Intro

While numerous methods of generating electricity have evolved, countless issues have emanated from them. Most of Earth's emissions are anthropogenic greenhouse gases (GHG) which originate from the burning of fossil fuels – coal, natural gas, petroleum, and hydrocarbon gas liquids – for energy production. Fossil fuels primarily consist of carbon and hydrogen

Based on a study from the Energy Information administration (EIA), currently 80% of the Earth's electrical production derives from nuclear and fossil fuels. As fossil fuels are burned, they gradually release carbon dioxide (CO2) and other greenhouse gases (GHG) into the atmosphere. Roughly 40% of global CO2 emissions come from electricity generation.

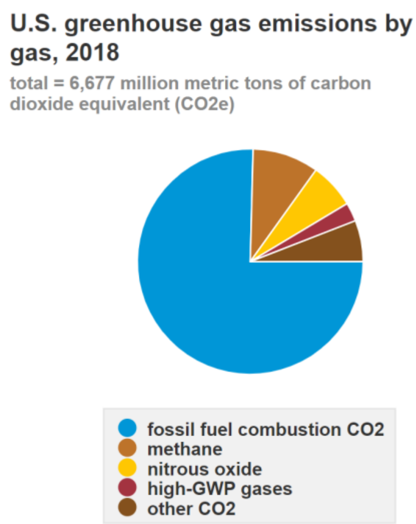

Figure 1: GHG Emissions of 2018

Credits: Energy Information Administration

According to the EIA, in 2019 about 46% of U.S. energy-related CO2 emissions aroused from burning petroleum fuels, 33% came from burning natural gases, and 21% came from burning coal. Although the industrial sector is the prominent consumer of energy, the transportation sector emits more CO2 due to its complete dependence on petroleum fuels.

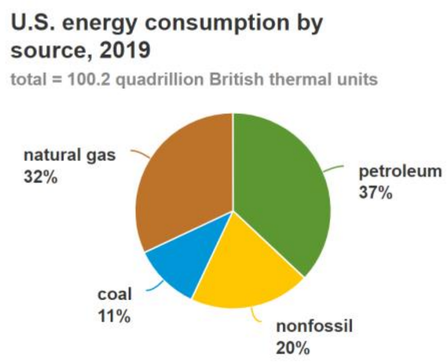

Figure 2: Levels of U.S. energy. by source in consumption in 2019

Credits: Energy Information Administration

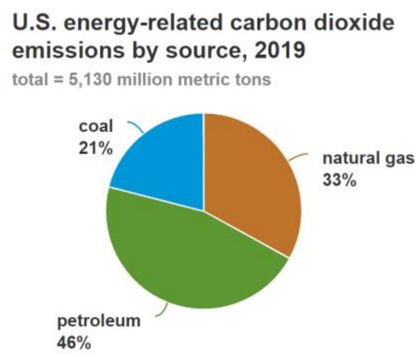

Figure 3: U.S. energy related CO2 emissions emissions by source in 2019

Credits: Energy Information Administration

All these emissions coincide with several issues which are hazardous to human health. Soot, or “particulate matter,” is made up of tiny particles of chemicals, smoke, dust, soil, or allergens, in the form of gas and solids that are carried in the air. The United States Environmental Protection Agency’s (EPA) “Plain English Guide to the Clean Air Act” states that, “The sources of soot include trucks, factories, power plants, incinerators, engines—anything that combusts fossil fuels such as coal, gas, or natural gas.” The smallest airborne particles contained in soot are especially dangerous because they can penetrate the lungs and bloodstream, lead to heart attacks, worsen bronchitis, and even precipitate deaths.

The present-day world is increasingly dependent on energy with the drastic evolutions of science and technology. Increased economic growth and social development is resulting in a large gap between energy demands and the availability of fossil fuels. This current situation is precarious, thus driving to the search of an alternative to fossil fuels.

The U.S. energy supply is composed of a wide variety of energy resources. For example, renewable energy, which consists of resources that replenish themselves and are not exhaustible. And even green power, which is a subset of renewable energy resources and technologies that provide the greatest environmental benefit.

