow for more informed decision making and efficient deployment, creating reductions in cost and overall increases in productivity. With a lower demand of energy in particular areas, Bombora would likely limit the number of units deployed. Another collaborator would be the public administrators of certain states and counties, who have a better understanding of the policies that could limit the membrane's technology and capabilities. By creating a relationship with these zonal regulators, we would be able to create a strategic plan that could benefit both parties and optimize consumer wellbeing and satisfaction. The next capability we seek is efficient and consistent raw materials for the product. Each of the raw components are essential to our manufacturing and Bombora must maintain active communications with each of the supplier companies to ensure smooth transitions and continued success. If one of the firms ever discontinues a necessary input, Bombora would quickly have to adapt and find a new upstream source. Further, if Bombora adjusts their existing technology, it would likely require modifications to either the frame or turbine. As for the maintenance of the actual membrane, the plan is to pass on the maintenance requirements to our parent company, Innergex. Innergex has experience working with many diversified projects, and understands the requirements for maintaining large scale energy farms. They have more labor resources and can allocate manpower to the different sites, as well as figure out when checkups might be necessary. This collaboration is especially important, for if our technology is not functioning properly, we must be able to train workers to identify the problem and determine a solution quickly and efficiently. While the training might be quite costly for Bombora, it would not require spreading labor resources across the many farms. As for the researchers that might have external guidance on the product, we are looking for researchers that understand future implications of deployments, how climate changes might impact wave patterns, and others than understand patterns and specific attributes of different bodies of water. While Bombora does not directly control where their energy is allocated, they could work with the energy suppliers and local educational institutions to create a strategic plan to increase usage from Bombora's energy. Many institutions are working to expand on renewable sources of energy, and as a relatively new company, it might be beneficial to find a specific market to target. Bombora must be able to identify the energy suppliers it wants to work with, which would require some consulting agency that understands the energy sector and specific utility companies. Lastly, Bombora will have to collaborate with energy suppliers to ensure that the technology can integrate into the electric grid.

Collaborator assessment

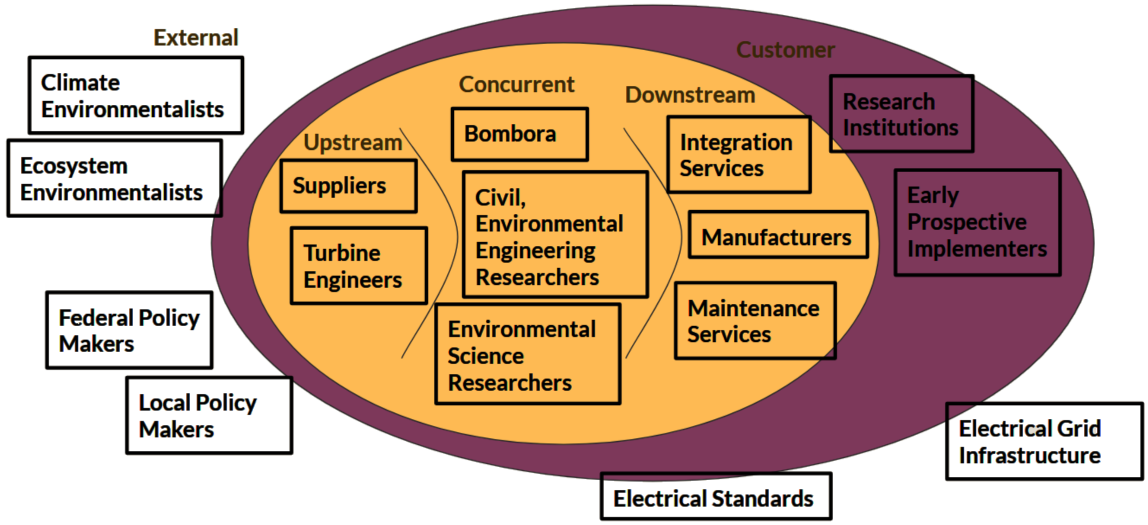

Figure 27. Value Network Diagram for mWave wave farm deployment

Stakeholder	Dependence (L/M/H)	Interests	Posture (NN..PP)	Approach
Energy Distributors	H	Additional, potentially significant, sources of renewable energy	Negative	Collaborate
Coastal Property Owners	M	Property utilization for revenue	Neutral	Collaborate
Local Public Administrators	H	Advance public preferences, expand local industry	Neutral	Educate
Product Manufacturer	H	Manufacturing supply line expansion	Positive	Collaborate
Product Deployment	H	Expanding operations and assignments	Positive	Collaborate
Climate Change Environmentalists	L	Expand renewable energy sources, lower greenhouse gas emissions	Somewhat Positive	Negotiate
Ecosystem Environmentalists	L	Disruption of natural ecosystem, pollution, land use	Very Negative	Negotiate
Federal Regulators	H	Acquisition of licenses and permits for deployment	Neutral	Educate
Local Coastal Industries	L	Business continuation	Somewhat Negative	Negotiate

Figure 28. Collaborator Evaluations and Assessment

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Collaboration form

The most pivotal collaborators for Bombora are the energy suppliers that they transmit their energy to, and would probably form a close partnership with most of these companies. This would likely be a mutually beneficial deal, for the suppliers are clearly trying to expand into the renewable sector and diversify their distribution portfolio. This type of collaboration would be classified as a joint venture, as Bombora would have a market to distribute to and the supplier would expand on their renewable resources. Ownership would not be transferred from either party, yet both sides would see benefits. As for the collaboration with the local public administrators, this would also be a partnership through a strategic alliance. As there do exist many specific regulations on different coasts, it might require that Bombora develop a compromise with the administrators to deploy the farms and form a collaborative advantage. Certain policies might have to be adapted or removed, yet this connection would benefit social welfare and reduce reliance on fossil fuels. Another collaborator that is greatly important to the development of our technology are independent environmentalists and Non-Governmental Organizations (NGO's). Because different regions have unique policies and regulations regarding the water treatment, it would require that Bombora clearly identify a strategy that complies with the local polies and standards. This type of collaboration would probably come in the form of a public policy consultant, figuring out an efficient and effective method of deploying the technology. Bombora would use their capabilities to bolster their design and strategy by understanding the specifications of the waters they are deploying in. This form of collaboration would help Bombora access data from an environmental team without having to hire more researchers. Bombora's minimal experience with property manufacturing and deployment requires downstream partnerships to be established. The company would establish a strategic alliance with turbine, transmission line, and other component designers by investing efforts to improve component efficiencies. This would raise value of the parts for designers while refining mWave functionality to better capture and retain energy. Raw material suppliers, manufacturing companies, and installation companies would be employed via subcontracting to carry out downstream processes of constructing and deploying the technology. Bombora has not established an infrastructure for these processes and lacks experiences in successful completions of these projects.

Project Valuation & Financing

Profit Model

Bombora's profit model would likely operate under an altered subscription service, in which utility companies and independent firms would pay for the electricity either for distribution or their own consumption. If working with electricity suppliers, it is likely that the price would be determined and set by the government for standardization and consistency. Bombora would require governmental subsidies under this price system, for the current cost of production and deployment greatly exceeds existing technologies. Yet Bombora does have critical benefits that could justify the higher pricing, including its renewable nature and potential for scalability and durability. As Bombora and Innergex begin to commercially deploy the membranes, they will gain experience with methods of optimization and efficiency, which would be the first step in cutting costs. Secondly, Bombora's operations on the ocean floor enable the potential for a vastly scalable and secure infrastructure. The mWave does not obstruct any natural views and has little limitations on its geographic deployment, which allows for a greater flexibility in terms of production. Because it is not exposed to the external weather patterns, the membrane is inherently protected from extreme storm events. The mWave converter has the unique ability to shut down in extreme storm conditions, which would further decrease long term costs. If Bombora were to operate directly with a large firm operating near the ocean such as an airport, this would likely take a more traditional profit model in which the airport or whatever coastal company could pay for their specified number of mWave units and use its resources as they need. This could also potentially take the form of a subscription service, in which we sell the rights to the membrane and charge a fee for certain units of electricity needed. Early profits are difficult for Bombora with the high operational costs, but through subsidies and experience in the commercial markets, there is huge upside and lots of potential for a scalable and low-cost venture.

Pro forma financial statement

Year of Launch

According to Bombora's website, the first full scale single cell trials and installation were estimated to be completed by the end of 2017. Because there is no information on the success of this project, we predict that the first full scale launch will not be for another 5 to 7 years. After the first unit trials, we assume that it will still require substantial work to finalize the design and prepare for a commercial deployment. The projected deployment of the 60MW wave farm, which will be classified as a product launch, is set to occur in 2024.

Total and Served Market

The considered total market is the renewable energy market (International Energy Agency, 2015). The total electricity generation from this component has been calculated as 43.6 billion megawatt hours per year (BP P.L.C., 2013). Due to a lack of full scale deployments, the wave power served market represents an insignificant percentage of the total market. Companies looking into wave power implementation will likely still be in the testing and smaller scale stage. As a result, the served market percentage will begin at 1%. As improvements to wave power technologies, market familiarity, and scalability costs continue to occur, this market percentage will slowly increase to 4% by 2031.

Industry Share

Before Bombora's wave farms are installed and deployed, the renewable sector will continue to be dominated by wind farms and other forms of hydropower such as reservoir and run-of-river. Fortunately, the renewable sector is not a monopoly market in which one type of energy dominates the full market, but rather companies are looking to expand and diversify their portfolio to accommodate different needs and business structures. Within the wave power sector, Bombora has clear advantages on efficiency and innovation, yet still are lacking in finding a profitable cost model. As shown in figure 28 below, we believe that Bombora can capture up to 2% of the renewable sector after deployment and hopefully up to 40% of the wave power market.

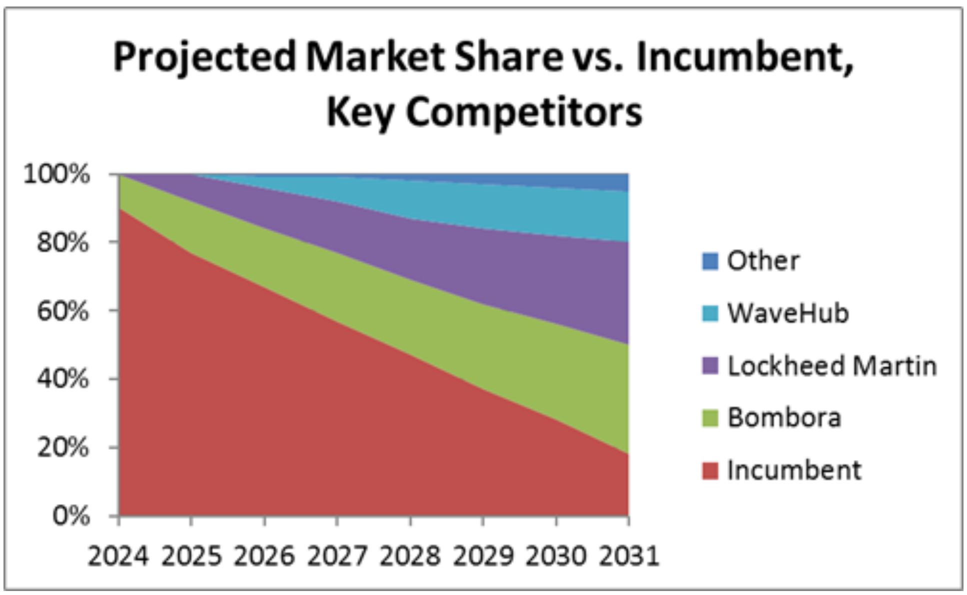

Figure 29. Projected Market Share

Price

Bombora will be selling electricity in units of megawatt hours. The price is determined by the cost of each mWave cell and each cell's energy generation potential. Considering these costs, $270 is required to produce one megawatt hour. A 23.9% government tax credit is estimated from comparable renewable energy technologies lowering the cost to $205.60 per megawatt hour. End users are charged around $150 per megawatt hour due to set utility prices. Further benefits may be applied from the government for renewable energy expansion initiatives.

Capital Investment

Bombora mWave

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Our capital investment will start off relatively small for research and development, but will quickly increase in actual deployment stages in local regions. As companies and utility companies see advantages of the new technology, demand will likely increase and Bombora will require more investments towards capital and expanded production. The capital investment will peak with the deployment of the second generation mWave wave farm. Costs will decrease with operating revenue and a focus on production costs and improvements in technology design.

Initial Cost/Unit

Because the mWave must be extremely efficient and durable in the ocean, the cost of the inputs is likely going to outweigh the economic value of the device, due to the necessity for high quality inputs and raw materials.

Experience Curve Factor

The estimated experience curve factor for Bombora is around 10%, which is considered a fairly modest rate of growth. For the first few years after initial deployment, Bombora would be focusing more on the improvement of the technology and the development of a stable infrastructure to support it, rather than the reduction of manufacturing costs. They must prioritize efficiency and functionality over cost, at least before they establish a trusted consumer base. As Bombora grows and learns in the market, manufacturing costs will naturally go down. However, we don't see the cost reductions to greatly impact the experience curve factor, which is why it would not exceed the specified 10%.

Research & Development

Research and development is a critical aspect for Bombora, as the technology requires a great deal of understanding of the local conditions, how the physical membrane can be optimized for certain wave patterns, and whether it is economical to deploy in certain regions. For this region, we see investments into R&D to be one of the greater costs for cover the many variable factors of different areas. This cost is only significant in the early stages of deployment, as Bombora does not have the experience in a commercial market and only gains understanding through testing and assumptions. Once they are able to deploy and operate under a larger scale, less money will be needed for research and development. The only other time we see there to be a great need for development capital is if Bombora plans to expand into different markets or wants to create a new product.

Other Operating Expenses

Other than research and development, the other operating expenses should be fairly low for Bombora. The company operates with less than 20 employees, and their operations do not require substantial office space for large scale manufacturing. If Bombora does ever undertake their own manufacturing, they will likely need to expand their infrastructure to support the new capabilities. Bombora currently outsources these processes to other companies, minimizing operational costs.

Service Life Assumption

Because Bombora's selling product is the electricity that the membrane generates, there is no assumed life cycle for this energy. If we were to sell the membrane itself, we predict the service life of the mWave to be around 20 years, due to subjected wear over times and changing wave conditions. Maintenance on the product would occur periodically to ensure that the deployed farms continue to operate optimally.

Discount Rate

We predict our company cost of capital to be around 30%, due to the inherent risk of the new product in an existing market. Further, we saw the project risk premium to be around 10%, due to the extra risk that comes in such a populated renewable energy market. In addition, the high investment required to deploy an mWave wave farm causes this project to have significantly higher risks.

Risk-Free Rate of Return

Keeping to the template of the pro forma spreadsheet, the general inflation rate was set at 1.68% while the risk-free rate of return was set around 2.25%.

Results

We define our total market to be all utility companies and direct consumers that rely on renewable energy for their electricity. The served market consists of the consumers in this set that rely on wave power specifically, and have shown to actually utilize energy captured by wave power generators. As seen in Figure 29 below, we predict that Bombora will capture more and more of the served market as time goes on and it proves itself as a reliable and stable energy supplier. As noted earlier, Bombora has a number of benefits within the wave power sector, and there does not exist another company that operates on the wave floor. This goal stems from the assumption that Bombora's cost/unit will continue to decrease as we scale and generate more revenue, and companies will realize the advantages of using our energy. As time goes on, Bombora is likely to gain some name recognition and build consumer trust. Because the total market is so large in comparison to our served market, it is difficult to assess the hold that Bombora has on a certain market. Yet it is still evident that Bombora's presence does increase as time goes on within the wave power market.

We calculate our gross margin to be –26% in 2031, which is net negative for each dollar that is gained in revenue. Currently, Bombora's cost per MWH is significantly higher than competitors, but if we can improve the efficiency of the device through further R&D and decrease the cost per MWH, it is attainable to achieve a profitable model. Unfortunately, due to the huge lack of efficiency, Bombora does not have a payback period because it is operating in the red. For us to attain more stable data, it requires that we can obtain more accurate cost structures as well as find a more efficient and less costly model of the membrane and its operations. Due to the lack of hard data and current cost structure, it is difficult to estimate explicit cash flows and the payback period for future deployments.

