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Phycoremediation: Improving Water and Air Qualities while Sequestering Carbon in Punta Catalina.

The Anthropocene is the current epoch in history that began when human activities started to have a significant global impact on Earth's ecosystems. Anthropogenic impact or human impact on the environment includes drastic rise in global climates, geographic changes and even increased rates of biodiversity extinction due to human related causes. Perhaps the most significant anthropogenic impact on the environment is the increase in levels of carbon dioxide. The natural carbon cycle has been dramatically disrupted in such a way that equilibrium between carbon capture from photosynthesis, carbon deposition from in the soil and oceans, and carbon release from biological and geological sources is no longer at balance (Crofcheck 2012, 1-2).

Most scholars will argue that the imbalance in the carbon cycle began with the Industrial Revolution, in which humanity began to burn fossil fuels-coal, natural gas and petroleum for energy. The combustion or burning of fossil fuels releases great amounts of carbon emissions and other harmful gases onto the atmosphere, and currently at a rate that disrupts natural equilibrium with Nature (Crofcheck 2012, 1-2). Deforestation, urbanization and energy production from fossil fuels are some environmental issues that have increased the amount of carbon or CO_2 in the atmosphere. In response to the increase in carbon dioxide, new design approaches such as sustainability or sustainable design have begun to address these environmental concerns through the use of new technology and old practices such as learning from vernacular architecture to meet modern needs.

In this paper, I will address the potential of microalgae to sequester carbon and recycle it in the process of phycoremediation, in order to provide improved water and air quality to local communities. Finding sustainable solutions or approaches to existing technology or mechanisms is as important as developing renewable energy or other sustainable developments. In order to improve our environment we need to improve our existing ways of doing things such as producing energy. A lot of what society and industry consider "waste" such as wastewater, waste heat or carbon dioxide is actually valuable inputs or nutrients for other processes such as phycoremediation. Society must learn to "upcycle" and eliminate the concept of waste from there mentally but rather learn to see "waste as food."

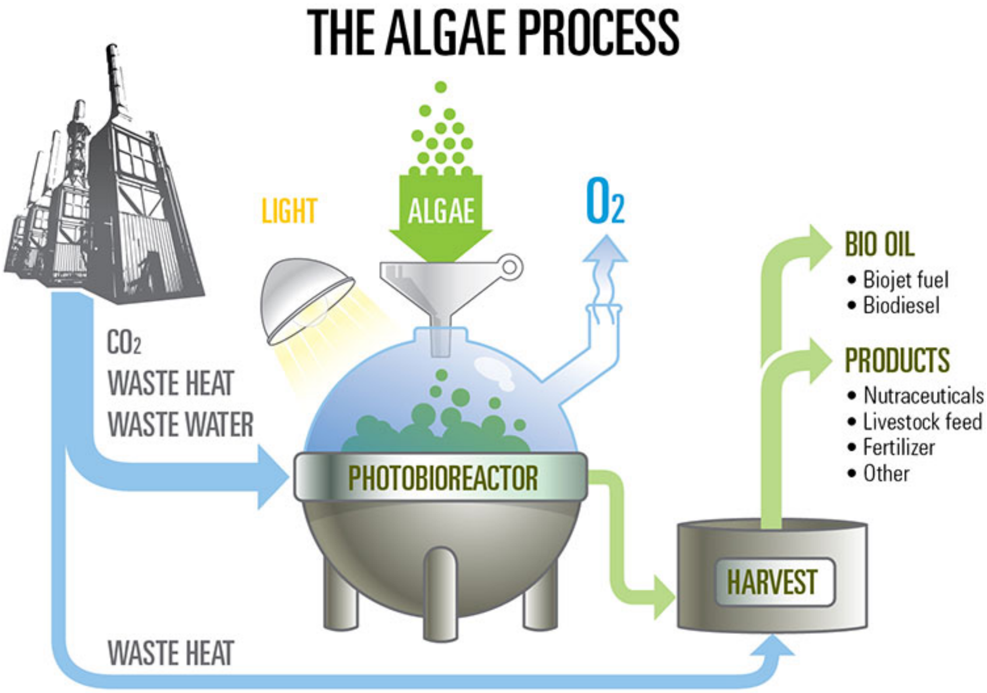
The process called phycoremediation is a form of bioremediation in which algae are used to remove pollutants from wastewater and waste heat or air (Clarens 2010, 1813). Phycoremediation allows for improved water and air qualities by removing harmful pollutants but also by purifying the water and air in a biological process. Improved water and air qualities have environmental, economic and social benefits and help address socio-environmental concerns of local communities. This paper will describe how phycoremediation can be integrated into the process of energy production from fossil fuels in order to make the process more sustainable.

