Introduction

Cars, planes, and home heating: these are just some of the many uses that we humans have for fossil fuels. Despite this, fossil fuels are not the best source of energy to power our global civilization. As we look for new sources of renewable energy, there is another source of energy that we can tap into that has been largely unexploited as of now. This is Ocean Energy. A lot of current ocean energy work may go to off-grid energy projects including aquaculture and unmanned underwater vehicle charging, but it has also a huge possibility to provide power for many people. It has been estimated that “harnessing just 2 one-thousandths of the oceans' untapped energy could provide power equal to current worldwide demand”2. The ability to control the potential energy output of the ocean would be astounding. Ocean energy could help fix the problems of the Global Energy Crisis and even Climate Change.

The Global Energy Crisis

We have relied on oil and natural gasses for decades, and have been dependent on them as our sole sources of energy until very recently. Fossil fuels are rapidly depleting with an estimated 50 years of natural gas and oil, and about 110 years of coal (10). Thus, humans must turn to renewable forms of energy before further exhausting fossil fuels to extinction. This is the situation we may be facing soon. Fossil fuels were created hundreds of thousands of years ago by old organic matter being compressed and exposed to high heat under the earth’s crust for centuries. In essence, the fossil fuels that we use are the result of the earth compressing and heating prehistoric animals and plants. This process takes a very long time, and as we are using much more fossil fuels than are being created, they are likely to run out if we do not significantly reduce our usage of them. The Global Energy Crisis is the situation our entire planet is facing as our population continues to grow and our supply of fossil fuels begins to dwindle. The more people on Earth, the more fuels we use. We need to cut down on our energy use, in addition to implementing renewable energy sources so that we don’t run out of energy in the foreseeable future.

Even now, there are people without reliable access to power, with about 1 billion people without a steady source of or connection to energy in 2020 (IEA.org). That is more than fifty times the entire population of California without energy. Even now, when we have sufficient fossil fuels, people are not getting reliable access to power. Natural gas is the largest provider of power to people, and according to an OurWorldInData prediction, in fifty years, when we run out of natural gas, imagine how many people will be without power. Assuming a population of about 12,000,000,000 by 2120, more than half the world will be powerless unless we can get a reliable source of energy. In 100 years, when we are completely out of fossil fuels (OurWorldInData), and the predicted population is 12 billion[17], what will we do? Energy will be more expensive than gold unless we come up with a reliable solution to this problem. In the following image (fig. 1), it is shown that we predict to use many more fossil fuels, so they are likely to run out. Although

renewables are also predicted to be used more, they will need to be used even more frequently to be able to maintain our current rate of energy consumption.

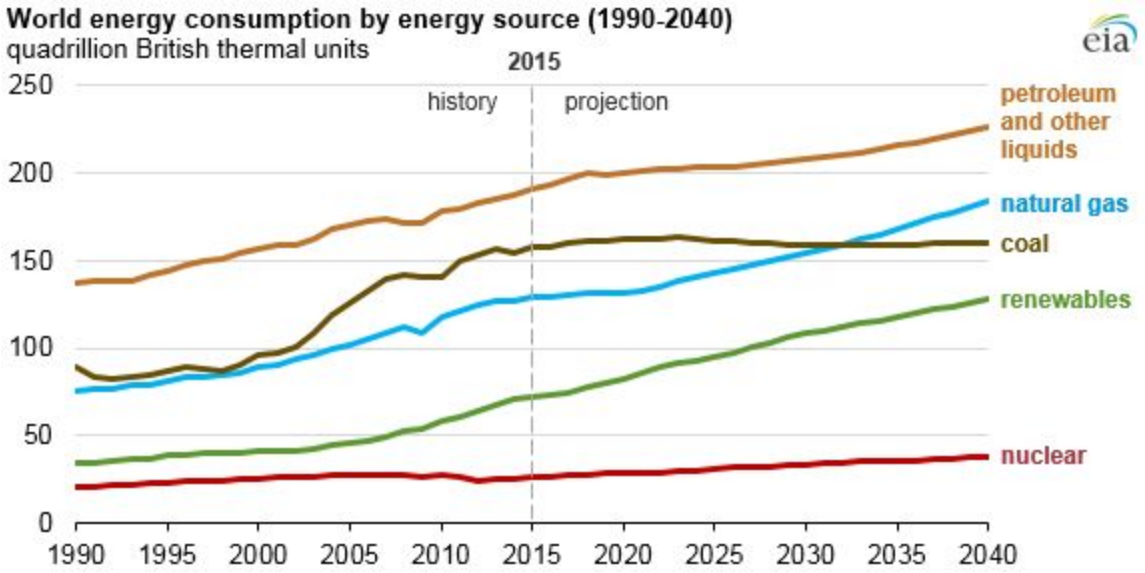

Figure 1: Graph shows the predicted amount of energy that humans will get from each energy source. This shows fossil fuels rising in usage, as well as renewables increasing. If we continue this upward trend, we will run out of fossil fuels.

This is where Ocean Energy steps in. Although there are other sources of renewable energy such as solar, wind, and biomass energy, ocean energy has been exploited much less. Although we have other sources of renewable energy, ocean energy has great untapped potential. Ocean energy has huge potential to generate massive amounts of energy for humans: some wave-energy devices can produce “500 kilowatts of electricity per hour — enough to power more than 400 homes — around the clock” (Renewable NorthWest). The total estimated energy resource for wave and tidal energy combined is 30,700 TWh/year. The total energy used in the United States in 2019 was about 29,355.6 TWh (EIA). That means that ocean energy alone could power the entire United States and another country around the clock. Were we to be able to harness enough of the ocean’s energy, we would be able to power the entire world with the energy of the ocean. Another upside of ocean energy is its predictability: scientists will be able to predict wave patterns weeks in advance, which lets them know when wave energy will be more available. Tidal energy is even more predictable: because it is based on tectonic plate movement, it can be predicted years before collection. The main idea that demonstrates the superiority of ocean energy to fossil fuels is its renewability: it will never run out, as long as the moon is still orbiting the Earth.

Climate Change

One of the biggest crises going on in the world right now is Climate Change. Climate Change is the gradual warming of the planet, and its greatest cause is the Greenhouse Effect.

The greenhouse effect is the effect that scientists have blamed as the cause of the Earth's rising temperatures, which have been rising since the mid-1900s. Certain gasses that are in the atmosphere prevent heat from escaping the planet; they act as a set of clothing around the Earth, insulating it. Following is a list of these such gasses from NASA: water vapor, carbon dioxide, methane, nitrous oxide, and chlorofluorocarbons. Heat enters our atmosphere from the Sun, and, pre-1900, it would leave through the atmosphere. However, since our society began releasing greenhouse gasses, it has been more difficult for the heat to leave our atmosphere, to the effect of sharpening the climate change cycle to unprecedented temperatures. There are many different types of greenhouse gasses, and although some are naturally occurring, the majority of them are caused by human activity. Fig. 2 shows how much temperatures have risen since the early 1900s. Global temperatures have been rising at an astounding rate, and they have yet to plateau.

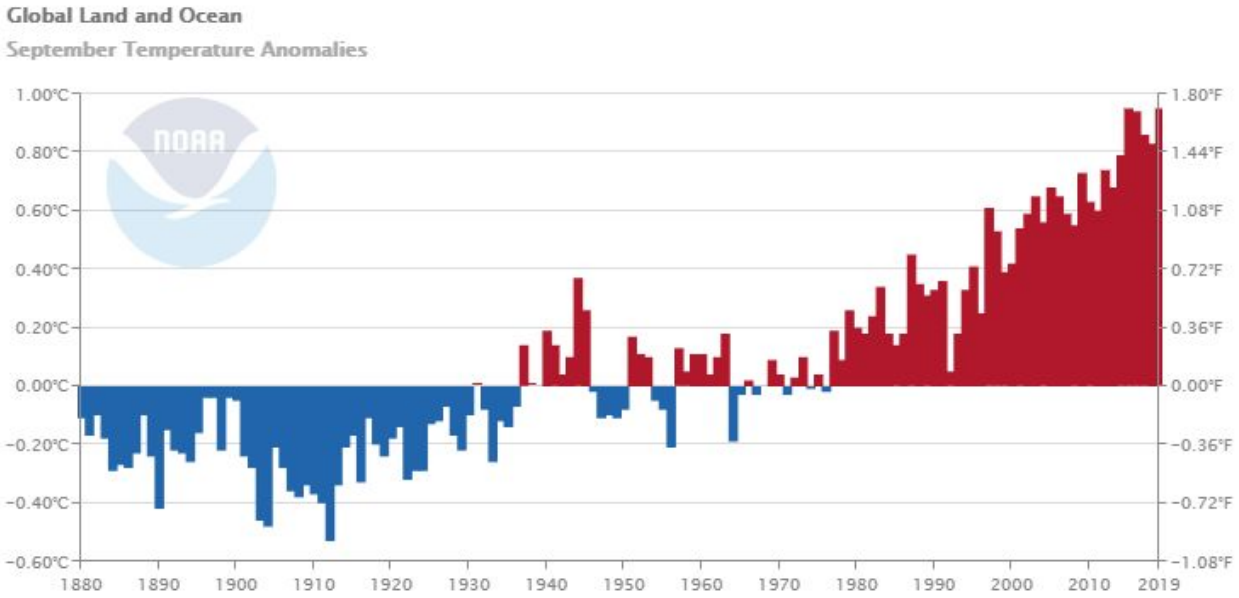

Figure 2: This graph shows that global temperatures have been rising since around 1900, shortly after the Industrial Revolution. We want to keep temperatures from rising more than 2 degrees Celsius to prevent great damage to the planet and environment.

Left unchecked, global warming would have disastrous effects on the planet. There are several main predicted outcomes of unchecked climate change. "Taken as a whole, the range of published evidence indicates that the net damage costs of climate change are likely to be significant and to increase over time" (Intergovernmental Panel on Climate Change). The earth will see rising temperatures in most regions, and the climate as a whole will be warmer. Ice will occur much less, and there will be either smaller or even no frost seasons; the polar ice caps will also melt. As a result of this ice melting, sea levels will rise between 1 and 4.3 feet by 2100, according to the 4th National Climate Assessment. There will be changes in the weather

patterns too, as precipitation patterns will become more irregular, hurricanes will become much stronger and more intense, and droughts and heatwaves will become commonplace. 12

Ocean energy could contribute to the fight against climate change, however, as it serves as a more clean source of energy. Where fossil fuels release carbon dioxide into the atmosphere, which insulates the planet, ocean energy would not release carbon emissions, which are the most abundant greenhouse gas in the atmosphere, but would still provide sufficient energy for our use 11. In addition to this, ocean energy could allow for more aquaculture, which would let us cut down on cattle, pig, sheep, and chicken farming. “In an average American diet, beef consumption creates 1,984 pounds of CO2e annually” ClimateNexus. Marine energy would provide another clean alternative to fossil fuels, could we harness its power.

Arguments Against Ocean Energy

In addition to the numerous benefits of ocean energy, there are of course some drawbacks to using ocean energy that have been presented. One of these arguments is that “Only power plants and towns near the ocean will benefit directly from [ocean energy]”18. This is correct, but ocean energy can be applied to things besides residential power. For example, the blooming “blue economy” of the ocean could be powered entirely by ocean energy. Aquaculture, the farming of fish and other marine life for human consumption, could greatly benefit from ocean energy, and the energy that once went there could go somewhere else. “These power needs are estimated to range between 4 and 715 megawatt-hours per year, depending on the size, location, and purpose of the operation (e.g., shellfish farm, fish farm). This power has historically been provided by diesel generation and only occasionally by renewables”19. Ocean exploration and unmanned oceangoing vehicles could be powered at charging stations that get their power from the waves. Another argument against using wave energy is the environmental effect. Wave energy could disrupt the ocean environment and things could spill off of the platforms and pollute the ocean. This, however, is trivial compared to the disruption caused by oil drilling in the ocean. There were 5 oil spills in 2019, and a total of 1000 tonnes (2,205,000 pounds) of oil spilled into the ocean(ResourceWatch.org).

Challenge

Fossil Fuels

Fossil fuels are any fuels that have been created from the remains of ancient life. They are made up of the carbon that was found in those organisms. They are the world’s leading source of energy and one of the greatest causes of climate change.

