Wave Energy Converters and Design Considerations for Gulf of Mexico

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ABSTRACT

This article presents an investigational study on wave energy converters (WECs) and the design considerations for possible implementation in the Gulf of Mexico (GOM). The types of WEC available from the market are studied first. The design considerations for implementing a WEC in GOM are then evaluated. There are several different types of devices that can be used in the system design. Each device type has different attributes that may be helpful or hurtful for the area and wave activity in the GOM. From the evaluation there is a recommendation of the optimal device design conditions, and three device types are recommended for further pursuit as design candidates. Six different WEC projects that are currently being developed and most are ready for commercial testing are examined. Our study evaluates the usefulness of the WECs for the GOM, and provides design factors of both physical and economic scaling. The result of this investigation reveals that while none of the devices can be installed "as is" in the GOM because of wave power or geometry requirements, there are some that have the potential to be modified and scaled down to fit the GOM climate.

Keywords: wave energy converter, Gulf of Mexico, design considerations, investigational study

INTRODUCTION

The University of Louisiana at Lafayette (UL Lafayette) wave energy research team is in the process of developing a wave energy converter (WEC) for the Gulf of Mexico (GOM). The goal of this device is to provide partial power to platforms in the GOM and the outer continental shelf would be a target area of operation. In order to fully develop a WEC, several stages of study are required:

1. Feasibility Study on using WEC in GOM. The feasibility study consists of gathering information to aid in the development of a WEC. This step includes activities to (a) compare wave energy to other alternative energies, (b) review the physical characteristics of the GOM, (c) assess the platform activity in the GOM, (d) develop equations for waves and wave power, (e) estimate the wave power available from the GOM, and (f) observe trends in location and weather information.
2. Investigative study on WEC. Research efforts are required to (a) review the types of WEC available in the market, (b) identify the type of device that would best fit the area, (c) evaluate WEC design considerations, and (d) survey WECs already in production or development.
3. Development of Wave Energy Converter. Developing a WEC can be broken down into the following steps: (a) select one wave energy converter, (b) find or develop power and efficiency equations for the device, (c) run simulations on device to theoretically prove concept, (d) develop system for power generation and storage, (e) design system integration to platform.
4. Economic Analysis. Economic analysis involves information gathered from steps 1, 2 and 3 to (a) find the average costs or a range of costs for fuel operations on platforms, (b) use power equations for device and waves to develop device efficiency, (c) estimate production, instillation, and maintenance costs for full scale device, and (d) assess the economic viability of using a WEC on a platform.
5. Development and Testing of System. Development and testing is a long intensive process that requires several steps as blow: (a) develop lab and testing facility, (b) develop testing and instrumentation methods, (c) develop device prototype, (d) analyze and test prototype device, (e) full scale testing and deployment.
6. Integration into platform. This step involves the following activities: (a) finalize the designs, (b) get approval for system installation, (c) install onto working platform.

The steps for designing and implementing a WEC are very complicated and require significant efforts of research, development, and testing. There are projects that have developed WEC, but they are in areas that are very different from the GOM's wave climate. There are preliminary estimates of wave power from some studies, but none of them fully disclose their process of extrapolation and can have inflated estimates.

Our work on feasibility study on using WEC in GOM has been summarized in [1]. This article expands our research in evaluating the WEC technology available today. In the following sections, the types of WEC available from the market are studied first. There are several different types of devices that the team can use to implement their system. Each device type has different attributes that may be helpful or hurtful for the area and wave activity in the GOM. From the evaluation there is a recommendation of the optimal device design conditions, and three device types are recommended for further pursuit as design candidates. Six different WEC projects that are currently being developed and most are ready for commercial testing are examined. The study evaluates the usefulness of the WECs for the GOM, and provides design factors of both physical and economic scaling.

TYPES OF CONVERTERS

Oceans and seas have two main sources of movement that can be captured into energy: tidal currents and waves. According to the Department of Energy (DoE) [2] and the European Marine Energy Centre (EMEC) [3] there are seven classifications of devices: point absorbers, submerged pressure differentials (SPD), attenuators, oscillating wave surge converters (OWSC), overtopping devices, oscillating water columns (OWC), and others or unclassified technologies that do not fall in any category or can be considered in a combination of categories. These devices are reviewed and some of the most important design considerations are made to recommend the best type of device for the Gulf of Mexico. Additional information on WEC can be found in [4, 5, 6].