Imagine living in a place where you do not have access to electricity twenty-four hours a day, where water is becoming more and more scarce and the tremendous heat of the day is becoming more and more unbearable. This is the Dominican Republic. The Dominican Republic is an island-nation in the Caribbean with one of the fastest growing economies and populations in the region. As a developing country, the Dominican Republic faces many issues but the greatest are probably energy, water and human health. I have over a year living in a small city named Bani on the south coast and because of my family's economic position, I do have access to electricity all-day, everyday- and even then, I sometimes experience energy blackouts. Energy is a big concern for most of the population, who like the majority of the world population, depend on energy for almost everything.

Although the climate in the Dominican Republic is considered tropical-wet, water is becoming highly scarce in the region. The Dominican Republic and Puerto Rico this year have experienced a severe drought and water has become sacred here with some cities taking actions such as banning the washing of cars in order to save water. The drought has caused severe water-saving behaviors as well as highly affected agricultural production in most of the island because the canals and dams have gone mostly dry. In the past months alone, many communities have had to purchase water in order to sustain themselves because local water sources were becoming extremely limited and short. Ironically, we are on an island surrounded by vast amounts of water that we cannot drink because of its salinity. With low precipitation and dams going dry, water scarcity has become a major concern in the Dominican Republic.

The Punta Catalina Thermo Project is a thermoelectric, coal-fired power plant being installed in the city of Bani in the Dominican Republic. Punta Catalina Thermo is a project that will consist of two coal-fired thermal power plants; an offshore terminal and other associated facilities such as domes, conveyors and water treatment systems as well as an electric substation. The project's client is the Dominican government CDEEE (Corporacion Dominicana de Empresas Electricas Estatales / Dominican Corporation of State Electrical Companies) that has contracted with Maire Tecnomont S.p.A, the Odebrecht Group and Ingeniera Estrella to complete the project by 2017 (Raffaelli 2013, 16). Coal-fired thermal plants are infamous because of their polluting and hazardous effects or byproducts. However, the Punta Catalina Thermo is just one step to solving the energy crisis in the Dominican Republic. This paper will explore how this project could be more sustainable rather than advocate for ways in which it might be halted.

A sustainable approach that may be taken by Punta Catalina Thermo to help mitigate its environmental and social effects and capture carbon emissions is through the use of microalgae. Microalgae or microphytes are microscopic algae, typically found in freshwater or marine systems. They are unicellular species that exist individually, or in chains or groups. Depending on the species, their size may range from a few micrometers to hundreds of micrometers (Wang 2008, 15). Unlike terrestrial plants or higher plants, algae do not have roots, stems or leaves. Microalgae capable of performing photosynthesis are essential to life on Earth as they produce about half of atmospheric oxygen and use carbon dioxide to grow photoautotrophically (Wang 2008, 15).



The diagram above represents Wiliiam McDonough's idea of how to integrate microalgae into energy production in his book *The Upcycle* and my sustainable proposal for Punta Catalina Thermo; using photobioreactors connected to pipelines that lead from the coal-burning power plants to algae ponds/farms in order to capture carbon dioxide as well as waste heat and wastewater (McDonough 2013, 121). The process will work as currently planned; the Punta Catalina Thermo project will not be altered from its current modes of operations. Algae ponds/farms will add to the operations process of the thermoelectric plant. By installing photobioreactors, the greenhouse gas emissions such as carbon dioxide will not be released into the atmosphere but rather transported to the algae ponds/farms. In these algae ponds/farms, micro-algae will be grown using the carbon released from the thermo power plants as well as wastewater released from the said process and sunlight (Barnabe 2013). The micro-algae will be harvested in either open ponds or algae photobioreactors, both which do not compete with food production for arable land (Barnabe 2013).

In a typical thermoelectric power plant, carbon dioxide is released into the atmosphere, wastewater is released into water sources and waste heat is lost (Sayre 2010, 723). In this proposed scenario, the otherwise considered “waste” products of such a process become the fuels or inputs of another process in a symbiotic manner; one mans trash is another mans treasure. The key in this proposal is not only the sequestering of carbon but also the advantages that may be obtained from growing algae such as wastewater treatment and waste heat capture. By treating wastewater and waste heat, improved water and air qualities for the local communities can be obtained, therefore improving human health concerns and improving their quality of life.

The use of microalgae to sequester carbon and to treat wastewater is a relatively new technology. Pollution is a man-made phenomenon arising from either when the concentrations of naturally occurring substances are increased or when non-natural synthetic compounds known as xenobiotic are released into the environment (Molina 2001, 115). Wastewater is very often released into waterways without any treatment or with only primary and secondary treatment due to high cost of tertiary and quandary treatment. Tertiary water treatment removes all organic ions from water such as nitrogen and phosphorous, while quandary treatment removes heavy metals such as arsenic and mercury, soluble minerals and toxins from water (Molina 2001, 125).

