Introduction

As Coastal Studies Institute is the home site for North Carolina's Renewable Ocean Energy Program (NCROEP), one of the main goals in hosting the North Carolina Renewable Energy Challenge (NCREC) is to introduce students and educators to the research being pursued to meet the program's mission. That mission is to use renewable ocean energy wisely to effectively and economically power North Carolina's Blue Economy and, in the process, create jobs and economic opportunities. In pursuit of that goal, Coastal Studies Institute (CSI) offers a competition division focused on marine hydrokinetic energy. This is a unique division of competition that isn't currently offered at any other KidWind event.

For the NCREC's marine energy division of competition students will be constructing a wave energy device to be tested in a wave tank. While this task may seem daunting, competition in this division will provide students and educators a look into a field of emerging technologies.

What is Marine Energy?

In the United States, just under 40% of the population lives in proximity to the ocean. Harnessing the movement of waves, tides, and currents could provide a reliable and renewable source of electricity to coastal communities. While there is more energy in the ocean's movement is than we can access, the energy that is available to be harnessed could provide nearly 60% of our country's annual electrical needs. As one example of this, the Gulf Stream, a warm ocean current, sits just off the coast of North Carolina. Research being undertaken at CSI is examining ways that we can use this current to generate electricity.

It is important to understand that marine energy isn't just limited to the ocean, it includes any energy generated from:

- Waves, tides, and currents in oceans, estuaries, and tidal areas
- Free flowing water in rivers, lakes, streams, and man-made channels
- Changes in salinity (salt levels) or pressure
- Changes in water temperature.

Within the umbrella of marine energy is marine hydrokinetic (MHK) energy, which is specifically the energy generated from the movement of a body of water. The NCREC Marine Energy division of competition focuses on the use of wave energy converters which is one of several ways we can use MHK to generate carbon-pollution-free electricity.

The idea of generating electricity from the energy contained in ocean waves is not a new one, there are patents for harnessing wave energy that date back to the late 1700s. These designs were primarily static structures that culminated in the creation of the first oscillating water column device in the early 1900s. An example of this type of device can be seen below in Figure

1. In the time since, a variety of different methods to capture energy of waves have been designed and implemented.

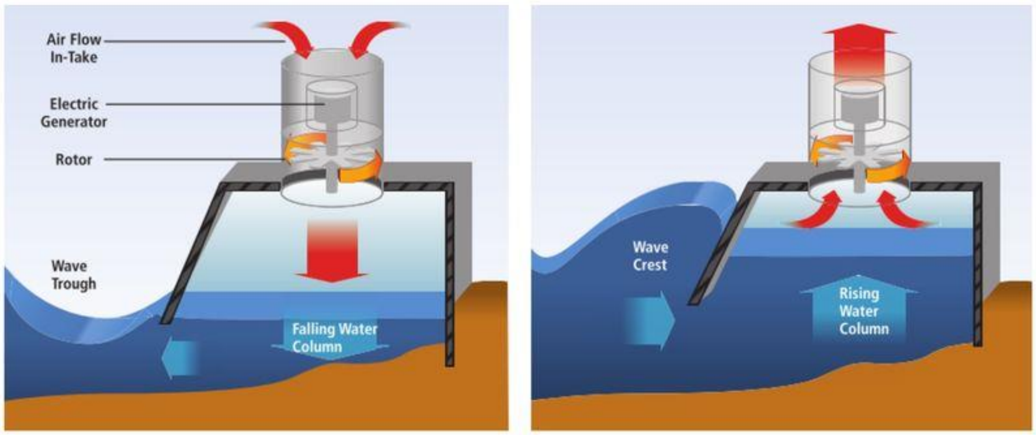

Figure 1 Wave energy conversion using the principle of the oscillating water column. (Intergovenrmental Panel on Climate Change, 2011)

Waves

Success in this competition will require an understanding of how waves are formed and how they move. Waves are a result of the wind blowing across the surface of a body of water. In the ocean waves can be affected by weather, tides, and underwater events such as earthquakes. Waves themselves are created from the friction that exists when wind blows across the surface of a body of water. As a result of that friction the water is moved in the same direction as the wind. Wave motion is created because water is denser than air and as a result does not move as quickly. This phenomenon causes the surface of the water to rise but is then be pulled back down due to earth's gravitational pull. The energy from this motion is transferred beneath the surface of the water and is counteracted by water pressure which forces the water back up again. This circular movement is shown in Figure 2.

