

## Waves: An Alternative Energy Source

A Classroom Activity for Ocean Gazing Episode #14: Dungeons and Darwins

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**Grade Level:** 9-12

**Lesson Time:** 1-1.5 hrs.

### Materials Required

[wave energy chart](#) (pdf), [sample answer sheet](#) (pdf), [electricity usage table](#) (pdf), [discussion questions answer sheet](#) (pdf)

### Summary

Evaluate the feasibility of wave energy as a practical alternative energy source using ocean observing system (OOS) buoys.

### Objectives

- ✓ Describe the process of energy production.
- ✓ Identify types of wave energy and wave energy technologies.
- ✓ Formulate energy flux and power produced by wave energy sources.
- ✓ Appraise output and value of wave energy alternatives.

### Vocabulary

Renewable, Non-renewable, Sustainable, Kilowatt hours, Wave height, Wave period

### Introduction

\$2.60 a gallon, \$2.85 a gallon, \$3.49 a gallon! Since 2003, we've seen gasoline and other fuel prices sky rocket, with little relief in site. Not since the [energy crisis of 1973](#)

have people of all walks of life so earnestly explored alternative energy sources. Our lives have become so dependent on [non-renewable energy](#) sources that it is hard to imagine life without them.

But what about [renewable or sustainable energy sources](#)? Using [water](#), the [sun](#), the [wind](#), even [trash](#), people are harnessing renewable energy all around us and most of the time it goes on unnoticed. From simple ideas, like a water mill, to more sophisticated, like the solar panel, the technology is available to shift a lot of our energy demand to more environmentally-friendly sources. By harnessing natural processes, we decrease the [dependency on other countries](#) and the destruction of our own back yard for fossil fuels.

Another source of renewable energy that is gaining focus and popularity is wave energy, utilizing the ocean's waves to create electricity. If you have ever surfed, boogie-boarded, or just swam in the ocean, you know how much power can be unleashed when a wave crashes. What about those swells outside the [surf zone](#), can they produce as much energy? The answer is an emphatic yes! Scientists have figured out ways to harness energy from the rise and fall of the water as a wave moves past.



### *Energy Production*

Most people never think twice about the electricity that powers the lights in their house, the computer, the TV, or the hot water heater, until that is, they hit the switch and nothing happens. Regardless of whether it comes from a [coal-fired power plant](#), a [hydroelectric power plant](#), or a nuclear power plant, electricity is produced pretty much the same way. Electricity comes from the spinning of a generator, typically powered by steam, which is produced by the burning of coal or oil, or the [splitting of atoms](#).

Once the electricity is produced, it is moved through a [power grid](#). After traveling mile after mile, and being stepped-down several times, it is fed into your house and is available at the flick of a switch.

The electricity that a power plant produces, and the customer consumes, is measured in [kilowatt hours \(kWh\)](#). In 2001, electricity consumption by 107 million U.S. households totaled 1.140 trillion kWh ([U.S. Department of Energy](#)), or approximately 10,000 kWh of electricity per household. For comparison, the sun radiates approximately 174,423,000,000,000 kW of energy to the Earth per hour!

When designing a new power plant, in addition to the important decision of what type it should be, other factors must be taken into consideration. Distance to the consumer and the power grid are very important determinants of the location of the new plant. After all, if the cost of producing the electricity and getting it to the consumer is higher than the price the plant receives for the power, it will not be in business for very long. It is widely accepted that in order for a power plant to be economically viable, it needs to produce electricity at a cost at or below \$0.10/kWh.

This is now the goal of those exploring alternative energy sources and increasingly, scientists and engineers are reaching that goal.

### *Wave Characteristics*

Water waves can be generated any number of ways &mdash; a rock being thrown in the water, a passing boat, underwater earthquakes (tsunamis) &mdash; but the most common wave generating force is wind.

Every wave, regardless of whether it is a sound wave, light wave, or ocean wave, has the same [components](#). The wave characteristics we'll be using in this data activity are wave height and wave period. ([Click here for an interactive demonstration](#).) As waves move into shallow water or encounter obstacles, their forward direction will [change](#). This plays a large part in the placement of an effective wave energy power plant.