Point Absorbers

Point absorbers are a simple technology that consists of a buoy or floating body that is used to capture the waves' heaving motion (Figure 1). When the float moves up and down it can drive pistons that cause rotation or hydraulics to run and create energy. Wave direction is not an issue for point absorbers, because they are operating at a single point, waves coming from any direction can be captured. Point absorbers are relatively small when compared to the size of the waves. Often point absorber systems are used in arrays, where multiple devices are attached in series or parallel to capture more energy. Point absorbers can be used offshore in various depths of water.

Li and Yu [7] present a summary of methods used to simulate point absorbers. They reveal that the simulation of point absorbers requires knowledge of body dynamics and wave theory. The analytical solutions of free surface waves can be derived from potential flow method, where the flow is assumed to be incompressible and irrational. The velocity potential is then obtained by solving the Laplace equation [7].

Attenuators

Attenuators can be classified as a WEC that uses a bending action to move pistons or hydraulics, which create energy. One common version of an attenuator is a long device, which has several sections that float in the water (Figure 2).

The principle of floating-pitching device, whether it is composed of a single body or a number of connecting bodies, has rotational freedom [7]. The wave action moves one section causing a "bend" between

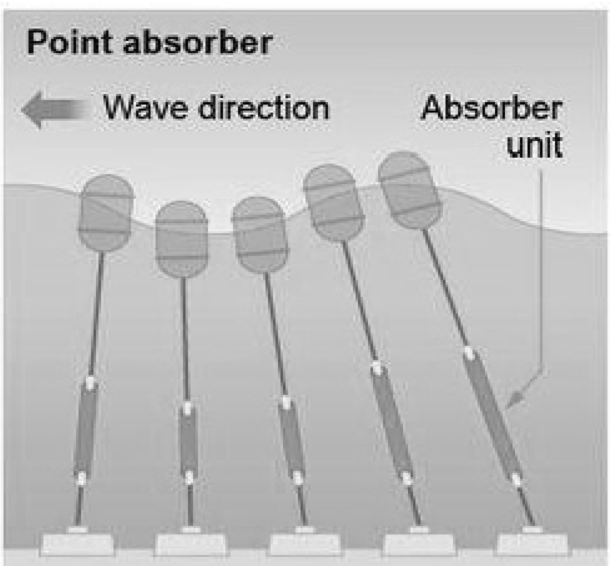

Figure 1. An illustration of point absorber [2]

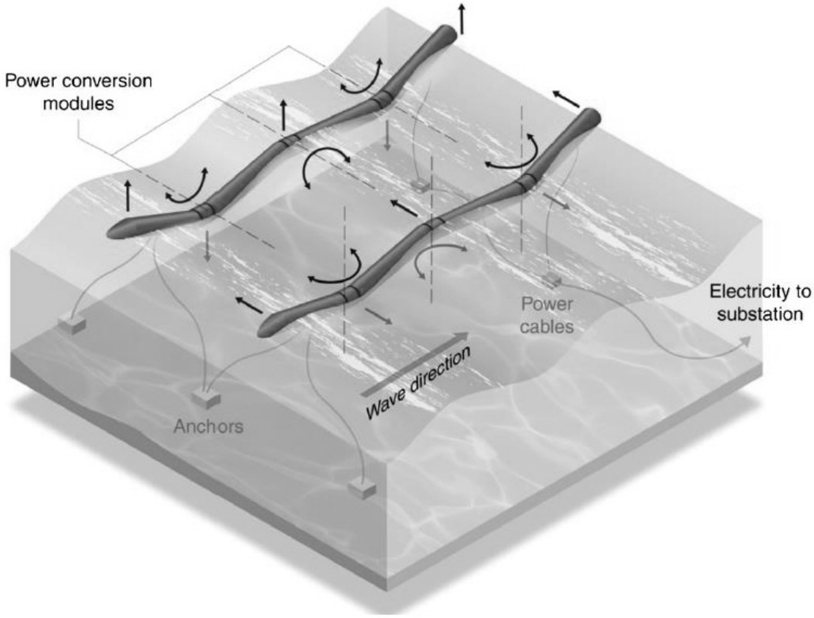

Figure 2. An illustration of attenuator device [7]

the first and second section. This bend creates a point where a piston or hydraulic system can be used to generate energy. These devices are usually larger than one wavelength so that they can capture the most effective bending motion. The device converts wave energy from its pitching motion. The principal axis for floating-pitching devices must be either perpendicular (terminator) or parallel (attenuator) to the wave direction.

Most attenuators are used near shore, but there are some designs that could be used further offshore. Attenuators need to be positioned parallel with the wave direction of travel in order to capture the wave [8].

Submerged Pressure Differentials

SPDs are completely submerged devices that use the weight of the waves moving above the device to pump compressed air. It comprises two main parts: a sea bed fixed air-filled cylindrical chamber with a moveable upper cylinder. As a crest passes over the device, the water pressure above the device compresses the air within the cylinder, moving the upper cylinder down. As a trough passes over, the water pressure on the device reduces and the upper cylinder rises. SPDs work like point absorbers, but instead of using the waves to pull up, they use the weight of the waves to push downward [8]. Because SPDs are located below the surface of the waves, some of the energy potential is lost because the energy decreases with the depth. While there is a slight loss of energy potential, there are some benefits to being located underwater, such as resistance to corrosion and event activity. An artist's impression of which is shown in Figure 3.

In Submerged Pressure Differential devices, its principles work on the basis of a pressure differential being created due to the movement of the waves [9]. In the Archimedes Wave Swing device, this is done through the compression of air inside flexible membranes.

Oscillating Wave Surge Converters

OWSCs are "flap-like" devices that move with the motion of the waves coming to shore. It often includes a paddle, or a flap, that is connected to a hinge deflector on the seabed; the top of the device is generally above the free surface (Figure. 4). It is sometimes called a wave surge converter, because it converts wave energy from the horizontal

Figure 3. An illustration of submerged pressure differential [9]

movement of the water particles. Unlike the floating-pitching device, one end of the bottom-hinged device is fixed. The device is usually anchored to the seabed, and it can be fully submerged or some part of the device can stick out of the water. It is most useful on or near the shoreline and is relatively large when compared to other devices.

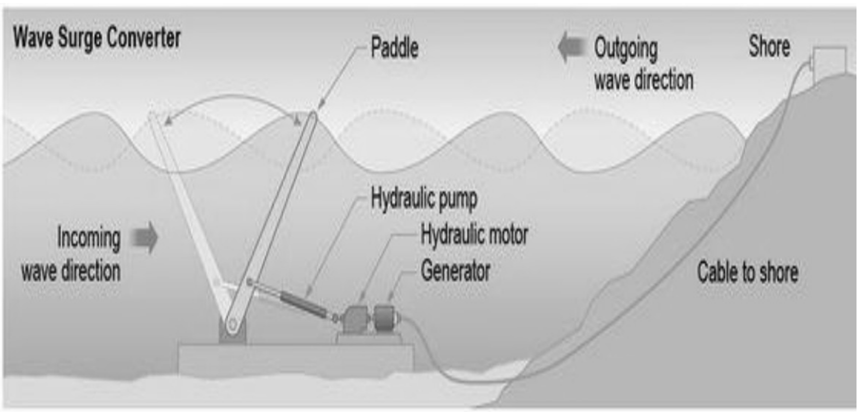

Figure 4. An illustration of oscillating wave surge converter [2]

The Oyster project developed by Aquamarine Power is an example of an OWSC [10]. It includes a paddle, or a flap, which is connected to a hinge deflector on the seabed. The top of the device is generally above the free surface. It is called a wave surge converter, because it converts wave energy from the horizontal movement of the water particles. Unlike the floating-pitching device, one end of the bottom-hinged device is fixed [7]. That is, it shares a similar working principle.

Overtopping Devices

Overtopping devices are designed to capture the energy of falling water, and have been compared to hydroelectric dams [11]. The overtopping device includes a large structure that embraces the incident wave and an outlet with turbines inside the large structure (Figure 5). Waves flow over the device and into an opening where the water drops through a turbine, capturing the energy. These devices require higher waves to get more energy from gravity and typically are very large. Overtopping devices also need to be located near the shore.

The overtopping device includes a large structure that embraces the incident wave and an outlet with turbines inside the large structure. The device converts wave power by utilizing the wave overtopping phenomenon to let the water fall through the outlet of the designed structure [7]. When the water falls through the outlet, it passes one or more turbines similar to a traditional hydro dam, the potential energy is converted into electric power. The design involves both kinematic energy and potential energy in the conversion process.

Oscillating Water Columns

An OWC is a dome-like device that sits in the water and uses the passage of waves to create a pressure variation, to push air or water through an opening, which turns a turbine (Figure 6). These devices can be less efficient because most use waves to compress air, and are not directly capturing the wave force [8]. OWCs work best when located near shore or on the shoreline.

The oscillating water column includes a special chamber with a bidirectional turbine inside as mentioned by Al Hicks, NREL. One end of the chamber has an inlet that allows the incident wave to enter and the other end contains the turbine. The device converts wave power by utilizing the wave elevation to compress or decompress the air in a chamber. The compressed air goes through a bi-directional turbine. That is the principle of how an oscillating water column works.

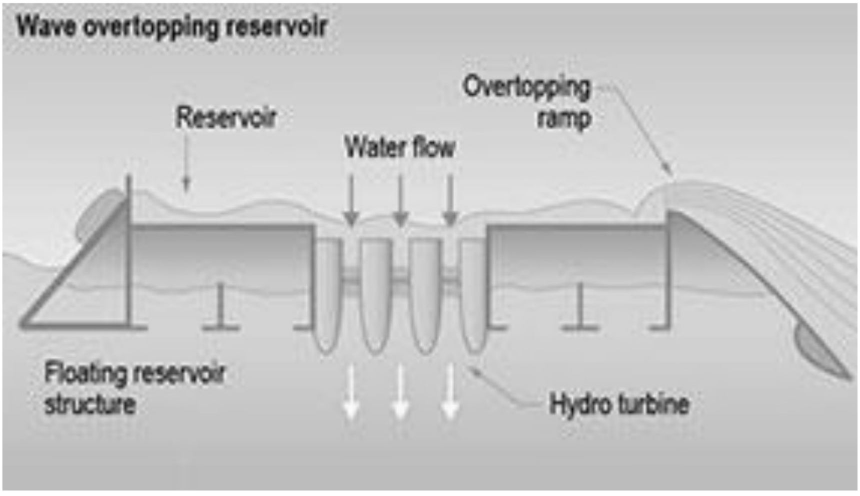

Figure 5. An illustration of the overtopping device [2]

Figure 6. An illustration of oscillating water column [12]

Other WECs

There is always room for new ideas and inventions that do not fall into one of the categories. These could be hybrid devices, or are completely different from the ones described above. Some of these devices include specialized systems that can be adapted to other WECs, like Scientific Aspect Research Associates' (SARA) magneto hydrodynamic (MHD) energy conversion system [13].

DESIGN CONSIDERATIONS

When looking at the GOM as a possible energy source, it is important to tailor the device that will be used to the conditions in this area. An ideal device would be one that can work offshore, uses multiple small units, resists corrosion or is completely below water, is easily tuned, and does not need a specific wave direction. The typical design considerations are discussed below.

Location

Some of the devices listed above have location restrictions to either near shore, on the shoreline, or offshore operations. Near shore can be considered up to 25 meters from shore and offshore is typically anything further than 25 meters [10]. There are some limitations with the different locations. Waves near shore typically have less energy than those waves offshore. Some near shore devices have to be designed for the shoreline geometry; therefore, it becomes difficult to mass-produce this technology. Working near shore also means that the device cannot interfere with the beach community and local property owners who do not want to look at "ugly" devices that obstruct their view or the activity on and near the beach [5].