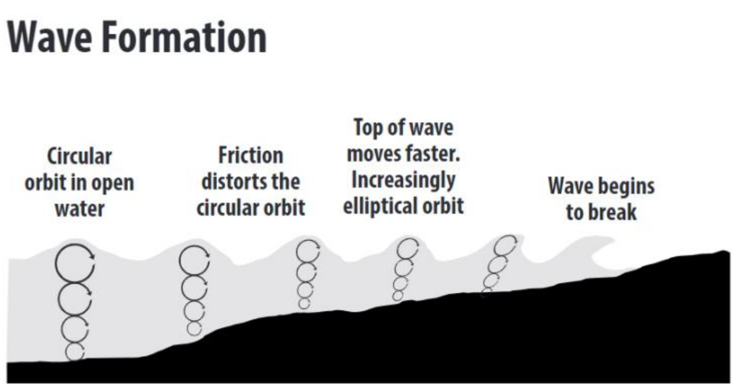

Figure 2 Wave Formation

As can be seen in Figure 3, ocean waves can be measured in the same manner as light and sound waves. The highest part of the wave is called the crest while the lowest is the trough. Wave height is measured from crest to trough and wavelength is the distance between two crests or two troughs. The amount of time that it takes for two crests or two troughs to pass a stationary point is called wave period and it indicates how quickly the wave is moving.

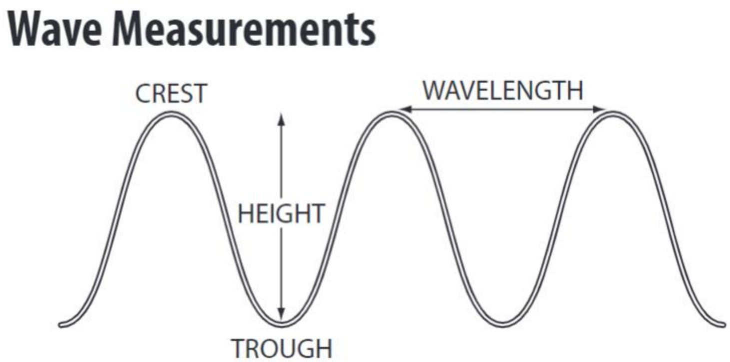

Figure 3 Wave Measurements (National Energy Education Development Project, 2016)

Wave Energy Devices

For this competition students will be asked to design a wave absorbing device, a device harness wave energy directly by using wave-induced water motion. In this category of devices there are three primary types: point-absorbers, attenuators, and surge converters. Each of these devices converts kinetic energy into electrical energy as a portion of the device being moved by waves. While you are only limited by your imagination as to

Point Absorber

Point absorbers are the simplest style of wave absorbing device and is especially promising for wave energy generation as they have a small footprint compared to other type of wave energy devices. As pointed out by Faizal, Ahmed, and Lee, "A point absorber is capable of absorbing wave energy from a wave front greater than the physical dimensions of the device itself" (Faizal, Ahmed, & Lee, 2014). While you are only limited by imagination as to the type of wave energy device you and your team chooses to build, it is recommended that for this competition you build a point absorber.

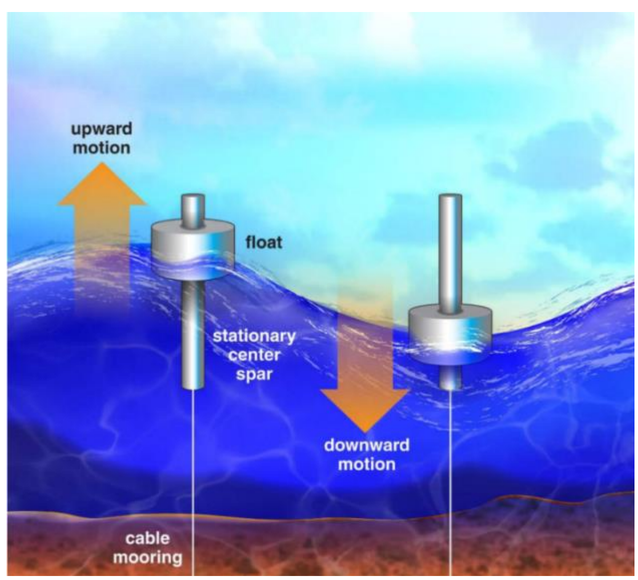

Figure 4 An Illustration of a point absorber. Illustration by Al Hicks, NREL (Li & Yu, 2012)

Attenuator

Another type of device is known as an attenuator. These devices are similar to point absorbers but work by having multiple connected segments. These devices are oriented perpendicular to the wave movement and the segments move up and down in a flexing motion as waves pass underneath them.