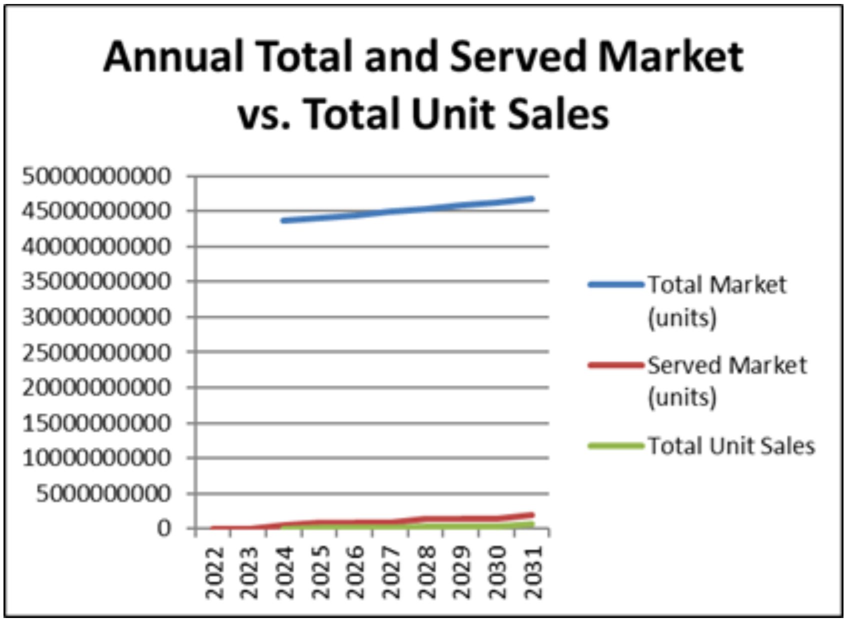

Figure 30. Annual Total and Served Market vs. Total Unit Sales

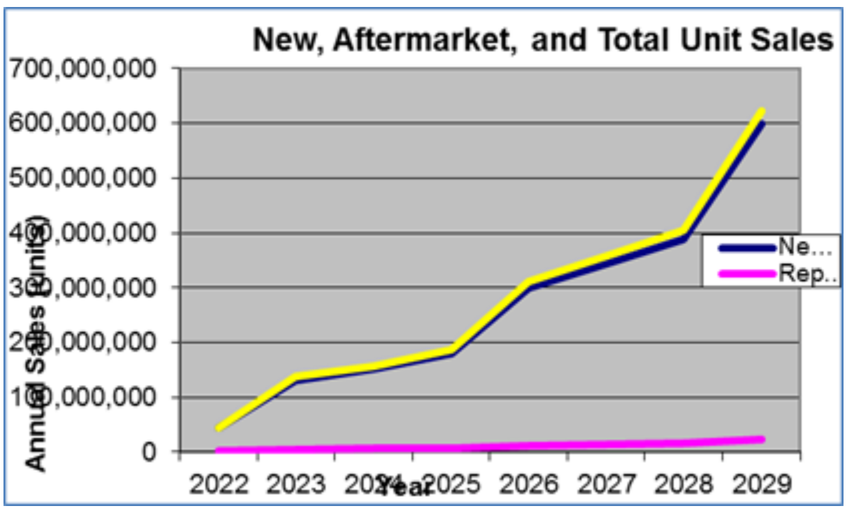

Figure 31. New, Aftermarket, and Total Unit Sales

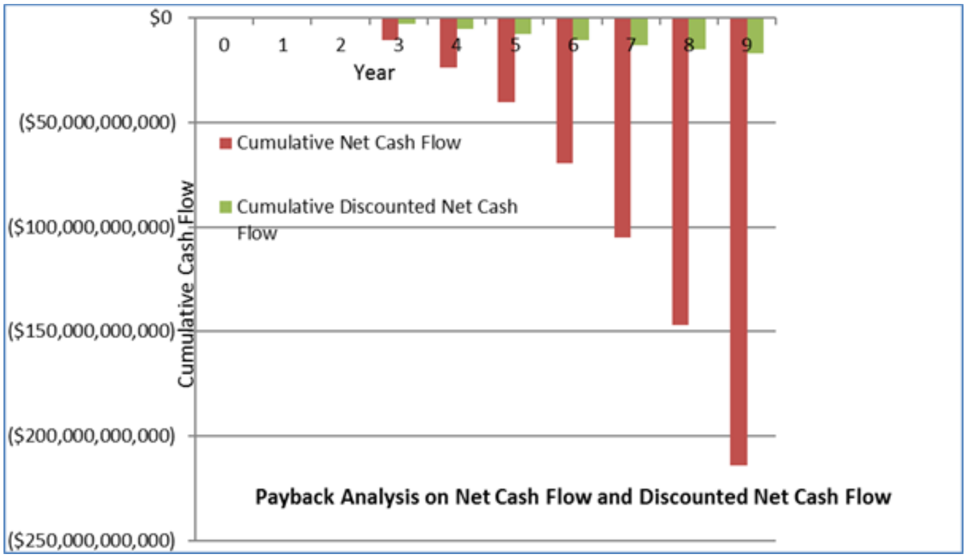

Figure 32. Net Cash Flow

Capital Requirements and Sources of Capital

Bombora has accumulated the majority of its initial capital through private investments and corporate partnerships, yet still requires more funding for large scale developments and deployments of the technology. Because investors do not usually provide all of the needed investment at once, Bombora would go through three separate investment rounds

Round 1

The first round of funding would probably come from a smaller investment of about $3 million from a larger firm that might want to utilize our resources. This money would go towards specific development and further research into the prototype for the mWave targeted for the specific region.

Round 2

In the second round of funding, Bombora would bring the investor or company the specific prototype for the membrane that they want to utilize. Bombora would brief the investor on the design, weight, size, and efficiency of the particular membrane, requesting an additional $8 million for further development of the necessary technology, various materials required for an accurate and functional membrane, and the manufacturing of the prototype. Robust tests for mWave functionally would be conducted, and the collected data would be provided to the investors for later rounds.

Round 3

Bombora would provide the investing company a working mWave that represents the prototype design and fits the specifications of the market regulations and the desired electricity requirements. If possible, the company would demonstrate how the membrane works in the specified location and show the amount of energy generated. Otherwise, the data previously collected would be used to show the efficiency and effectiveness of the membrane's electricity capturing potential. A final investment of $160 million of funding that would go directly into further developments of larger scale wave farms. The investor is promised a significant share in the company and explained future objectives and services of the mWave, as shown in Figure 22 above.

Regarding self-sustenance, Bombora is capable of sustaining itself within 7-9 years of the membrane's release into the commercial market. This does rely on the assumption that the membrane functions properly and does not require significant maintenance and does capture the predefined MW of electricity. Bombora's major differentiator is its deployment on the wave floor, so these assumptions also rely on the fact that no other company creates a model operating on the ocean floor. Bombora is still relatively early in its stages of deployment, but assumed to be capable of being self-sustaining in the next 12-15 years, optimistically by 2030. Trends are moving more towards renewable energy, which could create a greater push towards companies such as Bombora and accelerate growth and profitability in the market. Once Bombora can maintain a self-sustaining foothold in the market, they can begin expanding its technology and create more specialized forms of the wave farms designed specifically for local regions and wave patterns.

Bombora mWave

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Project Valuation & Financing-Real Options Analysis

Real options projects

Bombora must accomplish a few key projects in order to achieve a viable path to commercialization. The first step for Bombora is further investment into the research and development sector. Bombora still does not have a fully developed and refined product, which will require extra funding into optimizing capabilities and functionality. After finding a viable product that seems ready for market, Bombora will test this through a small 6MW wave farm off the coast of Portugal. Bombora has already deployed and trialed single cell units, but their next goal is testing the functionality of a small scale wave farm in the next few years. After successful deployment of this smaller project, the next step would be expanding on this farm and deploying a larger and come integrated 60MWwave farm, hopefully in more commercial and electricity dependent location. We believe that this is the standard strategy for achieving commercialization, as Lockheed Martin's wave energy sector is following the same path with an expansion of turbines and units.

