2025 Marine Energy Collegiate Competition

Initial Design Report

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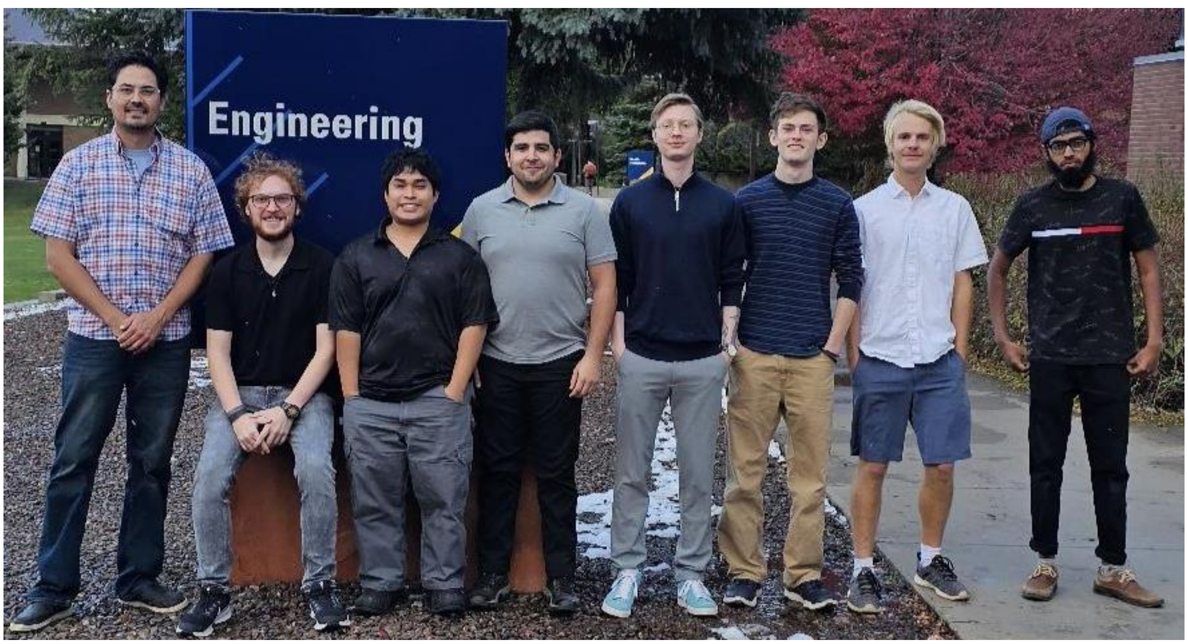

Project Sponsor: Department of Energy

Faculty Advisor & Sponsor Mentor: Carson Pete

Instructor: David Willy

DISCLAIMER

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EXECUTIVE SUMMARY

The Marine Energy Collegiate Competition (MECC) is a competition hosted by the Department of Energy's Water Power Technologies Office (WPTO) and facilitated by the National Renewable Energy Laboratory (NREL). The 2025 competition is comprised of 23 college teams from schools from across the nation. The purpose of the competition is to "… inspire students to innovate in and accelerate the merging marine energy industry" [1]. The competition will facilitate networking between current marine energy companies and the teams enrolled in the competition. Networking with industry professionals is done to provide more information about the potential career opportunities available to students and to gain insights into the potential of marine energy. The competition consists of four required and concurrent challenges and two optional challenges. The four required challenges are, a business plan, a technical design plan, a build and test report and a community connection challenge. The two optional challenges are a poster presentation and a 90 second quick pitch at the final competition.

The competition has a cash prize pool of $480,000. The competing teams that meet all deadlines will be eligible for up to $20,000 in total cash awards and will compete for a part of the $20,000 grand prize cash pool [1]. When accepted to compete each team will receive $5,000 to be used for the competition totaling in $115,000. Then each submission stage each team that submits and are accepted will receive an additional $5,000 again totaling $115,000 for all the teams. The submission stages are the application, January submission, February submission and final event a detailed table can be seen in **Appendix A.2.10**. The overall top three winners of the main four challenges will split the final prize pool of $20,000. The specific amounts for first, second and third place have yet to be announced. The four main challenges will be judged by a panel of NREL and WPTO employees at each submission stage and the final event. The two optional challenges will be judged by the attendants of the final competition by popular vote. The team that earns the highest score in any one of the challenges will receive a trophy. This includes the winners of the best poster and best quick pitch. There is also an additional Rookie of the Year Award which is a trophy awarded to the lead institution that is competing for the first time with the highest combined score.

The design our team has chosen can be seen in detail in section 4 of this report. The design is like a yo-yo where there will be a wire wrapped around a cylinder that when a wave moves the cylinder up the wire will want to unravel, spinning the cylinder. Inside the cylinder will be a planetary gear system, sprag bearings and fly wheel all working together to spin a generator. In talking with the team's advisors, the internal gearing mechanism has started to come together. The team is still working on the design and feasibility of the internal gearing and will be prototyping different systems to test different ideas. The testing plan for this device will include sensors in the internal cylinder that will gather data on acceleration and revolutions. These data points will be used to determine how much power could be produced from the different gearing systems. After prototyping a full-scale design will be created and tested at a towing tank provided by our industry mentor Leixin Ma, a professor at Arizona State University. Overall, this project is a way to build the future generation and test their knowledge so that they can grow. Our design will test us, and we have already learned a lot about mechanics and renewable energy.

Table of Contents

1 BACKGROUND

This chapter establishes the foundation for our capstone project, framed by the guidelines of the Marine Energy Collegiate Competition (MECC) and NAU's capstone course. Our problem statement, aligned with the MECC's core objectives, reflects the Water Power Technologies Office's (WPTO) goal of raising awareness about marine energy's potential to support a clean energy future. By examining the deliverables, we identify key milestones that guide our project's development, organizing them into tasks specific to the competition, client, and course. Additionally, we define the success metrics—rooted in competition criteria—that will ultimately determine the project's achievement.

1.1 Project Description

The Marine Energy Collegiate Competitions goal is to inspire the future generation of renewable energy innovators through six different challenges. A business challenge where we are tasked to identify a space in the blue economy market that our marine energy device could fill. Where the blue economy is the exploitation, preservation, and regeneration of the marine environment as defined by NREL. As well as a risk management strategy and a financial analysis. The business challenge also needs three end user interviews of people in the blue economy. These interviews are to ask about the blue economy and how our device will fulfill the needs of the end users. There will also be a final report write up for the competition on the business plan.

A Technical Design Challenge tasks the team with evaluating the performance and market potential of their product within the blue economy sector. This includes not only a thorough assessment of the product's functionality and efficiency, but also its alignment with current market demands and sustainability goals. As part of the challenge, the team must identify and engage with at least three potential end users, ensuring that these individuals or organizations represent key stakeholders who would directly benefit from the product. By conducting interviews, the team will gather valuable insights into user needs, preferences, and potential areas for improvement. In addition to these interviews, the team is expected to analyze the feedback and integrate it into their design refinement process. This ensures that the final product is both technically sound and meets the practical needs of its intended audience. A comprehensive final report, summarizing the design process, user insights, and market positioning, must be prepared and submitted before the competition deadline. This report will serve as the culmination of the team's efforts, providing a detailed account of their technical and market evaluations.

A Build and Test Challenge is designed to give our team the chance to express why we tested our design the way we did. The final report needs to include a clear description of the scaling factors considered while fabricating the model scale device. A description of the experimental test plan and how the experiment was conducted. The experiment results should be compared to the experiment goals to validate whether the experiment was successful. As well as a description of how the experimental raw data was postprocessed to be usable for analysis. After the experiment there should be a summary of lessons learned and what modifications could be done in the future.

A Community and Connections Challenge is a way to develop future generations and inspire them to pursue renewable energy. There are three required interviews with people in the marine energy industry. From these interviews the goals the team aims to achieve, the market that they are addressing, and an overview of the design should be addressed. The information gained from the interview should be summarized in a final report. Combined with the interview is a community outreach section, where the team informs the community in some way. This can be up to the team as to what they do but some suggestions are something like a K-12 curriculum awareness or a technology demonstration.

As well as a poster presentation that will be judged by popular vote at the final competition. The poster will summarize the four main challenges above. There will also be a 90 second quick pitch about the project and its success. The quick pitch will also be judge by popular vote of the final competition attendants. The budget for this project is the awarded $5,000 for each submission stage totaling $20,000. Most of these funds will be used for travel expenses for networking events and the final competition. The remaining will be used on materials for our project. For fundraising our team needs to fundraise $2,000. We will be setting up a Go Fund me to try and reach this goal as well as taking testing device donations from our industry mentor Leixin Ma.

1.2 Deliverables

Our project deliverables are organized into three distinct categories: competition-specific, client-specific, and course-specific. These deliverables ensure a cohesive integration of our academic requirements, the needs of our client (The U.S. Department of Energy), and the goals of the competition. They also serve as key milestones to track and guide our project’s progress. In this section, we outline these deliverables, providing a structured framework for the successful execution of our capstone project.

1.2.1 Course Deliverables

Our academic course includes a rigorous set of deliverables designed to assess both our progress and understanding of project management and execution. These deliverables ensure that we stay on track and demonstrate our ability to meet the course's high standards of performance. The key requirements include:

1. **Staff Meetings:** Regular meetings to discuss project updates, challenges, and proposed solutions, ensuring alignment with course objectives and milestones.
2. **Oral Presentations:** Scheduled presentations to instructors and peers, showcasing the project's progress, outcomes, and final conclusions as part of the academic evaluation.
3. **Written Reports:** Comprehensive reports detailing the research, methodologies, findings, and recommendations, demonstrating in-depth understanding and academic competency.
4. **Timecards:** An excel sheet keeping track of the time spent working on capstone deliverables. This is to keep every team member accountable for their time and to keep track of effort into the project.

1.2.2. Client Deliverables

These deliverables are specifically designed to align with the expectations and requirements set by our Faculty Advisor, Carson Pete. As a key figure in the success of our project, the Faculty Advisor plays a vital role in not only supervising the team but also guiding us through each phase of the course and the competition. His involvement ensures that we remain focused on our goals, adhere to the necessary guidelines, and maintain a competitive edge. Key responsibilities include:

1. **Regular Team Updates and Meetings:** The team will hold regular meetings with the Faculty Advisor to present project progress, discuss challenges, and receive feedback and guidance.
2. **Advisory Support:** The Faculty Advisor will offer support to help the team develop essential skills for effective competition in all aspects of the project.
3. **Guidance on Compliance:** The Faculty Advisor ensures the team's activities and deliverables comply with the competition's guidelines and requirements.
4. **Communication Liaison:** Acting as the primary point of contact between the team and the competition's Prize Administrators, the Faculty Advisor will facilitate clear and timely communication.
5. **Decision-Making Assistance:** The Faculty Advisor will provide insights and advice to help the team make informed decisions related to project development, challenges, and competition strategies.
6. **Project Planning Input:** The Faculty Advisor will offer input on project planning, budgeting, and fundraising, ensuring the team stays aligned with both course and competition goals.

1.2.3 Competition Deliverables

The Marine Energy Collegiate Competition (MECC) presents a series of challenges, each requiring distinct deliverables that are integral to our overall performance. These deliverables are divided into midyear submissions and final presentations for the respective challenges. Below is an overview of the key deliverables for each challenge within the competition:

1. **<u>Technical Design Challenge:</u>**
    a. **Midyear Submission**: The midyear submission will consist of a one-page report outlining the blue economy market selected by the team, including the rationale for this choice and a brief overview of the key issues the team intends to address.
    b. **Final Report**: The final report will include a cover sheet with team member information, an executive summary of the project, and a detailed narrative describing the technical design challenge.
2. **<u>Build and Test Challenge:</u>**
    a. **Midyear Submission**: The team will submit a one-page report detailing the project's process and outlining the key testing objectives.
    b. **Final Report**: The final report will include a cover sheet with team member information, an executive summary of the project, and a comprehensive narrative describing the project's design, build, and testing phases.
3. **<u>Business Challenge:</u>**

   a. **Midyear Submission**: Teams will provide a detailed team roster, including team members' names, email addresses, roles within the team, academic year, hometowns, declared majors, and contact information for faculty advisors from partnering institutions.
   b. **Final Report**: The final report will include a cover sheet with team member details, an executive summary of the project, and a comprehensive narrative outlining the project's design, build, and testing process.
4. **<u>Community Connections Challenge:</u>**
   a. **Early Midyear Submission**: Teams will provide a concise overview of their team and project, detailing the technology concept, as well as key learnings from previous experiences.
   b. **Interview & Outreach**: The team gathered valuable insights from interviews, defined their outreach objectives, discussed industry partnerships, developed a comprehensive social media strategy, and created timelines for event planning and promotion, adhering to specific formatting guidelines for reports, including image and caption standards.
   c. **Final Report**: The final report will include a cover sheet with team member details and a comprehensive summary of the Interview & Outreach methods employed.

1.3 Success Metrics

The success of our project depends on learning the functionality of energy conversion from the ocean. As well as the rigorousness of our testing procedure to make sure there is plenty of data on our design to prove if it was effective or noneffective. These data points will be compared to the benchmarks and explained how our design exceeds, meets or falls below these standards using the engineering requirement is the House of Quality (QFD). Another success metric will be the effectiveness of our community connections challenge. If what we accomplish spreads awareness and advocates for renewable energy to a wide range of people, then the community connection challenge will have been a success. The business challenge will be a success if the identified market and end users would benefit from our design in a way that other designs would fall short.

2 REQUIREMENTS

As we advanced with the project, our team identified key project requirements, particularly those aligned with the completion deliverables. These requirements—such as energy output and cost efficiency—serve as the technical benchmarks necessary to meet both the customer’s expectations and competition standards. In Section 2.3, we introduced the House of Quality (QFD), a crucial tool for analyzing the relationship between customer needs and engineering specifications. The insights gained from these sections underscore the vital importance of our requirements, emphasizing their role as the foundation of our project’s success.

2.1 Customer Requirements (CRs)

In alignment with the guidelines established by the Marine Energy Collegiate Competition (MECC), the team conducted a thorough review of the rules pertaining to both the Technical Design Challenge and the Build and Test Challenge. This meticulous examination allowed the team to identify a set of essential customer requirements that are crucial for ensuring the project's success. By analyzing the competition criteria in detail, the team aimed to capture the expectations and needs of stakeholders effectively. The following key customer requirements have been determined as integral to the overall project design and implementation:

- **User Safety**: The product must undergo a safety inspection by the MECC administration. Our goal is to design a device that ensures user safety, both for residential and commercial markets, with remote and autonomous shutoff capabilities for added protection.
- **Design Presentation**: Marine energy converters come in various forms, each with its own strengths and weaknesses depending on the mechanical design. Our device will be tailored to balance these characteristics, highlighting our design's advantages.
- **Cost Efficiency**: Working with an initial budget of $20,000, where approximately half will be allocated for travel, our design must remain well under budget while maintaining high energy conversion efficiency.
- **Environmental Safety**: Protecting marine life is a priority. The generator must minimize harm to the environment, a critical factor in whether the device is deemed fit for marine deployment.
- **Aesthetic Appeal**: Given the proximity to coastlines and tourist-heavy areas, the device's visual impact is important. A design that detracts from the natural beauty of the ocean could negatively affect local economies, so we aim for an aesthetically pleasing solution.
- **Adaptability Across Climates**: Per the Build and Test Challenge, the device must be tested in at least six different operational environments. This ensures it can function efficiently in various climates and regions around the world.
- **Ease of Manufacturing**: With strict deadlines for delivering the final product and documentation, it's crucial that the device is simple to manufacture, allowing the team to meet all competition requirements.
- **Grid Integration**: The generator must be designed either for seamless integration into the public power grid or for use with a remote battery system that requires minimal maintenance.

These customer requirements outline the primary objectives of the project, acting as a strategic roadmap for achieving the expectations and standards established primarily by the Marine Energy Collegiate Competition rulebook, our Faculty Advisor, Carson Pete, and the capstone course framework. In the following sections, a comprehensive House of Quality (QFD) will be presented, illustrating the relationship between these customer requirements and the engineering requirements discussed in Section 2.2. By effectively addressing and fulfilling these requirements, the project aspires to develop a sustainable and impactful hydropower solution while simultaneously meeting academic standards and competition goals. This approach not only emphasizes the importance of stakeholder needs but also reinforces our commitment to excellence in design and execution.

2.2 Engineering Requirements (ERs)

The team conducted a thorough evaluation of various engineering requirements for this project, drawing from a diverse array of options that encompassed both the competition guidelines and specific personal considerations. This comprehensive selection process ensured that each requirement was not only aligned with the project's objectives but also reflective of the team's strategic vision. By carefully weighing the importance of each criterion, the team aimed to create a robust framework that would guide the project's development. The following engineering requirements have been identified as critical to the project's success:

- **Resistance to Marine Environment:** A significant challenge in marine energy collection is the wear and tear caused by seawater and marine life. The team will prioritize selecting materials that enhance the device's resistance to these factors and ensure the device is designed for long-term durability and ease of maintenance. Section 3.4.4B of the competition rules emphasizes the need for a highly durable and weather-resistant device.
  - **Units:** IPXX rating
  - **Target:** IPX6
- **Energy Output:** The group will evaluate the two available energy output methods—battery storage or direct grid connection—to determine the most effective option based on the device's design and application.
  - **Unit:** Watts
  - **Target:** 200W
- **Continuous Operation:** Given the near-constant activity of the marine environment, the team aims to develop a device capable of producing energy as close to a 24-hour cycle as possible.
  - **Units:** Watts per day
  - **Target:** 4800 W/day
- **Efficiency:** The team's goal is to design a device that maximizes output relative to input, aiming for high efficiency with minimal environmental impact over time.
  - **Units:** Percentage (%)
  - **Target:** ≥ 50%
- **Laboratory/Controlled Testing Compatibility:** Since Northern Arizona University's Mechanical Engineering Department has not previously participated in this or similar competitions, the team faces limited access to professional-standard testing facilities. Therefore, the device must be designed to fit within the constraints of the available controlled environments, ensuring it can be effectively tested in a lab or tank simulation.
  - **Units:** Length (cm)
  - **Target:** < 80 cm
- **Compatibility with Diverse Marine Conditions:** According to section 3.4.4A of the MECC competition rules, each device must be tested in at least six different environmental conditions. This requires the device to be versatile enough to operate effectively in a range of marine environments, from varying temperatures to differing wave intensities.
  - **Units:** Quantity of environmental resistance
  - **Target:** ≥ 6
- **Majority Use of Marine Energy:** Section 3.3 of the MECC competition rules mandates that at least 51% of the total energy system be powered by marine energy. The team may supplement

this with other renewable sources, such as solar or wind, to enhance the overall system performance.

  - **Units:** Percentage (%)
  - **Target:** ≥ 51%

- **Remote Shutdown Capability:** Section 3.4.4C of the MECC competition rules requires that the device pass a safety inspection and include the ability for remote shutdown in the event of extreme conditions or for maintenance purposes.
  - **Units:** Time (s)
  - **Target:** 2 second

These engineering requirements are not standalone components; they represent interrelated factors that are essential to the successful execution of the hydropower project. The House of Quality (QFD) will illustrate the connection between these engineering criteria and the corresponding customer requirements, providing a structured approach to assess how effectively the project design aligns with customer expectations. This framework will serve as a formal tool to ensure that the design meets both technical objectives and stakeholder needs.

2.3 House of Quality (HoQ)

In our pursuit of designing an efficient and well-structured marine generator, we have developed a House of Quality (QFD) diagram, which is included in **Appendix A.1**. This tool has provided us with key insights into the technical priorities of the engineering requirements, as they relate to customer needs, highlighting the core challenges and objectives of our project. Our initial analysis focused on evaluating the correlations between each engineering requirement and how they impact other technical criteria. By using a structured rating system—positive correlations ("+"), no correlation (blank cells), and negative correlations ("-")—we were able to determine the degree to which each requirement influences other aspects of the design. Understanding these interdependencies is essential for making informed decisions throughout the design and development process, as changes to one requirement may significantly affect others.

To quantify the relative importance of each engineering requirement, we assigned numerical values based on their associations with customer needs: strong correlations rated at 9, medium at 6, weak at 3, and none represented by blank cells. These values were calculated from the QFD analysis, reflecting the strength of each requirement's relationship to customer needs. Notably, remote shutdown capability holds the highest technical importance score of 220, underscoring its critical alignment with customer priorities. This feature addresses safety concerns, such as the need for emergency shutdowns during major storms or maintenance, which are vital to customer risk management. Similarly, marine durability ranked highly due to its direct relevance to customer expectations for longevity and minimal repair needs. Additionally, a high score for laboratory and controlled testing emphasizes the importance of the generator's volume and performance for the Build and Test Challenge.

