

Abstract

As the world tries to shift to renewable energy, it is becoming clear that the ocean will be a vital component of the solutions. This paper educates the reader on the impacts of climate change, outlines three possible ocean-based energy solutions that the world can use in place of fossil fuels, and describes why these energy sources are necessary due to the impending climate crisis and the global demand for energy. First, the environmental, financial, health, and humanitarian impacts of climate change are presented. Three potential solutions to aid in the battle against climate change are then discussed, including the Sea Carpet, a floating platform hybrid, and algae biofuel. These innovations demonstrate that a world powered by renewable energy is possible due to the resources' accessibility, affordability, and reliability. This analysis provides evidence that action must be taken in order to save the planet.

Thesis Statement

According to the Intergovernmental Panel on Climate Change (IPCC), 89% of global CO2 emissions came from the fossil fuels industry in 2018. [1]. Finding renewable energy sources that are reliable, independent of weather conditions, and have little to no effect on the climate and the surrounding environment is difficult due to money, time, and resource constraints. The inventive solutions presented in this paper are innovations to existing, natural energy sources that aim to revert the damage that has been inflicted upon the Earth's climate. At the heart of each climate solution explored in the following analysis is the ocean.

Problem Statement

It is difficult to find renewable energy sources that are reliable, independent of weather conditions, and have little to no effect on the climate and surrounding environment. While the technology and supplies are readily available, fossil fuels are much easier to extract and process,

as these systems have been perfected throughout the decades. According to Samantha Gross and Bookings, “The earth gets plenty of energy from the sun for all of us, even for our modern energy-intensive lives. The problem is that this energy is diffuse. The sun that warms your face is definitely providing energy, but you need to concentrate that energy to heat your home or move a vehicle” [2]. Currently, over ½ of the world’s energy comes from fossil fuels while only 1/3 of energy comes from renewable resources [3].

Renewable energy resources are unreliable in that, depending on the area, they can’t always generate enough energy to power an entire community. According to the Sierra Club, “Over 50 communities across the US have made the transition to clean electricity for all, each powering their entire community with renewable electricity.” However, “The first communities to make the transition to 100 percent renewable energy were in locations with special access to renewable resources” [20]. While desert communities may have unlimited access to solar energy and Midwestern states have almost unlimited access to wind energy, other areas do not have the same advantages. If a community in an area with wind turbines was slated to operate on wind power but the region had an unreliable wind forecast, then the community would not be able to rely on this source alone.

Since the goal of renewable energy sources is to help improve the climate crisis, damaging the environment while installing these systems is counterintuitive. However once installed, the noises, moving parts, and other features that come with the energy-producing machines can have negative effects on the environment. The Office of Energy Efficiency and Renewable Energy says wind turbines can “reduce, fragment, or degrade habitat for wildlife, fish, and plants. [...] spinning turbine blades can pose a threat to flying wildlife like birds and bats” [4]. With rising CO₂ emission levels and scientists saying that the threshold for point of no

return could be as soon as 2030, it is essential, now more than ever, to solve these problems [5].

Introduction

The nature of chalky, suffocating coal and thick, crude oil has become more well known throughout the past decade due to the impending climate crisis. Scientists are constantly urging the human race to stop using fossil fuels. One of the first issues that pose difficulties in overcoming is that, while the public may know that fossil fuels are bad, many simply don't care. The American people's concerns about climate change have declined since 2008 due to biased media coverage and changing short term weather conditions [6]. According to NOAA, only 40% of voters are "very concerned" about climate change [7].

That being said, fossil fuels have played an essential role in the development of society as the world knows it today. Electricity, derived from fossil fuels, has allowed advances such as gasoline-powered transportation, heated and cooled homes, and just about anything requiring electricity. While fossil fuels have accomplished much in terms of human advances and innovations, continued use of coal and oil will surely mean the end of the planet. As previously stated, fossil fuels are a leading contributor to human-induced climate change as they are responsible for 89% of global CO₂ emissions [1]. Other contributors include deforestation, improper waste removal, and animal agriculture among others. The world must find renewable energy sources that are reliable, independent, and that have less of an impact on climate and the surrounding environment in order to save the planet.

Recent reports show that renewable energy is feasible in terms of cost. According to Dominic Dudley at Forbes and Global Averages, hydroelectric power is the cheapest renewable energy source, costing on average \$0.05 per kW [21]. Other renewable energy prices can range, considering "the cost of producing electricity from a biomass energy plant, for example, can

range from as low as \$0.05/kWh to a high of almost \$0.25/kWh.” However, Dudley’s aim is to point out that renewable energy prices are now able to compete with the cost of developing plants based on fossil fuel energy, as those prices range from \$0.05/kWh to \$0.15/kWh [21].

Renewable, ocean-based, energy solutions aren’t far-fetched technologies anymore. Scientists, engineers, and other inspired professionals have already started to work on ocean-driven alternatives. Cars running on algae fuel, floating energy platforms, and wave energy harvesting devices are potential solutions in the battle against climate change, and provide hope that the future will be renewable.

Challenges and Methodology

Environmental Impacts

When discussing fossil fuels and climate change, the mind wanders to the environment: How are fossil fuels affecting the environment? Why are ice caps melting, costing animals their homes, and why are there fires burning uncontrollably? Unfortunately, fossil fuels not only affect the environment in these manners when being used, but also when being produced.

As fossil fuels are being used they produce carbon emissions. When CO₂ emissions increase, they create a thick bubble that traps the sun’s heat close to the Earth, which increases the overall temperatures on the planet, a process known as “global warming.” When the temperature on the planet increases, ice caps melt, ocean temperature levels rise, and ocean acidification occurs. The melting ice caps in Antarctica and Greenland are not only destroying the homes of native animals but are increasing the volume of water in the oceans [11]. With sea level rising, land is being forced underwater. It is predicted that by 2050, “the United States alone would lose nearly 50,000 square miles, which today are home to 23.4 million people.” [12] Rising ocean temperatures also cause coral bleaching, the eradication of marine ecosystems,

extreme weather forecasts, and ocean acidification. As previously stated, ocean acidification causes harm to many marine animals, including shellfish, an important food source for coastal communities [13].

When fossil fuels are being produced, companies tear up land, disturb communities, and destroy the ocean. Oil drilling and installation operations can produce harmful noises to the surrounding wildlife and cause severe population decrease. When oil pipelines are installed they not only disturb the land around it but also contaminate the surrounding water and soil [15]. A common way of collecting oil is through offshore drilling. Offshore drilling poses the possibility of causing oil spills. For example, the Deepwater Horizon oil spill was a devastating display of the potential destruction that is inherent to oil rig operations. The spill occurred in April 2010, in the Gulf of Mexico, inducing an explosion that killed 11 people and dumped over 200 million gallons of crude oil into the surrounding waters [14]. Not only did this event cost billions of dollars in legal and clean up fees, but also caused the destruction of the surrounding ecosystems, an action that will take decades to recover from. “Dirty blizzard” dispersant and oil clumps smothered coral, and marine life populations decreased after contracting lung diseases due to the inhalation of oil [22].

While fossil fuels have many negative effects on the environment, it is worth noting that the installation of renewable energy sources do not take place without disruption as well. The installation of wind turbines, for example, can disturb the surrounding land and animals [16]. Negative environmental impacts of solar panels can include “land use and habitat loss, water use, and the use of hazardous materials in manufacturing,” [16].

Finding and using renewable energy sources can be a solution to these struggles, however changing weather patterns due to climate change make them increasingly hard to use. Some of

the most well-known energy sources such as wind and solar depend on specific weather systems. With the climate's unpredictable weather forecasts, society cannot depend on these generators.

Due to these negative effects, current renewable energy sources are inflexible and limited to specific places. It is necessary to develop new renewable energy sources that will not only decrease carbon emissions, but that will also be harmless to the surrounding environment.

Financial Impacts

When it comes to choosing the type of energy to use, an important factor that plays into the decision-making for everyone, from policy-makers to average families, is money. Energy expenses aren't straightforward, as there are many costs to take into account, including transportation, production, and health, to name a few.

According to an International Renewable Energy Agency (IRENA) report and IRENA's Director-General Francesco La Camera, switching to a renewable energy system "makes economic sense", in that the shift could save \$160 trillion in global economic climate change costs. La Camera also says that "By mid-century, the global economy would be larger, and jobs created in the energy sector would boost global employment by 0.2%. [...] The global energy transformation goes beyond a transformation of the energy sector. It is a transformation of our economies and societies" [23].

By comparing the LCOE (Levelized Cost of Energy) for renewables and fossil fuels, it is clear to see that the cost from start to finish for renewable energy is cheaper than that of fossil fuels [24]. According to the Lazard 2019 Levelized Cost of Energy Analysis, the cost of renewable energy continues to decline and continues to become "cost-competitive with conventional generation." The unsubsidized analysis comparison of the levelized cost/MWh of renewable energy (wind and solar) and conventional energy (nuclear, coal, gas, etc.) shows that

the conventional technology of coal can cost anywhere from \$66 to \$152 while wind only costs \$28 to \$54 [25]. Lazard's report also explains that "Regional differences in resource availability and fuel costs can drive meaningful variance in the LCOE of certain technologies." Meaning certain areas may be more equipped for certain types of renewable energy [25].

While the production of renewable energy is decidedly affordable, the home installation and initial costs cause hesitation in consumers and may drive individuals away from integrating renewable energy into their own homes. Solar energy, for example, costs on average \$15,000 to install at a household in the U.S. While this price has decreased in the last 5 years, the initial cost is not something every citizen can afford [18]. Researchers say that installing solar panels will save money in the long term because they are low cost and low maintenance once attached to the roof [18] [26]. The problem is, affordable solutions need to be put in place as soon as possible. Climate change is happening now, thus action must be taken if there is any hope of restoring our climate.

Humanitarian and Health Impacts

The impacts of fossil fuels are present in all aspects of life, one of which is in the humanitarian department. The biggest public health risks that fossil fuels pose are the "universal and potentially irreversible consequences [of] global warming." [8]

If climate change is irreversible, then so are the climate-change induced food shortages, floods, fires, and droughts that put countless lives in danger [8]. These issues might not come to mind when one thinks of climate change impacts, but the climate crisis will cause threats to food security, rising ocean temperatures will cause floods and storms, uprooting houses and businesses in the process, and increased droughts will trigger the mass displacement of farmers,

businesses, and civilians that will have to leave to find water [8]. These climate change disasters will require more humanitarian aid in terms of food, shelter, and medical attention [8].

The dependence on fossil fuels causes a domino effect of negative consequences for the Earth and its inhabitants. Rising CO₂ levels not only cause health problems but also increase ocean temperatures. An increase in ocean temperatures means that the rate at which water can absorb CO₂ decreases and leads to ocean acidification. Ocean acidification causes harm to many sea creatures including coral and shellfish [27]. As the acidity of the ocean increases, the shell thickness of shellfish decreases. Without the protection, shellfish growth and survival rates decrease [27]. “For oysters, scallops and other shellfish, lower pH means less carbonate, which they rely on to build their essential shells” [10]. The acidity has a similar impact on coral as it is also protected by a calcium carbonate shell. “Increasing ocean acidification has been shown to significantly reduce the ability of reef-building corals to produce their skeletons. [...] These results suggest that ocean acidification could severely impact the ability of coral reefs to recover from disturbance. Other research indicates that [...] coral reefs may erode faster than they can be rebuilt. This could compromise the long-term viability of these ecosystems and perhaps impact the estimated one million species that depend on coral reef habitat” [27]. With a decrease in viable seafood, many island communities will lose main sources of food. Food shortages could lead to human migration, or the need for humanitarian assistance in feeding these communities [8].

Even before the permanent damage is done, the public will still face health risks simply by breathing. The increase in SO₂, NO_x, and soot in the air causes chronic respiratory health concerns, burnt lung tissue, and acid rain which can be harmful to aquatic organisms [9]. “The total health cost [due to particulate matter] was estimated to be more than \$100 billion per year”

[9] [28]. According to the Harvard School of Public Health, burning fossil fuels “releases pollutants that lead to early death, heart attacks, respiratory disorders, stroke, [and] exacerbation of asthma” [29]. Natural gas leaks can cause evacuation and raise health concerns due to exposure [29].

On top of air pollution, the mining of fossil fuels, chemicals released into drinking water and food through the extraction process, and other fossil fuel side effects can lead to cancer, health disorders, and even fatality [9]. “In 2010, it is estimated that fine particle pollution from US coal plants resulted in 13,200 deaths, 9,700 hospitalizations, and 20,000 heart attacks” [9]. A recent Harvard University study with a goal of showing “the monetary value of clean energy projects in terms of improved public health” states that “energy efficiency measures and low-carbon energy sources can save a region between \$5.7 million and \$210 million annually”[17].

This analysis only scratches the surface of the negative humanitarian effects of fossil fuels. It is impossible to cover every single impact as the domino effect will only continue to span outwards as time goes on.

Solution and Discussion

Developing and applying renewable energy technology to harness renewable resources is one solution aimed at decreasing the effects of climate change. A great source of this energy can be found in the ocean, through its diverse environment and marine life. The following innovations are examples of technology that have been researched and presented as potential solutions to aid in the fight against climate change.

Sea Carpet

Wave energy, the process of harnessing the waves in order to convert their natural forces into usable energy, is an increasingly researched resource that could be a viable energy solution.

An innovation in wave energy, developed in 2014, is the Wave Carpet [30]. The Wave Carpet, also known as the Sea Carpet, consists of a flexible, durable material that imitates the muddy seafloor it lays on in order to absorb the waves [31]. Dr. Mohammad-Reza Alam and his team at the University of California, Berkeley explained, “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.” By removing almost all of the energy from the waves, the Wave Carpet can generate enough electricity to power over 400 homes [31].

This abundant source of power beneath the surface is practical and appealing to locals as the machine is out of sight and out of mind, so to speak [31]. The consistency of the ocean’s waves constantly initiating movement on the seafloor make the Wave Carpet a reliable energy source. Based on tests conducted so far, the wave energy that is produced can be used to power electrical grids and Alam says “every square meter of the carpet can get about 2.5 kilowatts [of electricity] out of water near the coast of California,” which is twice the amount of electricity used each hour by a typical American home [31]. While most wave converters are unable to be close to shore and therefore require more cabling which increases expenses, the Wave Carpet is the opposite. The Wave Carpet is cost-effective in the sense that it is laid close to shore (within three miles out and 72 feet deep) as “it is easier and cheaper to get the power to shore from these sites than it would be from farther out.” However, creating all of the Carpet components would be expensive considering this type of machine has never been built before [31]. In terms of location, this energy source must be in an area with high wave activity and low storm risk. If the Wave Carpet is damaged, then it could be potentially expensive to fix. As wave energy is very dense, each patch of Wave Carpet is able to be smaller and take up less space and produce more energy per square meter than solar panels [31].

As for the Wave Carpet's impact on its surrounding environment, it is hard to say, describes Deborah Greaves, an ocean engineer at the University of Plymouth in England. The converters will make noise and disturb the surrounding environment while being installed but should be quiet once up and running [31]. Greaves says that it can create less powerful waves near the shore which means less mixing of nutrients, affecting animals that live in the environment. But once installed, the wave converters could create a geometric artificial reef for marine ecosystems to ecologically flourish, and "can help provide some coastal protection by reducing erosion". "It's possible that converters could even attract fish to them if the smaller critters they eat seek refuge there. That could, in turn, attract hungry predators. This might help boost marine life in the area. But fish, seals, and other animals might also get tangled up in long cables that anchor surface-floating energy converters." explains Greaves. Considering the Wave Carpet is closer to the floor, they are less likely to interfere with migrating animals, though [31].

While the Wave Carpet has not been tested at full scale, the team was able to conduct tests on a small one in a lab tank. The prototype of the device demonstrated how the Wave Carpet moves up and down with the waves [31]. The Wave Carpet demonstrates the potential technologies that may be implemented in the ocean and the versatility of devices that can capture wave energy, and will continue to be a model for creative potential of wave energy converters.

Hybrid Platform for Energy Resources

If the power to harness the wind, sun, and waves has been created, why not use their combined energy to create a single machine? The prime location for this hybrid technology would be the ocean, where all of these elements are in excess. A floating hybrid platform doing just this has been created by SINN Power, a German company focused on wave energy technology; the floating hybrid platform is built with solar panels, windmills, and the ability to

convert the power of the waves it resides in [32].

The reliability of the platform can be measured by the fact that most of its generated energy would be converted from the waves; as that is the most dependable source of the three onboard. The platform “raises or lowers itself, depending on the height of the waves around it” in order to create the optimal situation for energy generation [32]. The hybrid’s ability to adapt to its surrounding environment is key when it comes to impact. In order to withstand what can be the sometimes weathering environment of the ocean, the platform is built with saltwater resistant materials and sturdy, distributed buoys. The machine is also equipped with technology that can anticipate damage before it occurs, preventing future expenses [33]. “IP68-rated electrical sensors continuously transmit data to diagnostic centers, enabling the early detection of anomalies and preventing potential failures.” Dr. Philipp Sinn, the CEO of SINN Power, explains. “By analyzing power output patterns, [...] they can easily optimize a service plan for potential customers and anticipate repairs before serious damage occurs” [34].

This lightweight and durable hybrid is designed to be affordable and easily accessible. With this energy solution, there are many opportunities to shape and expand the platform to make it fit in specific areas. With the ability to customize the size and array, the hybrid is designed to be cost-efficient and economical [33].

The hybrid can not only contribute to offshore wind farms but is ideal for island communities as well. “The floating platform can supply renewable energy to islands across the world, for example, and contribute to the worldwide implementation of offshore wind farms” Dr. Sinn continues [34]. Without the need for portable energy generators, the communities will be able to be self-sufficient and can rely on the 26 kilowatt-producing platform as a more permanent source of energy [32].

In 2018, the prototype for the hybrid platform was a patent application prototype. As of now, the hybrid is floating and generating energy off the coast of Greece [32]. “Starting later this summer, it [SINN power] hopes to offer solar panel manufacturers the chance to test and demonstrate photovoltaic arrays on a floating platform off the Greek coast as part of an off-grid energy solution” [32]. Dr. Sinn also says that the company is “preparing the floating platform to be used as a showcase, to enable wider access for potential customers. Politicians and representatives from other European nations have already visited. The next goal is in the autumn, when hopefully we'll be able to start marketing our unique electronics set” [34].

Algae Biofuel

Fossil fuels are not just used for powering homes and businesses, but also for powering cars through gasoline. The problem with current gasoline is that, according to the UCS, “Our personal vehicles are a major cause of global warming. Collectively, cars and trucks account for nearly one-fifth of all US emissions, emitting around 24 pounds of carbon dioxide and other global-warming gases for every gallon of gas.” The total US transportation sector produces almost 30% of all US carbon emissions [35].

A new fuel alternative has emerged from the depths of the ocean. This new, environmentally friendly biofuel is made from naturally growing algae. Not only is this new type of fuel better for the environment, but the algae is easier to source than fossil fuels, and “the fuel yield is 10 to 100 times more per unit area compared to other second-generation biofuel crops such as rapeseed and palms.” Scientists also say that “algae can yield 5,000-20,000 gallons per acre per year” [36].

While the algae biofuel does release CO₂ when burned, the emissions are then reabsorbed by the growing algae [36]. The biodegradable, non-toxic algae can be used to make

biodiesel and bio-jet fuel. This biofuel is cost-effective in that it can be used in existing diesel engines without alterations (the same goes for biomethanol) [36]. The biodiesel and biomethanol can be sold by itself or as a mix with petroleum diesel making it more attainable and affordable for the public. If an oil spill were to occur with biofuel, the “spills are comparatively harmless to the environment” [36].

One could say that there are implications to the growing and harvesting process as it is expensive, and the algae is slow-growing. According to Kris Walker at Azo Cleantech, “certain strains of algae tend to produce more carbohydrate than oil and can be fermented to produce biobutanol and bioethanol.” The problem is, the species of algae are hard to identify as there are over 30,000 of them [36]. For the algae to be the most “lipid-rich” it is best to grow them in translucent membrane-covered greenhouses and ponds. It is not ideal to grow them in open ponds which could be a difficulty in some locations. However, potential algae desert farming is not only an ideal way to grow algae, but the salt from the desalinization ponds can be used by local businesses [36]. When growing the algae, different types of water, including wastewater and ocean water, can be used. After the oil is removed, the rest of the algae can be used as livestock feed or fertilizer [36].

Algae biofuel has been tested in all types of vehicles from cars to airplanes since 2008 when Solazyme drove the first standard car (Mercedes C320) using algae biofuel [37]. Intertek, a company devoted to product quality assurance and testing, tests algae materials and biofuels. Companies can send in their developed algae fuel and Intertek will test it in cars, jets, or other requested forms of transportation [38]. Intertek says that it’s “research and production support helps clients optimize R&D efforts, and reduce and avoid issues caused from contaminated or out-of-specification biofuels.” The company is able to do so by measuring growth rate, product

contents and composition, and nutrients effects, as well as testing the products in vehicles [38].

Intertek is not the only company working with biofuel. ExxonMobil is in the process of developing biofuel using products ranging from algae to “methane emitted from microbial activity in landfills.” They say “about 50% lower life cycle greenhouse gas emissions will be produced by algal biofuels as compared to petroleum-derived fuel” [39]. Biofuel is usable, affordable, and reliable, and is finally beginning to become accessible.

Conclusion

Without creating a change in the way humans use energy, the world will continue to perish. The global economy will suffer the loss of billions of dollars due to climate change-induced damage, while the amount of human life, biodiversity, and clean living environments lost will be priceless. The future is bleak for all life on Earth, even for those that fail to see the dire need for change. The switch to renewable energy is resisted due to its cost and lack of accessibility. While current energy sources are unreliable, weather-dependent, and frequently have negative impacts on the surrounding environment, renewable energy sources may pose as more independent, clean, consistent power sources.

The research in this report demonstrates that ocean-based solutions can solve issues surrounding climate change. Members of society, including researchers, students, and industries, are working tirelessly to ensure that humans have a future on this planet. It is possible to achieve the energy standards that are necessary for human life to be sustained while also saving the planet and human life. If the world turns to the oceans, fueling cars with algae biofuel and relying on floating hybrid platforms and Sea Carpet-like technologies for harvesting wave and offshore energies, there is an opportunity to put the climate back on track. It is time for the human race to take action and tap into the many resources and opportunities that the ocean

provides us.

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