Option value calculation

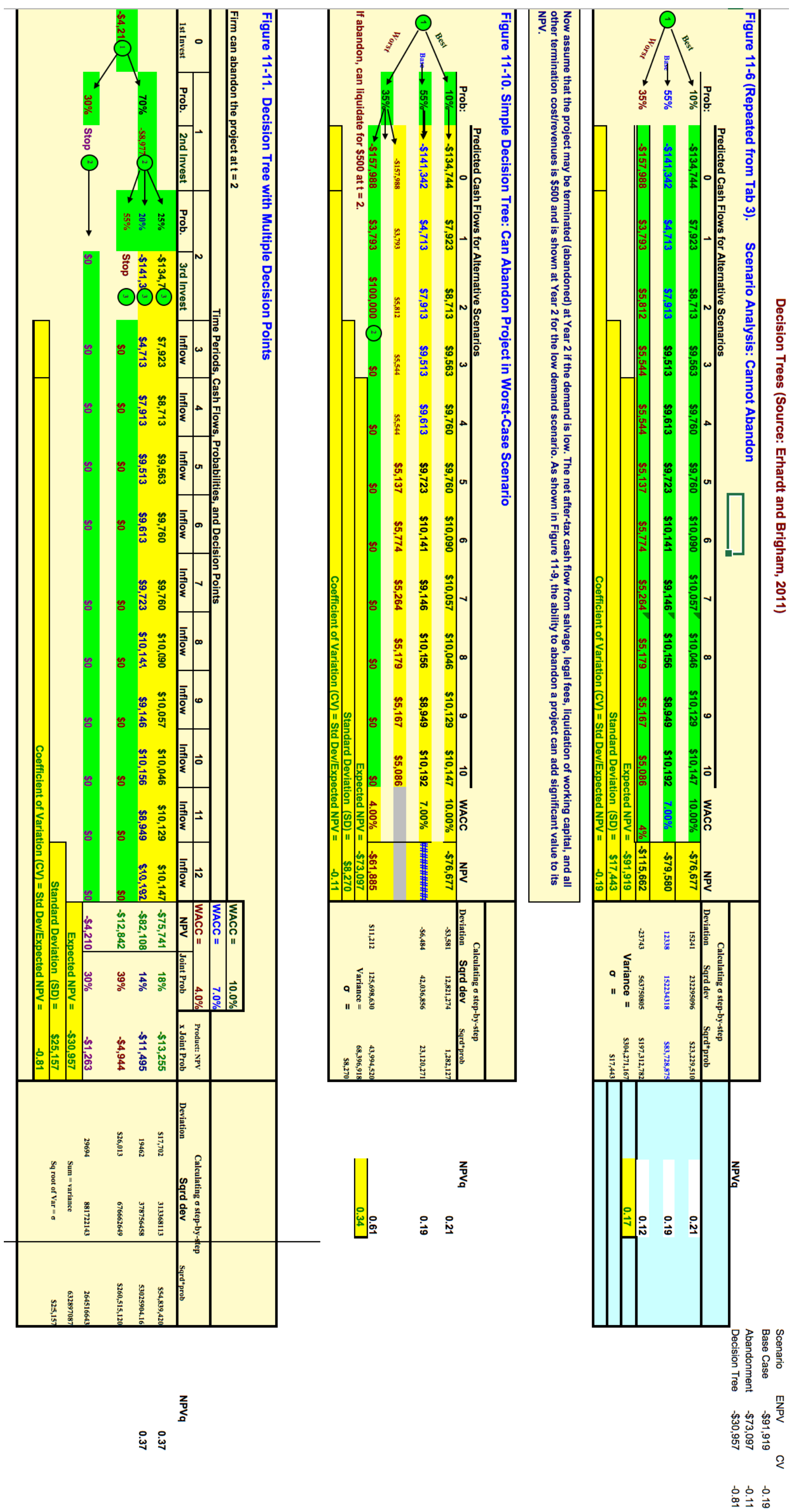

Figure 33. Payback Analysis Decision Trees

Bombora mWave

Sachit Bhat, Gabriel Hoppock, and William Ju

Before we deploy the 6MW wave farm, it is necessary that we first invest around 1.5 million dollars into continued research and development. The membrane is not fully ready for deployment, and there are minor tweaks that can cause this extra cost. This would include changes in raw material suppliers and inputs, expanded capability insights of the original design, and testing within Bombora's facilities. The first project, the small 6MW wave farm, is likely going to cost around 8 million to deploy. This estimate stems from the high cost of the first installation and adjustment costs of initial deployment. Bombora will not have the expertise in installing an actual farm into the ocean, which could require extra labor costs and supervision. Finally, the third project would likely cost around 145 million. This is going to be much more expensive than the other two, due to the much higher energy generation requirements and integration into the grid. Based on our cost of energy study, we estimate that we will optimistically drive in around 11 million in revenue. This number could vary based on the maintenance and installation costs, but this is a fairly optimistic number, which maintenance costs staying relatively stable.

Options space map

Due to the very high cost of our projects, Bombora will experience net losses through the first ten years of our estimates. We do not see any profitability in this time period due to the very high cost of building and deployment and the extremely limited information and prospects for investment and revenue generation. This net loss comes directly from the calculated costs and numbers provided from the cost of energy study, in which Bombora is still much pricier than its renewable competititors. These cost estimations place us at a point where it is ideal to never invest, as the Expected Net Present Value for our base case is around -100,127 NPV, and a coefficient of Variation of -.19. Unfortunately, Bombora does not have control on the market price of energy, which is determined by regulations and energy suppliers. Thus, the cost is inherently going to continue to outweigh this profit. Unless Bombora is able to drastically cut costs and find a path to increased revenue, we do not see viability for the company in the long run and it would be quite difficult to garner significant investments.