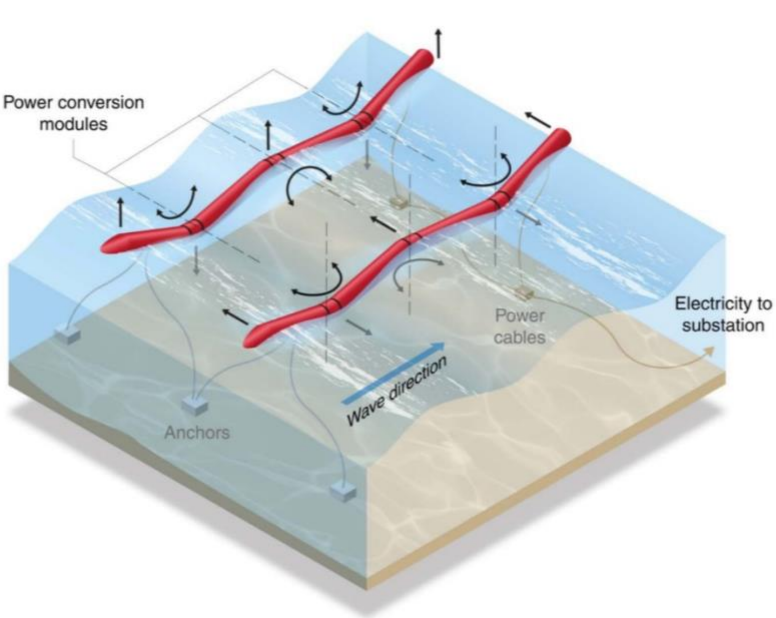

Figure 5 An illustration of a wave attenuator. Illustration by Al Hicks, NREL (Li & Yu, 2012)

Surge Converter

The final type of wave energy device is called a surge convertor. This type of device is essentially a flap that moves back and forth with the wave action near the shore. This is the least useful design for permanent wave energy collection due to their environmental impacts and the difficulty that exists in anchoring them to the shoreline. This type of wave energy converter is the least recommended style of device for this competition.

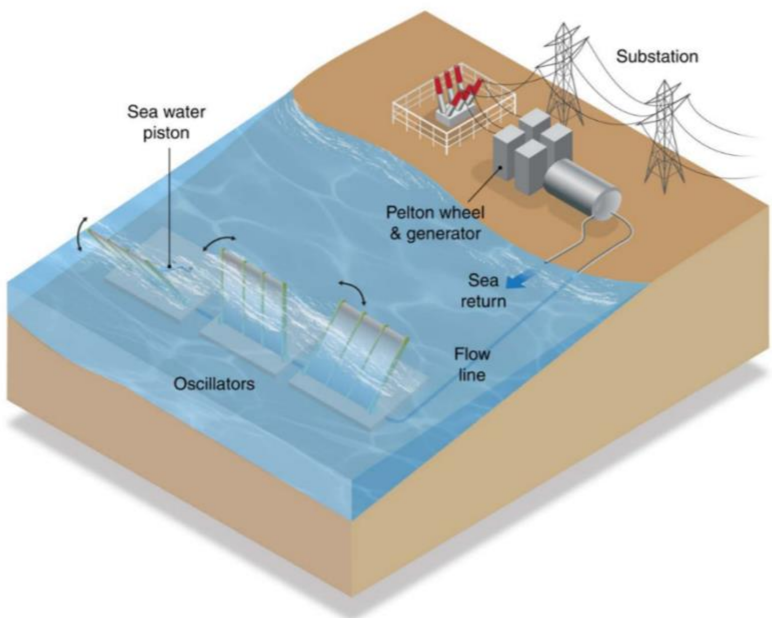

Figure 6 An illustration of a point absorber. Illustration by Al Hicks, NREL (Li & Yu, 2012)

WEC Resources

It will be important for you and your team to do some research when deciding what kind of device, you want to construct and how you want to construct it. To help you get started here are some links to resources that you might find useful:

- Exploring Ocean Energy and Resources - NEED
- Build a Buoy – COSEE and NOAA
- A Primer on Wave Energy Devices – SeaGrant Oregon
- Wave Energy Engineer: Building a Model Wave-Energy Generator – SeaGrant Oregon
- Ocean Power – US Department of Energy

Preparing for the Challenge

Participation Checklist

- Form a team
- Register for event
- Learn the basics: ocean energy, point absorbers
- Get materials
- Build wave energy converter
- Keep a notebook
- Attend challenge and have fun

What To Bring to the Challenge

- WEC device
- Project Profile Form, plus Team Notebook and any extra documentation for judging
- Extra parts and necessary tools, just in case
- Pen/ pencil
- Snacks*
- Water bottle

  *Pizza will be provided for lunch. All food must be consumed outdoors.

Challenge Divisions

- Middle School
- High School

Equipment to Build Your WEC

You will need some basic gear to get started. We have kits and materials to get you exploring, but you can use parts and designs from anywhere to participate as long as you are not violating any of the rules. Some things you *may* need to include:

- Electromagnetic Induction Method (Copper Wire and Magnets)
- Floatation
- Mooring Attachment Points or Ballast
- Separate Mooring (optional)

WEC Design Rules

As you construct your WEC, please keep the following rules in mind:

1. Each team that registers must have its own device. Different teams, even if from the same school or organization, cannot share one device and simply change a basic part for each team.
2. The device must be moored inside the wave tank and operate within a 3m square testing area.
3. There are no budgetary restrictions for your design, but it is important to keep in mind that part of the judging process is the economical use of resources. Please use materials responsibly.
4. Power must be generated solely by the waves produced in the tank.
5. Your device must be attached to one of our two provided moorings, or you can build and bring your own.
6. The use of 3D parts and components is allowed. While you do not have to use files you created yourself, you should bring documentation about the CAD files to the event and be prepared to discuss the design and 3D printing process. Judges will want to make sure that you understand this technology if you decide to use it.
7. Judges have the final call for safety. If you're not sure about something, please inquire prior to the event.

Connections

- You must have two wires connected to your wave energy device. You must label which wire is positive and negative. These wires will be connected to our data logging system.
- ***More details coming soon. Please check back later for more information. Any updates to this section will be highlighted.***

Power Output

- Our data-logging software and hardware can measure Direct Current at 30V/1A. Teams in all divisions must make sure to regulate their power output below these specifications. If your turbine exceeds this output, even for a millisecond, it may be disqualified as the equipment will not be able to properly record its power and energy output. This is very important!

- If your turbine produces so much power that it damages the generator before testing is complete, you will be able to retest your turbine as long as you can repair or replace your generator.
- Judges reserve the right to use other methods to collect power and energy output data if the probeware is unable to collect data.
- ***More details coming soon. Please check back later for more information. Any updates to this section will be highlighted.***

How Your WEC Will Be Tested

- WEC devices will be tested in a 10-meter-long, 2-meter-deep, and 3-meter-wide wave tank located at the Coastal Studies Institute.

- All teams will be given time to tweak their devices before actual testing begins. How much time will be determined by the number of entries across the entire NCREC and available free time.
- Competitor devices will be deployed and moored in the wave tank by a NCREC judge.
- Competitor devices can be attached to a common mooring provided by the competition or teams can provide their own mooring for use in the wave tank.
    - The provided mooring will consist of a two-inch loop in a polypropylene line on a subsurface buoy approximately 60 cm from the surface of the water.
        - ***Photo of common mooring coming soon. Please check back later.***
    - Competitor provided moorings can also be used. The depth of the water in the wave tank is approximately 130 cm. Competitor provided moorings must use sufficient ballast to keep their mooring in place during wave tank testing.
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- Teams need to provide wire connections for measuring power output from their devices. Wire connections should be at least 3m long.
- In order to receive full marks for functionality, your device must be able to start producing power without external assistance once the wave paddle is activated.
- During testing, there will be 30 seconds of wave generation as before power output data is collected. After this initial wave generation period, power and energy output data will be collected for 30 seconds. Your energy output score will be calculated using a Verneir data-logging system that collects voltage and amperage readings simultaneously.
- Devices will be judged on total power produced (watts) in two different wave fields. Teams will choose two of the four available wave fields for their device testing periods. Available wave fields include the following:
  - .05m wave height, .5 second period
  - .05m wave height, .75 second period
  - .05m wave height, 1 second period
  - .05m wave height, 2 second period

- If your WEC breaks once the timer is started, you will either be given two minutes to set it up again, or you will be allowed to remove the device to make repairs. In the latter case, you will be moved to the back of the line for retesting.
- Depending on the event rules, size, and time frame, you may have between 1 and 5 trials for testing, and only your best trial will contribute to your final score. CSI reserves the right to further specify once registration closes. Organizers will indicate a final decision to coaches prior to the competition.
- Judges have final say on rulings, disputes, and safety.