Offshore technology does have the benefit of more wave activity, but it also becomes more difficult and expensive to install and maintain. When working with deep water it may not always be feasible to anchor directly to the seabed. WECs could be anchored to platforms, but because the installation would be closer to the surface, design considerations would have to be made so that the anchoring system could withstand the wave activity. Offshore locations also experience more event activity than near shore because landmasses and other things obstruct or slow down storms [4].

Area of Capture

The goal of having wave capture devices is to get as much energy as possible. This can be done by covering a large area of the waves. One way to accomplish this is to have very large devices that capture a large area. These can become very expensive to install and repair if they are broken. The second way is to use smaller devices that are connected together to cover more area [14]. These multiple device systems are set up in "arrays," which are different configurations of the multiple-unit system. According to EPRI [15], experiments were done to test the effectiveness of putting devices together, specifically point absorbers. If the WECs were placed too closely together, the first devices that felt wave action would lower the amount of energy captured by the other devices. With the units properly spaced, it was found that the devices could increase the other's effectiveness.

While it may be more expensive to build and install more WECs, the system does not have to stop working because one is damaged or off-line. The others in the array can continue working until repairs can be made. If devices are small enough, one unit may be replaced or removed for repairs in a safer, less expensive location. With the event activity that can be found in the GOM, multiple units would work better because of the ability of the system to continue working if some devices are damaged.

Tuning

WECs need to be tuned to the waves in order to get the greatest efficiency. Some devices are more difficult to tune than others, and some devices can self-tune or be tuned remotely. Tuning is usually dependent on the wave height and period and can be affected by the dominant wave direction.

Wave direction can be a factor in design because out in the ocean, waves change direction often [4]. Some of the device types require that the wave capture occur in a particular direction, either perpendicular or parallel to the wave direction. If a WEC has a directional requirement, there could be lots of energy lost. Devices could be remotely repositioned or could be designed with a self-correcting maneuverability. There would still be energy losses in the time it takes the device to right itself and the energy that it would take to correct its position. Not all waves travel in the same direction at the same time. Not just shifting wave direction, but wave groups can interfere with each other and cause a dominant wave direction to be difficult to determine. Near shore, the direction of waves is not as erratic as offshore [16].

Environmental Considerations

While the idea of wave energy is one that provides a clean source of energy, other environmental impacts must be considered like interference with wildlife and any type of leaking or run-off of the materials used in the device itself. If these devices were to be installed, environmentally friendly materials could be used, but they might cost more. Much of the wildlife impact has been considered because man-made structures are already in the GOM and research and regulations have been set up to handle the wildlife impacts of such structures [14]. Some of the devices would use a hydraulic system to create energy. Any use of hydraulic fluid, that is not salt water, would have to be designed with systems to prevent leakage or fluids would need to be biodegradable. With the use of an open system, using seawater as the hydraulic fluid, biological organisms and sea life could enter the system and interfere with its operation, which has the potential to cause great damage.

Durability

Durability to the elements is also a concern when looking at WEC design. With the salt-water environment, devices must resist corrosion. There are several types of corrosion but the main reaction of corrosion is between the salt, air, and metal surfaces. In the Minerals Management Service (MMS) report on the design standards of WECs, there are three areas in which the devices can be placed: topside, which is out of the water; in the splash zone, where water meets air; and subsea, which is under the water [14]. When devices are subsea, air is less of a factor and these devices can better resist corrosion.

Because of the presence of weather events like hurricanes and tropical storms, it is important that WECs are resilient and able to withstand the high activity without breaking. If devices can operate during these events, it is even better. Near shore devices have been developed more than offshore devices. Part of this is because near shore there are fewer events or the events are not as severe once they approach the shore. Devices that are offshore can avoid events by being subsea, or having a mode that submerges the device until the storm passes, like the design of Teamwork Technology's Archimedes Wave Swing (AWS) [17].