These findings are invaluable for prioritizing technical efforts and effectively allocating resources to meet both customer expectations and competitive benchmarks. The QFD diagram not only clarifies the relationships between customer needs and engineering requirements but also guides us in setting project goals, constraints, and design targets. This structured approach will remain a critical tool for monitoring our progress, ensuring alignment with stakeholder requirements, and successfully delivering a hydropower project that meets both customer and competition criteria. As we move forward, section 3.1 will further explore benchmarking analysis, offering additional insights and validation for our design's performance and technical merit.

3 Research Within Your Design Space

3.1 Benchmarking

1. **CorPower Ocean Buoy [2]**

CorPower Ocean is a company specializing in wave energy technology, and their buoy system is designed to harness the power of ocean waves. The CorPower Ocean Buoy uses a unique phase control technology that amplifies its movement in resonance with incoming waves, increasing energy absorption. This system converts the oscillating motion of waves into mechanical energy through a combination of hydraulic and electrical systems, making it one of the more efficient wave energy solutions. The buoy is compact, durable, and capable of producing high energy output relative to its size, with a focus on scalability and minimal environmental impact. CorPower Ocean's levelized cost of energy (LCOE) is said to be roughly $32-$55/MWh for their buoy by 2030.

2. **Sea Wave Energy Limited (SWELL) [3]**

Sea Wave Energy Limited (SWEL) is a company that develops wave energy converters to harness the energy of ocean waves. Their flagship technology, known as the Wave Line Magnet (WLM), is designed as a long, flexible structure that floats on the surface of the water and moves in response to wave motion. SWEL's design is intended to be highly adaptable, cost-effective, and capable of operating in a variety of sea conditions. The system focuses on absorbing wave energy across a large surface area, which is then converted into electrical power. SWELL aims to provide a reliable and environmentally sustainable source of renewable energy. With SWELL still being fairly new, they are trying to aim for a LOCE of $100/MWh when they come on the market.

3. **Eco Wave Power [4]**

Eco Wave Power is a pioneering company in the field of wave energy, known for its innovative, shore-based wave energy conversion system. Unlike offshore solutions, Eco Wave Power installs its energy-converting floaters on existing marine structures such as piers, breakwaters, and jetties. The floaters rise and fall with the motion of the waves, driving hydraulic pistons that convert the mechanical energy into electricity. This design offers a cost-effective and low-maintenance alternative to offshore systems, while reducing environmental risks associated with deep-sea installations. Eco Wave Power's solution is particularly suited to areas with developed coastlines, aiming for sustainable and accessible energy generation. Eco Wave power's LCOE is approximately $55-$85/MWh.

3.2 Literature Review

A comprehensive literature review is a critical step in any research project, as it establishes the foundation by identifying existing knowledge and addressing gaps that the project aims to fill. In our case, thorough research and annotation are essential for making informed decisions regarding the selection of a marine generator, assessing its longevity, and ensuring its safety for both the environment and people. By evaluating the current landscape of marine generators, their components, and potential challenges, we can effectively navigate the complexities of competition. At the start of this semester, our group conducted extensive research on marine generators and carefully reviewed the competition rules. The following sections summarize each team member's findings from a wide range of sources, including books, peer-reviewed articles, and online resources.

3.2.1 Aiden Lee

[5] Michael Borg, et al. "Offshore Floating Vertical Axis Wind Turbines, Dynamics Modelling State of the Art. Part III: Hydrodynamics and Coupled Modelling Approaches." Renewable and Sustainable Energy Reviews, Pergamon, 24 Nov. 2014, www.sciencedirect.com/science/article/pii/S1364032114009253

Source one is a paper on offshore wind turbines. While the wind turbine information is not useful it demonstrates how to use the Morison equation on structures in oscillating flow. The source explains the use of the Morison equation and the application. It does only have the stationary cylindrical body form of the Morison equation, but the moving cylindrical form can be easily derived from the equation in this paper.

[6] M. Nachtane, M. Tarfaoui, D. Saifaoui, A. El Moumen, O.H. Hassoon, H. Benyahia, "Evaluation of Durability of Composite Materials Applied to Renewable Marine Energy: Case of Ducted Tidal Turbine" in Energy Reports, 2018.[Online]. Available: DOI: 10.1016/j.egyr.2018.01.002

This source is journal entry in the Energy Reports journal about composite material used in ducted tidal turbines. This is a great article about how different materials hold up under water and under rotation motion. This article will be extremely useful when our team is planning our full-scale design. The article has all the properties listed for the materials tested and the testing procedure used to determine what material works better. The two materials tested were glass polyester and carbon-epoxy.

[7] L. Rodrigues. " Wave Power Conversion Systems for Electrical Energy Production." Repqj.com. Accessed Sept. 15th, 2024. [Online]. Available: https://repqj.com/index.php/repqj/article/view/1826/380-leao.pdf

This source is a PDF of 16 different marine energy converters and a description of how each one works. It also has equations that can be used to determine a waves potential power output. Along with power equations there are also a description of a wave and the different aspects that go into making a wave. This resource was instrumental and getting an overview of what marine energy design are out there. As well as getting a base equation for the potential power out put of a wave.

[8] C. F. Kutscher, J. B. Milford and F. Kreith, "Ocean, Hydropower, and Geothermal Energy Converstion," Principles of Sustainable Energy Systems, 3rd ed. FL, USA: CRC Press, 2019, ch. 13, sec. 13.3.

This source is a chapter from the *Principles of Sustainability Energy Systems* that overviews the different aspects of ocean, hydro and geothermal energy. The section about ocean energy has lots of equation for calculating energy that will be useful when calculating the energy out put of our prototype. The source also has a section on the importance and effectiveness of marine energy. This information will be helpful for our competition presentations.

[9] C. F. Kutscher, J. B. Milford and F. Kreith, "Ocean, Hydropower, and Geothermal Energy Converstion," Principles of Sustainable Energy Systems, 3rd ed. FL, USA: CRC Press, 2019, ch. 13, sec. 13.2.

This source is another section under the *Principles of Sustainable Energy System* chapter 13. It explains the specific calculations needed to understand motion of ocean waves. It also has the potential power out of the ocean waves. This source is extremely useful in understanding the motion of waves and how our device will be affected by that motion. The power equation will also be handy when comparing the power of the waves created and the power generated by our device.

[10] Dimopoulos, George G., et al. "A General-Purpose Process Modelling Framework for Marine Energy Systems." Energy Conversion and Management, Pergamon, 2 June 2014, www.sciencedirect.com/science/article/abs/pii/S0196890414003501.

This source is on modeling framework used in marine energy systems. For this source it talks about a chemical marine energy conversion system often used on shipping vessels. While this is not the specific type of marine energy, we will be pursuing it has very good information on the mathematical modelling of their chemical conversion that could be applied to our mechanical conversion.

[11] E. Oberg, F D. Jones, H. L. Horton, and H.H. Ryffel, " Internal Gearing" in Machinery's Handbook, 29th ed., NY, NY, USA: Industrial Press, 2012, ch. 12, sec 3, pp. 2169-2171.

This source is a section from the machinery's handbook all about internal gears and the industry standard internal gears. Our design will use a lot of internal gears so having this section will be very useful to make a gear train to our generator. We will be able to determine what gears will be useful and the effects of different gears when they are connected.

[12] Griffiths, John, et al. "Guidelines for Health and Safety in the Marine Energy Industry." Tethys-Engineering.Pnnl, British Wind Energy Association, 2008, tethys-engineering.pnnl.gov/sites/default/files/publications/EMEC-2008-Health-Safety.pdf.

This source is a document from Pnnls database about the safety measures the British Wind Energy Association uses in their marine energy industry. This is a great source to reference when considering safety measure our device would need to follow. As well as a starting point for a risk mitigation strategy for our business plan. The information about maintenance safety measure will be of particular interest since our device will be needing to have maintenance done routinely.

3.2.2 Asher Aspili

[13] A. O. Pecher and J. P. Kofoed, Handbook of Ocean Wave Energy. Cham: Springer International Publishing, 2017.

Handbook of Ocean Wave Energy is a comprehensive guide to wave energy conversion. Starting from the initial idea and conceptions of wave energy conversion to showing mechanisms that are utilized toward electric generation Power Take Off Systems (PTOs). These systems are crucial for efficiently capturing and converting wave energy into usable electricity, and the handbook discusses their design, operation, and the latest advancements in technology, making it an essential resource for researchers and practitioners in the field.

[14] W. G. Nickels, J. M. McHugh, and S. M. McHugh, "Chapter 13 Marketing: Helping Buyers Buy," in Understanding Business, 12th ed, New York, NY: McGraw-Hill Education, 2019, pp. 326–351

This chapter of *Understanding Business* dives into the strategies of marketing. Marketing is fundamentally important in showcasing an idea. The chapter explores various marketing techniques, from traditional advertising to digital platforms, highlighting how businesses can leverage these strategies to reach their target audiences and achieve their objectives. Additionally, it examines the interplay between market research and strategy formulation, underscoring the importance of understanding consumer behavior in crafting successful marketing campaigns.

[15] A. Barua and M. Salauddin Rasel, "Advances and challenges in ocean wave energy harvesting," Sustainable Energy Technologies and Assessments, vol. 61, p. 103599, Jan. 2024. doi:10.1016/j.seta.2023.103599

The article *Advances and challenges in ocean wave energy harvesting* highlights the accessibility and challenges of ocean energy harvesting. This article focuses on the mechanisms of wave energy transfer methods. The drawbacks of developing technologies and newer innovations are also mentioned here. This article also includes a comparison table that assesses the output performance of various devices. In conclusion, it outlines the challenges, potential solutions, and outlook for these technologies.

[16] M. S. Lagoun, A. Benalia, and M. E. Benbouzid, "Ocean Wave Converters: State of the art and current status," 2010 IEEE International Energy Conference, vol. 2, pp. 636–641, Dec. 2010. doi:10.1109/energycon.2010.5771758

This paper focuses on wave energy resources and their calculation. Also a classification of wave energy converters is also mentioned. Waves are a very promising energy carrier among renewable power sources, since they are able to generate copious amounts of energy resources in almost all geographical regions. To harness the energy in waves, presents a different set of technical challenges and a wide variety of designs have been suggested.

[17] G. Reikard, P. Pinson, and J.-R. Bidlot, "Forecasting Ocean Wave Energy: The ECMWF WAVE model and time series methods," Ocean Engineering, vol. 38, no. 10, pp. 1089–1099, Jul. 2011. doi:10.1016/j.oceaneng.2011.04.009

Forecasting of Ocean Energy shows the comparison of forecasting techniques will aid in selecting the best models for short-term energy management, ensuring stability in power grids when using ocean wave energy. This also informs the use of combined models to enhance forecast accuracy, aligning with goals to improve energy reliability and grid performance. This article examines real-world applications of these forecasting methods, demonstrating how accurate predictions can minimize disruptions and optimize energy distribution, ultimately contributing to a more resilient and sustainable energy infrastructure.

3.2.3 Patrick Grosse

[18] M. E. McCormick, Ocean Wave Energy Conversion. Courier Corporation, 2013.

In *Ocean Wave Energy Conversion*, Michael McCormick delves into the principles and technologies involved in converting ocean wave energy into electrical power. The book covers both theoretical frameworks and practical designs of wave energy converters (WECs). McCormick analyzes wave behavior, energy potential, and the mechanics of interaction between waves and devices. He explores designs for floating and fixed WECs while addressing key challenges in efficiently converting wave energy into usable power. This text is essential for groups processing site data into variable components for data acquisition tasks in wave energy projects.

[19] "Wave-Coast Interactions | manoa.hawaii.edu/ExploringOurFluidEarth." [Online]. Available: https://manoa.hawaii.edu/exploringourfluidearth/physical/coastal-interactions/wave-coast-interactions

Wave-coast interactions are dynamic processes in which ocean waves shape and transform coastlines, driving both erosion and accretion. These interactions influence the formation of coastal features such as beaches, cliffs, and sandbars. As waves approach the shore, the underwater topography, like the slope of the seafloor, determines how waves break. For instance, steep slopes produce plunging waves, while gentler slopes create spilling waves. Wave energy also governs sediment transport, crucial in the deposition and removal of sand. Understanding these interactions is key for determining optimal locations for wave energy generators.

[20] "The Engineering Handbook - Buoyancy." [Online]. Available: https://enghandbook.com/naval-architecture/buoyancy/

The section on buoyancy in *The Engineering Handbook* explores its principles within fluid mechanics and maritime engineering. Based on Archimedes' principle, buoyancy is the upward force exerted by a fluid, opposing an object's weight. The section covers the mathematical basis for calculating buoyant forces, considering an object's volume, density, and fluid properties. It also highlights practical engineering applications such as designing floating structures, underwater vehicles, and ship stability. Understanding buoyancy is crucial for predicting if objects will require modifications to achieve neutral buoyancy on the group's engineering project.

[21] A. Muetze and J. G. Vining, "Ocean Wave Energy Conversion - A Survey," in Conference Record of the 2006 IEEE Industry Applications Conference Forty-First IAS Annual Meeting, Oct. 2006, pp. 1410–1417. doi: 10.1109/IAS.2006.256715.

"Ocean Wave Energy Conversion - A Survey" provides a comprehensive overview of the various methods and technologies used to harness ocean wave energy for power generation. It explores the theoretical foundations of wave energy, focusing on the physics of ocean waves, wave power potential, and the interactions between waves and energy converters. The article categorizes different wave energy conversion systems, such as oscillating water columns, point absorbers, and attenuators, highlighting their operational principles, efficiency, and challenges in deployment. Overall, this helps inform the group's generator design, providing insights into key variables to consider for optimizing the system later in the project.

[22] J. Wu, L. Qin, N. Chen, C. Qian, and S. Zheng, "Investigation on a spring-integrated mechanical power take-off system for wave energy conversion purpose," Energy, vol. 245, p. 123318, Apr. 2022, doi: 10.1016/j.energy.2022.123318.

The article presents a novel approach to optimizing ocean wave energy conversion by integrating a spring mechanism into a mechanical power take-off (PTO) system. This design aims to enhance energy extraction by synchronizing with the oscillatory motion of waves, compensating for the irregularities in wave patterns. The research investigates how the spring integration can improve both energy absorption and the overall performance of the PTO system under varying wave conditions. Through simulations and experimental models, the study evaluates the system's dynamic response, power output, and mechanical resilience. The findings suggest that spring-assisted PTO systems could offer more efficient and reliable energy capture, potentially advancing the field of marine renewable energy. This research serves as a valuable reference for developing the internal components of the team's generator, as well as informing future design considerations.

[23] "Marine Energy Atlas." [Online]. Available: https://maps.nrel.gov/marine-energy-atlas

Wave energy converters (WECs) capture the kinetic energy from ocean waves and convert it into electricity. Various WEC designs, such as point absorbers and oscillating water columns, harness wave motion through winches, turbines, or hydraulic systems. However, no single design has become an industry standard due to ongoing challenges with efficiency, cost, and deployment. Exploring these technologies has given the group a better understanding of the blue economy and the potential obstacles in their project, particularly in optimizing WEC performance and integration.

[24] "Wave Energy Converters." [Online]. Available: https://theliquidgrid.com/marine-clean-tech-briefs/wave-energy-converters/

The Marine Energy Atlas, created by the National Renewable Energy Laboratory (NREL), is an interactive tool designed to empower researchers, developers, and policymakers in their exploration of marine energy resources across the United States. This platform provides extensive data on the potential of wave, tidal, and ocean current energy, enabling users to visualize various information layers—such as omnidirectional wave power—to identify and evaluate energy generation opportunities in diverse marine environments. By offering critical insights, the Marine Energy Atlas supports informed decision-making for optimal site selection in marine renewable energy projects.

[25] "Surf Reports, Surf Forecasts, and Surf Cams," Surfline. [Online]. Available: Surfline.com

Surfline.com is a leading online platform committed to delivering surfers real-time information on surf conditions, forecasts, and coastal weather. The site offers detailed wave forecasts, live beach cams, and expert insights, making it an invaluable resource for people of all skill levels. With an extensive database featuring location-specific information for thousands of beaches worldwide, Surfline.com serves as a vital tool for recording oceanic patterns. This data will facilitate remote testing under various environmental conditions, enhancing our understanding of surf dynamics.

3.3 Mathematical Modeling

In this section, mathematical models and data analysis tools are used to validate the maximum weight our generator can support and to analyze the variable impact forces it will encounter when deployed in the ocean. The process begins with the development of a MATLAB code, which calculates the device's overall volume and determines the buoyant force acting on it at the sea's surface. Key mathematical equations and assumptions are then applied to estimate the forces generated by waves and the intensity of different wave conditions. This modeling establishes the foundation for calculating the maximum energy the generator can harness, offering a systematic, data-driven approach to refining the dataset and ensuring a concise, region-specific datasheet.

3.3.1 Buoyancy Force Calculation in MATLAB – Patrick Grosse

As our device is currently in the early stages of development, accurately determining the buoyancy force is essential for guiding the design process and ensuring the system achieves neutral buoyancy. Neutral buoyancy is crucial for the device's operational stability, allowing it to remain suspended in water without sinking or floating uncontrollably. By applying Archimedes' Principle [20], we can calculate the buoyant force exerted on the device, which must counterbalance its weight.

Given the dimensional constraints of the testing environment, we can make reasonable assumptions about the device's overall volume. This volume, combined with Archimedes' Principle, allows us to derive the total upward force that will act on the submerged portion of the device. Understanding this relationship is critical for establishing the maximum allowable weight of the device while ensuring it remains near positive buoyancy in the water.

To facilitate this analysis, we have developed a MATLAB script (referenced in **Figure A.2.1, Appendix A.2**) that allows for the remote adjustment of the buoy's dimensions. By inputting various geometric parameters and other given parameters, the code calculates both the total volume and the corresponding buoyant force. This approach provides the flexibility to quickly iterate through design variations and evaluate their performance in real-world conditions, ensuring that the buoyancy force will adequately counter the device's weight when submerged in water.

3.3.2 Morison Equation: Force of a Wave – Aiden Lee

The Morison Equation is an equation that is used in the offshore construction industry to find the forces of waves. The full equation is as follows:

$$F = \frac{1}{2}\rho_w C_D D|U| + \rho_w C_M \left(\frac{\pi D^2}{4}\right)\frac{\partial U}{\partial t} \qquad \text{[Eq. 1]}$$

The constants and equations for variables are explained in **Appendix A.3.1**. The Morison equation has many different forms depending on the shape of the body in the flow. Equation 1 is for a cylindrical body in an oscillating flow. Equation 1 simplifies to equation 7 after substituting equations 2-7 as seen in **Appendix A.3.1** and the drag coefficient $\boldsymbol{C_D}$ going to zero.

$$F = \rho_w(\frac{mD^2}{6})(\frac{\pi D^2}{4})(-A\omega^2 \sin(k - \omega t - \varphi)) \quad \text{[Eq. 8]}$$

The drag coefficient goes to zero because the equation for drag in oscillatory flow, as seen in **Appendix A.3.1,** uses velocity relative to flow. Since, our design is a buoy it will be moving with the flow making its velocity relative to the flow zero.

The Morison equation is a very useful equation for our design and can be used for many different occasions. Our design will be anchor in some capacity so the force of the wave will be useful to find the force of tension in our anchor. The equation will also be used to find the power generated once our gear design is completed.

3.3.3 *Wave Intensity – Asher Aspili*

With the design of our device being based around wave energy, it is reasonable to look at how waves generate power per unit of area. Determining the intensity is the basis of solving the mechanical power generated through the modeling of ocean waves measured across a surface. The intensity of a wave is the energy per unit time that is transported across a unit area normal to the direction of energy flow. If a wave is moving across a large area, it will then decrease in its intensity. The equation of intensity of a wave is:

$$I = 2\pi^2 \upsilon \rho f^2 A^2$$

The υ is the velocity of the wave.

f is the frequency of the wave.

A is the amplitude of the wave.

To show the wave intensity an analysis through a MATLAB file in **Appendix A.2** was generated. This allows us to simulate the wave intensity by assuming wave amplitudes and wave frequencies. Modeling this equation gives us a better understanding of the mechanical energy that is being generated, in which we can use to convert this energy into electricity.