How Will Your WEC and Team Be Evaluated?

Teams can expect to be evaluated on energy produced. There will be judging and instant challenges that are also a part of teams' overall scores.

- 35% Energy Produced
- 30% WEC Design
- 20% Team Notebook (written documentation of design and other items)
- 15% Instant Challenges

Energy Produced: The total energy output of your device over the 30-60 second trial period will be collected using data-logging software. Each team's energy output will be ranked relative to that of the other competitors, and each team will receive points corresponding to its rank. Each WEC will be ranked by energy output. The highest producing WEC will receive the full number of available energy points, and the following WECs will receive points based on the rank with a 2-point deduction for each position they are from the top turbine. For example, if the top producing WEC received 35 points, and your WEC was the 6th-highest producing device, your team would receive 25 points, 2 less points for each rank down.

WEC Design: A panel of judges will examine your device design. This 15-20 minute interview is to get a better understanding of the process you went through as you designed your device. You should be prepared to discuss/defend the choices you incorporated into the design. Questions the judges may ask about your design include:

- When building your WEC, what kinds of obstacles or challenges did you face?
- What materials did you use to make your device? Why? What did you find important as you were building it?
- What techniques did you use to increase the power output of your WEC?
- What changes did you make to your WEC that led to the most performance gains?
- Discuss the craftsmanship of your design, including creativity, economic, and environmental decisions.
- Did you use recyclable materials?
- Can you take your WEC apart after the competition and reuse the parts?
- Were you able to perform any testing prior to the event? If so, how did you do it, and what did you learn?

The above questions can be used to help influence your WEC design process and/ or shape your Team Notebook and written documentation as outlined further below.

Written Documentation of Design: All students must complete a Project Profile Form (see final form following Ocean Energy Rules). This sheet should be presented to your judges when you enter the judging room. In addition to the form, teams may also share additional documentation that showcases with more detail their design process and knowledge of ocean energy science. It is up to each team to determine how they want to document this part of their project. In the past, teams have submitted:

- Team Notebooks
- Short reports
- Videos (max. 4 minutes)
- PowerPoints
- Science fair poster boards

Students must provide the means to play multimedia. We will not provide a computer, speaker, or other media devices.

Instant Challenges: Students will be asked to put their energy knowledge to the test in Instant Challenges. Instant Challenges do not require any preparation of planning beforehand, just a solid knowledge base to refer to for on-the-spot-engineering. Instant Challenges are short activities in which teams may be asked to complete short challenges, such as building a windmill to lift weights using common household materials or designing sails to most efficiently catch the wind. 10 points will be awarded for each challenge a team completes.

Final Scoring: The points from each area assigned will be added together for a cumulative score. The teams with the highest scores in each age division will be declared the winner.

WAVE ENERGY PROJECT PROFILE FORM

Team Name:

School Name:

This document is meant to help guide your design process and provide documentation to the judges about your wave energy device. You should present this document to the judges at the Challenge event.

1. Tell us about your generator. What brand and model is it? Where did you get it? Or did you make your own? Describe how you made it and what influenced your design.

2. What kind of power does your wave energy device generate? AC or DC?

3. Does your device fit in the 3 square meter operating area?

4. Does your device have wires long enough to protrude over the side of the wave tank to be connected to the power measuring system? Are your wires labeled + and -?

5. What was your maximum voltage output?

6. If your wave energy device was under a load at the time of testing the voltage, describe the load.

7. What materials did you use?

8. How does your device utilize the kinetic energy of waves?

9.Detail any computer software you used to design/print/ build parts of your device.

10. Detail any advanced manufacturing used to create your wave energy device (laser cutting, 3D printing, etc).

11.Describe any mechanisms or capacitors you have used to store electricity.

12. Detail any microcontrollers integrated into your device. Describe the goal and benefit of your microcontroller(s).

References

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