Biologically, microalgae are very similar to terrestrial plants in that they possess photosynthetic capabilities. Microalgae growth depends on several factors; light intensity, temperature, density, pH, water and carbon. Like terrestrial plants, microalgae taken in carbon, sunlight and water and release oxygen in return (Raouf 2012, 260). Science has proven that plants have the capabilities to capture toxins from the air such as in indoor environments, just as microalgae are capable of capturing heavy metals from water. Microalgae have gained scientific interest in wastewater treatment because of their ability of incorporating nutrients such as nitrogen into their growth (Raouf 2012, 263). Some species of microalgae have higher capacity to absorb carbon dioxide such as the species *Cyanidium celdanum* with a 90%-100% rate, the species *Chlorococcum littorale* with 60% and *Euglena gracilis* with 45% (Molina 2001, 126).

Mechanically, the technology behind using microalgae in wastewater treatment depends heavily on enclosed photobioreactors or open ponds. Photobioreactors are bioreactors that utilize a light source to cultivate phototrophic organisms such as microalgae, plants or cyanobacteria. Within the artificial environment of the photobioreactor, specific conditions are controlled depending on the desired species and thus allow for higher growth rates (Molina 2001, 128). These closed system photobioreactors come in various forms such as tubular photobioreactors or horizontal photobioreactors. Another mechanical or system used for growing microalgae is open ponds.

Open ponds are systems in which microalgae are grown in ponds that are open to direct sunlight and air exposure, thus eliminating the need for artificial lighting. These ponds contain needed nutrients and carbon dioxide and are pumped around in a cycle. These types of open systems are vulnerable to space limitation, contamination from outside sources and limit the growth rate of microalgae (Molina 2001, 130). Because of these traits, closed photobioreactors are being researched more thoroughly and can be more easily integrated into energy production systems.

Many countries have initiated research into the use of microalgae to capture carbon dioxide and to produce algae based products such as biodiesel. The United States, Canada and Germany are perhaps the leading nations in this kind of technology. The difficulty or barriers with growing microalgae depend mostly on the cost of such technology such as closed photobioreactors and the general skepticism of the process because it is a relatively new idea in the scientific community.

Punta Catalina Thermo Project could greatly benefit from the integration of phycoremediation into its operating process. Phycoremediation has the potential to mitigate environmental and social concerns related to burning coal as a source of energy such as water and air pollution, release of carbon dioxide into the atmosphere and the increase in related health concerns such as asthma and respiratory illnesses (Clarens 2010, 1816). Phycoremediation in Punta Catalina can also work to address local community needs such as potable water and improving water and air qualities. Carbon sequestration and the recycling of carbon dioxide by microalgae has tremendous environmental benefits such as reducing greenhouse gas emissions, reducing carbon dioxide in the atmosphere, reducing air pollution and naturally recycling carbon dioxide.

Improving water and air quality has both environmental and social benefits from the use of phycoremediation to treat wastewater and waste heat. Because microalgae has the capacity to perform tertiary and quandary water treatment by removing organic compounds and heavy metals, the end result is higher water quality. Microalgae can also be used to treat salt water in order to provide potable water if necessary, which is a tremendous advantage for the community around Punta Catalina. The treatment of wastewater into potable water provides water for the community for drinking purposes, irrigation needs and helps improve water quality in nearby waterways in which the water may be released into.

By sequestering carbon and recycling it to grow microalgae, air pollution is greatly reduced in the area because carbon dioxide is not being released into the atmosphere. Improved air quality helps improve the quality of life of facilities workers and the local community because they are exposed to less hazardous contaminants. Since carbon dioxide and other greenhouse gases are not polluting the air, land or water; numerous health risk are reduced that would otherwise be expected to affect the area such as respiratory illnesses like asthma, allergies, increase in cancers and other airborne and waterborne illnesses. Such illnesses are a direct and indirect consequence of air pollution. Another important social benefit to the community will be the rise in employment as well as the educational function of such a sustainable procedure. The local community will have access to numerous job opportunities and thus will be able to improve their quality of life economically. Being of close proximity and perhaps working within the micro-algae harvesting facilities will increase the local communities knowledge about sustainability, micro-algae and the need to reduce carbon emissions.

Phycoremediation to treat wastewater and to sequester carbon dioxide from coal-burning power plants such as Punta Catalina Thermo Project is a way of introducing sustainability into unsustainable practices. Is it also a way of slowly changing human behavior and mentality about waste, in that phycoremediation uses the waste of coal-burning power plants as its own nutrients for growing microalgae. The use of phycoremediation helps to sequester carbon, treat wastewater to tertiary and quandary levels and improve air quality in local communities. Although the technology behind phycoremediation is still under thorough investigation and highly costly, microalgae yields high value commercial products such as biodiesel that could offer the capital and/or operational cost related to the growth of microalgae and its related technology. Phycoremediation is a renewable cycle and process that work symbiotically with coal-burning energy production in a way to mitigate environmental and social concerns.

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