4 Design Concepts

4.1 Functional Decomposition

Figure 4.1: Black Box Model of marine energy generators

4.2 Concept Generation

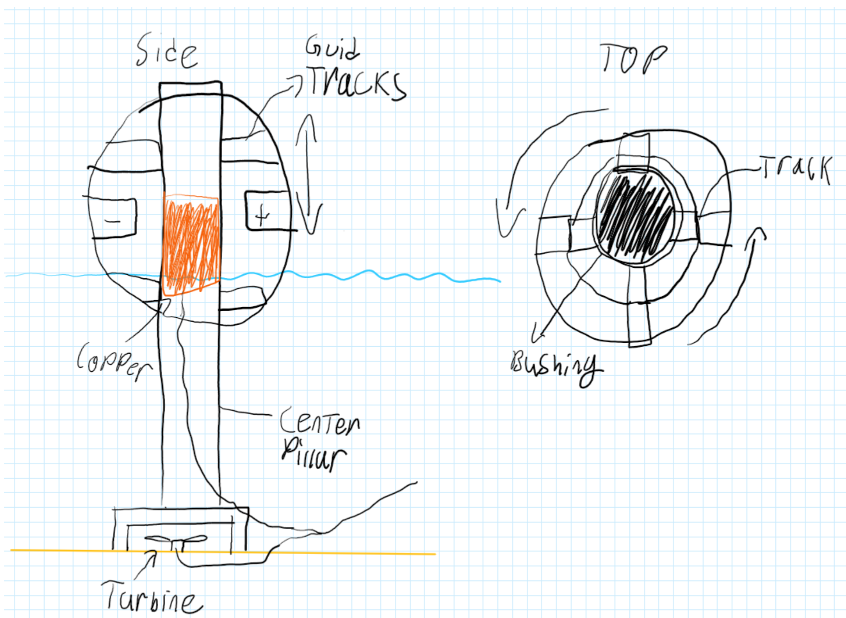

Figure 4.2.1: Spinning buoy with linear motion

Figure 4.2.1 is a design-like benchmark 1 in the bench marking. The top-level concept is that there is a buoy that will be guided by tracks that will move magnets around the copper center when the waves move under them. Where this design differs is in the sub-system level where the tracks will be attached to a bushing around the center pillar allowing for rotational motion as well. There is also a turbine below the center pillar ground attachment to try and gather some of the energy in the currents. The energy generated from the buoy and the turbine will be connected to an onshore power station. The power station will then collect the energy and deposit it in the grid. A positive of this design is that it will gather energy from linear and rotational motion of the buoy. There is also the turbine below that will be generating power from the currents at the sea floor. A negative about this design is that it must be within a certain distance of shore to be functional. It also has a lot of moving parts that would need to be maintained frequently and made waterproof.

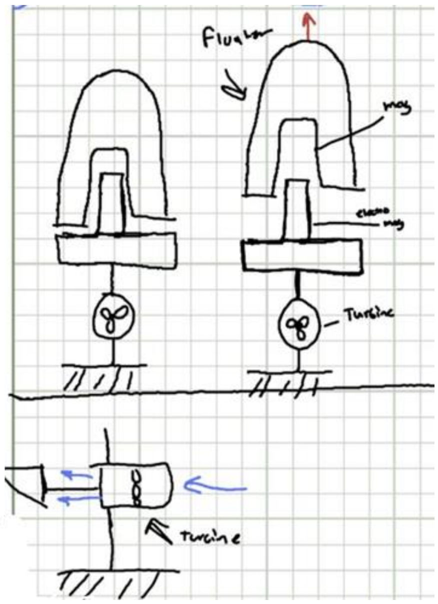

Figure 4.2.2: Archimedes buoy with multi-directional turbine

Figure 4.2.2 depicts a hybrid design combining an Archimedes buoy with a nautical turbine. The upper portion of the generator operates by exploiting the changes in water pressure as the water level fluctuates. When the water level rises relative to the buoy, the increased pressure causes the "floater" to sink. Conversely, when the water level drops, the "floater" rises. Internally, a rack-and-pinion system converts this linear motion into rotational motion, which is then transferred to a motor to generate energy. The turbine below the main generator functions similarly to a traditional wind turbine. It is mounted on bearings, allowing it to rotate freely with the direction of the water current. The energy produced by the generator is directed to a local power station, supplying electricity to communities that either depend on conventional power plants or have limited access to power. One advantage of this design is its low visual impact, as the buoy remains submerged, keeping it out of sight. Additionally, the turbine allows continuous energy collection. However, regular maintenance will be required to ensure the buoy remains watertight and to prevent potential leakage in the "floater." The design's submerged nature also necessitates periodic inspections to ensure optimal performance.

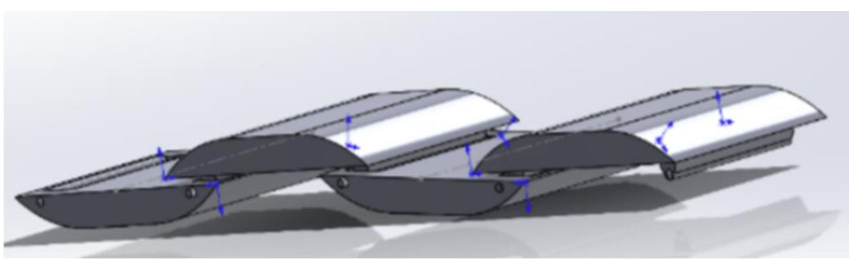

Figure 4.2.3: Wave Watch Piece Attenuator Linkage System

This concept (Figure 4.2.3) is a Wave Watch Piece Attenuator Linkage System. It operates by floating with the waves, harnessing the natural motion of the ocean to generate energy. The design features a large surface area, maximizing contact with the water, which makes it efficient in capturing wave energy. Its modularity allows it to be scaled across larger bodies of water, enhancing its overall energy production potential. However, this larger surface area introduces a higher margin of error in energy conversion efficiency, which could affect performance. Additionally, the cost of implementing such a system on a large scale may pose a significant financial challenge.

4.3 Selection Criteria

In this section the selection criteria used for our final design is explained. The criteria are broken up into quantitative and qualitative criteria. The quantitative criteria have equations associated with them to derive a number value that can be compared to other designs. The quantitative criteria equations come from the engineering requirements in Figure A.1.1 in **Appendix A.1**. The qualitative criteria come from the customer requirements used in Figure A.1.1 in **Appendix A.1**. The qualitative criteria have a rating of one through ten on how good a design reaches these goals. 10 is that the design matches these criteria perfectly or can meet the goal of the criteria and 1 is that it is not able to reach those criteria at all. These criteria were used to score each of the designs in a decision matrix and Pugh chart.

4.3.1 Quantitative Criteria

- **Continuous Operation:** The equation used for this is $F_t = \tau r$. This is the equation for tangential force on a gear using the torque and radius of the gear. The gears were determined to be the most probable area for failure by the team, because of this the force on the gears was used to determine continuous operation.
- **Efficiency:** To find the efficiency the equation $\eta = \frac{P_W}{P_g}$ was used. This is the ratio of the power of the wave over the power generated. Both the power generated, and power of a wave were estimated using equations from sources [7] and [10] in the literature review.
- **Testable in Lab or Tank:** To measure this an estimation of the length, width and height was compared to the length width and height of the towing tank offered from Leixian Ma at ASU.
- **Compatible in Multiple Environments:** To calculate the compatibility in multiple environments the graphs and charts of strength of materials was used in source [6] of the literature review. These graphs were compared to six different oceanic environments and possible forces exerted on the material.
- **Majority Use of Marine Energy:** To calculate the amount of energy produced by marine energy the equation $X = \frac{E_T}{E_m}$. This equation is the ratio of total energy produced over the amount of energy the marine energy device produced. The competition requires that 51% or greater of the energy produced must come from marine energy.
- **Remote Shutdown Capability:** To calculate the remote shut off capability, the equation used was $J = Ft$. This equation calculates the momentum of the device when in use and it can be used to find how long the shutdown procedure takes.

4.3.2 Qualitive Criteria

- **User Safety**: One of the required competition documents is a Safety Specification Form, necessitating that the generator include a remote shutdown feature. This is crucial for both safety in adverse environmental conditions and for conducting maintenance without on-site intervention.
- **Resistance to Nature**: The harsh conditions of the ocean pose significant challenges to marine generators, which is why so few exist. Our team aims to develop a design that is either highly durable, minimizing the need for frequent maintenance, or adaptable enough to withstand the extreme forces of nature, ensuring long-term viability.
- **Design Presentation**: This criterion helps eliminate designs that require large amounts of space or could become an eyesore, particularly near coastal cities. A compact, visually unobtrusive design is essential for public acceptance and integration into urban or natural environments.
- **Cost Efficiency**: With a limited budget of $20,000—half of which is allocated to travel expenses—keeping production and testing costs low is a critical factor. Our goal is to create a design that is both affordable to manufacture and efficient to test within the financial constraints of the competition.
- **Environmental Safety**: In addition to being resistant to environmental forces, the generator must also be safe for the surrounding marine ecosystem. It should not cause long-term harm to the environment in which it operates, aligning with sustainability goals and competition guidelines.
- **Adaptability Across Different Climates**: One of the key competition requirements is for the generator to be "compatible in at least six environments." The design must perform reliably in various oceanic conditions, from high-swell, stormy days to calm weather, ensuring versatility across different climates.
- **Ease of Manufacturing**: With a submission deadline just five months away, the simplicity of manufacturing is crucial. A design that is easy to produce will accelerate the testing process and allow for efficient gathering of materials and resources, ensuring the project stays on track.
- **Energy Output Type**: The generator's energy output should ideally connect directly to the grid for immediate use. However, incorporating a battery storage option is advantageous, as it reduces the need for long-distance cables, which could significantly raise project costs. A flexible energy output strategy is key to balancing efficiency and cost.

4.4 Concept Selection

In Section 4, we carefully evaluated and filtered out the design concepts generated by each team member using two key decision-making tools: the Decision Matrix and the Pugh Chart. The Decision Matrix was instrumental in narrowing down the pool of potential projects by selecting the top four concepts based on a balanced consideration of both the technical requirements and the customer needs. These requirements were derived from our project goals, stakeholder input, and relevant engineering constraints. The Decision Matrix allowed us to weigh and compare the strengths and weaknesses of each design.