Summary of Types and Characteristics

Table 1 shows some typical characteristics of the different devices. One of the most important factors is offshore vs. near shore. There are three devices that can easily be placed further offshore – point absorbers, submerged pressure differentials, and attenuators. Point Absorbers and SPDs are both smaller devices, and all can be easily used in multiple device arrays. The attenuator has the best ability to be tuned, but it also requires a specific direction of wave to operate, while point absorbers and SPDs could operate with waves from any direction. The only device that is completely submerged is the SPD, which means that it is both corrosion resistant and has a better chance of surviving harsh wave activity.

Out of all of the different types it seems that the best choice for the environment of the GOM is the SPD type, followed closely by the point absorber and attenuator. There are still developments issues that need to be overcome with any of these device types and some of the issues may prove to be more difficult to solve than others.

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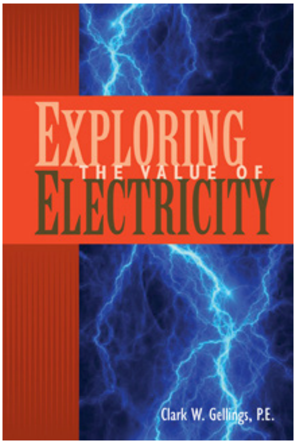

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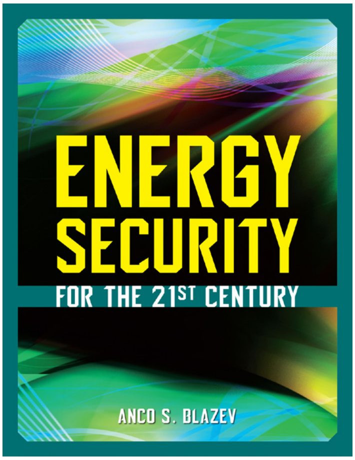

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Table 1. WEC device type and typical characteristics

Type	Location	Size	Specific Wave Direction	Splash/ Subsea	Tunability	Use Arrays
Point Absorber	Offshore	Small	No	Splash	Poor	Yes
SPD	Offshore	Small	No	Subsea	Fair	Yes
Attenuator	Offshore	Large	Yes	Splash	Fair	Yes
OWSC	Near shore	Large	Yes	Subsea/ Splash	Fair	No
Overtopping	Near shore	Large	Yes	Splash	Good	No
OWC	Near shore	Large	Yes	Splash	Fair	No

WAVE ENERGY CONVERTERS IN OPERATION

In different parts of the world there has been research and experimentation with wave energy converters. The EMEC [3] has a list of 147 companies that are pursuing different types of wave devices. Of the 148 devices, 57 were point absorbers, 32 were attenuators, 19 were OWCs, 9 were OWSCs, 8 were overtopping or terminator devices, 4 were SPDs, and 20 were others or unclassified. The companies were based in different parts of the world: 37 were located in the US, 29 in the UK, 15 in Norway, and 8 in Denmark.

The list had companies with various stages of projects, with many were in the conceptual stages while some were available for market use. The main objective of these projects is to supply electrical grids with power. The EPRI did a review on some of these companies in 2004 [17]. They started with a list of 17 companies and reviewed a total of 8, which met their criteria of companies that were supposed to be ready for production by 2006. Clement [18] also reported on the status of wave energy in Europe back in 2002, which named several companies and their devices. Throughout the research process, some technologies and companies were presented more than once. After cross-referencing different papers, six of these technologies stood out as "most mentioned" and they are represented in Table 2.

With these different devices and companies we can see what they have done and what has worked the best. Most of these companies have different goals than those of the UL Lafayette wave energy team, but some of the scale and pricing of these devices might be helpful in the scale and price expectations of the UL Lafayette project's device.