### *Wave Energy*

It should be obvious that taller waves will produce more electricity than shorter ones, but what about their frequency? As waves move, the water itself is not moving forward, but instead, in a [circular motion](#) caused by the forward motion of the energy. Therefore, as a deep water wave becomes taller, it also becomes longer. Longer waves travel faster; however, the wave frequency actually decreases. These tall, lower frequency waves produce the most electricity.

So where are the best waves to harness for electricity? As it turns out, just about any wave is capable of producing at least some electricity, however, the very best places to use [wave energy technologies](#) occur outside the United States. Places such as the United Kingdom and the west coast of Europe, southern Chile, South Africa, the west coast

of Australia, and New Zealand have the potential to produce electricity that far exceeds the world's demand. However, despite smaller wave power levels, the New England and northwestern coasts of the United States still possess characteristics that make them feasible sites for wave-generated electricity production.

### *Types of Wave Energy Technologies*

Although there are many designs currently available, there are four general forms of wave energy technologies. Two are stationary or land-based and two are floating or sea-based. The two we will focus on are the [LIMPET \(Land Installed Marine Powered Energy Transformer\)](#) system, and the [floating hinged contour device](#), specifically the [Pelamis](#) system. The LIMPET system found in Islay, Scotland is strictly an experiment in alternative energy sources. This 20 meter long energy converter built along the shoreline produces electricity as waves flow in and out of the system forcing air past the turbines. The Pelamis system is a floating structure of hinged cylinders. As waves cause the hinges to flex, hydraulic rams pump high-pressure fluid through the motors turning the generators and producing electricity. The Pelamis system is used in areas with a depth of 50 - 100 meters.

### **Data Activity**

Using [ocean observing system \(OOS\) buoys](#) from all over the coastal United States, we will evaluate the feasibility of wave energy as a practical alternative energy source. With real time data from the OOS buoys, we will calculate the amount of electricity that could be produced by either the LIMPET (land-based) or Pelamis (floating) systems at certain locations along the US coastline. Begin by printing the [wave energy activity chart](#). Access the wave data from the following ocean observing system buoys and fill in the missing wave height,

dominant wave period and site depth values on the chart.

### *Inshore Stations:*

1. [Gulf of Maine](#) - From the Gulf of Maine Ocean Observing System (GoMOOS) site, click on buoy "J," the Cobscook Bay buoy. (For water depth information click on the "Description of station & location" link in the upper right corner of the page)
2. [Johnnie Mercer's Pier, NC](#) - From the Coastal Ocean Research and Monitoring Program (CORMP) of North Carolina, click on buoy "ILM1" at Johnnie Mercer's Pier, NC.
3. [Diablo Canyon, CA](#) - NOAA National Data Buoy Center's (NDBC) buoy #46215 at Diablo Canyon, CA

### *Offshore Stations:*

1. [Gulf of Maine](#) - From the Gulf of Maine Ocean Observing System (GoMOOS) site, click on buoy "N," the Northeast Channel buoy. (For water depth information click on the "Description of station & location" link in the upper right corner of the page)
2. [Atlantic Ocean, NC](#) - NOAA National Data Buoy Center's (NDBC) buoy #41001 offshore of the Outer Banks, NC
3. [Pacific Ocean, CA](#) - NOAA National Data Buoy Center's (NDBC) buoy #46006 offshore of Eureka, California
4. [Lake Michigan](#) - NOAA National Data Buoy Center's (NDBC) buoy #45007 in southern Lake Michigan

Use the following conversions, equations, and graph to find the LIMPET Amount and the Pelamis Power Yield. These values are

the amount of electricity that these alternative systems could potentially produce at each particular location. Inshore locations will use the LIMPET system and offshore stations will use the Pelamis

system. After completing the handout, compare your answers with the Bridge's [sample answers](#) and answer the discussion questions.

LIMPET System	Pelamis System
<ul style="list-style-type: none"> <li>✓ Calculate the Energy Flux or “J” using the wave height and the wave period.</li> <li>✓ Calculate the LIMPET Amount (amount of electricity produced) by multiplying the energy flux by 20 meters (the length of the LIMPET converter).</li> </ul>	<ul style="list-style-type: none"> <li>✓ Calculate the Power Period or “T<sub>pow</sub>” using the wave period.</li> <li>✓ Go to the <a href="#">Power Matrix Graph</a> and use the Power Period and wave height, to find the Pelamis Power Yield.</li> </ul>
<p><b>Calculations:</b></p> $J = 0.5 \times (H_s)^2 \times T_p$ <p>LIMPET Amount = J x 20</p> <p>Where:            J is the wave energy flux (kW/m)            H<sub>s</sub> is the significant wave height (meters)            T<sub>p</sub> is the dominant wave period (seconds)</p>	<p><b>Calculations:</b></p> $T_{pow} = 0.857 \times T_{peak}$ <p>Where:            T<sub>pow</sub> is the power period (seconds)            T<sub>peak</sub> is the dominant wave period (seconds)</p>

*Inshore Questions*

- ✓ Using the data you calculated above, which inshore site (Cobscook Bay, Johnnie Mercer’s Pier, or Diablo Canyon) would make the best site for a LIMPET system? Why?
- ✓ What does the location of each buoy within each respective cove have to do with the size of waves they reported?
- ✓ Given that the California coast line measures 840 miles (1,351.85 km), if half of the coastline was dedicated to LIMPET systems, how much electricity would they produce?
- ✓ Would this cover your state’s electricity demand (see the [1990 - 2003 US electricity usage table from the US Dept. of Energy](#))? If so, how

much would there be left over? If not, how much more electricity would you need?

*Offshore Questions*

- ✓ Using the data calculated above for the Pelamis converter, which site, offshore New England, offshore North Carolina, offshore California, or Lake Michigan would make the best site for a Pelamis “farm”? Would all be effective sites?
- ✓ Based on their locations on the maps, what is an obvious disadvantage of the offshore NC and offshore CA Pelamis farms?
- ✓ The annual output of a Pelamis converter is approximately 2.7GWh at full capacity. Given this, how

many units would be needed in one area to produce enough electricity to cover your state's demand?

## Discussion Questions

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- ✓ Based on what you have observed in the Data Activity, do you see wave energy as a practical alternative energy source? Why or why not?
- ✓ Is it better to build bigger systems to harness storm-sized waves and run at lower efficiency the rest of the time OR build smaller, more efficient systems and a) risk destruction of the system during big storms or b) not harnessing the energy of larger storm waves? Explain.
- ✓ Explain how refraction increases the amount of energy that can be harnessed from a single wave by a shoreline converter.
- ✓ Explain how diffraction increases the amount of energy that can be harnessed from a single wave by an offshore converter.
- ✓ Discuss the advantages and disadvantages of each type of system and wave energy overall.

### [Discussion Questions Answer Sheet](#)

## Extensions

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- ✓ Using the US electricity usage table, explore/graph electricity usage state to state and year to year.
- ✓ Determine the feasibility of wave energy power to meet other states' electricity demands.
- ✓ If a 30 MW Pelamis farm, composed of 40 units, occupies 1.26 km<sup>2</sup>, approximately how much water-area would be needed for a farm that would meet your state's demand? To calculate, multiply 40 units by 2.7

GWh (the annual output of a Pelamis unit).

## Related Resources

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[Physical oceanography](#), [Technology](#), [Ocean Observing Systems](#)

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## Sources

To access an online version of this activity, you can go to the following URL:  
[http://www2.vims.edu/bridge/DATA.cfm?Bridge\\_Location=archive1005.html](http://www2.vims.edu/bridge/DATA.cfm?Bridge_Location=archive1005.html)

The related podcast episode for this activity can be found by going to the podcast section of [www.oceangazing.org](http://www.oceangazing.org)