Harnessing the Power of the Ocean: an Efficient and Portable Wave Energy Converter

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ENGINEERING GOAL

The goal of this project to design and build a small-scale device that generates electrical energy from the force of ocean waves.

Purpose

The device is designed to **help people who do not have access to electricity**, for reasons such as natural disasters, rural locations, wilderness, and poverty.

Design Criteria

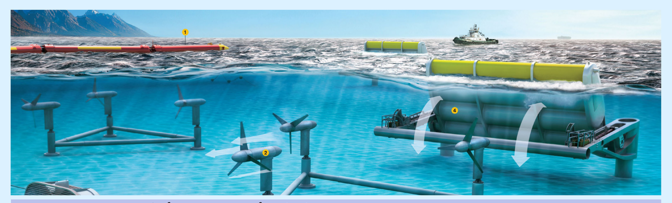
1. **Efficient:** able to supply power to basic needs such as light & radio
2. **Durable and Waterproof:** able to withstand the harsh ocean environment
3. **Practical & Coastal:** simple to use, easy to transport, and used on the coast

Design Constraints

1. **Cost:** under $50 for one unit
2. **Dimensions:** under 50 x 50 x 50 cm and below 5 kg
3. **Usability:** for **safety & ease of use**, the user shouldn't have to enter the ocean

BACKGROUND

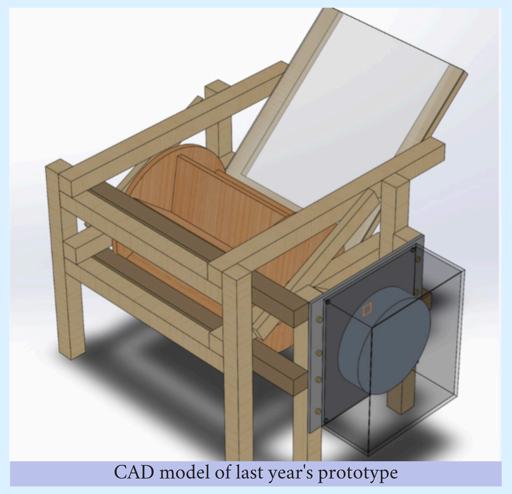
Wave energy is one of the **most significant natural resources** and has HUGE potential. Unlike solar or wind power, **waves are reliable and rarely cease**. However, wave power is far behind other alternative energy due to the **harsh conditions of the ocean** and technical challenges. The U.S. Department of Energy estimates that wave power could generate 1,170 terawatt-hours per year in the US - over 25% of US energy consumption. Current wave power advances are all **extremely large scale power plants**, like high-pressure hydraulic bouys in the middle of the ocean, and submerged tidal turbines.



A few types of existing wave energy converters

Last Year's Project

The previous device was based on a river hydropower turbine but adapted to the ocean. It did work, but it had many problems.



CAD model of last year's prototype

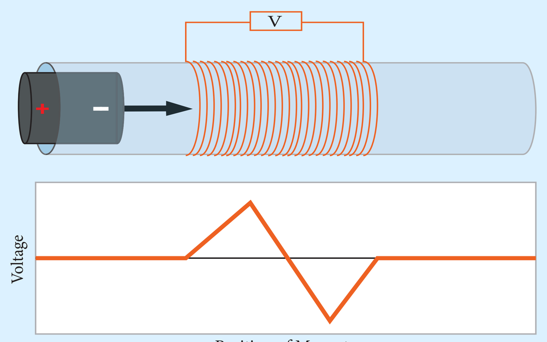
Last year's prototype at the ocean

1. **Inefficiency:** only used waves of a specific **height** - resulted in infrequent energy spikes
2. **Complexity:** nearly impossible to waterproof because of the alternator's rotating shaft, heavy and hard to transport
3. **Anchoring:** hard to safely anchor in the sand, constantly had to be re-anchored because of changing tides. A huge wave almost made it float away.

DESIGN

New design concepts were tested to address previous problems. After many failed designs, floating algae and a shake-to-light-up toy inspired a switch to a magnet and coil design.

How it Works



Faraday's Law

$$Emf = -N\frac{\Delta\Phi}{\Delta t}$$

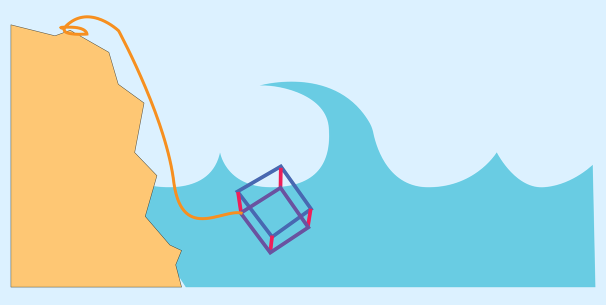
$Emf = \Delta V$
N = number of turns
Φ = flux = magnetic field × wire area
t = time

- The N/S magnet poles induce a current
- Wire turns, area and magnet strength, and speed increase voltage

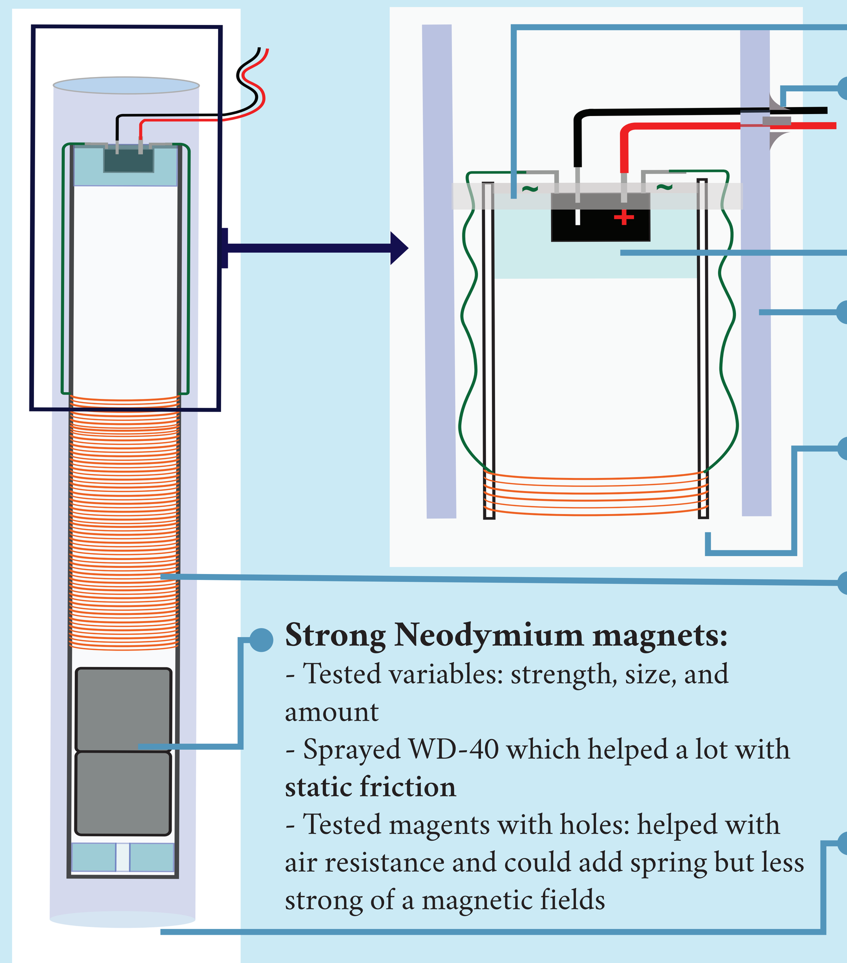
Design Advantages

This concept has fixed almost every problem from last year's prototype.