Financial and Health Issues

There are several financial and political issues associated with using fossil fuels to the degree that we are. The price of using fossil fuels as energy is around $0.03 to $0.17 per kWh, according to ecowatch.com. On the other hand, wave energy costs on average $0.09 per kWh, and tidal energy on average costs $0.08, according to Alternative Energy News. “Recent EPRI reports have found that, presently, the cost of power from ocean technologies ranges from 7 cents to 16 cents/kw in a low case scenario” (Alternative Energy News). The Pelamis Wave Converter, one of the few devices with enough information to provide a reasonable estimate, would cost between 4.74 and 6.3 million, and maintenance would cost between 1.72 and 8.48 million dollars (23). That means that, on average, to have a cost of ~10 cents per kWH, it would produce 106.2 million kiloWatts of energy over its lifetime. These estimates are based on the Levelized Cost of Energy, which is the average cost of energy throughout an energy plant’s lifetime. This is dependent on how much energy the plant can produce and how much the construction and maintenance costs are. One of the selected locations for these devices is French Polynesia, where it would produce around 1192 megawatts annually 23. Although you can get fossil fuels at a lower price than ocean energy, why do people feel that they are entitled to low price energy? Perhaps it is worth paying a few dollars more per year to keep the planet safe from climate change and conserve our finite resources. Our use of fossil fuels also gives a lot of power to countries in the Middle East, from where much of the world’s oil is supplied. “[The] Middle East is the world's largest oil producer, accounting for nearly 35 percent” (OurWorldInData). This means that the United States has to kowtow somewhat to those countries, as we depend on them for oil production. Drilling for fossil fuels is also not as safe as collecting ocean energy. There are many issues associated with oil production that cause harm mainly through pollution of water supply. Fracking can lead to contamination associated with cancer, birth defects, and liver damage. The following diagram shows how fracking causes water pollution.

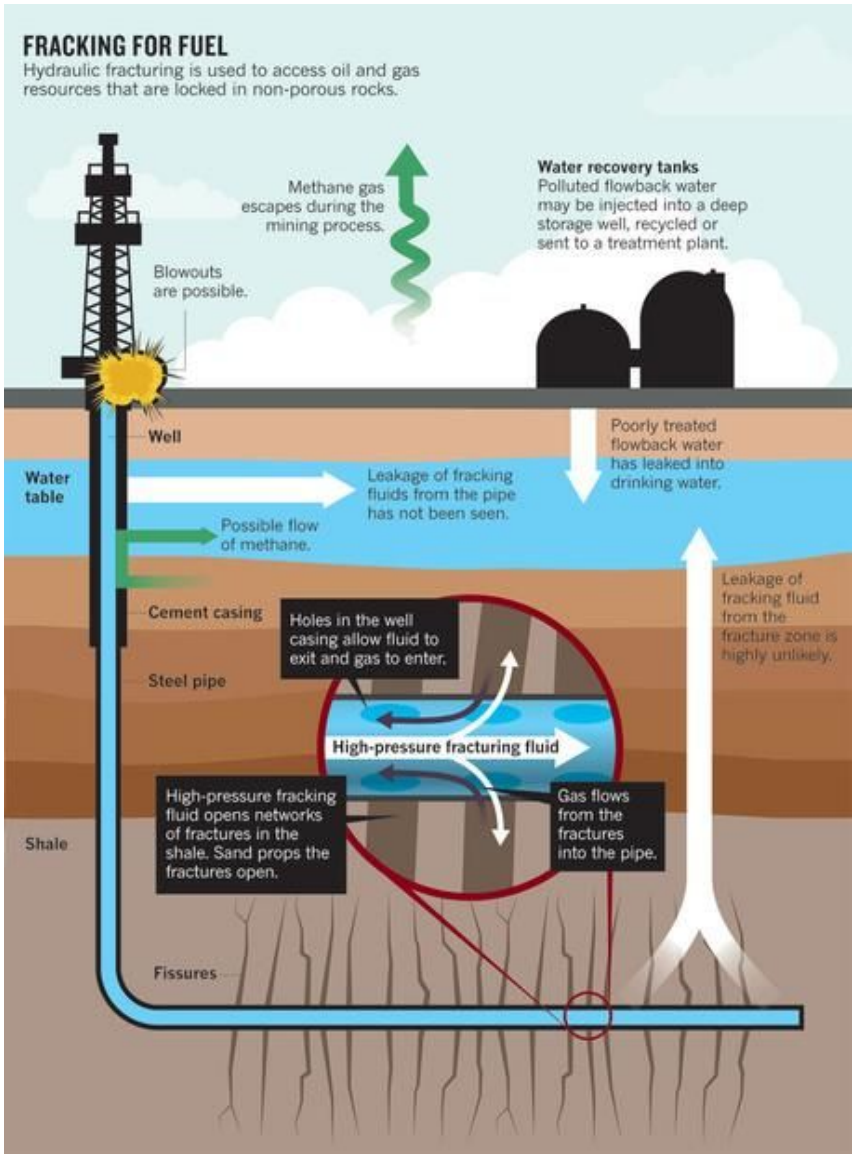

figure 3: demonstrates how fracking pollutes water and how fracking is used to collect oil

Workers also face serious health issues: “workers are on shift for an average of 12-hours a day dealing with highly combustible materials on a platform where cranes swing heavy equipment constantly overhead” (Time). Also, fossil fuels are running out, so their price will eventually become more and more expensive. Ocean energy, on the other hand, is renewable, meaning that it will be much more constant than fossil fuels.

Environmental Issues

In addition to the numerous financial and health issues, fossil fuels result in a great deal of environmental damage. The main environmental issues caused by fossil fuels are pollution and greenhouse gasses. The first type of pollution is air pollution caused by the burning of fossil

fuels. Nitrogen oxides are released when fossil fuels are burned, and these chemicals contribute to the formation of smog as well as the presence of acid rain. These nitrogen oxides eventually make their way back to the land, where they are washed into nearby bodies of water, harming their ecosystems. The second type of pollution is oil spilling, in which oil rigs release oil into the nearby ecosystem due to a human error or an accident. Oil spills are most often associated with tankers, barges, pipelines, refineries, drilling rigs, and storage facilities. “U.S. Minerals Management Services says the annual total of oil spills has increased from an average of four spills per year of 50 barrels or more in the 1990s to more than 17 per year from 2000 to 2009”(upi.com). These oil spills wreak havoc on the native ecosystem, polluting the water and coating animals in oil. Oil spills make useless the insulation systems that marine mammals have to keep warm, and birds’ ability to repel water. The animals die of hypothermia. “Juvenile sea turtles can also become trapped in oil and mistake it for food. Dolphins and whales can inhale oil, which can affect lungs, immune function, and reproduction. Many birds and animals also ingest oil when they try to clean themselves, which can poison them.” (National Oil Service). The second way that fossil fuels harm the environment is through global warming and greenhouse gasses. Fossil fuels release extreme amounts of greenhouse gasses, primarily carbon dioxide, resulting in global warming as previously explained. Deforestation is another major cause of global warming, and the main cause of deforestation is the beef industry. Ocean energy could provide energy to the new aquaculture industry, leading to less deforestation, which could contribute to fixing the planet.