After identifying the top four concepts through this process, we employed a Pugh Chart to further refine the selection. The Pugh Chart enabled us to rank these leading designs by directly comparing them against a baseline using specific criteria outlined in the competition rulings. This provided a structured way to assess how well each design met competition guidelines, engineering feasibility, and performance benchmarks. Ultimately, the use of these tools ensured that our final design choices were grounded in a rigorous and systematic evaluation process, aligning both with project objectives and MECC competition standards.

4.4.1 Decision Matrix & Pugh Chart

A critical part of our selection process is the Decision Matrix and Pugh Chart, both developed based on the criteria outlined in Section 4.3 as well as team inputs. Each criterion was deliberately weighted to reflect its significance in fulfilling both engineering requirements and customer needs. Both criteria, provides a systematic framework for evaluating and prioritizing the MECC competition rules, ensuring our final selection is both compliant and well-justified. **Appendix 7.2** presents the decision matrix, which integrates the qualitative and quantitative factors discussed earlier, ensuring a thorough assessment of the marine generator options.

The initial evaluations have yielded critical insights into the power output potential of each generator concept, forming the foundation for a detailed comparison of the designs. Using the comprehensive decision matrix, we systematically assessed all the concepts generated by the team, ensuring that each design was measured against key criteria. Among the top designs was the "Up & Down Rocker," created by one of our electrical engineers, which stood out for its ability to harness significant energy, particularly in environments with varying wave patterns. Another leading contender, the "Time Puller," secured the top ranking due to its ability to generate continuous power when installed in open-ocean conditions, making it highly favorable for sustained operation. Both designs, along with the third-highest ranked concept, underwent a rigorous evaluation based on the criteria laid out in **Appendix A.2**, which encompassed technical performance, feasibility, and potential for energy output.

The top three designs were then further evaluated using a Pugh chart, with the fourth-ranked design serving as the datum, allowing for a direct comparison of their strengths, weaknesses, and overall viability. In this phase, the team revisited the criteria from the Decision Matrix and the MECC competition rules, selecting key criteria to assess the final three designs. Using the fourth design as a baseline, we focused on the most important factors, ensuring that the assessment aligned with both technical performance and competition requirements. Through this analysis, the "Spinning Rod" design emerged as the winner, primarily due to its cost-effective manufacturing potential and its versatility in collecting data—one of the critical points in the Technical Design challenge. This thorough approach not only guaranteed that each design was rigorously vetted but also established a clear framework for determining the best design. Ultimately, it allowed us to select the solution that best meets our project's objectives in terms of efficiency, reliability, and full compliance with MECC competition guidelines.

4.4.2 Current State of CAD Drawing

To illustrate our conceptual model, a preliminary CAD design was developed, as shown in Figure 4.4.2. Moving forward, the team will refine this design, while collaborating with the electrical engineering sub-team to integrate the electrical components. Given that our report will evaluate the feasibility of our chosen system, the selection of an inexpensive motor as the generator is critical. Additionally, the team is exploring the possibility of mock-scale testing with a professor from Arizona State University, with a meeting scheduled for a later date. As a result of this shift in focus, the team will proceed with this model and initiate a detailed design for the generator.

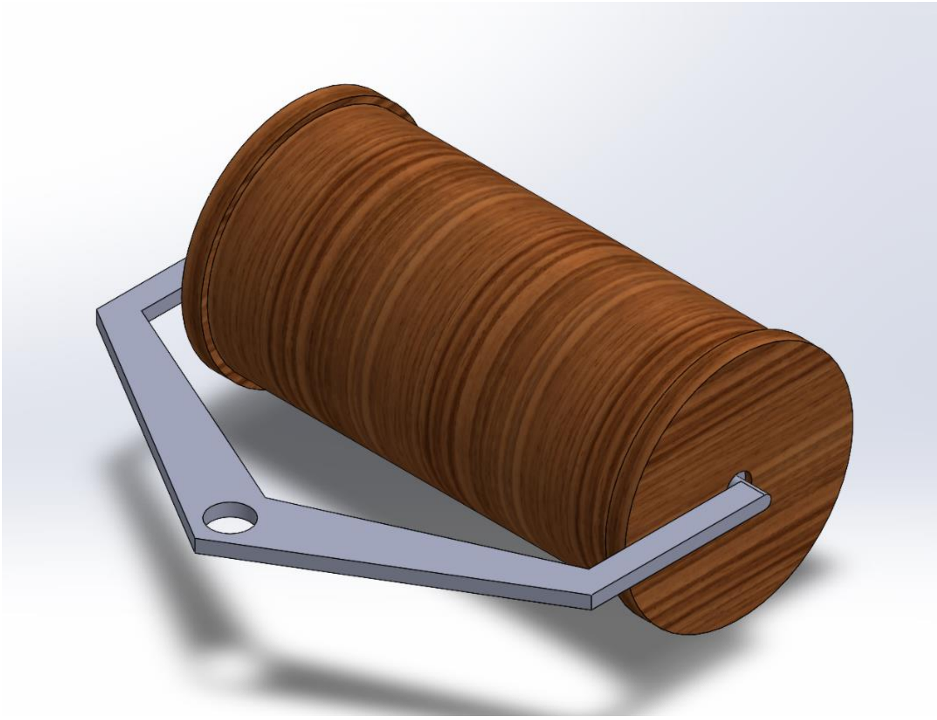

Figure 4.4.2: Render of initial draft of final CAD

5 CONCLUSIONS

In conclusion, the Marine Energy Collegiate Competition (MECC), hosted by the Department of Energy's Water Power Technologies Office and facilitated by the National Renewable Energy Laboratory, offers a unique opportunity for 23 college teams to engage with the evolving marine energy sector. By providing challenges focused on business, technical design, and community outreach, the competition not only fosters innovation but also encourages students to explore career opportunities in renewable energy. The competition’s format includes both required and optional challenges, allowing teams to showcase their strengths in various aspects of marine energy design and entrepreneurship. With a total prize pool of $480,000, teams have the chance to secure funding throughout the competition while competing for a share of the final prize.

Our team’s chosen design, which operates like a yo-yo mechanism to convert wave motion into energy, exemplifies the type of innovative thinking encouraged by this competition. With guidance from industry mentors and continued prototyping, we aim to refine our system's internal gearing and performance. This project has already expanded our knowledge of mechanics and renewable energy, and the competition will provide valuable experience as we move forward in this promising field. Ultimately, the MECC serves not only as a challenge but as a critical step toward preparing the next generation of engineers and energy professionals.

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7 APPENDICES

7.1 Appendix A.1: House of Quality (QFD)

#	Technical Requirement	1	2	3	4	5	6	7
1	Resistance to Marine Environment							
2	Energy Output							
3	Continuous Operation	+						
4	Efficiency	+		+				
5	Laboratory/Controlled Testing Compatability	+	-					
6	Compatibility with Diverse Marine Conditions		+	+		-		
7	Majority Use of Marine Energy	+	-					
8	Remote Shutdown Capability	+	+	+				

#	Customer Needs	Customer Weights	Weight %	Technical Requirements: Resistance to Marine Environment	Energy Output	Continuous Operation	Efficiency	Laboratory/Controlled Testing Compatability	Compatibility with Diverse Marine Conditions	Majority Use of Marine Energy	Remote Shutdown Capability	Customer Opinion Survey: 1 Poor	2	3 Acceptable	4	5 Excellent
1	User Safety	5	6.60	4							9					
2	Design Presentation	2	16.50	6	6			5	5	5	5					
3	Cost Efficiency	4	8.25				7	6								
4	Environmental Safety	4	8.25	5					6	6	8					
5	Aesthetically Appeal	3	11.00	6	6	6				6	6					
6	Adaptability Across Climates	5	6.60	7	7	8	9	7	8	8	8					
7	Ease of Manufacturing	5	6.60	8	8	8	8	8	8	8	8					
8	Grid Integration	5	6.60	7	7	7	7	6	6	7	7					
	Technical Requirement Units				W	W/ day	%	CM		%						
	Technical Requirement Targets			IPX7			> 50%		>= 6	>= 51%						
	Absolute Technical Importance			180	140	133	148	139	144	167	220					
	Relative Technical Importance			4	7	8	3	2	6	5	1					

Figure A.1.1: MECC House of Quality Analysis

7.2 Appendix A.2: Referenced Figures and Images

```
clear
clc
%Fixed Numbers
rho = 1025; %kg/m^3
g = 9.807; %m/s^2

%Input Numbers
r = input("Enter the radius of the cylinder in centimeters: ");
h = input("Enter the heigth of the cylinder in centimeters: ");

%Calculations
V = (pi*h*r^2); %Volume of buoy in CC
F = (rho)*g*(V)/(10^6); %buoyance force (conversion from CC to CM)

%Output Calculation
fprintf('Your buoy volume in cubic centimeters (cm^3) is: %.3f\n',V);
fprintf('Your buoyancy in Newtons (N) is: %.3f\n',F);
```

Command Window

```
Enter the radius of the cylinder in centimeters: 15.24
Enter the heigth of the cylinder in centimeters: 50
Your buoy volume in cubic centimeters (cm^3) is: 36482.938
Your buoyancy in Newtons (N) is: 366.733
fx >>
```

Figure A.2.1: Buoyancy & Volume MATLAB Calculation

```
% Intensity of a Wave

% Arbitrary Numbers Assumed
rho = 1025; % Density of ocean water in kg/m^3
f = 0.1;    % Frequency of waves in Hz
v = 0.6;     % Speed of waves in m/s
A = 0.2;   % Amplitude of waves in m

% Formula for intensity
I = 2 * pi^2 * v * rho * f^2 * A^2;

% Display the result
disp(['The intensity of the wave is: ', num2str(I), ' W/m^2']);
```

```
The intensity of the wave is: 4.8558 W/m^2
```