1. **Efficient:** all types of waves cause the magnet to slide around. This concept would efficiently capture all of the ocean's random, chaotic waves
2. **Simple design:** much easier to waterproof, with fewer moving parts and better durability and transportability.
3. **Anchoring:** freely floats around, attached to only a cord going back to land. The user can just **throw it off a cliff and energy would start generating within seconds.**



COMPONENTS & DIAGRAM



Waterproofing electrical wires:
- Holes: coated inside of hole with plastic bonder, outisde with marine epoxy
- Connections: soldered, zip-tied, coated in epoxy, and taped down

PVC Pipes:
Pros - strong tubes and PVC cement
Cons - too thick; **magnet strength decreases exponentially with distance**
Solution: I found super **thin (and weak) plastic tubes** and nested them inside of PVC

Coils:
- Used thin magnet wire
- **Tested variables:** AWG (thickness), turns, and distance on tube, configuration
- Used **~5845 turns of 38 AWG wire (26 grams) per coil**

Strong Neodymium magnets:
- Tested variables: strength, size, and amount
- Sprayed WD-40 which helped a lot with **static friction**
- Tested magents with holes: helped with air resistance and could add spring but less strong of a magnetic fields

Endplugs:
- Made with acrylic plastic rod and glued with epoxy
- Minimized magnet air resistance with a through hole

Hot glue barrier:
- Secures inner tube and prevents short circuits (used bouncy balls for this on prototype 3.1)

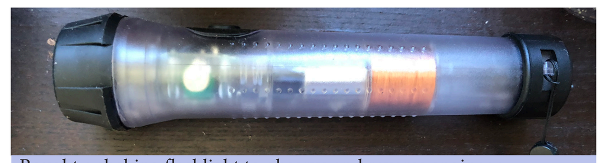
Bridge Rectifier
- When the magnet slides in [positive V], slides out [negative V] - **results in alternating current (AC)**
- Used a rectifier after **every coil,** converted to DC

Cube configuration:
- Strong and simple, 12 edges total - 12 tubes & coils
- **4 tubes in each direction: X, Y, and Z**
- Captures energy of all types and directions of motion, and magnets repulse at corners

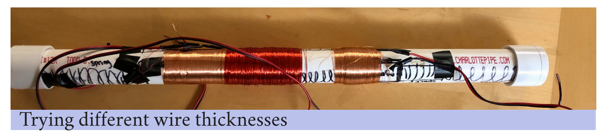
Wooden sail panel configuration

Pool noodles for durability

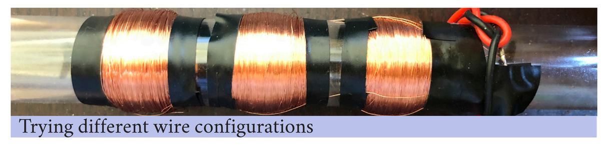
Making Coils



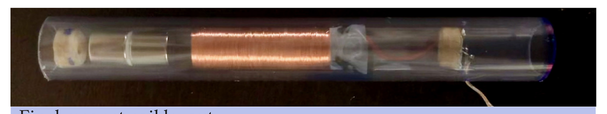
Bought a shaking flashlight to observe and reverse engineer