Global Energy Crisis and People

Another major issue facing humanity is the global energy crisis, or the lack of energy available to everyone. Where some people may be left without energy as of now, in the future, as fossil fuels begin to burn out, we will need to find sources of renewable energy in order to have energy available to the majority of people.

The Present

Right now, there are around nine hundred and forty million people without any access to energy. There are a total of about two billion people (as of 2008) without reliable access to electricity[9]. That’s about six times the population of the entire United States without reliable access to electricity to power their lives. The number of people without access to electricity has fallen below 1 billion people, but “despite all of these stories of progress and success, the world remains off-track in its efforts to achieve Sustainable Development Goal (SDG) 7.1 to ensure universal access to affordable, reliable and modern energy services by 2030” (IEA.org).

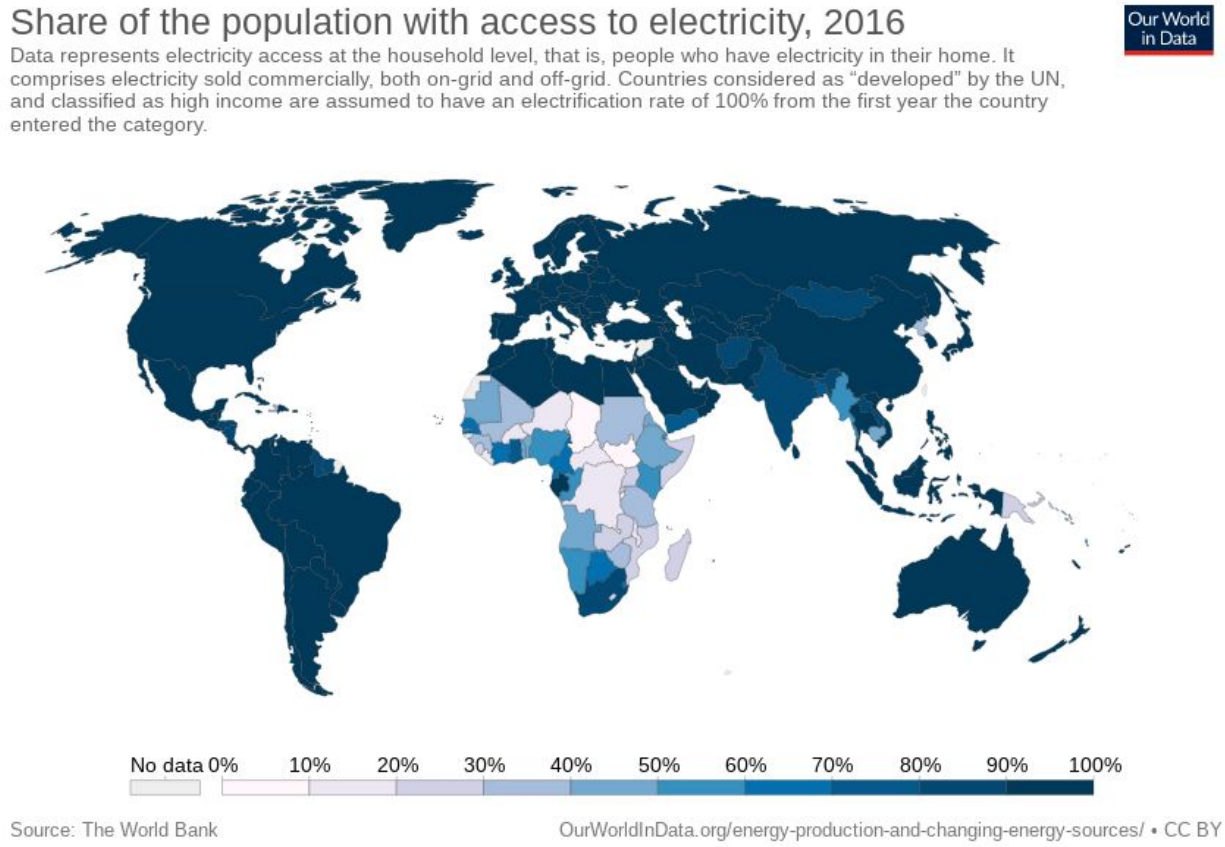

figure 4

Although the use of renewable energy has risen recently, they still account for a minority of the energy production in the world (as of 2018), at a mere 26.2 percent (c2es.org). As shown in figure 4, much of North America, Europe, and South America have reliable energy access, but the majority of Africa doesn't have reliable access to energy, and a sizable proportion of Asia lacks reliable energy access. The United States uses even fewer renewables than the rest of the world, at about 11 percent of US energy coming from renewables.

The Future

If there are just under 1 billion people without access to energy at all right now, imagine the future, with fossil fuels running out and the population growing at an estimated 81 million people every year (worldometers.info). The world's energy needs would be well over 50% higher in 2030 if governments continue with existing policies"9. In 55 years, the only fossil fuel that we will have left is coal 10. Unless we can find other sources of energy, such as ocean energy, we will be unable to provide power to the majority of the world. As previously mentioned, ocean energy can produce "500 kilowatts of electricity per hour — enough to power more than 400 homes — around the clock" (Renewable NorthWest). The total estimated energy resource for wave and tidal energy combined is 30,700 TWh/year. The total energy used in the United States in 2019 was about 29,355.6 TWh (EIA). Only 11% of US energy is renewable,

compared to 26 percent of global energy. We need to implement much more renewable energy to save our society. Without energy, our global civilization is brought to its pre-industrial knees. We need to be able to have a significant amount of our global energy be provided by renewables such as ocean energy so that we can keep living the way that we do today, and we need to conserve as much of our fossil fuels as possible so that we can provide everyone in the world with sufficient energy.

Global Warming

One of the most pressing issues for our global civilization is climate change: the planet is increasing in temperature at an unprecedented rate due to human activity since the industrial revolution. Greenhouse gasses, deforestation, and farming have been some of the leading causes of global warming.

