CONVERSION OF GREENHOUSE GASSES INTO ENERGY

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Fall, 2013

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Research Proposal

This project is to gather information and gain knowledge on how to convert greenhouse gasses into energy. The goal is to integrate the information into one comprehensive and concise resource. I will explain what the greenhouse gasses are to provide a basic context, before I venture into expressing how individual gasses do harm to the environment and humanity. I will also include previous findings and processes on how to convert these gasses into energy. My sincere hope is that my research paper will make people more aware of the how greenhouse gasses are created, the harm that excess greenhouse gasses cause, and to motivate endeavors to reduce greenhouse gasses by capturing and converting the gasses into profitable energy. This research will be accomplished by using literary resources such as books and journal articles. As this is a contemporary issue, I will utilize reputable and current online sources too.

Annotated Bibliography

Blockstein, David E. and Leo A. Wiegman. *The Climate Solutions Consensus.* Washington [DC]: Island Press, 2010. With wit and creativity these authors present what are greenhouse gasses, especially carbon, and what damage greenhouse gasses have done. The authors include a condensed history on climate change and the resulting danger to the environment and humanity. They conclude with the recommended actions on how to address the problems with carbon and greenhouse gasses. This book correlates with my project by providing ideas into how to battle greenhouse gasses, and specifically their focus on carbon. In summary it provides a wealth of information on the topic of greenhouse gasses.

Clean Tech, Clean Profits: Using Effective Innovation and Sustainable Business Practices to Win in the New Low-carbon Economy. Philadelphia: Kogan Page Ltd, 2010. This book presented an economic focus on how to handle greenhouse gasses and to make a profit. It was a helpful book in finding resources and various ways to convert greenhouse gasses into energy, thus helping with reducing and removing of them.

Dallas, Nick. *Green Business Basics: 24 Lessons for Meeting the Challenges of Global Warming*. New York: McGraw-Hill, 2009. Dallas offers readers a straight-forward book about the business aspect of global warming and greenhouse gasses. He precisely and swiftly goes through: defining greenhouses gasses, focuses on carbon dioxide, gives a brief history of carbon dioxide and humanity, and lists various ways of how to mitigate greenhouses gasses. It is a helpful book for my project because it presents complex topics more simplistically. It aids in understanding this complicated topic. The book also brings about an awareness and understanding of additional complex concepts in the project.

Dandekar, Hemalata. "Gobar Gas Plants: How Appropriate Are They?" *Economic and Political Weekly*. Vol. 15. Mumbai: Sameeksha Trust, 1980. 887-93. This article was a fascinating read as it discussed the technology of producing energy from methane gas that is already been used in India. It gives a first-hand experience on what the locals thought about it and how helpful, or not, it has been. For my paper this article is helping me to understand if such technology is viable or helpful. It also features companies already using conversion technology to demonstrate its feasibility.

Global Weirdness : Severe Storms, Deadly Heat Waves, Relentless Drought, Rising Seas, and the Weather of the Future. New York: Pantheon Books, 2012. This book is quirky and witty, yet informational and poignant. It focuses on: what climate change is, what it has done, what it is doing environmentally and globally, and what is the projected climate change going to cause. For my project, it presents vital knowledge in regards to the dangers of global warming, and why

it is important to find a way to convert greenhouse gasses into energy. The book also provides me with the data about reducing the existing greenhouse gasses by capturing their by-products. Energy is money and money appears to be the universal motivator to act. Hopefully, I will be able to convey these actions in my paper and perhaps reduce the predicted catastrophes detailed in this book.

Howell, Derek. *Your Solar Energy Home : Including Wind and Methane Applications*. Oxford: Pergamon Press, 1979. Howell provides, in detail, how an individual and company can use methane as energy. He provides information and blueprints into how precisely one can create a home or company powered by methane. This citation relates to the project by providing a thorough explanation of how methane can be converted into energy, and how one can utilize this method for personal or business use.

Hunter, Christopher, Karel Svoboda, David Baxter, and Maria Gutierrez. "Nitrous Oxide (N2O) Emissions from Waste and Biomass to Energy Plants."*Waste Management & Research*, 23.2 (2005): 133-147. This article describes various ways to convert N20 into energy. They explain where N20 comes from, and a condensed history of N20. They go on to explain why it is important to capture it to make energy. This article is vitally important to me, because it explains a way to convert N20 into energy. An issue very difficult to find any information on in relation to its conversion to useable energy.

Rajaram, Vasudevan, Faisal Zia Siddiqui, M Emran Khan. *From Landfill Gas to Energy: Technologies and Challenges*. Leiden, The Netherlands: CRC/Balkema, 2012. This online book presents a thorough study of how to convert landfill gasses into energy. It helps with the project by providing information on more technologies that can convert greenhouse gasses into energy, which is a fundamental part of the paper.

Turner, Martyn, and Brian O'Connell. *The Whole World's Watching : Decarbonizing the Economy and Saving the World*. Chichester, West Sussex, England: John Wiley, 2001. This book presents the issue of climate change with a focus on carbon dioxide, but it suggests how to convert other gasses into energy, too, such as methane.

U.S Environmental Protection Agency. *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2011.* Washington, D.C.: National Service Center for Environmental Publications (NSCEP), 2013.This report presents graphs and statistics of the United States greenhouse gasses. They break it down into refined detail and statistics. A bountiful source of data in the breakdown of each gas and its sources. It is helpful to the project, because it clearly shows where each gas is coming from, and how much from each source. It is a great resource about the sources of where greenhouse gasses come from.

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Introduction

What are greenhouse gasses? Are they truly harmful to people and the environment? If nothing globally changes in mitigating greenhouse gasses will it truly be cataclysmic? Is there anything being done to address this global issue? Can anything be done to handle these greenhouse gasses? I hope to address these questions and more with my study of this debated topic of greenhouse gasses. I propose that greenhouse gasses be converted into energy. Through this proposal I hope to address one of the biggest hurdles that mitigation of greenhouse gasses face: motivation. Energy can translate into monetary value for commercial and personal benefits. If we can reduce the existing greenhouse gasses and capture newly produced gasses by turning them into profitable and functional energy, perhaps it will provide the motivation to resolve this issue.

To help obtain this goal information must be compiled into one comprehensive and concise source. Through the use of literary resources such as books, journal articles, and online sources I will provide information that is rooted in solid science and break-through technologies. I will start by answering the question of what greenhouse gasses are to provide a foundation to support the rest of the paper. I will venture into why we should address this topic in regards to the harmful effects. I will also address the predicted effects if these gasses are not mitigated.

I will address the current efforts being attempted in mitigating greenhouse gasses. I will follow this discussion by developing my proposal to converting greenhouse gasses into energy.

The next section of the paper will be devoted to the major individual gasses that compose the term greenhouse gasses: Carbon Dioxide, Methane, Nitrous Oxide, and Fluorinated gasses.

I will explain what each gas is specifically and how it is created. I will single out how the gas as a lone component is harmful to the environment and us.   I will conclude the individual assessment of each gas by suggesting various the gas can be converted into energy.

My proposed ideas for the mitigation of greenhouse gasses is followed by the conclusion of the paper, where I shall summarize the main points. Moreover, I will conclude with suggestions for future research to continue to address the problems and solutions regarding greenhouse gasses.

2.

Greenhouse Gasses

The start of this topic begins with the foundation of what greenhouse gasses are. They are carbon dioxide, methane, nitrous oxide, and fluorinated gasses (see fig. 1). Fluorinated gasses are composed of three groups of chemical compounds: “hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF6)” (U.S Environmental Protection Agency 1-3). These gasses shall be individually examined later in the paper. The combination of these gasses are the source of the greenhouse effect. The greenhouse effect can be described as: the sun bombards the earth with energy, and

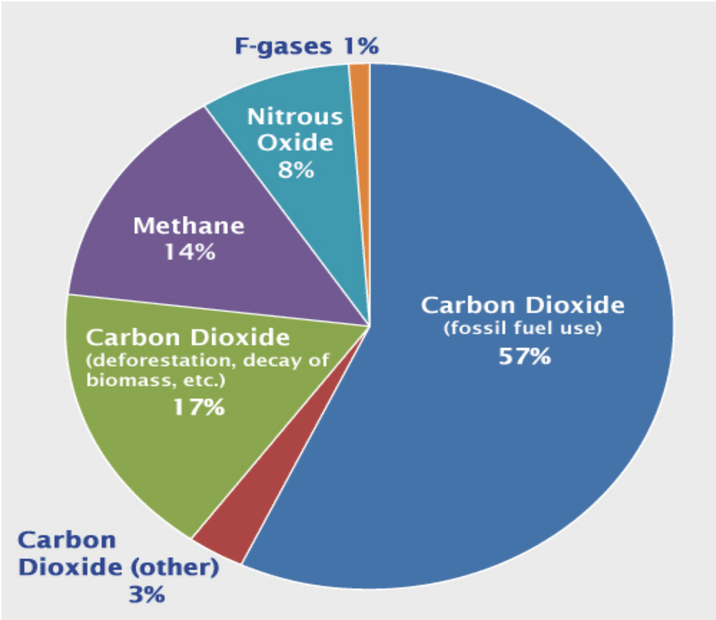

Fig. 1 Global greenhouse gasses emissions by category. "Global Greenhouse Gas Emissions by Gas". Graph. 2007. *Global Greenhouse Gas Emissions Data*. Environmental Protection Agency. Web. 03 Sept. 2013.

the energy that reaches the earth's surface, which was not reflected or already absorbed on the way to the earth's surface, gets absorbed by the land and oceans. While the oceans and land absorbs this energy, it also releases heat. As this heat is released and on its way out of the atmosphere it gets caught by greenhouse gasses. Once this heat is caught by greenhouse gasses these gasses then act like “a miniature version of what earth as a whole does: heat up, then radiate some of the heat away” (“Global Weirdness” 26). This process does not allow the heat to“ immediately escape to outer space; it first warms up other air molecules and ultimately warms the earth itself” (“Global Weirdness” 26). This process is called the greenhouse effect.

It is crucial to discuss the difference between the natural greenhouse effect versus the greenhouse effect enhanced by humans, because there is a an importance distinction. The natural greenhouse effect is a process that maintains an inhabitable temperature for our existence. The man-made greenhouse effect creates an excess of heat that is over loading the natural cycle of the earth. The problem is not with the earth's natural processes, but the problem is with excessive greenhouse gasses created by humans (see fig. 2). The scientific term is called: “anthropogenic climate change” (“Global Weirdness” 28).

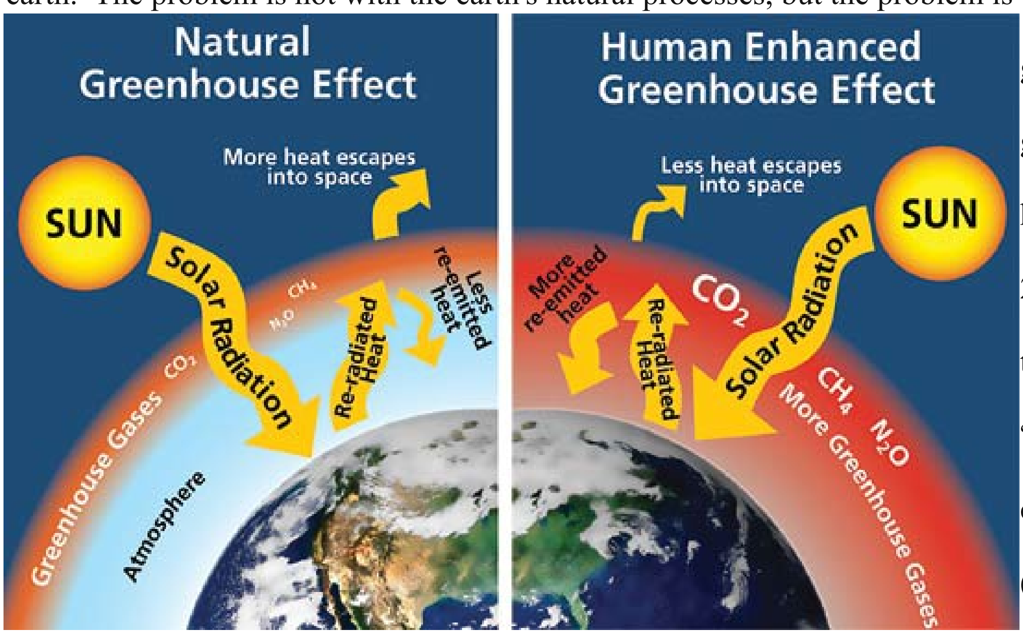

Fig. 2 Natural greenhouse effect versus human-enhanced greenhouse effect. “Natural greenhouse effect versus human enhanced greenhouse effect”. Illustration. n.d.. Climate Change. *National Park Services.* Web. 03 Sept. 2013.

Anthropogenic climate change is exhibited in the earth's temperatures. Since the 1900's, the average temperature of the earth's surface has risen 1.4°F, and it is predicted to rise another 2 to 11.5 degrees by the end of this century (U.S Environmental Protection Agency 1-3). The rising temperatures have already contributed to melting glaciers, rising sea levels, and rising sea temperatures. Sea levels have already risen "eight inches since 1900" ("Global Weirdness" 83), which equates to low-land areas having to deal with disappearing land and negative consequences for both humans and the natural environment. A prime example of these negative consequences are happening to the Maldives Islands in the Indian Ocean. Since the majority of their islands have an elevation of zero, the rising sea levels pose a direct threat to their citizen. To combat the rising levels of the sea the government of the Maldives have built a seawall around the entire island of Male, and plans to build more around other islands ("Sea Level Rise"). Another example of the negative consequences from the rising sea levels and temperature is the habitat of the polar bears. A combination of disappearing glaciers/ice and rising sea levels, due to the increasing temperature of the sea and earth, has placed the polar bears as the first animal to become an endangered species because of anthropogenic climate change ("Global Wierdness" 96). Who will be next?

It is scientifically shown that the excess greenhouse gasses caused by humans is heating up the earth; this rise in temperature comes with a host of actual and predicted consequences that will effect the earth's ecosystem:

> "mountain glaciers will start to melt, so the rivers they feed will flow differently. More water will evaporate from both land and oceans, leading to more rain and snow in some places and more drought in others. As the oceans warm major

> currents may speed up or slow down, which would affect weather patterns. Temperatures at the poles and the equator might change. The winds might start to blow in different directions changing weather patterns, again. Also, animals and plants that are in a particular geographic location might have to move somewhere else to find conditions that they are adapted to, or try to adapt, or just go extinct" (Global Weirdness" 27-28).

Another concern is the impact these greenhouse gasses will have upon the largest ecosystem on the planet: the oceans. The concern is that the excess carbon-dioxide is causing the oceans to become more acidic. These harmful effects on plants and animals that live in the sea, which in turn effects us.

Already earth is exhibiting the impacts resulting from these greenhouse gasses. One of the problems that has arisen due to the increased global temperatures is that plant and animal cycles are being disrupted. There is a startling statistic that the "growing season in the continental United States is two weeks longer than it was in the 1900's" ("Global Weirdness" 98). Also, these changes have already caused problem in the inherent life-cycle of the cuckoo bird ("Global Weirdness" 100-102). The cuckoo bird, flying from Africa to the United Kingdom, relies upon the nests of short-distance migratory birds to lay their eggs in; upon arrival the cuckoo bird sneaks their eggs into the short-distance bird's nest and it tends to their egg ("Global Weirdness" 102). With the earlier cycles, it is sometimes too late for the cuckoo bird: the short-distance birds have already built their nests, and have hatched their young. This leaves no tended nest for the cuckoo bird to use ("Global Weirdness" 102). Additionally, certain species can adapt to change better than others, so with these changing ecosystems we are losing the inherent ecological diversity of specific areas. The outcome of this has already been experienced globally: "in North America, populations of thirty-nine butterfly species moved 125 miles north. Cold-loving plants in the Alps moved higher into the mountains. And sea anemones off the California coast moved northward" ("Global Weirdness" 108). The bark beetles in Alaska are a another prime example of how the warming of the globe has caused problems. The bark beetle devastates the white spruce in Alaska, but was until recently kept in balance by the cold climate. Due to higher temperatures the bark beetles life cycle has been prolonged, and have consequently expanded their range, which has allowed the bark beetles to destroy an area equivalent to the size of Connecticut in just a few years ("Global Weirdness" 104). Not only are the micro-ecosystems of specific animals and plants being affected, but entire ecosystems around the world are seeing changes ("Global Weirdness" 103). During the latter half of the 20th century and continuing today ocean acidity has increased. This has contributed to the demise of coral. For example, nearly one quarter of the coral in the Indian Ocean have died, and most of the marine life that depended on it have suffered ("Global Weirdness" 106). Another problem that is happening globally is the increase in droughts, torrential rains, floods, and other extreme weather. The Intergovernmental Panel on Climate Change (IPCC) confirms that this is likely and connected to the problems that are caused by excess greenhouse gasses ("Global Weirdness" 118). The IPCC defines likely as: "at least a two-thirds probability that something is true" ("Global Weirdness" 118). These impacts may seem inconsequential to humanity, but the reality is the world is comprised of a multitude of micro-ecosystems that make up our earth's global ecosystem, and when one micro-ecosystem is harmfully effected it in turn affects others.

Unfortunately these are not the only climate changes caused by humans, there is more.

Not only are temperatures rising, and coral reefs dying, but deserts are expanding, and tropical cyclones are intensifying (Blockstein and Wiegman 20). The reason that tropical cyclones are intensifying is due to “an increase of as little as two degrees of warming will produce an increase in category 4 and category 5 tropical cyclone storms. In addition, the storms impacts on coastal regions will be exacerbated by sea level rise” (Blockstein and Wiegman 22). These anthropogenic climate changes are just a sampling of what the increased levels of greenhouse gasses are currently causing.

If the excessive greenhouse gasses are left unmitigated the future for mankind and the environment is precarious. Scientific research has already shown that the excessive greenhouse gasses have already raised the earth's temperature by nearly two degrees. So how does this higher temperature impact our future? Unfortunately it means many things. A warming as little as two degrees will “increase the frequency and magnitude of flash flooding in many regions, and large-scale floods in the mid and high latitudes because rainstorms will be more intense dropping more water in less time.” (Blockstein and Weigman 22). Also this increase in temperatures will be a catalyst for extreme heat events, which causes “human mortality to rise, crops to fail, forests to die and succumb easily to fire” (Blockstein and Weigman 22). Additionally, warming will lead to an increase of “droughts in the mid-latitude continental areas as inland summer drying becomes more prevalent. Such droughts can lead to vegetation die-offs as the soil dries out, and drier soil also exacerbates extreme heat waves” (Blockstein and Weigman 22). Furthermore, where there is heat and droughts, fires often follow; the frequency and intensity of fires will increase, too **(** Blockstein and Weigman 22). The impact on humanity caused by the increase of severe weather will “likely inflict exponentially increasing damage on housing, transportation and agricultural infrastructure" (Blockstein and Weigman 23). Humanity will be subjected to increasing "malnutrition (defined as the nonavailability of recommended daily calorie intake), infectious diseases, episodes of diarrheal diseases, and cases of malaria" (Blockstein and Weigman 23). Also it is known that water resource scarcity will rise as water quality decreases (Blockstein and Weigman 23). Global warming may cause a 20% to 30% extinction of species; a great shift in global biodiversity and ecosystems. (Blockstein and Weigman 25). It is scientifically predicated by science that anthropogenic greenhouse gasses will bring about these cataclysmic events and more by 2100. We must try to improve the mitigation of greenhouse gasses to lessen the repercussions of the existing and future greenhouse effects.

3.

Mitigation of Greenhouse Gasses

The awareness of greenhouse gasses, and their potential harm have been known for a long time:

> In the 19th century scientists realized that gases in the atmosphere cause a "greenhouse effect" which affects the planet's temperature. These scientists were interested chiefly in the possibility that a lower level of carbon dioxide gas might explain the ice ages of the distant past. At the turn of the century, Svante Arrhenius calculated that emissions from human industry might someday bring a global warming. Other scientists dismissed his idea as faulty. In 1938, G.S. Callendar argued that the level of carbon dioxide was climbing and raising global temperature, but most scientists found his arguments implausible. It was almost by chance that a few researchers in the 1950s discovered that global warming truly

> was possible. In the early 1960s, C.D. Keeling measured the level of carbon dioxide in the atmosphere: it was rising fast. Researchers began to take an interest, struggling to understand how the level of carbon dioxide had changed in the past, and how the level was influenced by chemical and biological forces. They found that the gas plays a crucial role in climate change, so that the rising level could gravely affect our future. (Weart)

It has taken a long time for individual nations to acknowledge that excessive greenhouse gasses are a problem, despite how long ago they were discovered and the known dangers their increase present. It has taken a longer time for nations to realize that this is a threat that needed international cooperation. Thus, endeavors to mitigate greenhouse gasses on an international scale has been limited. It was in 1979 at the First World Climate Conference where the beginnings of international concerted effort started.. Afterward attention and action towards excessive greenhouse gasses has been slow, but gaining more prominence as proof and consequences are becoming less deniable. These international conferences and the resulting protocols is a needed global approach to deal with this foreboding topic.

China is currently the leading culprit of producing excessive carbon dioxide. Prior to China, the United States had been the biggest contributor to the problem, hence the United States government has taken strides to tackle this issue. For example, on June 25, 2013 President Obama announced a plan to continue to reduce carbon emissions and to expedite resolutions for greenhouse gasses. The United States has made efforts through the EPA (Environmental Protection Agency) to address the problem; these include: “collection emissions data, getting reductions, evaluating policy options, costs and benefits, advancing the science, partnering internationally, partnering with states, localities, and tribes, and helping communities adapt" (see Appendix for more details) ("What is the EPA doing about Climate Change?").

As a nation, we've have a strong fuel economy standard, doubled renewable energy in the last year, and have decreased our pollution, but we still have so much more work to do (President Obama). To continue to cut back our emissions of greenhouse pollution, the President has continued old projects and instilled new plans. They are to:

> Reduce carbon pollutions from power plants, accelerate clean energy leadership, build a 21st century transportation sector, cut energy waste in homes, businesses, a and factories, support climate-resilient investments, rebuild and learn from Superstorm Sandy, launch an effort to create sustainable and resilient hospital, maintain agricultural productivity, provide tools for climate resilience, work with other countries to take action to address climate change, and lead efforts to address climate change through international negotiations. (President Obama June 25, 2013)

It is encouraging to see that steps are being taken to mitigate greenhouse gasses both nationally and internationally, and to try to reduce the harmful consequences that already exist. Unfortunately, the beneficial progress continues to meet resistance. A factor that usually causes such delays is the motivation to persuade people to participate. This is why I propose to mitigate greenhouse gasses by converting the greenhouse gasses into energy. Energy is an easy conversion into money, and financial gain is a great motivator. By converting greenhouse gasses into energy we can remove the existing excess greenhouse gasses and capture the newly produced gasses, and in turn profit from the mitigation of these gasses. The profit generated would hopefully be an incentive to motivate action.

4.

Carbon Dioxide

In 2007, Carbon dioxide emissions were 77% of the total volume of anthropogenic greenhouse gasses that entered the atmosphere (see fig. 1) ("Greenhouse Gas Emissions: Greenhouse Gases Overview"). So, knowing what the individual gas is, how that gas is created or what is the source of the gas, and how to mitigate the gas is important.

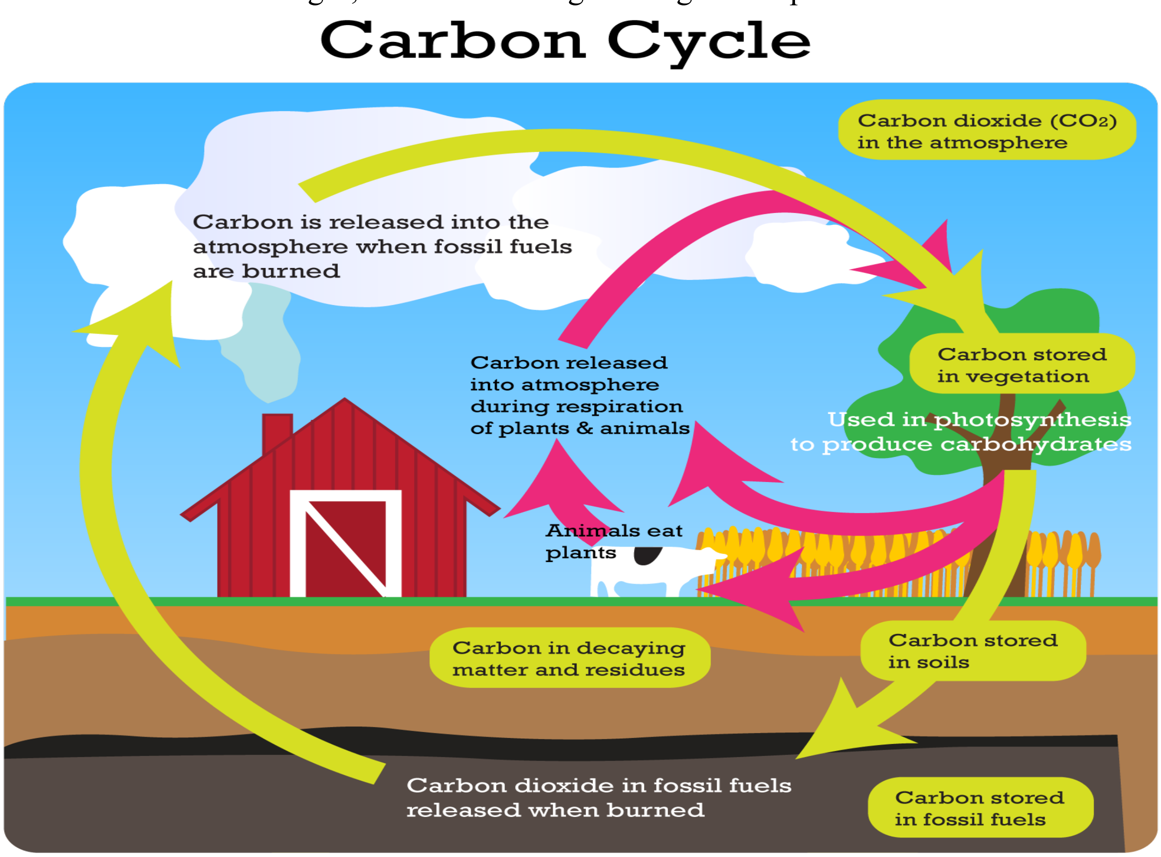

Fig. 3 Carbon cycle with anthropogenic addition. "Carbon Cycle". Illustration. 20 Feb. 2011. Cycles of Matter. *CK-12 Foundation*. Web. 07 Sept. 2013.

What is Carbon Dioxide (CO2)? It is a gas that is a natural chemical in the Earth's carbon cycle, but it is a natural cycle that humans have altered by adding more CO2 (see fig. 3). This excess CO_2 from humans diminishes the earth's flora and ocean water's ability to absorb it. (“Greenhouse Gas Emissions: Greenhouse Gases Overview”). The lifetime of carbon dioxide's in the atmosphere ranges from 50 to 200 hundred years (“Greenhouse Gas Emissions: Greenhouse Gases Overview”).

The sources of excess carbon dioxide comes from transportation, energy supply, residential and commercial buildings, industry, agriculture, forestry, waste and waste water (see fig. 4). It enters the atmosphere through burning fossil fuels (coal, natural gas and oil), solid waste, trees and wood products, and also as a result of certain chemical reactions (e.g., manufacture of cement) (U.S Environmental Protection Agency ES-8–ES-12).

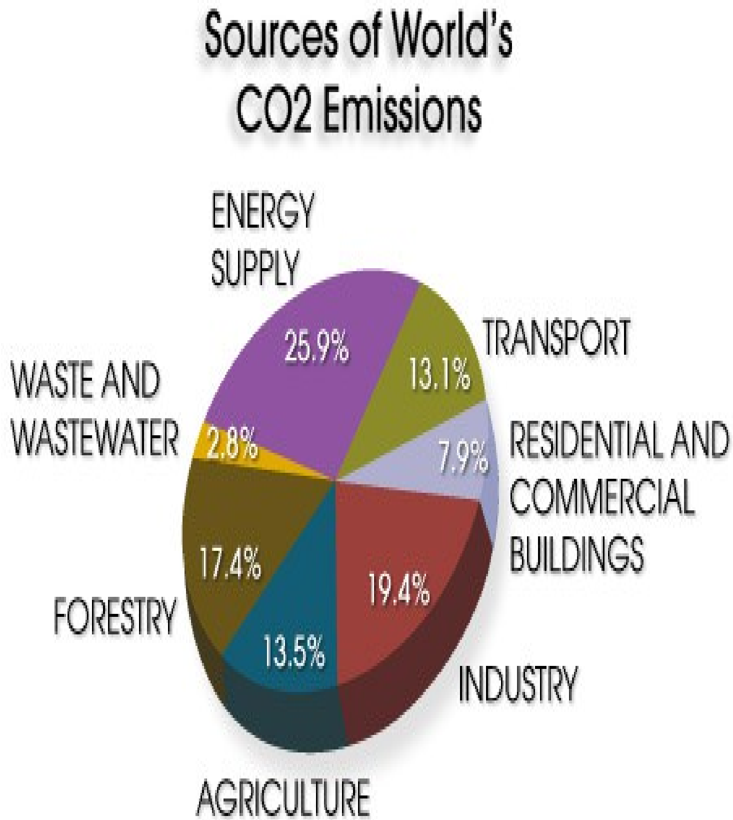

Fig. 4 Sources of CO_2 emissions. "Sources of World's CO2 Emissions". Graph. 21 Oct. 2008. Frontline: Sources of World's CO2 Emissions. *WGBH Educational Foundation.* Web. 03 Sept. 2013.

Carbon dioxide is the greenhouse gas that receives the most attention worldwide to reduce and mitigate due to the excessive amount that is anthropologically produced. A few suggested ways to convert carbon dioxide into energy is: reforestation, algae, solar synthetic fuel, converting it into methanol, liquid light, bacteria, and liquid fuel.

Reforestation is not as simple as it might conceptually seem, because while trees are an excellent at absorbingCO_2, one has to be careful to not create a monocrop and reduce biodiversity. Also when trees fall they release the CO_2 they had absorbed, so it is not a permanent reduction of CO_2. It is a temporary reduction until the trees are used for energy or other wood-related products. (Dallas 58)

Carbon dioxide can also be converted by algae; "algae naturally absorbs CO_2 through photosynthesis" ("Clean Tech, Clean Profits" 171). There are various methods utilizing algae to convert CO_2 into energy. Some proposals suggest using tubes filled with algae affixed to buildings; the algae from these tubes would be harvested before they start to decompose so that they will not release the captured CO_2 ("Clean Tech, Clean Profits" 171). This algae is profitable, because it can be used for biofuel or "feedstock for the production of a fertilizer that sequesters the carbon" ("Clean Tech, Clean Profits" 171). There is a real focus on algae usage for energy, because algae has a "high energy content with a value per unit mass at 18.5 to 35 MJ/kg, that rivals that of coal (which averages at 24 MJ/kg)" ("Clean Tech, Clean Profits" 171).

At the University of Delaware Chemist Joel Rosenthal and doctoral student John DiMeglio have converted CO_2 into a synthetic fuel. They discovered that bismuth can convert carbon dioxide into carbon monoxide, which is an extremely energy rich chemical that has many uses. Also bismuth is a relatively inexpensive catalyst, which can use solar energy for the conversion process. The outcome of this conversion, carbon monoxide, can be used as synthetic fuels to power cars, houses, and businesses. (Bryant)

In Canada, at the University Laval in Quebec City, a team lead by Professor Frederic-

Georges Fontaine developed an effective way to convert CO_2 into methanol that can be used as fuel for vehicles. They wanted to develop a simple conversion method that could be accomplished in a single step. This catalytic conversion process requires a source of hydrogen and chemical energy; the researchers used the hydroborane (BH_3) compound as their hydrogen and chemical energy source. Also they found that the chemicals borane and phosphine are an effective catalyst to accomplish the conversion. Their conversion method resulted in a reaction that is twice as effective as the best known catalyst, while producing little waste. In addition, this chemical reaction does not damage to the catalyst, so it can be reactivated by a new substrate. (Huppe)

At Princeton University Andrew Borcarsly, the founder of the New Jersey company Liquid Light, along with Emily Cole are the innovators of a process that turns carbon dioxide into fuels and industrial chemicals (Zandonella). The technology that Liquid Light uses is taking "CO_2 and mix it in a water-filled chamber with an electrode and a catalyst. The ensuing chemical reaction converts CO_2 into a new molecule, methanol, which can be used as a fuel, an industrial solvent or a starting material for the manufacturing of other chemicals" (Zandonella). To create this reaction and result the company uses sunlight to conduct the process. Also, with this new technology they discovered that "they could turn CO_2, which contains only one carbon, into a compound with a carbon-carbon bond. This carbon-carbon bond compound vastly increases the possibilities for creating commercial applications" (Zandonella).

Meanwhile researchers at the University of Minnesota have created a process that "uses two types of bacteria to create hydrocarbons from sunlight and carbon dioxide. These hydrocarbons can in turn be made into fuel, which the scientists are calling renewable petroleum" (Coxworth). It took teamwork between departments and colleges to discover and complete this finding. They found:

> That *Synechococcus* a photosynthetic bacterium adheres to carbon dioxide in sunlight and then converts that CO2 to sugars. Those sugars are then passed on to another bacteria *Shewanella* which consumes them and produces fatty acids. University of Minnesota biochemistry graduate student Janice Frias discovered how to use a protein to transform the fatty acids into ketones, a type of organic compound. Her colleagues in the university's College of Science and Engineering have developed a catalytic technology that converts those ketones into diesel fuel (Coxworth).

A diesel fuel that diminishes greenhouse gasses and is not from fossil fuel is a winning combination.

Scientific research is being conducted at the University of California, Los Angeles where a team has "genetically engineered a microorganism that converts carbon dioxide into isobutanol and 3-methyl-1-butanol, both of which could be used as a fuel source for cars, or other combustion engines" (Anthony). The microorganism is called " Ralstonia eutropha H16" (Anthony) and this bacterium "uses electricity from solar energy to fixate carbon dioxide into alcohols and feasts on the formic acid to produce the combustible alcohol" (Anthony). Once again successful scientific exploration to transform carbon dioxide into energy has been achieved.

These successful methods in converting the excessive greenhouse gas, carbon dioxide, into a beneficial by-product hopefully will encourage motivation and continuation in advancing these energy sources. All these processes that were discussed for carbon dioxide are carbon neutral, or better yet carbon negative. It is definitely an important and encouraging start to the mitigation of greenhouse gasses.

5.

Methane

By 2011, 14% of the total volume of anthropogenic greenhouse gasses were comprised of methane emissions (see fig. 1) ("Greenhouse Gas Emissions: Greenhouse Gases Overview"). Even though methane gas contributes only 14% of the greenhouse gasses it is more potently harmful than carbon dioxide. Knowledge of this greenhouse gas is vital in the mitigating of its contribution to greenhouse effects.

Methane (CH4) is a natural gas and is naturally absorbed by the soil and chemical reactions in the atmosphere, but over 60% of total CH4 emissions come from human activities and this overloads the earth's natural mitigation processes (see fig. 5) ("Greenhouse Gas

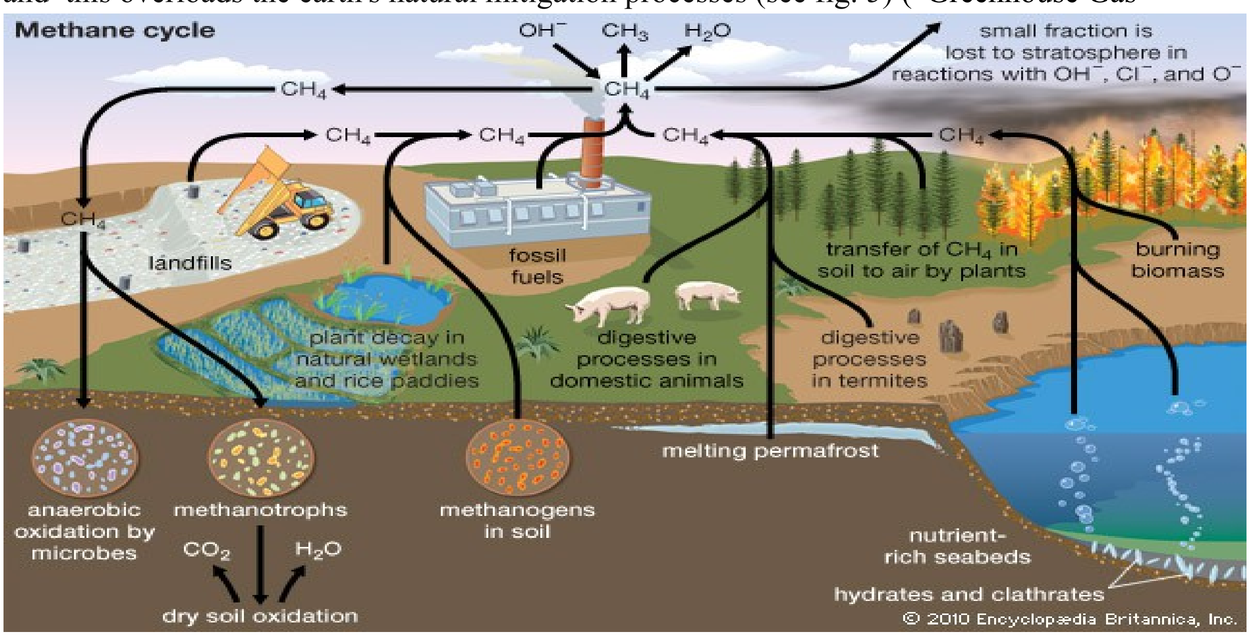

Fig. 5 Methane cycle with anthropogenic addition. "Methane Cycle". Illustration. 2010. Global Warming Gallery. *Encyclopaedia Britannica, Inc.* Web. 07 Sept. 2013.

Emissions: Greenhouse Gases Overview"). Methane resides approximately twelve years in the atmosphere, but unfortunately it is more efficient at trapping radiation than carbon dioxide. In fact, "methane is more than 20 times as effective as CO2 at trapping heat in the atmosphere over a 100-year period" ("U.S Environmental Protection Agency ES-12).

The sources of methane are: production and transport of coal, natural gas, an oil, livestock and other agricultural practices, and by the decay of organic waste in municipal solid waste landfills and wetlands (see fig. 6)(U.S Environmental Protection Agency ES-12-ES-13). As noted previously, methane is a naturally produced gas, but the majority of methane is generated by human activities. Anthropogenic methane is more controllable and easier to manipulate than natural methane; this enables the conversion of methane into energy

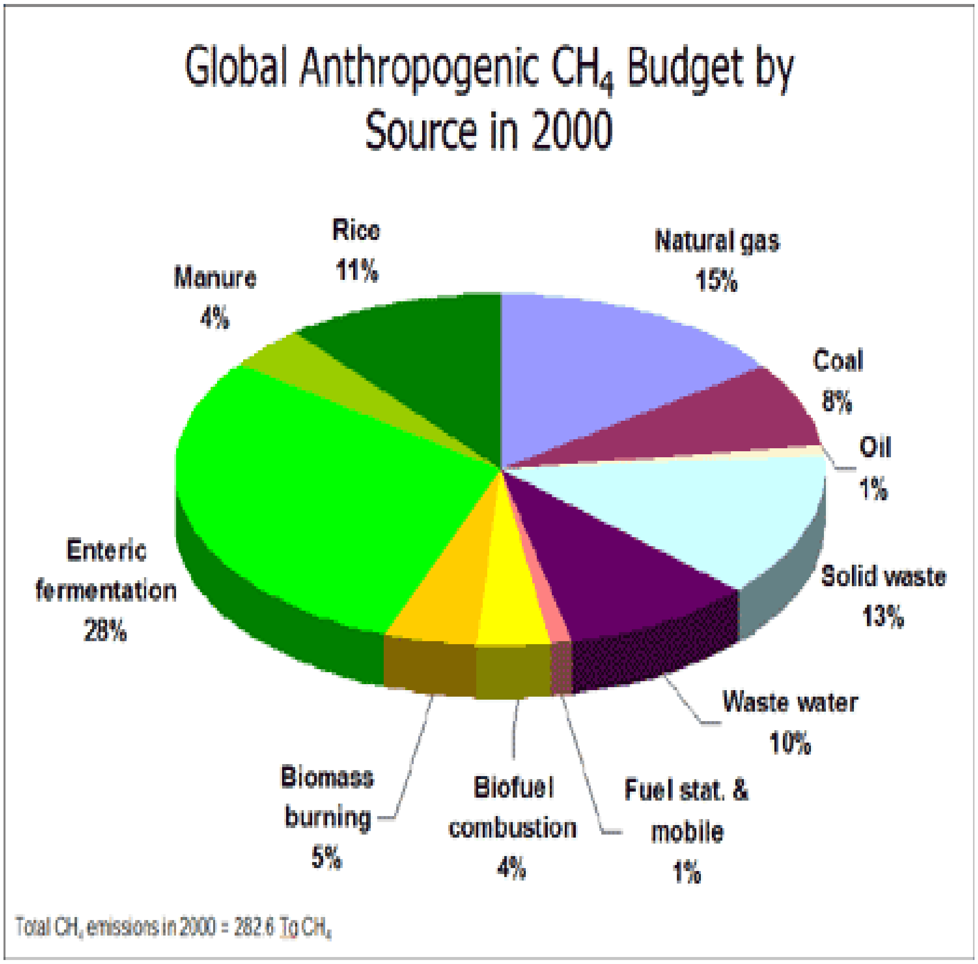

Fig. 6 Sources of Anthropogenic Methane in 2000. "Global Anthropogenic CH4 Budget by Source in 2000". Diagram. 2007. What the deep-sea and cows have in common. *Bamfield Marine Sciences Centre.* Web. 07 Sept. 2013.

through the processes of capture, digestor, decomposition, and gobar gas.

One form of converting methane into energy is by capturing the methane gas at the formation source, and then transporting it through pipelines just like any other usable natural gas. Methane is “a prime component of natural gas, and where there is coal or oil, there are often large deposits of gas. The gas is captured and piped to urban areas for commercial and residential use” (Turner 151).

Another way to capture and use methane as energy is through the process of a digestor (see fig. 7). In a digestor, the methane gasses from vegetable, animal, and human waste is captured and contained; this stored gas can be piped for energy purposes (Howell 183). This is a viable option for energy as it is continuous, and the waste material source that emits methane is limitless. The digestor applications in converting methane gasses into useable energy is not only an option for commercial use, but personal use, too (Howell 194).

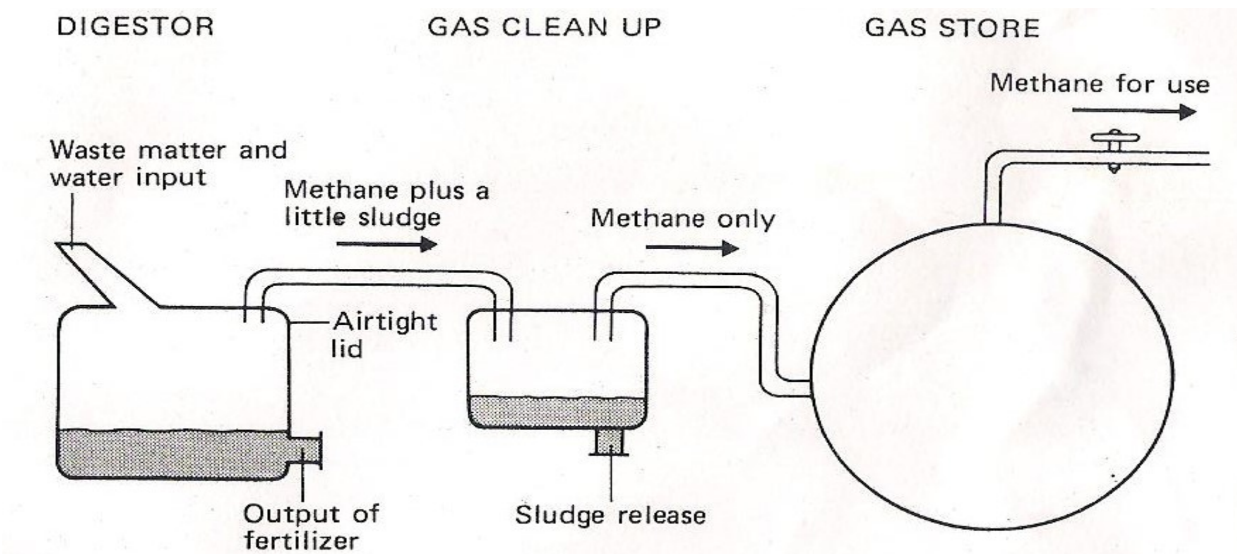

Fig. 7 Methane digestor. "Basic Methane Production and Storage". Graph. 1979. Your Solar Energy Home : Including Wind and Methane Applications. *Pergamon Press*. Print.

Methane gasses are already being successfully produced as useable commercial energy through the decomposition of organic matter in landfills as useable commercial energy . The “trash decomposes (or rots) in landfills creating methane gas; the methane rises to the top of the landfill and is collected in pipes. The pipelines carry the methane to its destination and is burned to produce heat or generate electricity” (see fig 8)("Methane Capture and Use"). The process of using methane from landfills is of high interest, because “landfill gasses are a recognized renewable energy resource. The gas serves as a base-load renewable energy for many utilities, and landfill gasses are a competitive renewable resource” (Rajaram 23). This ecologically beneficial method of mitigating methane and converting the gas into profitable energy is already being utilized. “Germany produces enough electricity from biogas to power 3.5 million homes” ("Methane Capture and Use"). Sweden has been “operating a biogas-powered train since 2005; it shuttles passengers between two cities that are 75 miles apart” ("Methane Capture and Use"). These successful methods of mitigating methane into usable energy is encouraging and hopefully motivating. It is a winning combination with the outcome being profitable for humans and the earth.

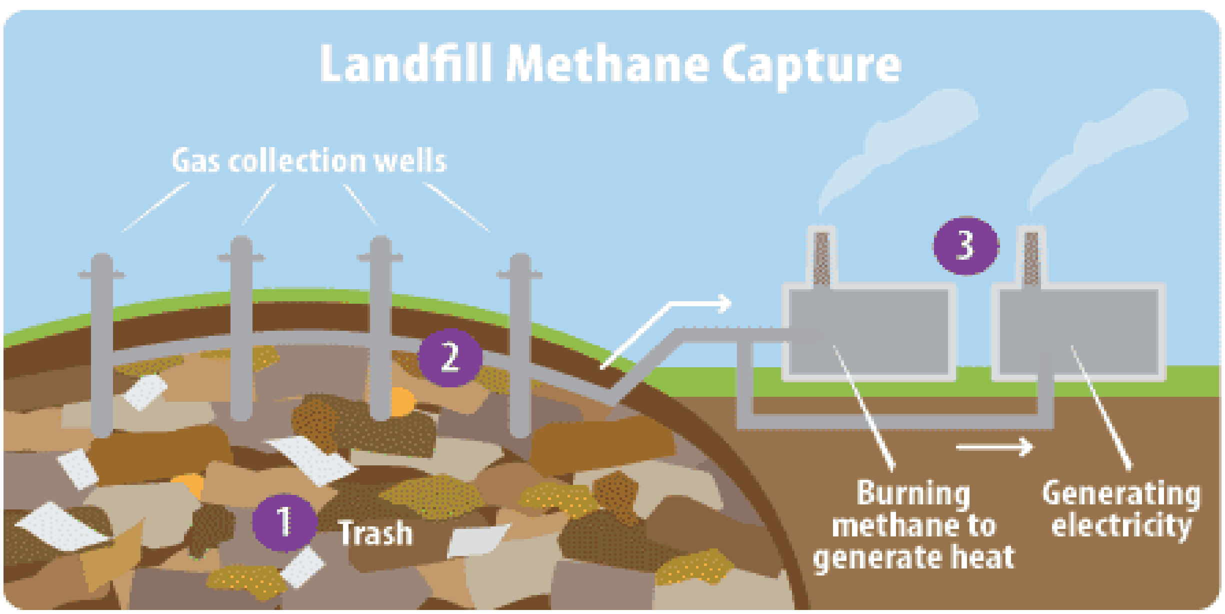

Fig 8 Capturing methane to convert into energy. "Landfill Methane Capture". Illustration. 21 June 2013. Methane Capture and Use. *EPA*. Web. 07 Sept. 2013.

Methane gas is also used as Gober gas; another eco-friendly alternative gas. Gobar gas is a term for methane gas that is generated from cow manure and other waste. The process is relatively simple and does not require sophisticated equipment or skill. The methane from the waste and manure is captured, and is used for energy. (Dandekar 887-93)

The conversion of methane gasses into usable energy is proven and is relatively simple with a profitable outcome: energy.

6.

<u>Nitrous Oxide</u>

Nitrous oxide (NO2) emissions by 2011 were 8% of the total volume of anthropogenic greenhouse gasses that went up into the atmosphere globally (see fig. 1) ("Greenhouse Gas Emissions: Greenhouse Gases Overview"). Even though nitrous oxide is a smaller percent of the total of greenhouse gasses than carbon dioxide and methane it is more potent than both, and it lasts much longer in the atmosphere. A basic understanding of the greenhouse gas is essential to understand the importance in its mitigation.

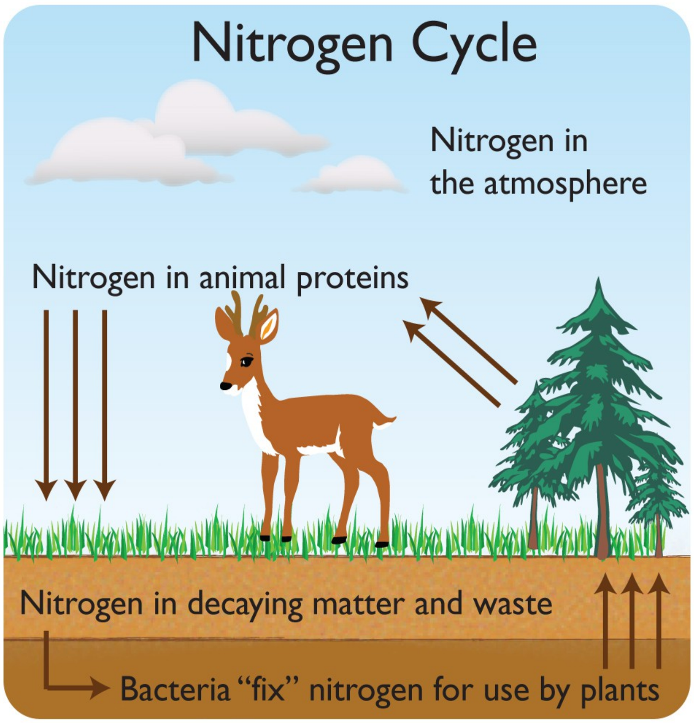

Fig. 9 Natural nitrogen cycle. "Nitrogen Cycle". Illustration. 20 Feb. 2011. Cycles of Matter. *CK-12 Foundation*. Web. 07 Sept. 2013

Nitrous oxide is a natural gas that the earth produces. Nitrous oxide circulates through many ecosystems that is called the nitrogen cycle (see fig. 9). The nitrogen cycle is the natural circulation of nitrogen that is in the soils, animals, plants, waters, and then into the atmosphere (Greenhouse Gas Emissions: Greenhouse Gases Overview"). However, 40% of nitrous oxide emissions come directly from human activities such as: agriculture, fossil fuel combustion, waste-water management, industrial processes, and transportation (see fig. 10)(U.S Environmental Protection Agency ES-14-ES-15). The primary source of these anthropogenic emissions come from agriculture, especially from fertilizers (U.S Environmental Protection Agency ES-15).

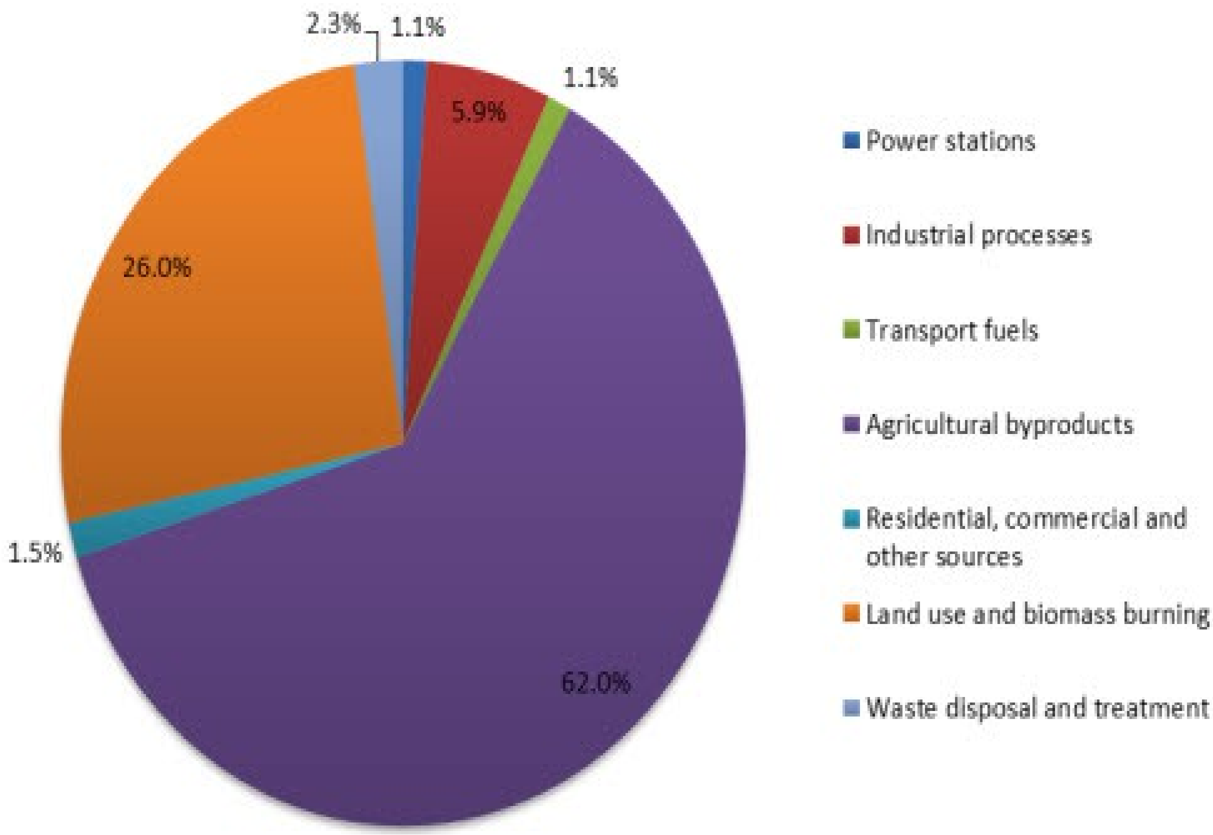

Fig. 10 Sources of nitrogen oxide. "Nitrous Oxide by Sector". Diagram. 11 Oct. 2011. GCSE & A Level Geography. *Tutor2u.* Web. 07 Sept. 2013.

Nitrogen oxide remains in the atmosphere for 120 years on average and is "approximately 300 times more powerful than CO2 at trapping heat in the atmosphere" (U.S Environmental

Protection Agency ES-14). Therefore, even one pound of nitrous oxide is a powrful contributor to global climate warming.

One way of reducing the atmopsheric content of NO2 is to convert it into useable energy or biofuel through the process of biomass combustion. Converting biomass into biofuel through combustion results in neutral emissions, and produces energy while capturing and eliminating waste that would otherwise pollute the atmosphere and environment (Hunter et. all 136). Any method that generates neutral greenhouse emissions is a step in the right direction, because doing nothing to mitigate greenhouse gasses leads down a cataclysmic path.

7.

Fluorinated Gasses

`In 2011, fluorinated gasses emissions were 1% of the total volume of anthropogenic greenhouse gasses that went up into the atmosphere (see fig. 1)("Greenhouse Gas Emissions: Greenhouse Gases Overview"). One percent might not seem like much in comparison to the other gasses, but these are the most potent and destructive of all the greenhouse gasses. In fact, these gasses have no natural source; they are fully and completely man-made ("Greenhouse Gas Emissions: Greenhouse Gases Overview").

Fluorinated gasses are divided into three groups: "Hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF6)" (U.S Environmental Protection Agency 1-3). Their life-span in the atmosphere varies; HFC's life-span is from 1 to 270 years, PFCs is 800 to 50,000 years, and SF6 is up to 3,200 years ("Greenhouse Gas Emissions: Greenhouse Gases Overview"). These gasses are so destructive that just one pound of HFC has the warming capability of 140 to 11,700 times more than one pound of carbon dioxide. One pound of PFC has the warming capability of 6,500 to 9,200 times that of one pound of carbon dioxide, and one pound of SF6 has a staggering 23,900 times more global warming capability than one pound of carbon dioxide (“Greenhouse Gas Emissions: Greenhouse Gases Overview”).

The sources of these harmful fluorinated gasses are varied, but all are man-made. For example, hydrofluorocarbons are used in refrigerants, aerosol propellants, solvents, and fire retardants (see fig. 11) (“Greenhouse Gas Emissions: Greenhouse Gases Overview”). Perfluorocarbons “ are compounds produced as a by-product of various industrial processes associated with aluminum production and the manufacturing of semiconductors” (see fig. 11) (U.S Environmental Protection Agency ES-15). While sulfur hexafluoride is “used in magnesium processing and semiconductor manufacturing, as well as a tracer gas for leak detection, and used in electrical transmission equipment, including circuit breakers” (see fig. 11) (U.S Environmental Protection Agency 1-6).

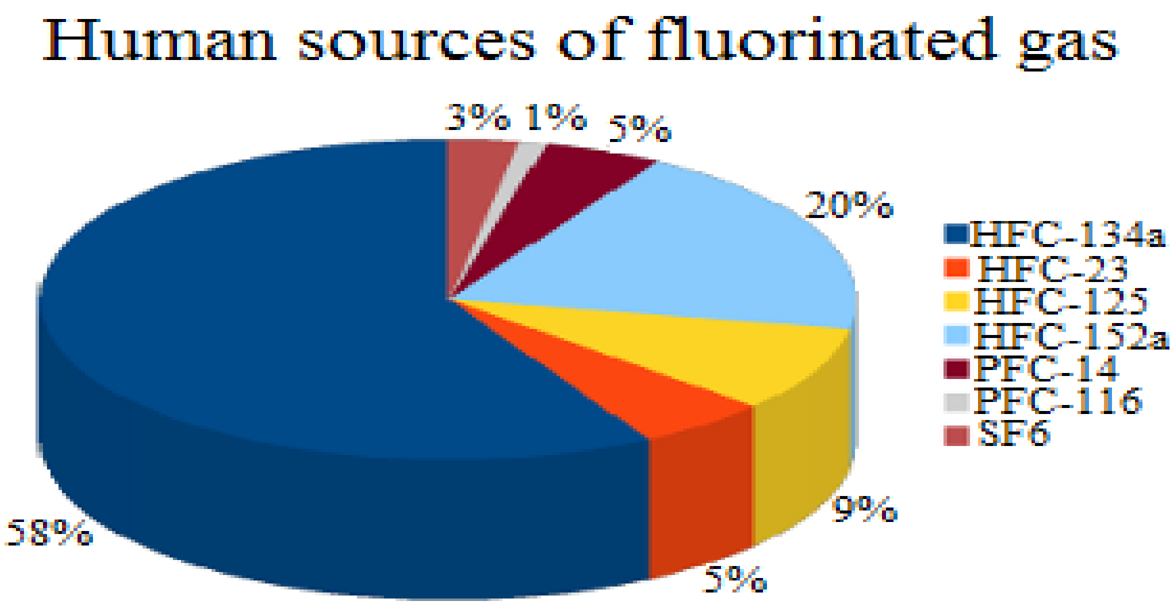

Fig. 11 The Sources of flourinated gasses. The number behind each gas is the specific chemical that is created by the human sources. "Human sources of fluorinated gas". Diagram. 2010. What are the main sources of fluorinated gas emissions? *Whatsyourimpact.eu.org* 2013. Web. 07 Sept. 2013.

Unfortunately, since these are man-made chemicals, and rather new to the greenhouse gas family, there has not been a discovered method to convert these gasses into energy. The only option is to eliminate these destructive and deadly gasses by not producing them. We created them, we are the only source for them, and since we can not convert them into useful energy, then we simply should not create them.

8.

Conclusion

Hopefully by providing a concise source of information about greenhouse gasses, and the ensuing hazardous effects caused by excess anthropogenic greenhouse gasses, along with the importance of their mitigation will generate the motivation to reduce these gasses by converting them into profitable energy. In this paper I have given detailed data about each gas and the various current methods of converting them into an energy source. I hope that condensing all the various scientific research data into a concise and comprehensive paper has illuminated this global problem and the need for a expedient resolution. Thankfully, there are successful methods for mitigating greenhouse gasses. The information I have compiled has shown that the conversion of these excess anthropogenic greenhouse gasses into energy has been a successful method to mitigate these gasses. This information should be used as motivation to implement these current methods and encourage the development of future processes of mitigation into profitable energy.

For future research a cost-benefit and financial profile of the various ways to mitigate greenhouse gasses needs to be comprehensively and concisely complied into an understandable document to help implement the processes. The combination of this foundational paper and a financially-focused paper will hopefully motivate the implementation of greenhouse gas generated energy. The implementation of greenhouse generated energy will create new job opportunities in a newly invented commercial job market, which will be ecological and financially beneficial. At the same time, these energy companies will be mitigating the current greenhouse gasses and preventing any further harmful consequences . It is a win-win situation for the earth and mankind.

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Appendix

Environmental Protection Agency's Action Plan on Climate Change
("What Is EPA Doing About Climate Change?")

- "Collecting Emissions Data: This information helps policy makers, businesses, and the EPA track greenhouse gas emission trends and identify opportunities for reducing emissions and increasing efficiency.
- Obtaining Reductions:
    - *Developing Common-sense Regulatory Initiatives*: EPA is developing common sense regulatory initiatives to reduce GHG emissions and increase efficiency. For example, the EPA's vehicle greenhouse gas rules will save consumers $1.7 trillion at the fuel pump by 2025, and eliminate six billion metric tons of GHG pollution.
    - *Partnering With the Private Sector*: Through voluntary energy and climate programs the EPA's partners reduced over 345 million metric tons of greenhouse gases in 2010 alone (equivalent to the emissions from 81 million vehicles) and saving consumers and businesses of about $21 billion.
    - *Reducing EPA's Carbon Footprint:* The EPA is monitoring emissions from its own energy use and fuel consumption. They are working to reduce greenhouse gas emissions by 25% by 2020.
- Evaluating Policy Options, Costs and Benefits: The EPA conducts economy wide analysis to understand the economic impacts and effectiveness of proposed climate policies. Advancing the Science: The EPA contributes to world-class climate research through the U.S. Global Change Research Program and the Intergovernmental Panel on

Climate Change. The EPA's Office of Research and Development conducts research to understand the environmental and health impacts of climate change, and to provide sustainable solutions for adapting to and reducing the impact from a changing climate.

- Partnering Internationally: The EPA is engaged in a variety of international activities to advance climate change science, to monitor our environment, and promote activities that reduce greenhouse gas emissions. The EPA establishes partnerships, provides leadership, and shares technical expertise to support these activities.
- Partnering With States, Localities, and Tribes: The EPA's State and Local Climate and Energy Program provides technical assistance, analytical tools, and outreach support on climate change issues to state, local, and tribal governments.
- Helping Communities Adapt: The EPA's Climate Ready Estuaries and Climate Ready Water Utilities programs help coastal resource managers and water utility managers respectively plan and prepare for climate change."