Table 2. WEC development companies

Company	Device Name	Device Type	Country Base
Ocean Power Delivery	Pelamis	Attenuator	UK
Wave Dragon	Wave Dragon	Overtopping	Wales/ Denmark
Ocean Power Technology	Powerbuoy	Point Absorber	UK/USA
Energetech	OWC	OWC	Australia
Teamwork Tech	Archimedes Wave Swing	SPD	UK
Aquamarine Power	Oyster	OWSC	UK

Ocean Power Delivery

Ocean Power Delivery is a company based in the UK and created the Pelamis. In 2004 the EPRI reported on the progress of the Pelamis [17]. Pelamis is an attenuator type device and the estimated cost in 2004 was $2-$3 million not including the mooring system. The device is 150 meters long with a 4.63 meter diameter and weighed 380 tons. Pelamis is "snake-like" and is composed of cylindrical sections that are linked together at joints [18]. The power system is located inside of the joints where hydraulics is used to create energy. The Pelamis captures both horizontal and vertical motion, and the loose mooring system allows it to rapidly correct itself with changing wave direction. According to the company's website, the Pelamis was the first to successfully transport energy to an onshore grid network [19]. A depth of at least 50 meters was required for the Pelamis to function properly, and the website mentions that the Pelamis is able to work in sea states with a power of at least 15 kilowatts per meter.

Wave Dragon

Wave Dragon is an overtopping device, which was developed in Denmark and Wales, and it was also reviewed by the EPRI in 2004. The device ranges from 260 meters to 300 meters in width, has a reservoir between 5,000 and 8,000 cubic meters, and weighs between 22,000 and 33,000 tons [17]. The size of this device makes it huge in comparison to most other devices and repairs must be done at the device site location. The Wave Dragon uses large wings (reflectors) to drive water into the reservoir. When water flows through the reservoir, it turns low head turbines to generate energy. The device takes advantage of its height out of the water and uses gravity to help turn the turbines. The cost for one of these Wave Dragons was estimated at $10-$12 million for only the device. The Wave Dragon website (www.wavedragon.net) mentions that a model of the system was created that needed only 0.4 kW/m sea state, which enables it to work in lower energy wave climates [20]. Because of the size of the device and how it uses gravity, it does not need to be constantly tuned for changing wave activity.

Ocean Power Technology

Ocean Power Technology, a US and UK based company, which developed the Power Buoy, declined to participate in the EPRI study done in 2004 [17]. The device is a point absorber type, and consists of a tube that has a buoy attached to it [21]. As the buoy moves with wave action, hydraulic fluid is pumped and turns a generator. The Power Buoy uses subsea stations to collect power from several different buoys. The Power Buoy stands 44 meters tall and the buoy is about 11 meters in diameter. It requires at least 60 meters of water and is usually located around 8 km offshore. Ocean Power Technology has performed tests in the Atlantic and has set up commercial sized testing in Australia and the Pacific. Individual units produce between 20 kW and 50 kW, so the company uses large arrays to provide for higher demands [18]. According to the Ocean Power Technology website (www.oceanpowertechnologies.com), the company is planning on building a commercial unit off the coast of Spain, which will generate 1.39 MW of power [21].

Energetech

Energetech has developed an OWC device that is about 35 meters wide, weighs 450 tons, and can be placed on the shoreline or up to 50 meters off shore [17]. The device uses walls to focus wave energy into the OWC [18]. What is novel about this device is the use of new turbine design that turns when air is being pushed out as well as when it is sucked back inside the chamber. With this new turbine design the efficiency has increased from 30% to 60%, this power system also allows for instant tuning, adjusting itself for each new wave. The estimated cost of the device is between $2 and $3 million for a single device, in 2004 dollars. This device was still in the development stages in 2004 and was starting full-scale development. There is no website for this company available for more current updates of this technology.

TeamWork Technology

TeamWork Technology is the company responsible for the development of the Archimedes Wave Swing (AWS). According to the company's website (www.teamwork.nl), the company was based in the Netherlands, but due to global market changes has moved to Scotland and is also referred to as AWS Ocean Energy [22]. EPRI included TeamWork Technology in the survey in 2004. The AWS is a fully submerged device, which uses an air chamber to oscillate with the passage of waves. The oscillation moves a direct linear generator, which creates the energy for the AWS. The device is about 9.5 meters in diameter, about 36 meters tall and needs depths of about 43 meters. The AWS can be tuned to different waves by allowing water into the air chamber, changing the dampening effect on the system. The company has tested the AWS at full scale and plans on performing further research with their New Wave Energy project.