Trying different wire thicknesses



Trying different wire configurations



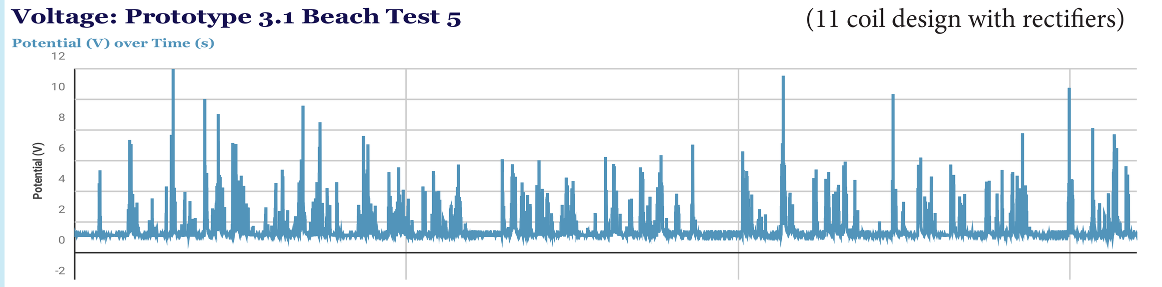
Final magnet coil layout

Prototype 3 ready at the beach

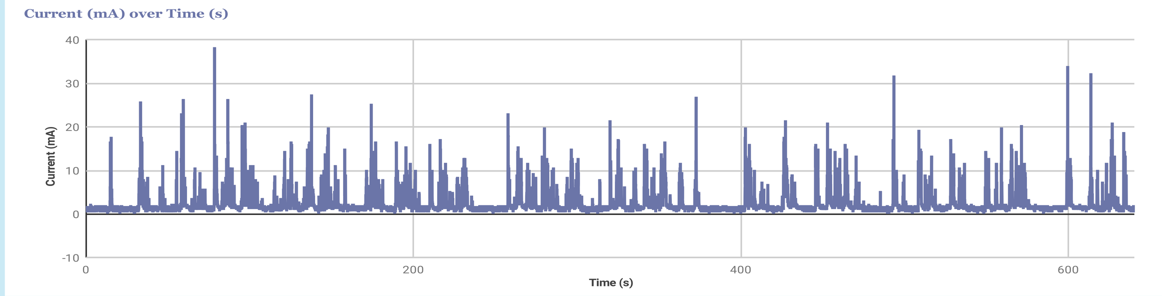
Underwater camera view: prototype 2

RESULTS: Prototype 3.1 vs. Prototype 1

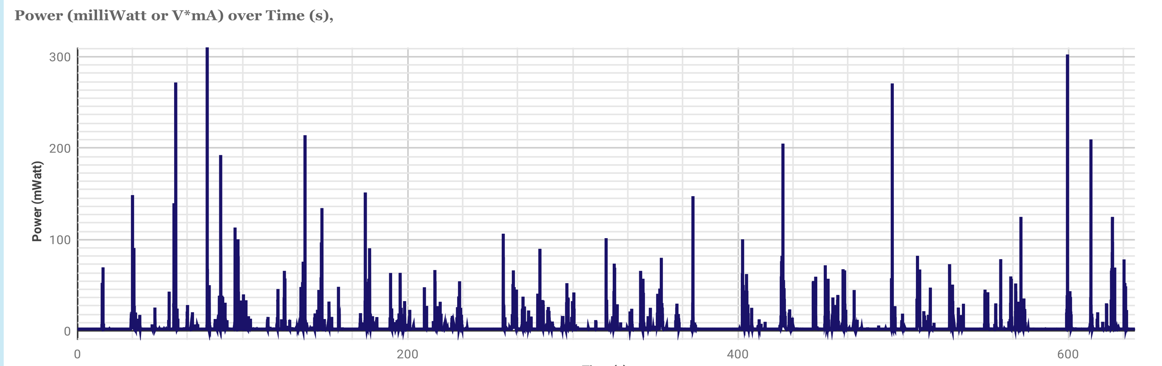
Voltage: Prototype 3.1 Beach Test 5 (11 coil design with rectifiers)