Improvement over traditional DCF analysis

The advantages of this option space and combination of projects is advantageous due to the option to back out early on. If Bombora is able generate early investments, it is likely that they will see the high cost of deployment and have the ability to back out early. We would like to optimistically estimate that Bombora will be able to cover these high costs within the next twenty years, but there are no explicit calculations that show this upward trend in growth. Thus, is it better for investors to back out early so the magnitude of the loss of the NPV is decreased. Further, this model allows to estimate probabilities of different cases depending on the success of the product. There are many variables and factors that can impact the growth of Bombora's membrane, and this model improves on the strict requirements of a DCF model. Bombora's prospect for success in our decision tree is quite low and puts the WACC at around 7%, due to the inability to pay back its security holders and properly finance its assets. In our case, the deployment of the 6MW will allow the investors to realize the true cost of such an expensive venture, and reevaluate whether they want to continue investing in our technology.

Technology/Business Roadmap

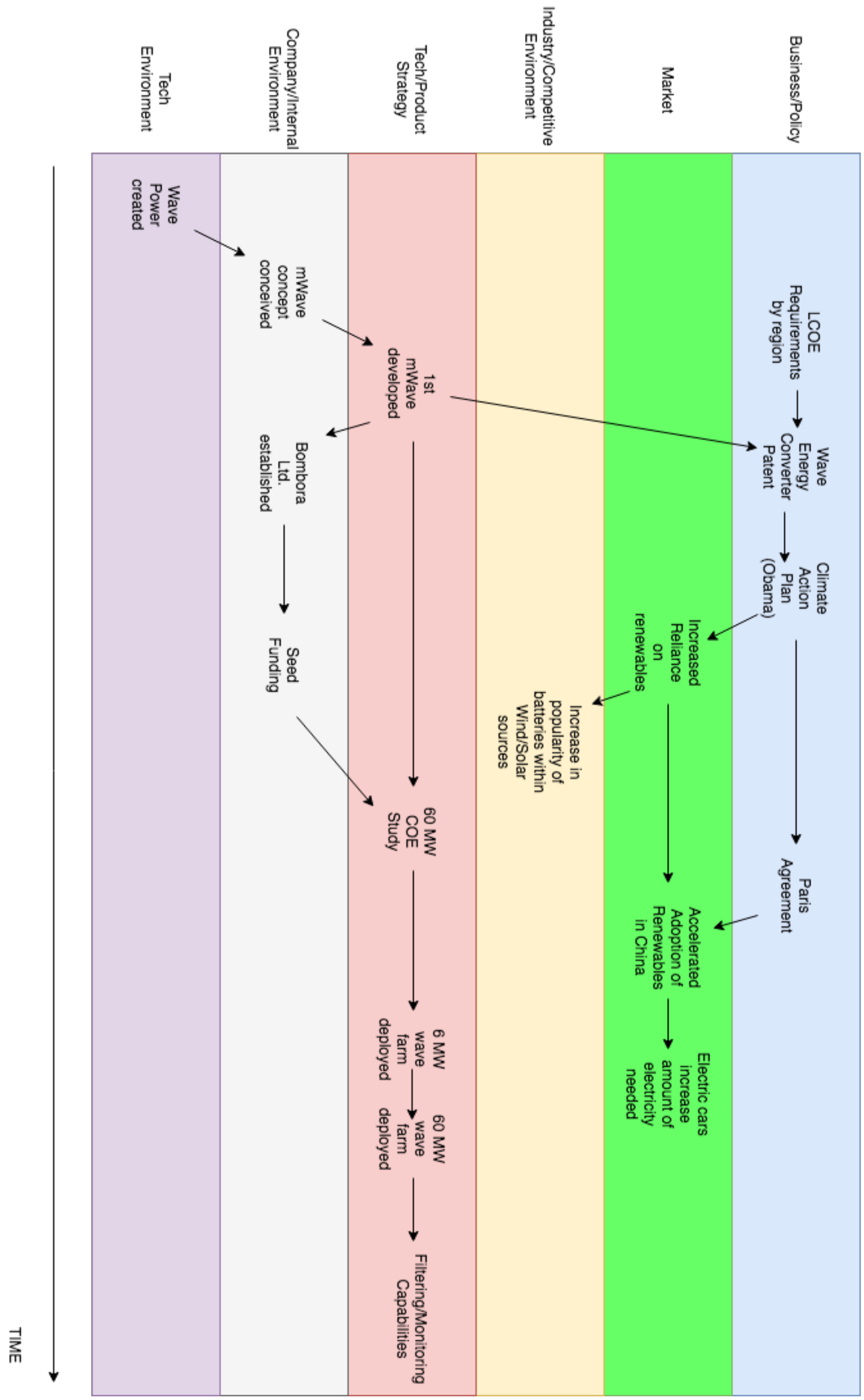

Figure 34. mWave Technology Roadmap

Our technology roadmap is fairly straightforward, yet there are certain components that are not as self-explanatory. After wave power was first invented, the mWave concept was then conceived and developed within the Bombora facilities. This prototype led to the establishment of Bombora Ltd., as well as a patent for their unique wave floor energy converter. This patent must adhere to the levelized cost of electricity requirements specified by governmental regulations and requirements. With the advancement of Obama's Climate Action Plan, there would be new hopes to cut carbon footprints, and help Bombora within the renewable sector. Within the industry, it is difficult to define an external competitive advantage that allows Bombora to provide an edge over rivals. Because the end result is the same electricity provided to consumers, there is no explicit feature that differentiates the product. Thus, our competitive environment stems around the increase in popularity and development of batteries within the wind and solar industries. This will have a negative impact on Bombora's foothold in the market, as wind and solar sources will advance with this progression. Still, with the adoption of the Paris agreement, industries will rely on more diverse sources of renewable energy including wave power. Electric cars have gained a lot of traction in the last few years, and this could further help Bombora's strategy, and open up a new market to infiltrate. Of course, much of the dependence on wave power is determined by energy suppliers and regulations that determine their energy portfolio.

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Appendices

Contact Log

Dylan Heath (LinkedIn inMail)

Dylan Heath of Bombora was contacted by Sachit Bhat on October 11, 2017 via LinkedIn inMail. He would refer us to Shawn Ryan who we contacted next.

Shawn Ryan (LinkedIn inMail)

Shawn Ryan of Bombora was contacted by Sachit Bhat on October 11, 2017 via LinkedIn inMail. We received a response to set up a Skype interview, however lost contact shortly after. We would later find that Shawn Ryan had left the company.

Allyn Wasley (LinkedIn inMail)

Allyn Wasley, Chief Financial Officer of Bombora, was contacted by Sachit Bhat on October 11, 2017 via LinkedIn inMail. No response was received.

Eugene LeBoeuf (eugene.j.leboeuf@vanderbilt.edu)

Eugene LeBoeuf, a Vanderbilt Professor of Civil and Environmental Engineering, was contacted by Gabriel Hoppock on October 13, 2017. A response was later recieved stating that he was currently on academic leave on active duty for the army. We were referred to other possible contacts who we engaged.

Bombora Contact Us (info@bomborawavepower.com.au)

The Bombora Contact Us address was contacted by William Ju on October 10, 2017 via the provided email. An automated response was received that provided little insight or accessibility to conduct a more comprehensive interview.

Roy Kuga (LinkedIn inMail)

Roy Kuga of PG&E energy company was contacted by Sachit Bhat on October 19, 2017 via LinkedIn inMail. No response was received.

Malcolm Spaulding (spaulding@uri.edu)

Malcolm Spaulding, a Professor at the University of Rhode Island, was contacted by William Ju on October 24, 2017 via email. No response was received.

Marcus Lehmann (MLehmann@lbl.gov)

Marcus Lehmann, designer of the Wave Carpet and CEO of CalWave, was contacted by William Ju on November 3, 2017 via email. A response was received that referred to business reports but showed little interest in a full interview.

George Hagerman (hagerman@vt.edu)

George Hagerman, a Senior Research Associate at Virginia Tech dealing with marine renewable systems, was contacted by Gabriel Hoppock on November 5, 2017 via email. No response was received.

Stephan Grilli (grilli@uri.edu)

Stephan Grilli, a University of Rhode Island Professor of Ocean Engineering studying wave interaction and dynamics, was contacted by William Ju on November 10, 2017. A response was received stating that he was currently outside of the country with limited availability. No further follow up was able to be secured.

Lockheed Martin (In-site contact us)

The Lockheed Martin contact us ticket was utilized with indication of gaining information about the company's tidal energy system by William Ju on November 10, 2017. The system would connect William with Vanderbilt alumnus Denis Garman, head of strategy and marketing for Lockheed Martin. A full interview was able to be conducted, gaining key information of realistic outlooks on the wave power market and the state of the company's current deployment.

Sam Leighton (sam@bomborawavepower.com.au)

Sam Leighton, CEO of Bombora, was contacted by Sachit Bhat on November 12, 2017 via email found on the OpenEI Database. No response was received.

Bombora mWave

Sachit Bhat, Gabriel Hoppock, and William Ju

Interview Summaries

Interview 1: Denis Garman

Denis Garman is currently the head of strategy and marketing for Lockheed Martin. He graduated from Vanderbilt in 1985 and has experience with 11 years in the gamble brand market, 12 years in global marketing in IBM, worked for Duke Energy creating residential energy and behavioral programs, and did a number of brand strategy jobs. Lockheed then brought him on to work in Dallas.

Lockheed Martin's tidal energy system is about 30 meters underwater, focusing more on tides and not the waves. There is a deployment off the coast of Scotland that actually performs better than expected. It was meant to be a 1.5MW system, but during trials reported up to 1.6MW.

Limitations in further deployment has less to do with the marine business as it does to other renewables. The price of other renewables has plummeted over the last 10 years, solar and wind competing with established incumbents. On-shore wind is beating coal and natural gas in terms of levelized cost of energy. Wave power is simply more expensive and therefore is not a critical piece of Lockheed Martin's portfolio at this time.

The deployment plan involves multiple stages. 1A involves the singular turbine deployment. 1B is deploying three turbines by the end of the year or early next year. 1C gets into a 150 deployment, 200MW range. That provides substantial amount of energy to support multiple applications. While the runway looks promising, governments such as the UK requires comparison of performance against other renewables as a measurement of technology viability. There is really no way to make that work with those environments. That makes it very challenging. As a vastly accelerating technology it's gotten very difficult to be competitive in the renewable space. Development efforts are highly reliant on the market conditions.

The technology curve, the learning curve that's going to be required, is going to have to be substantial to get on par with even off-shore wind. The requirements for being 100 feet underwater are quite different than simply putting something on land. It clearly impacts the costs associated with the product. While Lockheed Martin has a technically superior product that performs well and goes in and out of the water quickly, the market has moved, and so it's the nature of the commercial business. Around 4-5 years ago, wave power had its chance. It was just that the technology wasn't there and wasn't in the market. With policy and finance changes taking place that wants an even playing field, that really doesn't play well for wave technologies without some significant technology transformation.

The beauty in terms of tapping into wave and tides is that they never stop. That's the downside for solar and wind. I think there are some advantages there but because the initial designs and costs associated with those designs are greater relative to other spaces, it's easier to get a solar farm and five or six wind turbines to balance the load and then have storage to capture the excess capacity. That is what is starting to energy.

Companies exploring wave power kinetic designs seem to be in the pilot stage, some isolated to labs in universities. There is nothing in scale yet.

Bombora mWave

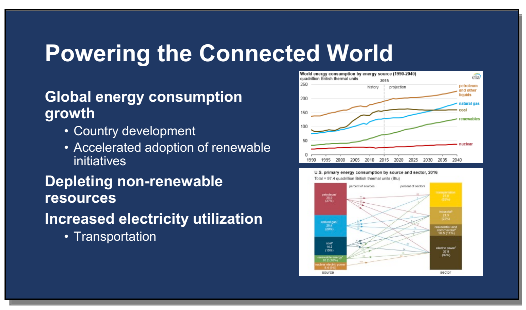
Sachit Bhat, Gabriel Hoppock, and William Ju

In describing the scale of the maintenance involved, it is too early to say. There have been some technical issues, some with the system, some with the operator, some of the cost elements have not settled. When the turbine was initially put it in and run, it ran 6 flawlessly. However, even when doing general maintenance, it is going to be a different cost quotient than when doing something land-based.

Final Presentation Handout

Slide 1

Slide 2



Bombora mWave

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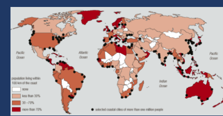
Slide 3

Primary Market Outreach

Coastal energy suppliers and utilities
- Established electrical grid infrastructure
- High initial cost
- Servicing high population density

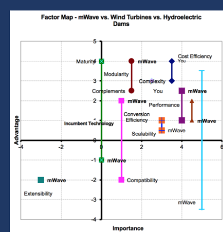
Government policy conditions
- Tax credit incentives
- Cost efficiency requirements (LCOE)



Slide 4

mWave Technical Specifications

Rubber membranes flexed by wave forces
- Rated 1.5MW
- Sustainable electricity for 500 households
- Minimal maintenance
- Discrete, submerged
- Resistant to extreme storms



Slide 5

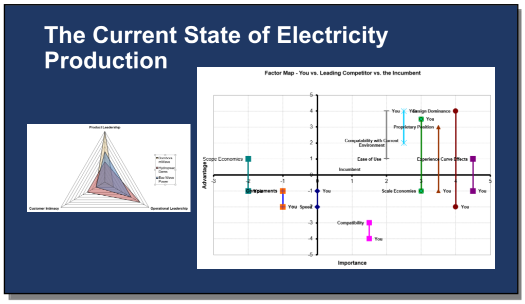
The Current State of Electricity Production

Technology	Market Position (% Renewable Production)	Maturity	Electric Production Consistency	Cost Efficiency ($/MWh)	Modularity	Scalability	Environment Constraints
Incumbent: Hydroelectric	24%	Established	Relatively consistent	63.9	Low	Low	Medium
Competitor: GE Wind	21%	Developed	Inconsistent	55.8	High	High	High
Competitor: Eco Wave Power	< 1%	New	Consistent	N/A	Low	Medium	Low
Bombora mWave	< 1%	New	Consistent	> 250	High	High	Low

Bombora mWave

Sachit Bhat, Gabriel Hoppock, and William Ju

Slide 6



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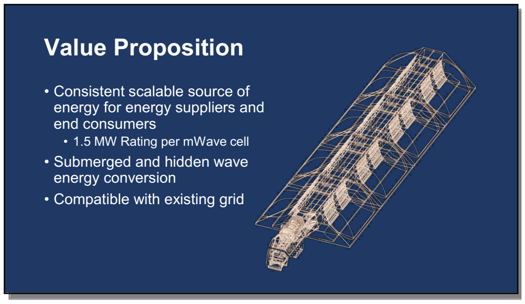

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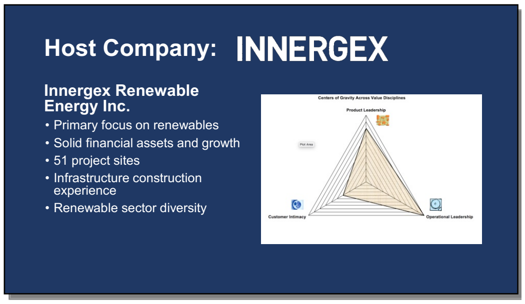

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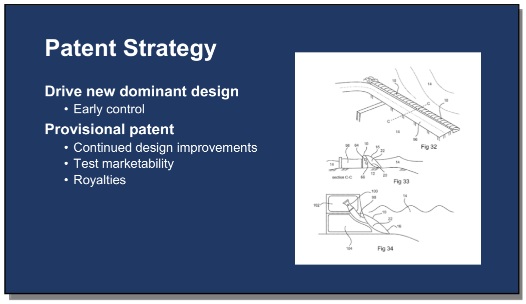

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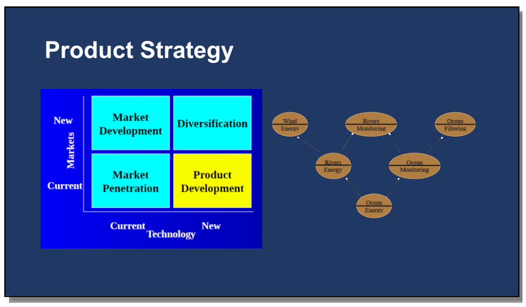

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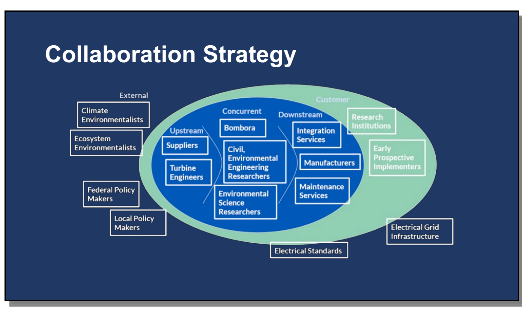

Bombora mWave

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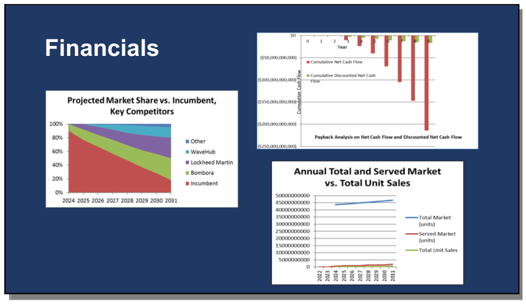
Slide 12



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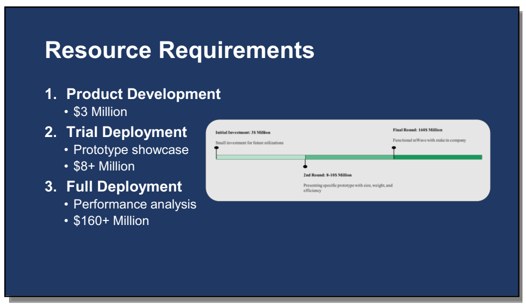

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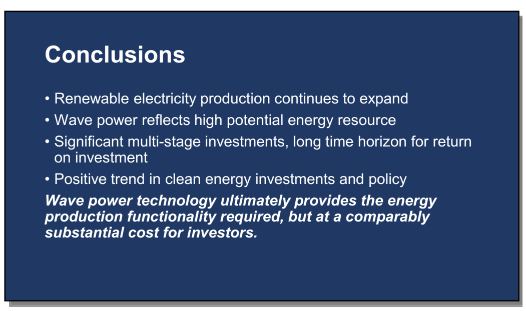

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