Fossil Fuels

Fossil fuels cause climate change through greenhouse gasses, which are the gasses released when fossil fuels are burned. These gasses rise into the atmosphere and act as a blanket around the planet, allowing the sun's heat to enter our atmosphere, but not letting it leave, so that our planet is rapidly being warmed up by the sun. Water vapor, carbon dioxide, methane, nitrous oxide, and chlorofluorocarbons are the main types of greenhouse gasses[12]. The most common of these gasses is carbon dioxide, as it is the main gas that is released when fossil fuels are burned.

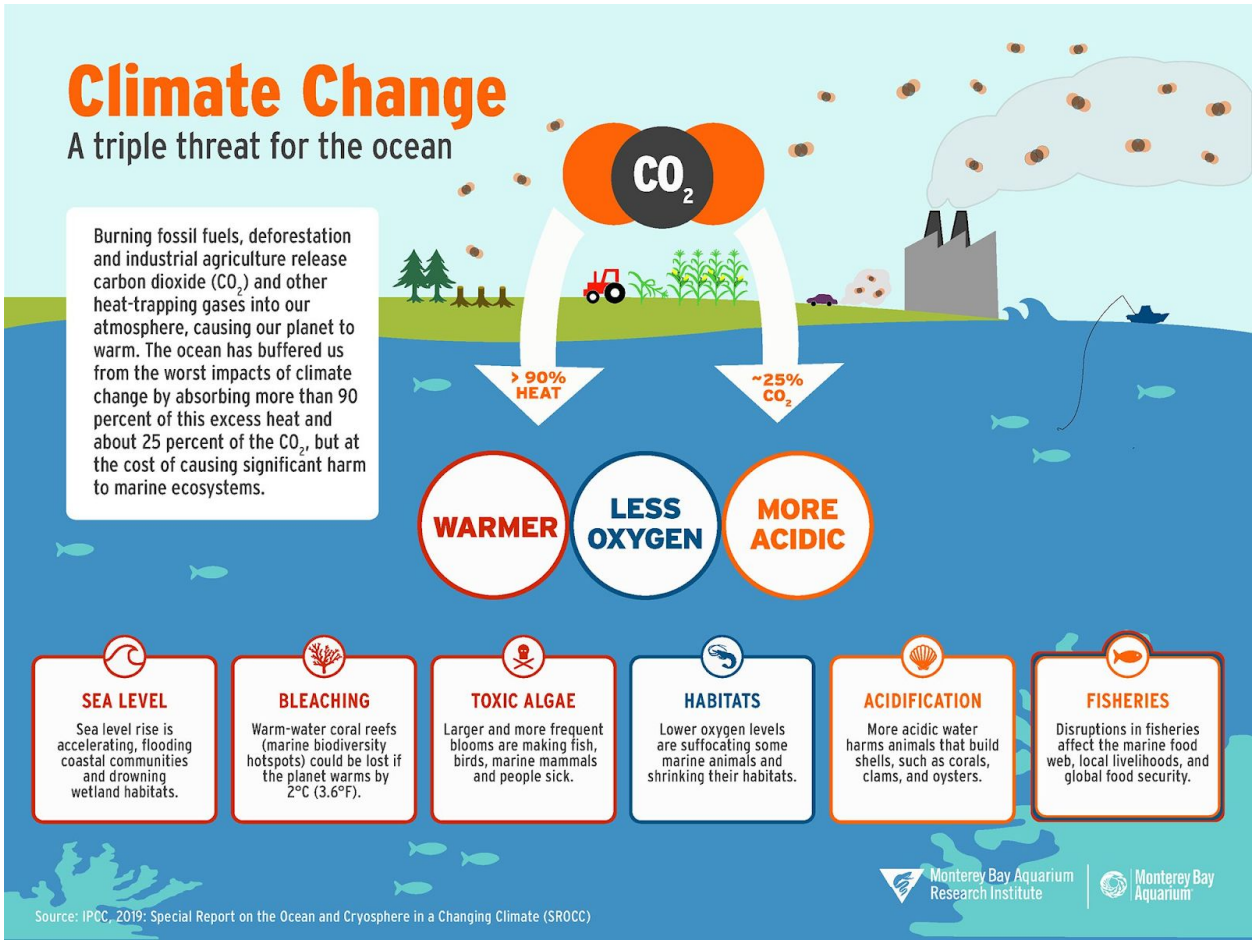

figure 5: Demonstrates how climate change affects the ocean environment. Some might say that ocean energy is disrupting ocean habitats, but global warming would have a much more significant effect than ocean energy would.

Ocean energy, of course, would help slow down the effects of climate change, as it would provide a source of energy that will not release much, if any, carbon dioxide into the atmosphere. Fig.5 shows how climate change affects the ocean and gives an example of how one ecosystem would be affected. Climate change being accelerated by the release of greenhouse gasses would be detrimental to our lives and well being, as it would cause massive damages to our cities and environment.

Farming and Deforestation

Farming and agriculture has an extreme greenhouse gas output, and, according to the World Wildlife Fund, is the third leading cause of global warming, just behind fossil fuels and deforestation. According to an NPR story linking agriculture and climate change, “[a] panel of scientists looked at the climate change effects of agriculture, deforestation and other land use, such as harvesting peat and managing grasslands and wetlands. Together, those activities generate about a third of human greenhouse gas emissions, including more than 40% of

methane”22. Fertilizers release nitrous oxide, another greenhouse gas, which adds to the effect of the other agricultural effects. Cattle and sheep also are another culprit in the cause of climate change: they graze at large scales and release huge amounts of methane gas, which is another type of common greenhouse gas. “At [the UN intergovernmental panel on climate change], the panel broadly suggested that farmland would need to shrink and forests would need to grow to keep Earth from getting more than 1.5 degrees Celsius hotter than it was in the preindustrial era”22. Ocean energy would be able to provide energy to aquaculture, and fish not only produce much less methane than cows and sheep, but also take up little to no land, so deforestation is not as large an issue with aquaculture.

According to the WWF, the second leading cause of climate change is deforestation, as trees, through photosynthesis, convert the greenhouse gas carbon dioxide (along with water and sunlight) and convert it to energy in the form of ATP and Glucose, releasing O_2, or oxygen, which is not a greenhouse gas. In addition to this, the carbon taken in through photosynthesis is stored in the plant, and when the plants are burned or destroyed, the carbon is released as carbon dioxide. “The problem [global warming] cannot be solved if the role of tropical deforestation is ignored”21. Although wind power and solar power are excellent in that they can produce renewable energy, they still use a lot of land, which could lead to deforestation. Ocean energy, although it can interrupt the marine ecosystem, leads to less deforestation, and is still able to produce renewable energy.

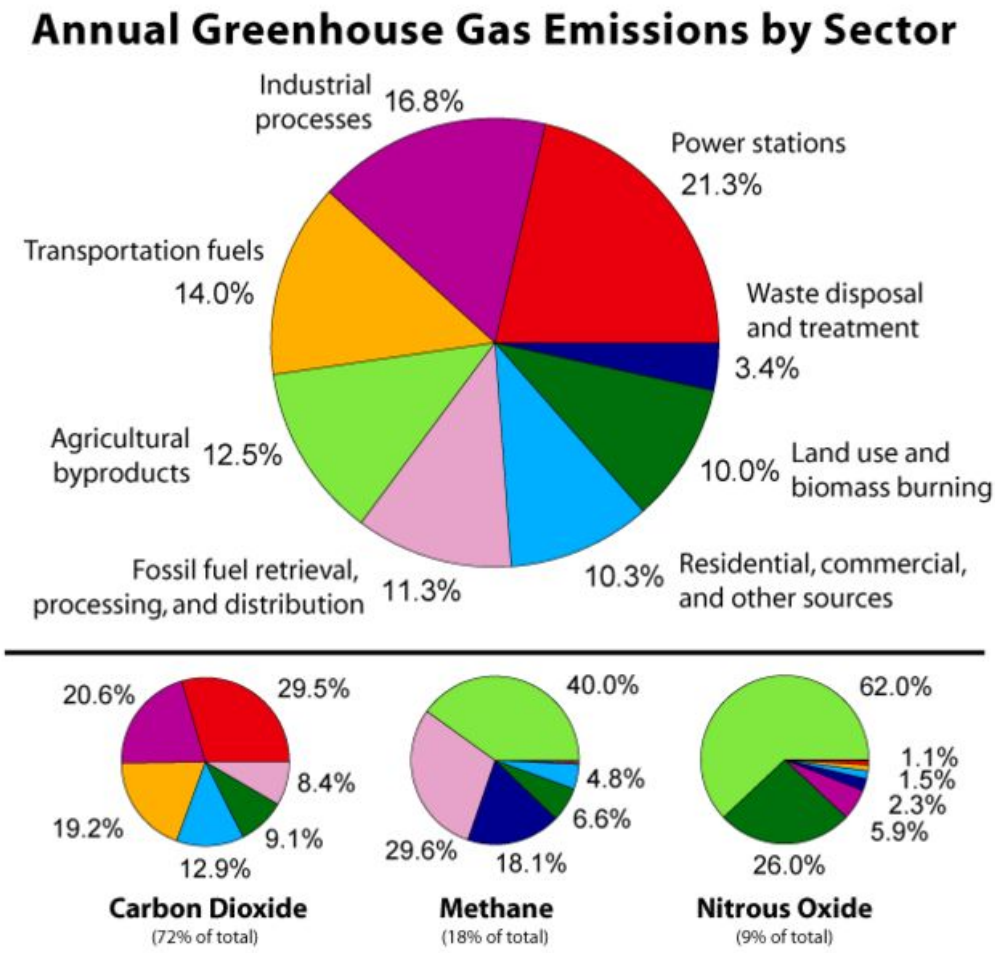

figure 6: These charts show what contributes to climate change. Agriculture, as shown, produces over 20% of the greenhouse gas emissions.

Proposed Solution

Overview

There are two main types of marine energy sources: wave and tidal energy. Wave energy is the power generated by waves, which are caused by wind blowing over the top of the ocean. Tidal energy is generated by rising and falling tides. They are very easily predictable and caused by the moon and tectonic plates.

Methods of Collection

There are two main types of ocean energy that are to be collected: tidal energy, which is due to the rising and falling tides of the ocean, and wave energy, which is due to the waves, which are caused by wind blowing over the top of the ocean. Tidal energy is harnessed using the rising and falling of the tides during the day. There are two types of waves that can be

collected: swells, which are the rising and falling water in deeper ocean, and breaking waves, which are waves that formed in a more shallow area. There are three types of tidal energy converters: barrages, streams, and lagoons. Tidal barrages use a technological system similar to a dam, in which doors are opened at low tide, allowing the water to rise and fill the dam. The doors are closed at high tide and the water falls back through a turbine, which produces energy. Tidal streams are fast-flowing bodies of water that have been caused by the tides. A turbine is placed in the stream, which can collect energy even more efficiently than wind, as water is denser. This can, however, disrupt the surrounding ecosystem. Tidal lagoons are bodies of water that are partially enclosed by a man-made structure, and they generate power through turbines as the tides fluctuate. They have little environmental impact but their actual energy output has yet to be determined. 26 There are also three types of wave energy technologies. One uses floats, buoys, or pitching devices to capture the energy of the rising and falling of the water. The rising and falling of the water generates power through hydraulic pumps. Another uses the waves to push air through a turbine through a cylinder. This method is called an oscillating water column, or OWC. A third uses a tapered channel, which drives the water into an elevated reservoir. The water is released from there, through turbines, which generates its energy. The most common of these is the method using floats, buoys, or pitching devices to capture the energy of the rising and falling of the ocean. 4 Fig. 7 shows some energy collection methods that have been and are being developed. Figure 9 also demonstrates some prototypes that have been proposed for energy collection.

figure 7: This image depicts some of the methods used in collecting marine energy. (Top to Bottom) The first device is similar to the Pelamis and captures the power of the swells. The next one shows how waves might push the device down, generating energy. The next two show some turbines that generate power when water is pushed through them.