Aquamarine Power

Aquamarine Power has developed the Oyster technology, which is an oscillating wave surge converter (OWSC). The device consists of a closed loop hydraulic system with the hinged flap driving pistons. This device needs to be located near shore and uses the surging action of the waves, instead of heave, to oscillate the device. Oyster 2 was designed to be about 26 meters wide. Henry [10] suggests that the device be located near shore to maximize the surge force, but that a minimum of 10 meters is desirable because of a dramatic energy drop-off after this point. It is also suggested that the flap prevents water from leaking through, over, or under, so as to maximize the capture, and that there be some "freeboard" (part of the flap should be above the water surface). According to the company website, the idea started in 2003 in Queen's University and has created several generations of the Oyster device, the latest being the Oyster 800 [23].

Device Suitability Comparison

All of these technologies have merits in one way or another. Most are designed for much larger waters than those found in the GOM, but some have the potential to be adapted for use offshore or for lower wave climates. Ocean Power Delivery with their Pelamis has had some of the biggest success. Because of the large size and self-tuning ability, it is a good candidate for adaptation or similar device testing. Ocean Power

Technology with the Power Buoy is another great candidate because they are closer to offshore technology than any of the other devices. The AWS from Teamwork Technologies is slightly less desirable because of the use of air in the system, which is going to account for efficiency loss and because of the energy loss from being below the surface.

The other technologies from Wave Dragon, Aquamarine Power and Energetech are not as favorable because of the near shore requirements and the complicated anchoring and mooring systems that they require, which would be extremely difficult to adapt to offshore locations. The Wave Dragon does have one promising aspect because it is the only one that had a prototype model that worked in low energy wave states, but not much testing was done with this model. A summary of comparison is shown in Table 3.

Table 3. WEC suitability comparison

Device	Strength	Weekness
Pelamis	Most successful, self tuning, large capture area.	Not tested offshore
Wave Dragon	Scaled to low sea activity, large activity range	Large, intrecate anchoring system
Power Buoy	Furthest offshore, mutliple units	Needs higher sea states,
OWC	Utilizes in and outflow of waves	Nearshore, intrecate anchoring system, large, uses air
AWS	Can easily dampen system, high survivability, low corrosion	Uses air in system,
Oyster	Uses surge forces and heave	Nearshore, intrecate anchoring system, large

With the prices of the different devices it seems that the smaller, multi-unit devices are running in the $2-$3 million range. The UL Lafayette team's design could be smaller than the ones for these companies because of the smaller power requirements needed and the smaller waves of the GOM. Further economic analysis would require more information from platforms and the design needs of the UL Lafayette team.

CONCLUSIONS

The research reported in this article is an investigational study on wave energy converters for use in capturing wave energy in the GOM. At this time, the perfect device or combination of devices has not yet been found that can work with low activity wave climates. This research has found that there is no "off the shelf" model that can be used directly for the GOM. This is consistent with other WEC projects because much of the design must be customized to the installation location. For the GOM it is believed that the best device will be an offshore, multi-unit system, that resists corrosion by having minimal to no parts above water, is easily tuned, and does not require a specific wave direction in order to operate. It is also found that the best theoretical device would be a submerged pressure differential, but design issues could still prove difficult to overcome and a different WEC type such as point absorber might be considered.

Wave energy projects have been in the business of trying to capture the most energetic waves possible because their objective is to power towns and cities. But through reviewing different companies and devices, some of their products and ideas can be used as inspiration for the development of UL Lafayette's own WEC. While none of the companies have devices that could be installed "as is" in the GOM because of wave power or geometry requirements, there are some that have the potential to be modified, and/or scaled down to fit the GOM climate.

The Power Buoy and Pelamis are the most successful and adaptable for the GOM. The AWS is next in line, but because it relies on compressed air to tune and operate, it is less desirable. The Wave Dragon has the potential to be scaled down to fit the GOM wave climate, but what makes the Wave Dragon economically viable is its large size. The OWC and Oyster technologies are not a good fit for the GOM because of the need for complex mooring and anchoring systems. It is also noted that the average cost of the two most viable WECs is in the $2-$3 million range, which can provide for the baseline of costs estimates for a similar project.

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