Figure A.2.2: Wave Intensity MATLAB Model

Decision Matrix

Applications

Scale 1-10

Key information	Spinning Ball w/ Under Turbine	Bobber	Time Puller	Resivour	Attenuator	Up Down Rocker	Lever mech	Spinning rod
User Safety	3	2	6	7	8	9	7	8
Design Presentation	7	7	7	4	4	6	7	8
Cost Efficiency	5	5	7	7	6	8	6	7
Environmental Safety	4	8	8	8	4	8	4	7
Aesthetically Appeal	6	10	9	1	4	4	7	7
Adaptability Across Climates	7	9	9	5	7	8	7	7
Ease of Manufacturing	3	7	7	3	8	8	8	8
Energy Output	8	8	8	10	8	9	9	8
Resistance to Marine Environment	7	6	7	6	4	7	6	8
Continuous Operation	10	10	10	5	10	7	7	8
Efficiency	7	6	7	5	6	4	6	7
Laboratory/Controlled Testing Compatability	3	4	6	5	8	7	6	8
Compatibility with Diverse Marine	4	5	8	6	6	7	7	7
Majority Use of Marine Energy	10	10	10	10	10	10	10	10
Remote Shutdown Capability	5	4	9	8	5	9	7	6
TOTAL	59.3	67.3	78.7	60.0	65.3	74.0	69.3	76.0

Table A.2.1 Decision Matrix

Pugh Chart - Marine Energy Collegic Competition					
Marine Generator Top Concepts					
		Concept			
		1	2	3	4
		Time Puller	Lever Mech	Spinning Rod	Up & Down Rocker
Criteria	Cost Efficiency	-	D A T U M	++	+
	Repairability	0		0	++
	Manufacturability	-		+	+
	Design Simplicity	-		++	++
	Portability	+		++	-
	Operational Safety	0		0	0
	Resilience in Extreme Conditions	0		-	-
	Data Collection and Analysis	+		++	0
	Comprehensive Considerations	+		++	-
	Potential Testing Locations	++		+	--
	Sum of +'s	5		12	6
	Sum of 0's	3		2	2
	Sum of -'s	3		1	5
	Total	2		11	1

Table A.2.2: Pugh Chart

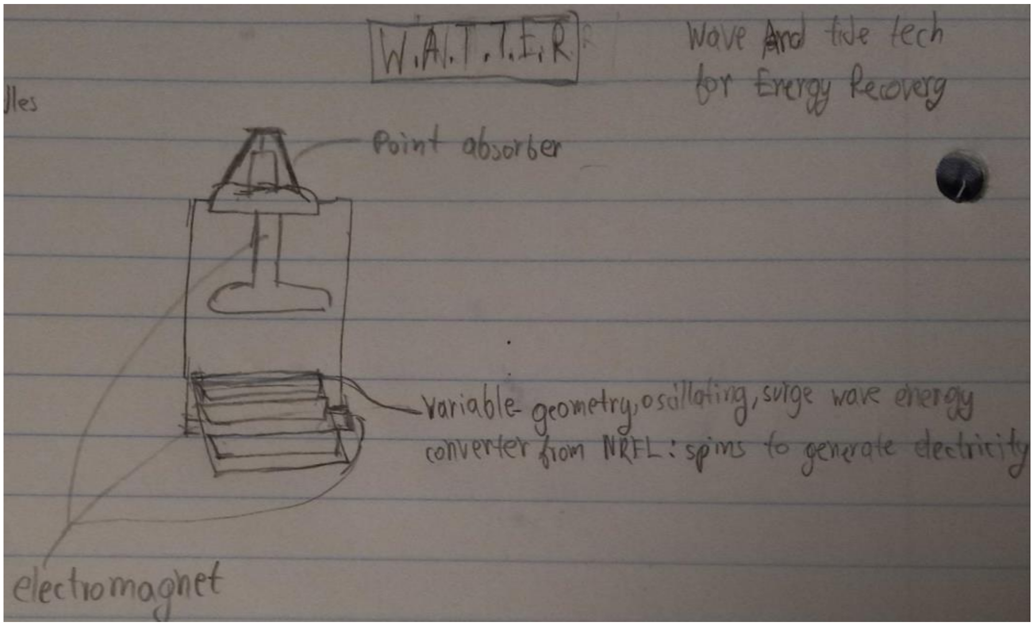

Figure A.2.3 Lever Mech

The Lever Mech is a combination of both a point absorber and the window device developed by National Renewable Energy Laboratory (NREL). A point absorber is a buoy that has a floating cylinder insider connected to a cable. As waves moves the buoy the outer cylinder moves with respect to inner cylinder and generate electricity based on Farady's Law of Electromagnetic Induction. NREL's windows are like curtains/shatters to prevent high speed waves damaging its mechanical movement. Placed on seabed, as waves pass through the window moves back and forth moving the cylinders inside coils at both ends to generate electricity. Lever Mech combines both, it floats like a point absorber and connected to NREL's windows which also floats thus making it spin 360 degrees to generate electricity.

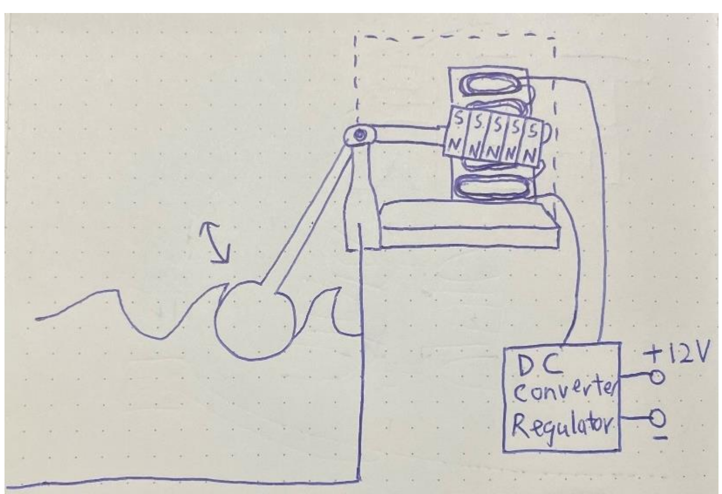

Figure A.2.4 Up-Down Rocker

The Up-Down Rocker design is a shore-mounted wave generator. It has a long buoyant arm hinged on the mounting base, which touches the surface of the sea. The opposite end of the hinged rocker has permanent magnets mounted in lines on a bar which will move across copper coils in the mounting base. The motion of magnets across the coils will generate an electric field, which can be rectified and utilized on equipment near the generator. The motion of the incoming waves will move the rocker arm up and down. These could be installed on a wide spot such as a levee to absorb as many incoming waves as possible.

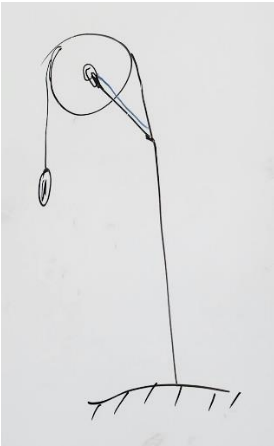

Figure A.2.5 Spinning Rod (LOG)

The Spinning Rod (LOG) is a point absorber that functions similarly to a pulley. The biggest advantage of this method is that it transmits all motion of the buoy to it to a single axis of rotational energy, greatly simplifying the design. To do this the anchor cable is wrapped around a floating cylindrical drum which is forced to rotate when waves, swell, or tides increase the distance between the drum and the anchor point. There is a counterweight on a cable wrapped the opposite way as the anchor cable so that the drum will re wrap the anchor cable when the force of the ocean on the drum decreases, returning it to center. Inside of the drum is a planetary gear with the planet gears fixed about the central axis to a fork that spans around the outside of the drum to both sides. This fork is attached to the anchor cable to prevent it from rotating with the drum. The sun gear is attached a flywheel which is then attached to a generator this serves to increase the rotation speed of the generator and make the power output more consistent. The maximum power input is limited by the net buoyancy force of the buoy and the acceleration upward is limited by the flywheel. This serves as a basic protection from rough weather or unexpected large waves. It is also possible to configure the Spinning Rod (LOG) to passively wind itself down to the lowest possible point without letting itself rise back up so that it can weather storms just beneath the waves if needed.

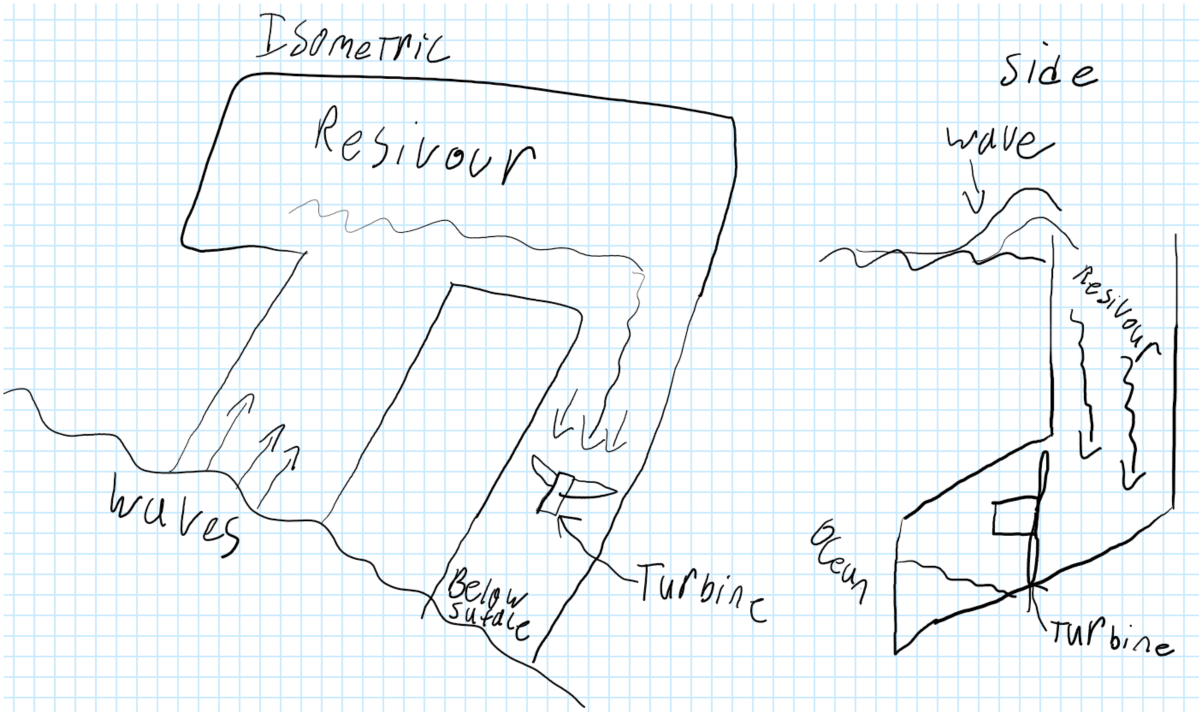

Figure A.2.6: Reservoir design

Figure A.2.6 is a reservoir that would be built at the shore to capture the breaking waves. The waves will break over the side filling a reservoir. The reservoir will have a slope down to a channel where a turbine is and the flow from the slope will spin the turbine. The turbine will be connected to a generator and a storage system on shore. The positive of this design is that it is simply with little moving parts. However, it would have to be very large to generate any meaningful energy and would take up on shore space.