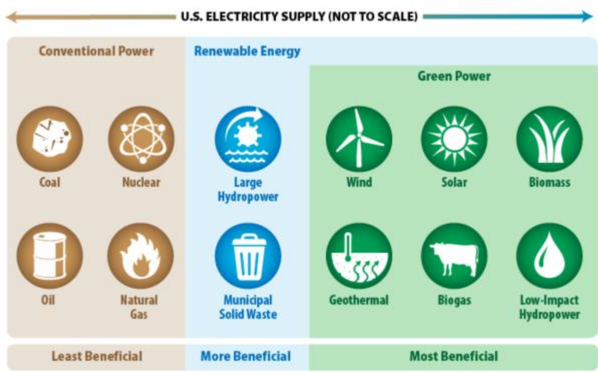

Figure 4: U.S. Energy Production Supply

Credits: Environmental Protection Agency

However, there are large gaps in these types of energy production. For example, solar technologies, which are green energy, cannot produce electricity when the sun is obscured. Instead, they continue to provide power through net metering, in which surplus power is transferred to a public power grid, often powered by fossil fuels. Most importantly, particular materials are needed which require heavy mining into Earth. While several other sources of energy seem attractive, such as biomass energy, biogas, and wind power, they all share several deficient factors-- either the abuse of animals or mass occupation of land.

Recently, scientists have found a way to capture the energy produced using microbial extracellular electron exchange processes for catalyzing oxidation and reduction reactions—commonly referred to as microbial electrocatalysis-- through a technology called a microbial fuel cell (MFC).

MFCs are electrochemical devices that convert the chemical energy contained in organic matter (domestic wastewater, sludge, benthic mud) into electricity by means of the catalytic (metabolic) activity of electrochemically active microorganisms. MFCs, like any typical fuel cell, comprise of an anode and cathode, which are separated by a proton exchange membrane, and are electrically interconnected through an external circuit with a resistor or load. The electrons produced by bacterial respiration are released from the substrate oxidation in the anode chamber (electron donor) are transferred to the cathode chamber (electron acceptor). The electrons flow from the anode to cathode via the external circuit, generating electricity as the main product. In the cathode, the incoming electrons are combined with oxygen as well as the protons, which are diffused through a proton exchange membrane (PEM), to form pure water. One of the most important significance of MFCs is to "produce electricity from wastewater, providing a new way to simultaneously treat wastewater while obtaining a source of clean and renewable energy" (ResearchGate).

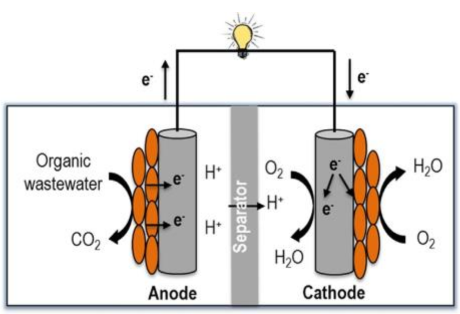

Figure 5: Double chambered MFC undergoing redox reactions
Credits: Encyclopedia of Interfacial Chemistry

In MFCs where the electrochemically active bacteria contained in the anode are considered anaerobic, inorganic compounds such as nitrate or sulfate must serve as the terminal electron acceptor instead of oxygen, which would be used in aerobic conditions. Denitrification is a microbially facilitated process where nitrate serves as the terminal electron acceptor. Nitrate is reduced to nitrite, nitric oxide, nitrous oxide, and finally dinitrogen. The stepwise reduction of nitrogen generates the electrochemical gradient that drives anaerobic respiration. In addition to posing as a terminal electron acceptor in anaerobic respiration, nitrate serves as an essential nutrient for bacteria.

Coffee grounds serve as an excellent source of nitrate, as they have a 2% composition of nitrogen by volume, they are not acidic, and therefore do not have a strong chance of killing the bacteria, they share the same, optimum C:N ratio with anaerobic respiration (20:1-30:1), and finally, their texture is ideal and easy for bacteria to break down.

This study utilized nitrate as a terminal electron acceptor and essential nutrient in anaerobic processes of electrochemically active microorganisms to augment the overall performance of an MFC. Three MFCs were built, with the first as the control, the second with a 5% addition of coffee grounds (source of nitrate), and the third with a 10% addition of coffee grounds. Benthic mud was used as the substrate in the anodic compartment of each MFC. It is expected that the MFC with a 10% addition of coffee grounds will increase the performance, when compared to the control, the most, due to a greater supply of nutrients for microorganisms and stable final electron acceptor during respiration.

The MFC technology is not only attractive because of its ability to generate electricity from waste, but specifically because of its purpose of serving as an eco-friendly technology.

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