HHO A VIABLE MEANS OR REDUCING EMISSIONS

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Methods and Applications Final

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Abstract

This paper explores current HHO technologies. It concludes with the findings that an HHO cell is a viable alternative for further exploration and experimentation. Further, it finds that the cost of electric production is high in the previous experiment due to the nature of HHO cells to have a high current draw at voltages at or around auto batteries and charging systems. Alternative voltages of 30 volts or higher are recommended for use. To add findings include an alternating current to be acceptable only when put through a half or full wave rectifier to create a pulse. Constant d.c. voltages are shown to have too high a cost in heat production so a pulse is recommended. An HHO cell can be tuned to have very little or even 0 current draw when the frequency of the pulse is adjusted. In this experiment, it was found that a voltage of about 30 volts at 22440 Hz was sufficient to produce 28 mL of gas per minute with a very small HHO cell that cost less than 20 dollars to produce. Finally, this technology is recommended for further study but is not recommended for continual use as better alternatives are available.

Keywords: HHO, Hydroxy, Hydroxyl, Browns Gas, Gas Cell, fuel from water, alternative fuels.

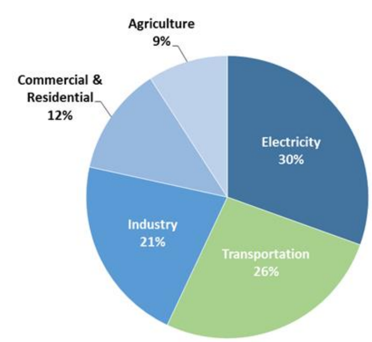
LIST OF ABBREVIATIONS AND NOMENCLATURE

HHO : Hydroxy, Hydroxyl, BG Browns Gas, SI : Spark Ignition, CI : Compression Ignition, LPG : Liquefied Petroleum Gas, CO : Carbon monoxide, HC : Hydrocarbon, CO_2 : Carbon dioxide, NOx : Nitrogen oxide, HEV : Hybrid Electric Vehicle, H2ICE : Hydrogen Fueled Internal Combustion Engine, KOH : Potassium Hydroxide, NaOH : Sodium Hydroxide, NaCl : Sodium Chloride, EEW: : Electrically Expanded Water W : Watt, SFC : Specific Fuel Consumption, HECU : Hydroxy Electronic Control Unit, TDC : Top Dead Center BDC : Bottom Dead Center, EEPROM : Electrically Erasable Programmable Read-Only Memory, F : Force, T : