From Tank to San Francisco Bay: Design and Deployment of an Oscillating Buoy Wave Energy Harvester

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Abstract

As global energy demand increases, scaling renewable energy becomes more important than ever. While renewable energy forms such as wind and solar have room for expansion to better meet global needs, both systems are highly dependent on environmental conditions and limited by spatial factors. Moreover, the ocean is full of unexplored energy-generating potential. Unlike wind or solar, ocean waves are consistently active and full of power. Currently, wave power generating projects are showing great potential but are not yet implemented on a wide scale. State the issue here of why those haven't scaled or been further deployed. This paper builds upon two years of design experimentation on wave energy conversion. After a year of initial experimentation with multiple methods, the linear buoy device proved to be the most viable for further exploration. This paper will explore its design by utilizing the rising and falling of a buoy to move a magnet linearly through a copper coil, generating current. After experimenting with differences in wire gauge and magnet strength, the most effective design involved four coil wires in series connected to four separate buoys. This design was placed in both the testing tank and in the San Francisco Bay, generating power in both scenarios. When the output wave energy is analyzed according to the scale of the design, the potential uses for wave energy to power lights, security systems in waterboarding areas are significant areas of opportunity. The two-year research and development of the design offers a look into how renewable wave energy could change urban living, where energy consumption and production function in harmony with the environment, promoting sustainability and efficiency.

Keywords

Renewable energy, Wave energy conversion (WEC), Linear buoy generator, Oscillating Water Column (OWC), point absorber, attenuator, terminator, electromagnetic Induction, Faraday's Law, Lenz's Law, Walton Generator

Introduction

Climate change has become the defining crisis of the twenty-first century. Severe wildfires, rising sea levels, and chaotic weather patterns are apparent symptoms of the rapidly warming planet. Greenhouse gas emissions have led to global temperature increases that threaten environmental stability. The Intergovernmental Panel on Climate Change urges the need to avoid exceeding a global temperature increase of 1.5 degrees, as the consequences would have catastrophic, irreversible effects (IPCC, 2023, p. 13). As temperatures continue to increase at an increasingly rapid rate, immediate action is required to avoid disaster. At the 28th annual United Nations Climate Change Conference, 198 countries endorsed "a global goal to triple renewable energy capacity by 2030"(IPCC, 2023, p. 8). In 2023, renewable energy capacity reached a new high of nearly 510 gigawatts, a 50% increase over 2022, marking the fastest growth over the last twenty years (IPCC, 2023, p. 7). For instance, China was the national leader in expanding solar, implementing as much solar PV as the entire world managed in 2022 (IPCC, 2023, p. 7).

Despite significant progress in renewable expansion, the current trajectory still falls short of renewable requirements. The COP28 goal of tripling renewable energy capacity would be to reach over 11,000 GW in renewable energy capacity by 2030, which is an ambitious goal even considering current positive trends, which only forecast renewable capacity to reach around 7,300 GW by 2028 (IEA, 2023, p. 8). Boundaries that hinder the implementation of wind and solar energy make reaching energy capacity goals a challenge. Both solar and wind are limited by policy uncertainties and difficulties with permitting, especially in regions where renewables are socially rejected. Many countries also lack the necessary financing to accelerate renewable expansion (IEA, 2023, p. 7).

Literary Review of Wind and Solar

Wind energy is one of the most abundant and promising forms of renewable energy, accounting for 8% of global electricity generation in 2023 (McKenna, 2025, pg. 1). However, many technical and social challenges must be addressed to continue growth. According to the report System Impact of Wind Energy Developments, "wind energy is one of the most mature and cost-effective renewable electricity technologies"(McKenna, 2025, pg. 7). The abundance of wind energy makes the technology reliable and well understood compared to newer, less explored alternatives. Wind energy has played a major role in displacing fossil fuel-based electricity, reducing greenhouse gas emissions that contribute to global warming.

One major drawback of wind energy is noise pollution. The noise generated by the turbines of wind power affects wildfires by impeding breeding patterns, which could result in a potential decline in the population of vulnerable species (McKenna, 2025, pg. 3). Wind turbines impact gene flow as they create boundaries to the movement of wildlife (McKenna, 2025, pg. 3). Noise from wind turbines also frustrates residents who have reported sleep disturbances, increased stress, and related health consequences (McKenna, 2025, pg. 3). While the noise from turbines cannot directly be heard, the low-frequency noise may lead to annoyance. These negative impacts can be mitigated by considering the environment and the residential areas surrounding wind farms.

The turbines extract and harness the kinetic energy of wind through the rotor. When placed near each other, windmills impede the output of other wind farms up to ten miles away by lowering the speed of the wind in the vicinity (McKenna, 2025, pg. 3). Many windmills in one area can even alter weather patterns, usually appearing through elevated surface temperatures, different precipitation, and evaporation patterns. Because of the adverse side effects of wind power, productive wind farms have to be located far from demand centers, and the distance between energy generation and use requires long-distance transmission systems. The most significant projects involved with wind energy are often connecting rural generation sites to urban demand centers (McKenna, 2025, pg. 9). This complicates the integration of wind energy, demanding more resources for transmission systems compared to other renewable alternatives.

The most significant drawback of wind energy is its intermittency. The energy output of wind turbines is highly dependent on conditions and wind speeds, making grid integration a challenge that necessitates backup storage systems when wind is less available (McKenna, 2025, pg. 9) Events of extreme wind, on the other hand, require forecasting and flexibility to manage events of higher

Solar power faces a similar challenge. Solar grids appear as a limitless energy source for power grids, especially as photovoltaic technology advances and the cost of solar PV drops, making it competitive with traditional fossil fuels (Talukder, 2024, pg. 2314). Solar PV has shown significant success when integrated with innovative grid technology. Solar panels can be placed conveniently on top of homes, allowing consumers to generate their own electricity. Smart grids enable consumers to generate, store, and sell excess energy back into the grid.

However, integrating solar energy into a grid built for non-renewables has complex technical and regulatory challenges. Solar energy is highly dependent on weather and sunshine, making the energy output inconsistent. This leads to voltage instability in power grids, with 72% of grids facing voltage fluctuation (Talukder, 2024, pg. 2313). To maintain a stable power supply, excess solar energy harnessed during daylight must be stored for use during non-productive hours. Currently, energy storage utilization is low at only around 30%, which would be detrimental to the reliability of solar power. Current grid systems cannot compensate for energy fluctuations, 65% of which require significant investment to achieve reliability (Talukder, 2024, pg. 2321)

Literary Review of Wave Energy

While wave energy has expanded like wind or solar, it was experimented with as early as 1799 by French engineers (Azam, 2024). Today, the technology offers many opportunities where wind and solar energy lack reliability. Unlike the sun or wind, waves are a more consistent source of energy and less susceptible to weather changes. Because water is denser, it offers a higher energy density compared to wind power. Specifically, waves provide an energy density of 2-3 kW/m^2 compared to wind and solar, which offer 0.4-0.6 kW/m^2 and 0.1-0.2 kW/m^2, respectively (Azam, 2024).

Waves are an untapped resource that could integrate with other renewables to achieve climate goals. In 2023, energy consumption hit 29,471 TWh, representing a 2.2 percent increase from 2022. Currently, government bodies estimate that only 0.5~0.6% of wave energy resources are being utilized for electricity production (Azam, 2024). If maximized, wave energy is predicted to exceed 32,000 TWh every year, a value greater than the energy consumption in 2023 (Azam, 2024).

Unlike wind and solar, where most systems look similar, wave energy has many alternative designs that are each suitable for different types of waves. Many solutions use the oscillation of waves to generate electricity, an approach that can be categorized into three categories. Point absorbers exploit the change in wave height, terminators capture energy from the surging of water, and attenuators consist of multiple segments harnessing energy from the wave pitch (Azam, 2024).

In 2006, Uppsala University developed a point absorber wave energy converter that utilized a floating buoy, anchored to a translator, generating energy from the rising and falling of the waves. Power output fluctuates based on factors such as buoy size and the weight of the translator that anchors the device (Lejerkog. 2015). The translator was made up of an octagonal tube with eight sides. Each side within the tube had steel sheets wound with a three-phase winding. Within the compartment, there was a piston rod, also shaped like an octagon, surrounded by eight sides of Ne-FE-B magnets. The piston rod was connected to a buoy at the water's surface, allowing the oscillation of the waves to move the magnets up and down throughout the coil. The 2700 kg translator generated a significant power of 450 volts and 20 kW (Lejerkog. 2015).

The Atargis CycWEC uses the terminator WEC to generate electricity from the surging of water beneath the surface. The design is fully submerged, invisible from the surface of the water. The terminator is composed of oncoming wave crests, making the design generate a much higher proportion of energy as wave sizes increase compared to other WEC technologies (CycWEC Design, n.d.). The design is anchored to the sea floor and utilizes a horizontally rotating hydrofoil to extract power via a rotational generator. Hydrofoils can move at a faster rate than the speed of the fluid, influencing the device by utilizing lift to reduce hydrodynamic losses, thus generating a much greater amount of electricity. Many surface-level designs have had to abort testing because of storm events. The fully submerged CycWEC avoids this issue, avoiding surface-level (CycWEC Design, n.d.).

The company SWEL, based out of Cyprus and the UK, has tested a design called “the Waveline Magnet”, which utilizes the attenuator approach to generate electricity (Sea Wave, n.d.). The designs consist of many segments that float on top of the wave parallel to the direction of the crests. The designs provide flexibility and adaptation to various shapes, frequencies, and heights of waves to extract energy efficiently. Described by SWEL, the design is made to “embrace the surface of the sea, or the ‘wave line’”(Sea Wave, n.d.). Because the design does conflict with the water's direction, it is inherently more robust as it moves the sea’s forces than remaining stationary.

Wave Swell Energy, based in Australia, takes a different approach to generating and capturing energy, utilizing a design called an oscillating water column. An Oscillating Water Column uses the rising and falling of a wave to force air through an outlet to spin a turbine (Uniwave, n.d.). Wave Swells' design is more robust than other floating forms of wave energy, with the only moving part being an air turbine placed far above the water level. An oscillating water column works when water rises within an enclosed chamber, which increases the air pressure. When there is an outlet at the top of the chamber, air exits spinning a turbine. Most oscillating water columns operate with bidirectional airflow caused by the falling of the water level, creating a momentary vacuum. This poses a challenge to most designs requiring a turbine to accept two directions of air movement. Wave Swell’s oscillating water column saves costs by operating unidirectionally by being placed along the shoreline of oncoming waves, making the design more robust (Uniwave, n.d.). The design also offers coastal protection, protecting against sea level rise as an additional benefit.

The immense variety of approaches to generating electricity from waves shows that there is still a need for testing new ideas and refining existing designs. Additionally, wave energy has not been explored for implementation in Urban environments. In contrast, technologies such as solar are commonly placed on top of houses to generate electricity for both grid implementation and local power generation. Wave energy could be applied on a similar scale in waterboarding areas to provide a reliable nearby power source. A two-year wave energy harvesting experiment evaluated various approaches to generating electricity, exploring how wave generators could be implemented into urban living.

Methodology

Phase 1:

To test various ways of generating electricity from waves, a demonstration environment made from a four-foot fish tank was used to compare different designs. On the right side of the tank, a mechanism that manipulated the water created artificial waves that could be used to test WEC designs. At first, this mechanism was manually powered, involving a panel of acrylic that was attached to a rotatable axis on one end, which could be used to push water to create waves.

With a way to create testable wave motion, the process of designing small-scale versions of various WECs could begin.

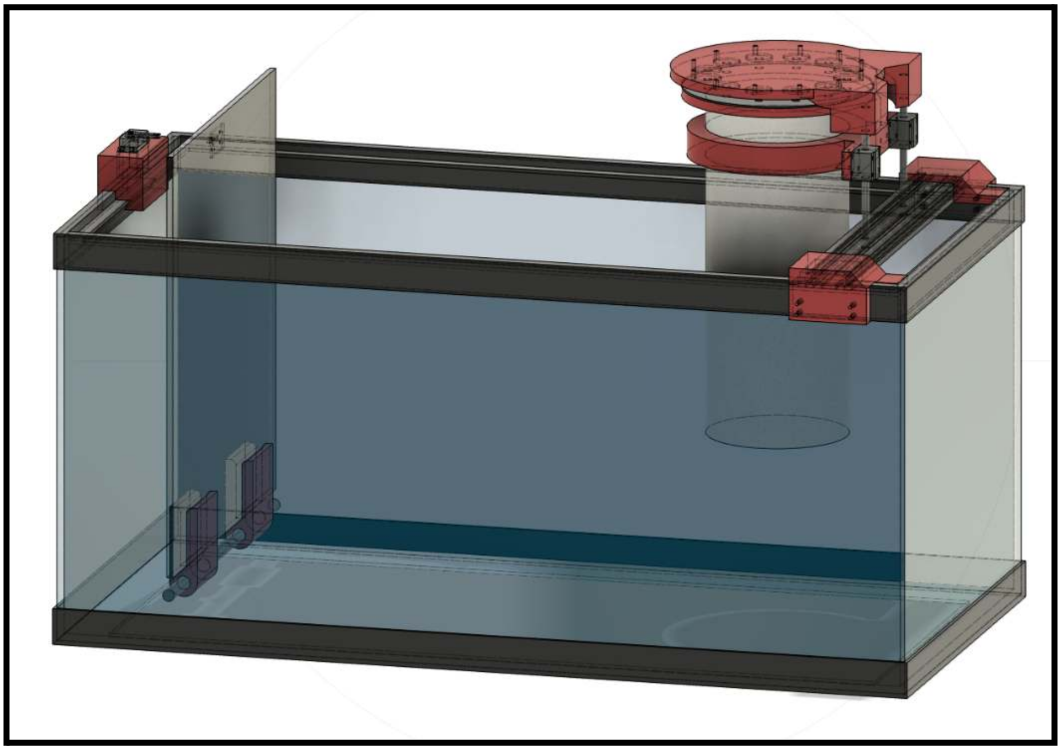

Figure 1: A model designed in Fusion 360 of the tank and wave-making device on the left. On the right is a design of the piezotric buoy energy harvester.

The first idea tested used the same method as the Waveswell project. The oscillating water column is effective because it is not as dependent on wave height or shape, as the compression of air in the chamber can work effectively in various conditions. This design was replicated on a smaller scale by creating an enclosed chamber on the left side of the tank, across from the wave simulator. This worked by creating a box out of acrylic that was sealed off, only open on the bottom, which was fully submerged below the water level, making it air-tight. On top of the column, a hole was added to allow air to escape from the enclosure space. As the wave rises, air would be forced out of the chamber as the volume would shrink, compressing the air. As the wave falls, air would enter the chamber as the volume increases, lowering the air pressure and creating a vacuum effect. To harness the energy generated from the moving air, a fan from a hair dryer was placed over the drilled hole.

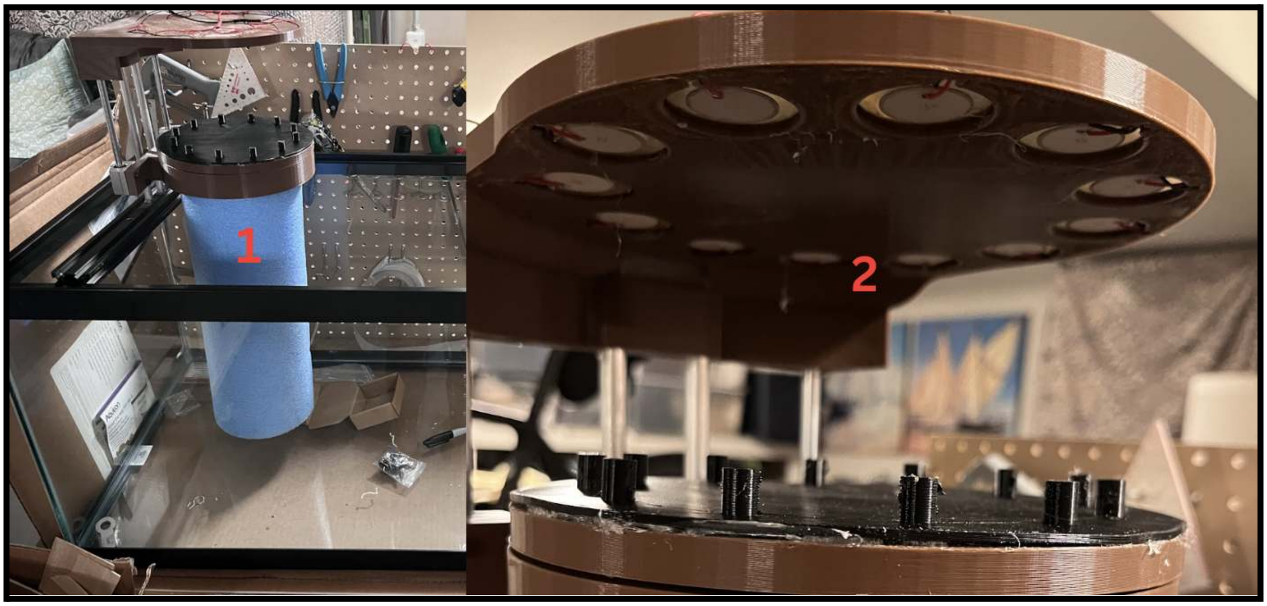

Photo 1: The exercise foam roller connects the moving part that collides with the piezo-electric tiles. This design was anchored to the side of the tank with linear bearings.
Photo 2: A close view of the piezo-electric tile and moving collider.

Another design during the first year of the project used piezo-electric tiles to generate electricity from the rising and falling of a buoy colliding with a ceiling component. Piezotricity generates electricity from mechanical stress. When a force is applied to a material that exhibits piezoelectric properties, the manipulation of the internal structure of the material creates a dipole moment and generates a voltage (He & Briscoe, 2024). In the design, eight small piezoelectric tiles were wired evenly in both series and parallel. The tiles were attached to a stationing component that rested above a buoy that would rise and fall, colliding with tiles, generating electricity. The buoy was anchored using a linear bearing, which ensured that the component only moved on a specific pathway. This method of wave energy harvesting is riddled with many limitations, as piezoelectricity generates a very low amount of current and fluctuates based on the wave frequency immensely. Piezoelectric tiles also endure significant wear during their use, as they rely on mechanical collision, which reduces the life span of the harvester.

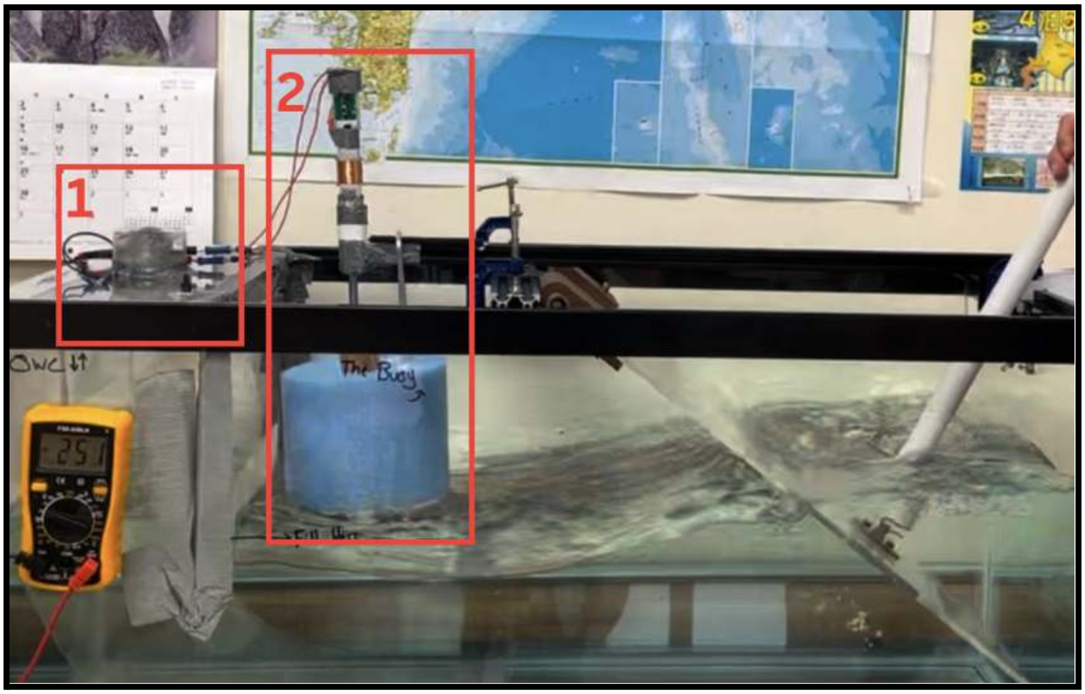

Photo 3: In box one, the oscillating water column design in the phase one testing tank. To the left, box two shows the linear buoy wave energy harvester, also in the phase one testing tank.

The third design was focused more on simplicity. This design involved a copper coil and a magnet to generate power to induce a current. For the first iteration of this design, a shaker flashlight was used, which contained thinly wound copper and a loose magnet that moved linearly within the coil to generate electricity when shaken. Once disassembled, the magnet was attached to a rod, which was anchored to a buoy made from an exercise foam roller. The buoy was held in place with a linear bearing, which controlled the buoy's motion, restricting it to only moving vertically. The copper coil was integrated above the magnet in a stationary position, allowing the magnet to move freely through the coil. When waves were created, the buoy would rise up and down, moving the magnet and therefore generating current. While the voltage generated was less than a volt, the design was replicable for scaling up to a larger size, something important for the second phase of this project.

Phase 2:

The second year of the project was intended to explore the linear buoy wave generator further and create a design capable of working in a real ocean environment. Throughout the design phase, various gauges of copper wire, along with different sizes of magnets, were tested. The experimental tank, which was built the year before, was also upgraded, this time using an automated reciprocating mechanism. The consistency of the new testing environment enabled more reliable experimentation.

The working law behind the design is Faraday's Law of Electromagnetic Induction. Faraday's equation calculates that the magnitude of EMFs generated is proportional to the product of the number of turns of the coil and the change in magnetic flux over time (Kingman 596). This mathematical relationship guided the experimentation. Magnetic flux refers to the strength of a magnetic field; the stronger the magnet, the greater the magnetic flux. With a higher amount of copper coils, the number of rotations is greater, resulting in stronger EMFs. The measure of time in the relationship is directly related to the wave frequency in the design. As waves act upon the buoys more frequently, the time at which the magnetic flux is altered is reduced, thus increasing the magnitude of EMFs generated. Faraday's law reveals the key factors in generating a larger value of EMFs to be the magnet strength, speed, and the number of coils in the design.

In all of the experimentation, grade N52 neodymium magnets were used, the strongest magnets readily available. The first coil used 18-gauge copper wire with a medium-sized N52 neodymium magnet. This proved to work inefficiently as the large thickness of the wire prevented the design from having enough rotations to harness large amounts of electricity effectively. In the second iteration, the 30-gauge wire generated significantly more power but was too fragile. After over twelve failed coils, 26-gauge copper was shown to be the most effective in balancing durability with power generation. Each coil used a one-pound spool, which was wound using a jig created from wood and an electric drill to speed up the process of winding over 2000 ft of copper.

Photo 4: Depicted are the many failed attempts to create an effective coil, experimenting with different gauges and lengths of wire.

Each coil with a pound of 26-gauge copper wire and one in N52 neodymium magnet generated around 1 to 2 volts when placed in the testing tank. The design was replicated three more times to increase the project's energy output. In total, nearly nine thousand feet of copper wire were used in the design. All four harvesters were wired in series, resulting in a higher voltage output. This was accomplished by wiring the end of one coil to the beginning of the next, effectively making all four coils one long continuous circuit. When wiring all four harvesters, it was essential to ensure that each coil was wound in the same direction to generate a consistent energy flow direction that did not oppose neighboring generators.

Each magnet was attached to a rod that was anchored to a foam roller cut out, which acted as a buoy. All four linear buoy harvesters were placed along the length of the tank, oscillating individually in response to the simulated wave motion. The result was four harvesters working simultaneously, rising and falling with the water directly below the mechanism. When measured with a multimeter, the voltage generated in the tank varied from eight volts to fourteen. However, the electricity being generated was alternating current, meaning that the direction of the energy would switch depending on whether the magnet was rising or falling.

According to Lenz's Law, the direction of the current induced in a coil opposes the magnetic flux produced (cite). As the magnet rises with the water level, the magnetic field moves up through the copper coil, leading to EMFs moving in the opposite direction of the magnetic flux. Contrarily, as the magnet moves downward, the change in the movement of the magnetic flux causes the current to oppose its previous direction. When testing the wave generator with LED lights, the alternating current was demonstrated by wiring a circuit where the lights were equally distributed with opposite polarities. As current would flow in one direction with the rising of the wave, one half of the LEDs would light. As the wave would fall, flipping the current direction, the other half of the LEDs would be turned on. While fascinating, most devices require direct current.

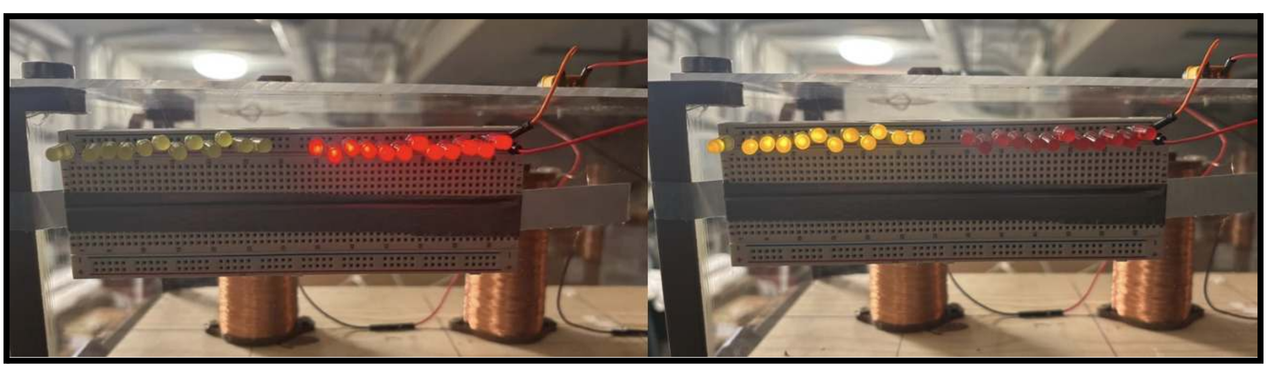

Photo 5: Above, the LEDs are wired with opposing polarities. When current flows in one direction, the red LEDs light up.
Photo 6: When the current direction switches, the yellow LEDs light up.

Diodes are one-way gates for electricity. Even just a diode can be used to convert alternating current into direct current to power low-power circuits. However, there are drawbacks to such a simple rectifier, as it leads to peaks of current rather than a consistent energy flow. Every time the diode limits current flow from one direction, energy is cut off, causing a pulsating effect (Hutsich 2).This effect can be avoided by the use of a full bridge rectifier, which uses four diodes that reverse energy to continuously flow in the same direction, even when it flips (Hutsich 2). With the use of a full bridge rectifier, the displayed current no longer flipped from negative to positive on the multimeter. The output current did slightly reduce by about twenty to thirty percent. This reduction was optimized by choosing a diode with the lowest possible forward voltage drop, which measures the amount of voltage lost when converting current direction.

Another way to convert to direct current while also increasing voltage output involves the use of a Walton generator. A Walton generator uses diodes to charge capacitors to create a greater output voltage. This works by wiring multiple half-wave rectifier diodes with capacitors in series to move current in a given direction to charge multiple capacitors at once, which can be used simultaneously to produce a greater voltage. The wiring of components is shown in photo 3 below (Park 2). However, the greater magnitude of voltage comes at the cost of a reduction in current. The design was made using a breadboard wired with four diodes and four capacitors, shown in photo 4 below. When a Walton generator was added between the generator and the multimeter, the voltage nearly doubled while the current was drastically reduced.

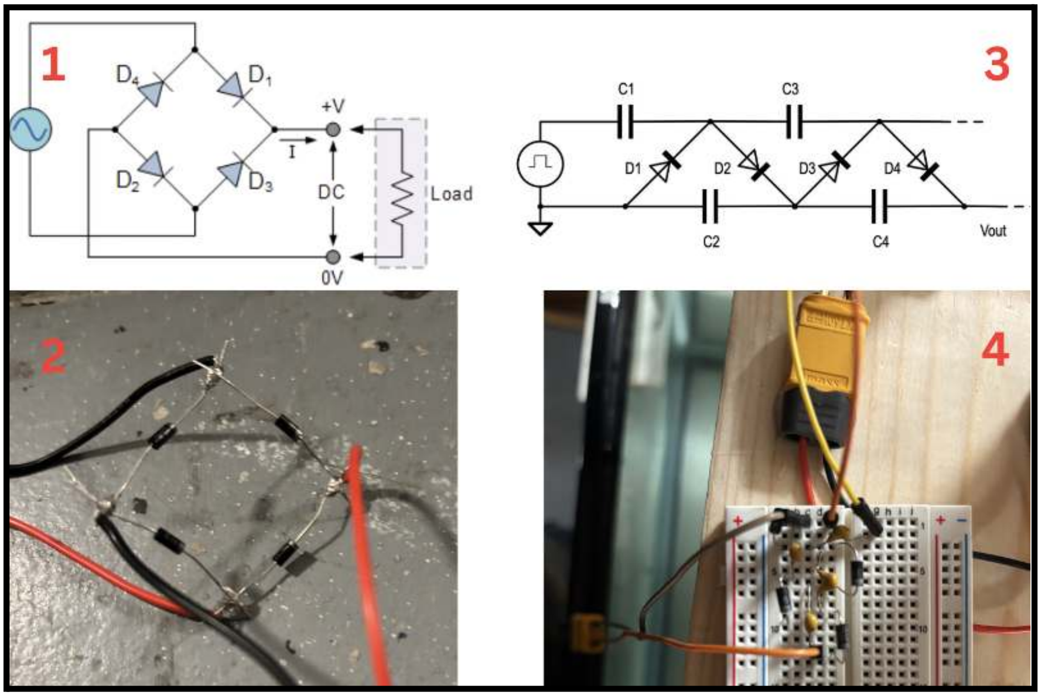

Figure 2: Section (1) shows a diagram of a full bridge rectifier. The letter D refers to diodes with the direction of the current flow indicated by the position of the arrow. Section (2) is a picture of the full bridge rectifier that was built and used. The black components are the diodes. Section (3) depicts a diagram of a Walton generator. The letter D refers to diodes, while the letter C refers to capacitors. Section (4) displays a picture of the Walton generator that was made on a breadboard. The yellow pieces are the capacitors, while the black pieces are the diodes.

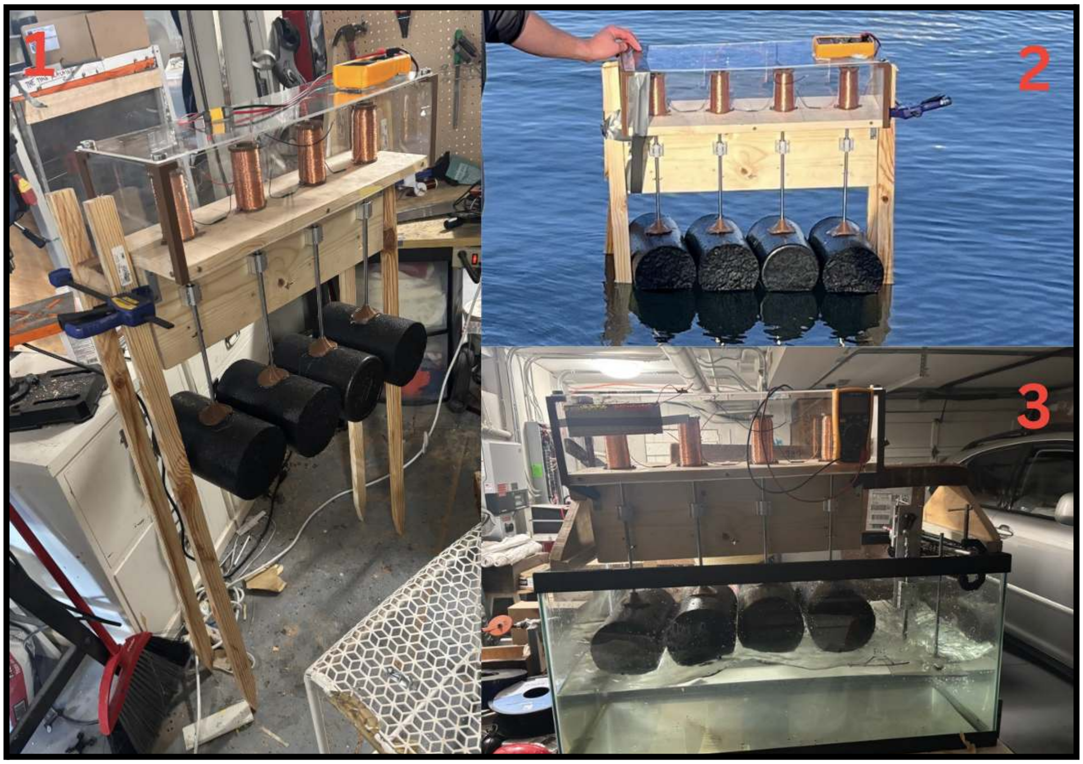

Figure 3: Section (1) displays the system integrated on top of wooden stakes that could be anchored into the ground. Section (2) shows the generator placed in San Francisco's Crane Cove to undergo testing. Section (3) depicts the same generator placed in the testing environment for a more convenient demonstration.

Using wooden stakes that were attached to a rectangular piece of plywood, the four-part energy harvester could be anchored above the water to be tested. This contraption was placed on the beach of Crane Cove in San Francisco. The design was tested around 5 pm for around 30 minutes. At this time, the water movement was very minimal. This caused the buoys to have a small range of motion and generate less power than in the controlled tank environment. The height of the waves was less than an inch and had a wave frequency of three seconds. This frequency was much slower compared to the testing tank, with water slowly surging towards the shoreline rather than quickly passing under buoys. In the bay, the design only generated around 10% of its performance in the tank.

To measure and analyze the performance of the harvester, three trials of each scenario were recorded to find the mean voltage and current under various conditions. Each trial lasted fifteen seconds, and the displayed voltage and current were recorded every three seconds. Using a total of 15 values, the average voltage was calculated for each scenario. The scenarios included three averages from the testing tank, using no rectifier, a full-bridge rectifier, and a Walton generator. The fourth scenario of measurement was in the bay using the wooden anchoring contraption with no additional rectifying device.

Results

	In a tank, alternating current	In a tank with a full bridge rectifier	In a tank with a Walton generator	Generator in the bay
Mean Voltage	-4.2 V, + 4.3V	+ 3.6V	+ 7.1V	-1.4V, + 1.5V
Max Voltage	-6.9V, + 7.1V	+ 5.2V	+ 12.2V	+ 1.9V
Mean Current	620 mA	480 mA	200 mA	190 mA

Table 1: Portrays the results from several different experimental designs, listing mean voltage, max voltage, and mean current

In the experimental tank, the linear buoy harvester generated a range of approximately 3 to 7 volts, measured by a multimeter. The current generated had a mean value of 620 mA. The output fluctuated in polarity when plugged directly into the multimeter, which displayed a value that changed from negative to positive.

Watts takes into consideration both voltage and current to measure power. Watts are the product of volts and amps. When the harvest was plugged directly into the source, the mean wattage was 2.64 watts. This is enough power for small devices such as LED lights or to slowly charge a phone.

With a full-bridge rectifier integrated into the circuit, the voltage dropped from a mean value of 4.2V to 3.6V, but no longer fluctuated between negative and positive values. The current also dropped to 480 mA. The overall power loss that results from using the rectifier is because diodes have a minimum forward voltage to direct current, meaning that some power will always be lost when converting from alternating current to direct current. This loss can be minimized by using diodes with a lower forward voltage in instances where power generation is low, such as for a project at this scale. The full-bridge rectifier resulted in an output power of 1.73 watts.

When rectified with the Walton generator, the voltage increased to a mean of 7.1 volts, with sporadic peaks exceeding 12 volts. However, the current dropped significantly to only 200 mA. The Walton generation involves both diodes and capacitors, which creates more resistance. The Walton generator increases voltage at the expense of current by charging multiple capacitors simultaneously for their shared use. The resulting wattage using the Walton generator was an average of 1.42 watts.

Finally, the design was placed in the bay. With a small range of motion and low wave frequency, the wave energy harvester generated an average of -1.4 V and +1.5 V, along with a current of

190 mA when directly plugged into the harvester. These values were much lower compared to the testing tank, showing how significant wave pitch and frequency are in impacting the linear buoy design.

Discussion

The linear wave buoy harvester demonstrates a scalable approach to generating electricity from wave motion. While the output values were low for formal applications, it was significant for a design of such a small scale, which suggests considerable potential for integrating wave energy harvesting in larger applications. If scaled to a larger size, the WEC could have numerous practical applications, especially in urban waterboarding areas such as San Francisco. The expanded design could power lighting or security systems powered by integrated energy harvesting systems.

In the experiment, there was a significant performance drop when moving the harvester from the tank into the bay. On the day of testing, the wave height was low, along with the wave frequency. The conditions show how wave energy, while consistent, still fluctuates significantly based on conditions. To compensate for the different wave oscillating heights and frequencies, the strength of the magnet could be increased to induce a greater force of induction for a slower-moving system, increasing the overall power generated. Other methods to improve adaptation involve altering the height of the coil to compensate for changes in wave pitch. If wave energy systems are created with adaptability and tailored to the specific ocean environment in which they are implemented, they will have significant success. Wave motion is always present to some level. While power generation may be lower under certain conditions, it will still always have some level of generation, unlike wind or solar will fully stall when wind and sun are not present.

Another drawback that must be addressed is the corrosive nature of seawater. To avoid interfering with sea life and create robust designs, corrosion-resistant material should be used to prevent damage. It is also essential to consider designs that will not be tampered with by sea life or cause harm to other animals. Both of these challenges can be managed by a design that integrates with the environment.
The design's modularity shows significant room for expansion and implementation in various landscapes. Each coil and buoy functions independently, allowing simple repair along with the ability to expand horizontally. The design also has the potential to be placed out of sight, such as integrated discreetly below a doc. In cities like San Francisco, where on-site energy harvesting is limited to rooftop solar panels, wave energy provides a more consistent and comparable alternative option. Wave energy harvesters have the potential to transform modern energy systems, especially as the energy grid system becomes more adapted to renewables.

Conclusion

The two-year wave energy project has demonstrated a low-cost, small-scale linear buoy harvester equipped for scalability and modular expansion in water bordering areas. The discrete design of the linear buoy harvester under docks appeals to urban environments such as San Francisco, offering an effective power source in coastal regions. The device could be implemented in grid systems or used directly for dock lighting, security systems, and other coastal infrastructure. While the challenges of corrosion and wave fluctuation must be addressed, implementing adaptable energy harvesting technology along with site-specific alterations could overcome such hurdles. With less than one percent of potential wave energy being exploited, harnessing ocean energy is a necessity to meet global energy demands sustainably. Wave energy compensates for the challenges associated with expanding wind and solar, enabling the ability to work in tandem with solar and wind, stabilizing renewable energy production. As the climate crisis accelerates, policymakers, engineers, and communities must recognize how wave energy could be the future of renewables and transform coastal living.

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