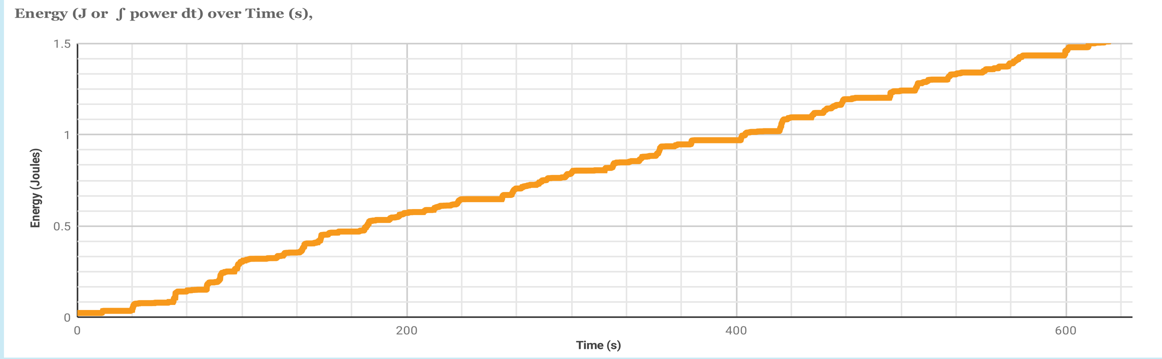
Current: Prototype 3.1 Beach Test 5



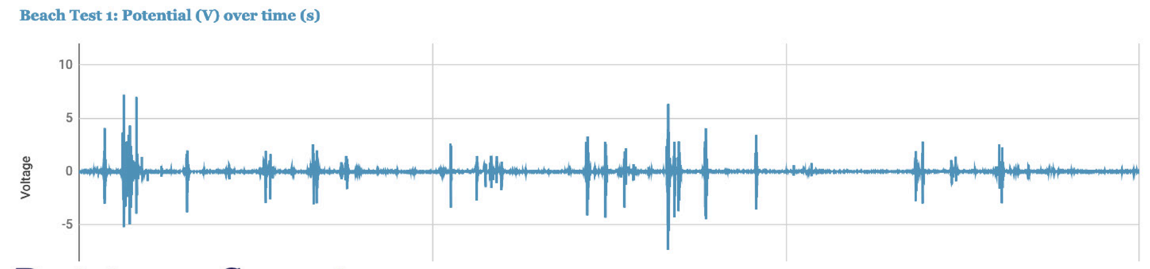
Power: Prototype 3.1 Beach Test 5



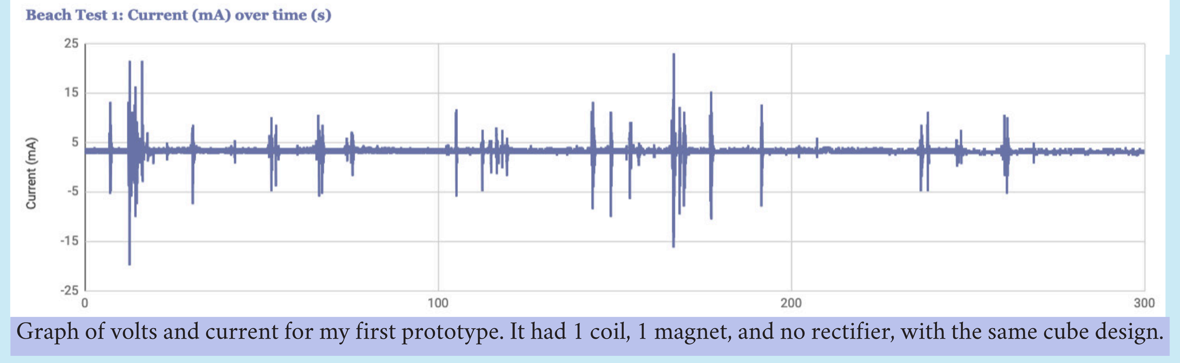
Energy: Prototype 3.1 Beach Test 5



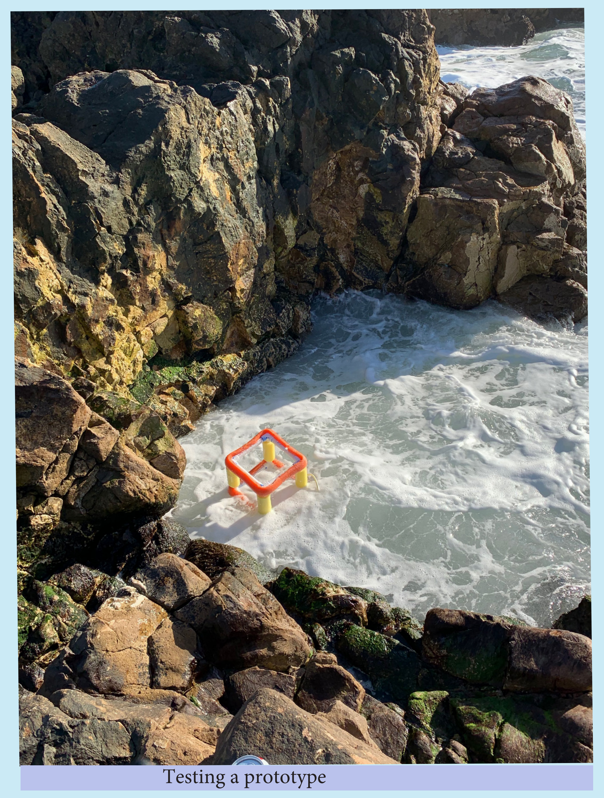
Prototype 1: Voltage



Prototype 1: Current



Graph of volts and current for my first prototype. It had 1 coil, 1 magnet, and no rectifier, with the same cube design.



Testing a prototype

Soldering a lot of coil connections

TESTING METHODS

- Location: Pescadero Beach on a rock
- Sat on a rock, threw prototype off
- Measured using a Vernier Labquest Analog-Digital converter & Logger Lite
- Recorded 20 times per second
Volts & Amps with a ~5Ω resistor
- Used Volts and Amps to calculate Watts and Joules
- Final Testing Day (Beach Test 5): Measured for 15 min, a total of ~18000 data points

Prototype 2 & measuring box

ANALYSIS

- 1.5 Joules in 10 minutes. Overall, 11 Joules per hour
- Peak: 11 Volts and 35 milliAmps
- Continuously functioned for over 15 minutes in high surf
  - Survived being thrown off a rock and pulled back up
  - Completely waterproof in the harsh ocean environment
- Observation: the more frequent smaller "twisting" motion was the source of most of the energy, not the big spikes

CONCLUSION

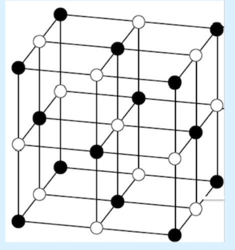