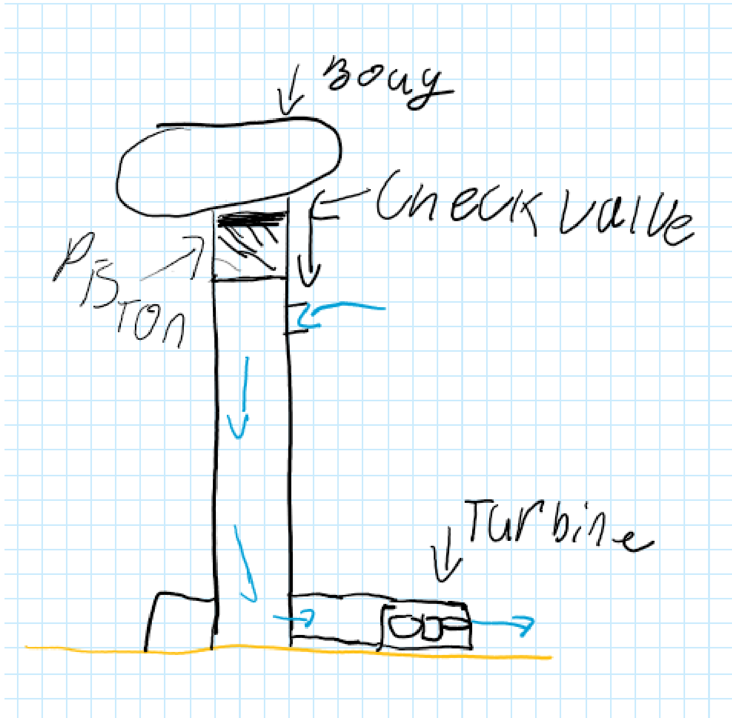

Figure A.2.7: Piston pump design

This design is like a piston pump where the top would move up and down pushing water through the tube. The tube would be connected to a turbine where the moving water would generate electricity. The turbine would then be wired to an onshore facility where the electricity would be stored and dispersed to the grid. The positive of this design is that it is a simple design that has been used for centuries just on a larger scale. The negatives is that the check valve would be a critical component that if it breaks the whole thing would stop working. It would also have to be heavy in order for the buoy to be able to force the water down when the waves dip. The weight that it would have to be would be too much for buoyancy to be able to lift the plunger.

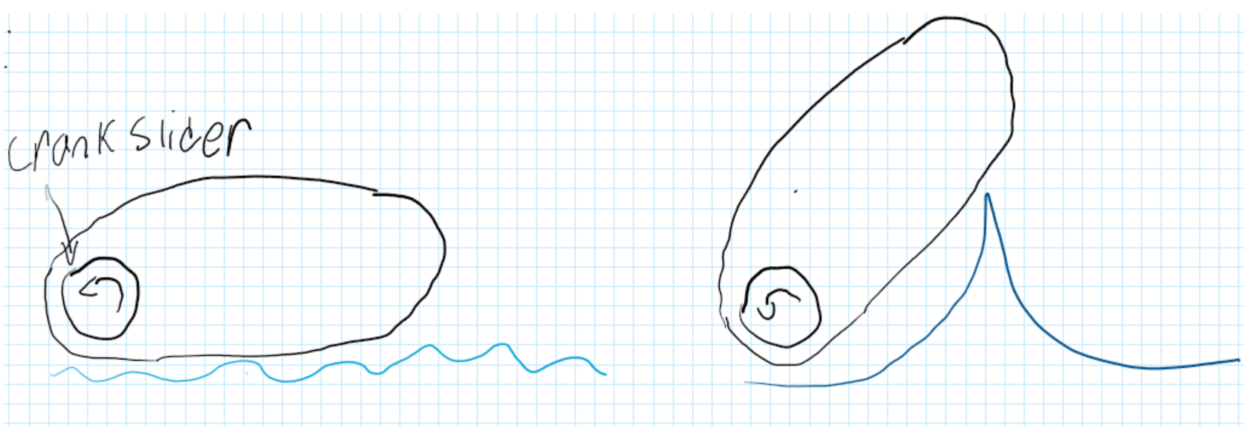

Figure A.2.8: Crank slider buoy

This design is a buoy design where the waves will tilt the buoy which is connected to a crank slider that will convert the rotation into linear motion. The crank slider would be connected to a stator that would be able to generate electricity. There would be multiple of these buoys all in a line similar to benchmark 3. The positive of this design is that it is scalable to be able to produce a needed amount of energy. The negatives are that it would have to be on shore or connected to an offshore rig making it more costly to produce.

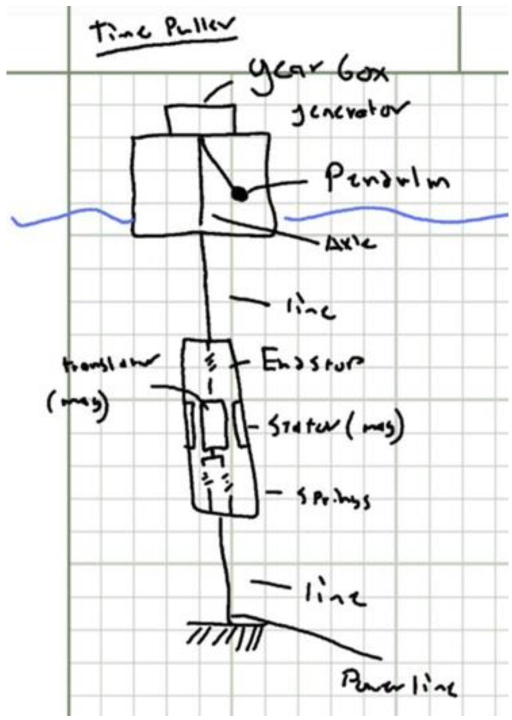

Figure A.2.9 Time Puller design

This design functions like a pendulum mounted on a spring. As the surface of the water fluctuates, the top portion of the buoy stays tangential to the sea's surface, while an internal pendulum rotates due to its lower center of gravity, maintaining a natural swinging motion. Submerged below the buoy is a spring mechanism that compresses and expands in response to the changing water levels, capturing energy from the rise and fall of the sea. This system effectively converts the vertical movement of the buoy into mechanical energy, which can then be transformed into electrical power. The combination of the pendulum’s rotation and the spring’s compression offers a dual mechanism for energy collection, allowing for continuous operation even with subtle changes in water elevation. This design not only capitalizes on natural ocean dynamics but also ensures efficient energy generation through relatively simple mechanical processes.

Stage	Cash Prize per Team	Total Cash Prize Pool
Application to Participate	$5,000	$115,000
January Submissions	$5,000	$115,000
February Submissions	$5,000	$115,000
Final Event	$5,000	$115,000
Grand Prize*	TBD*	$20,000*
Total	$20,000 (+grand prize awards)	$480,000

**Grand Prize cash prizes will only be distributed to first-, second-, and third-place winners. Specific amounts for winner placements will be announced closer to the final event.*

Figure A.2.10: Prize distributions for submission stages

Award	Criteria	Prize
First Place	The team that earns the highest combined score in the four challenges	Trophy Split of a $20,000 grand prize pool. Cash prizes will be paid to each winning team's lead institution.
Second Place	The team that earns the second-highest combined score in the four challenges	Trophy Split of a $20,000 grand prize pool. Cash prizes will be paid to each winning team's lead institution.
Third Place	The team that earns the third-highest combined score in the four challenges	Trophy Split of a $20,000 grand prize pool. Cash prizes will be paid to each winning team's lead institution.
Individual Challenge Awards: • Business Plan Challenge • Technical Design Challenge • Build and Test Challenge • Community Connections Challenge	The team that earns the highest score in the associated challenge.	Trophy

Figure A.2.11: First Part of Prize Table

Rookie of the Year Award	For teams in which the lead institution is competing as the lead for the first time, an award will be given to the team from the institution who scores the highest combined score in the four challenges*	Trophy
Best Quick Pitch	As voted on by conference attendees	Trophy
Best Poster	As voted on by conference attendees	Trophy

** For multi-institution teams to be eligible, the lead institution must be leading for the first time.*

Figure A.2.12 Second Part of Prize Table

7.3 Appendix A.3: Mathematical modeling

A.3.1 Morison Equation:

$$F = \frac{1}{2}\rho_w C_D D|U| + \rho_w C_M \left(\frac{\pi D^2}{4}\right)\frac{\partial U}{\partial t} \qquad \text{[Eq. 1]}$$

F = Force

ρ_w = Density of water

C_D = Drag Coefficient

D = Diameter

U = Velocity of fluid

C_M = Inertia Coefficient

$\frac{\partial U}{\partial t}$ = Acceleration of wave

$$\frac{\partial U}{\partial t} = -A\omega^2 \sin(k - \omega t - \varphi) \qquad \text{[Eq. 2]}$$

A= Amplitude of wave

k= Wave number

ω = Angular Frequency of wave

t= Time for one period

φ= Phase shift angle

$$k = \frac{2\pi}{\lambda} \qquad \text{[Eq. 3]}$$

λ= Wave length of wave

$$C_D = \frac{1}{2} F_D \rho v^2 A_r \qquad \text{[Eq. 4]}$$

F_D=Force Drag

A_r= Area relative to flow

ρ= Density of fluid

v= Velocity of flow

$$F_D = 6\pi\mu r v \qquad \text{[Eq. 5]}$$

μ=Dynamic Viscosity of Fluid

r=Radius of Object in Fluid

v= Velocity relative to flow

$$C_M = \frac{mD^2}{6} \qquad \text{[Eq. 6]}$$

m= Mass of object

$$m = \rho\pi r^2 h \qquad \text{[Eq. 7]}$$

ρ= Density of material

r= Radius of cylinder

h= Height of cylinder

$$F = \rho_w (\frac{mD^2}{6})(\frac{\pi D^2}{4})(-A\omega^2 \sin(k - \omega t - \varphi)) \qquad \text{[Eq. 8]}$$