Energy Destination

Ocean energy can either go to on-grid or off-grid energy use. On-grid energy use is energy that goes to powering the energy grid, which ends up powering residential areas. Ocean energy can only travel so far, but according to un.org, 40 percent of the world's population lives near an ocean, which is a significant amount of people that could be powered by the ocean. The primary off-grid energy destination would be the "blue economy", which is the economy and industries that can be found in the ocean, such as ocean exploration and aquaculture. Aquaculture is the cultivation of marine animals for human consumption. According to the Food and Agriculture Organization, the industry was projected to be worth $55 billion by this year. In addition to being financially successful, it is also environmentally friendly, as, according to americanprogress.org, "Oysters are particularly efficient at removing carbon from the surrounding water, with one square kilometer of oysters able to sequester nearly 960 metric tons of carbon per year." Aquaculture is a huge industry that could be powered almost entirely

by marine energy, as their proximity allows for maximum efficiency. As energy.gov says “Shore-based aquaculture operations may be a potential user of marine energy as a power source.” In addition to this, excess energy that is produced and not used by the aquaculture industry “The U.S. [The] Department of Energy's Water Power Technologies Office (WPTO) has investigated the opportunities for marine energy to enable coastal and maritime markets across the blue economy”25. Marine energy, however, would also only be useful for some locations, where there is more energy potential in the ocean. If there are fewer or weaker waves, it is much less efficient than it would be somewhere with large waves that carry more power. Northern Europe, for example, has rather more energetic waves than the Gulf of Mexico, so it would be much more useful for Northern Europe to be powered by marine energy than the Gulf 3. Figure 8 provides a more in-depth view of where is the most efficient for energy collection.

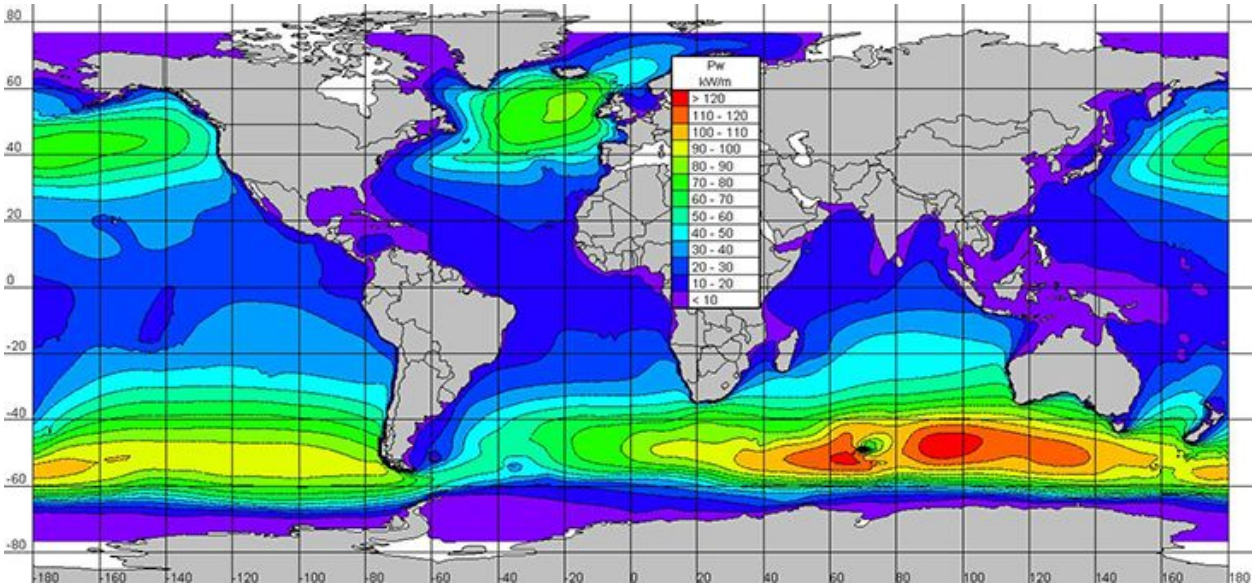

figure 8:This is a map of where there would be the most efficient energy production. Red has the most energy production, where purple has the least. The United States’ northwest, the southern tip of Africa, Northern Europe, and the Coast of Chile have the strongest waves and therefore would be the best suited for marine energy.

Devices

As of now, the most developed type of device for the collection of ocean energy has come from Pelamis. In 2004, their first full-scale prototype was called P1, and, at 120 meters long, was the first offshore energy device to add power to a national energy grid 24. They developed another device, the P2. “The P2 comprised five connected sections which flex and bend in the waves. This movement was harnessed by hydraulic rams at the joints which in turn drove electrical generators located inside the device”24. It became the first device to be purchased by a utility company.

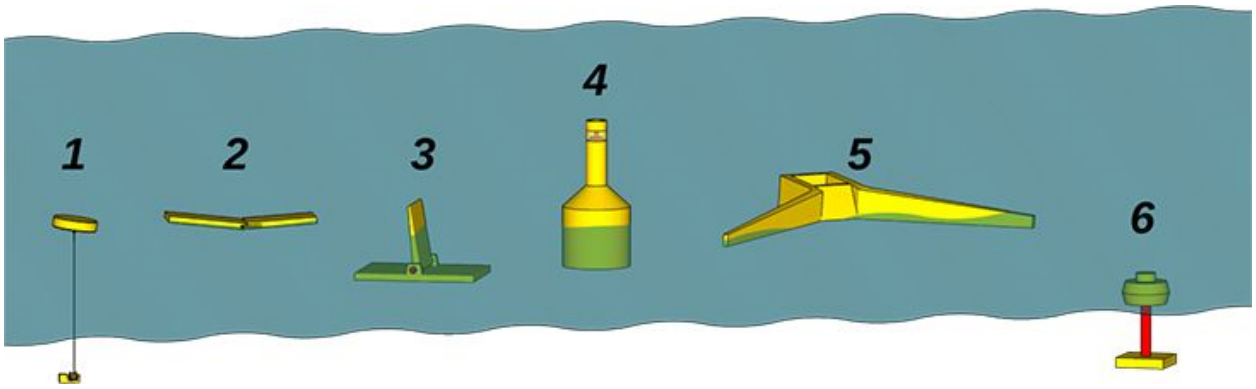

figure 9: This is a rendering of what some of the wave-energy-capturing devices may look like.

The Wave Dragon is one converter in development, and it collects energy from the waves that pass over its top. The device floats on top of the water but is still invisible from the shore. “Wave Dragon says the project would have a capacity of 7MW, which should produce enough green electricity each year to meet the annual demand of 2,000-3,000 homes and offset the release of approximately 10,000 tonnes of CO2” 5. A sea carpet is another technology that scientists are investigating. This resembles a flat carpet and is based on mud in wave energy absorption, as places with mud are good at absorbing a wave’s energy. “The “carpet” part of his converter is made from a smooth sheet of rubber. It rests near the seafloor, where it can bend and flex right along with the waves. As it moves up and down, it pushes posts in and out of a piston pump. The pump converts the piston’s movement into electricity, which then travels along a cable to the electric grid”3. According to its developer, each square meter of the device could produce enough energy to power two American homes, which is about 14 times more size-efficient than solar power. SRI International, in California, developed a device that uses an “artificial muscle” to generate power. The prototype had a very low power output when tested, but SRI International says that the technology could eventually compete with wind turbines. It has a very simple design, simply a rubber sheet attached to a weight. “Initially, a small battery applies a voltage across the electrodes; when the rubber springs back into its original shape, it forces the electrodes apart, increasing the voltage between them. This excess energy can be siphoned off to generate a current. Part of that current feeds back into the system, so the battery is used only for the first cycle” 1.

Historical Perspective

This section will provide a brief history of ocean energy, and explain some downsides and challenges associated with marine energy.

Background

Methods of collecting energy from water have existed for a long time, going back to water wheels, and the first generation of ocean energy devices, dating back one hundred years. Although tidal barrages (devices similar to dams that allow tidal energy to be captured) have

existed in France, China, and Canada for over 50 years 5, they have not been used often due to the environmental repercussions that are associated with them. “Despite this, South Korea is currently building the 254 MW Sihwa-ho Lake tidal plant, estimated to be capable of supplying the equivalent of 862,000 barrels of oil per year, which is scheduled to be finished this year” 5. In the 1970s, there were oil shocks, meaning that in the 1980s, oil was dirt cheap, so marine energy was economically unsound. Since the 1990s, however, oil prices, carbon dioxide emissions, and global temperatures have been rising, so we have looked more toward ocean energy. The very first commercial wave farm was Aguçadoura, located in Portugal. It was commissioned in September of 2008 and only lasted until November. It employed the Pelamis technologies to gather wave energy. “New Jersey-based developer, Ocean Power Technologies has launched a project that features the nation's first commercial wave power farm off the coast of Reedsport, Oregon” (Alternative Energy News). This was the first US commercial wave farm. They received a patent for their Power Take-Off System for use with Wave Energy Conversion Buoys. There are, at current, 11 wave power stations in the world, and the United States possesses two of those. The majority of them are point absorber stations. There are 10 tidal power stations globally, and the United States has none. There are 11 proposed tidal power stations, although none of them are proposed by the United States.

Challenges and Downsides

As wonderful as ocean energy is, there are still some downsides to it, and some challenges that come with using renewable marine energy.

Environmental

Global warming may have devastating effects on the ocean ecosystem (as shown in figure 5), but ocean energy is not entirely innocent in this regard either. Wave and Tidal energy, along with other renewable energy sources are most certainly better than fossil fuel alternatives, as they do not release greenhouse gasses and are much less likely to have an incident as environmentally detrimental as an oil spill. Coasts’ erosion patterns might be slightly changed due to the wave energy devices altering the waves in some way. During construction of these devices, there may be some environmental impacts as well: the ocean floor may be scoured and concrete pillars may be erected to stabilize the devices, there would be some atmospheric pollutants released during its construction, and there is a chance of hydraulic fluids being released into the ocean environment. Although these effects are detrimental to the ocean ecosystem, it harms the ocean less than an oil spill or climate change. Ocean animals might be harmed if they are caught in the devices, and the noise pollution may affect them as well. Despite this, ocean energy is a much better alternative to fossil fuels environmentally, as it does not release greenhouse gasses, the primary cause of climate change. Climate change has drastic effects on the ocean, and ocean energy, by helping prevent climate change, is doing the marine ecosystem a world of good.

Financial

Ocean energy, although it is predicted to become very cheap as technologies improve, is not the cheapest source of energy. In the future, it is predicted to have a cost similar to that of wind turbines, which generate energy at a rate of 4.5 cents per kWh (Ocean Energy Council). The best wave energy generator as of now is in the United Kingdom, generating energy at about 7.5 cents per kWh. “In comparison, electricity generated by large scale coal-burning power plants costs about 2.6 cents per kilowatt-hour. Combined-cycle natural gas turbine technology, the primary source of new electric power capacity is about 3 cents per kilowatt-hour or higher” (Ocean Energy Council). Although fossil fuels are cheaper, they have been proven to be much worse for the environment and will heighten the effects of climate change. People are willing to pay a few dollars more for organic food, so why not pay a few more dollars to save our planet. Another financial challenge associated with marine energy is the expense of the development of prototypes. As pmiind.com states, “Ocean-energy device costs remain extremely high because there are no benefits of manufacturing at scale. Each device has to be painstakingly designed, constructed, and tested in laboratories, then turned into prototypes to be tested in actual ocean waters.” It is expensive to develop the devices, and, as of now, the companies are seeing very little financial payoff, so they must almost always be government-backed. There have been some devices, however, that have shown potential, and we will be able to have mass ocean energy eventually.

Technological

As mentioned in the previous section, technology needs to advance somewhat in order to have ocean energy become as common as solar and wind power. One issue with technology is corrosion from the ocean. To be strong enough to stand up to the waves, the devices are often made of metal alloys; unfortunately, steel and other economically sensible alloys are greatly corroded by the salt in the water. This means that the devices need to have another level of installation to prevent its corrosion, or the devices must be constructed with more costly metals. Ocean creatures can also damage the devices when they latch on to parts of the devices, which necessitates frequent maintenance.

Conclusion

So marine energy: is it a panacea for all the energy and environmental ills of humanity? Not quite, although it has the potential to resolve some of the major issues that humanity is facing right now. The global energy crisis, in which around 15% of the world has no access to energy, could be in part amended by energy provided by our oceans. Left unchecked, this issue could spread to more than half the population in the future, as fossil fuel supplies dry up and the population continues to grow. In addition to the global energy crisis, fossil fuels have been the leading cause of the other threat to our global society: global warming. This phenomenon, if left unbridled, could result in the collapse of our entire human civilization. Ocean energy provides a source of energy that doesn’t emit deadly greenhouse gasses, which makes it a far superior

source of energy than fossil fuels. The fossil fuel industry has caused countless health and environmental issues, such as oil spills and birth defects due to fracking. Ocean energy has a relatively small environmental impact, while still being a reliable source of energy. Ocean energy can be collected through the waves or the rising and falling tides by turbines or through floating devices. It is a renewable energy source that can help control global warming and provide energy to the entire world, all while having relatively few downsides. Ocean energy is the future of energy and the future of humanity.

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