Prototype 3.1 of the "Wave Power Cube" has met the engineering goal, criteria, and constraints.

- ***Efficient:*** can easily power multiple LED lights, a radio, and other essentials
- ***Durable:*** withstood the harsh ocean environment - massive waves, corrosive saltwater, sharp rocks, and sand
- ***Practical:*** weighed about 1 kg and was under 30x30x30 cm - easy to transport
- ***Safe and easily usable:*** no need to enter the ocean or get wet, just throw it over a cliff and wait for the energy to come!
- ***Easily scaled up and mass produced:*** each unit is simply replicable, and multiple units can be attached together, or one device can be enlarged or extended

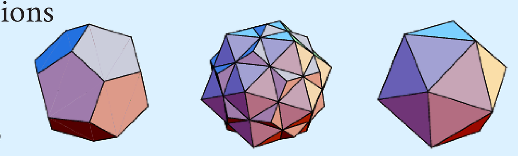
Overall, the "Wave Power Cube" successfully converted the chaotic and powerful ocean waves into usable electricity, in a practical way that can help people.

Next Steps

In the **near future**
- Test in different locations & wave conditions
- Charge a battery from AAA to phone battery and test for longer
- Test new sail panels and continue to refine them



Next prototype iterations
- **Different formations instead of just a cube:** Lattice, decahedron, allows for smaller units in more directions
- **Long cord** to throw off of a real cliff
- Battery that charges directly from the prototype
- **Weaker magnets** for a better cost-efficiency ratio



Acknowledgements

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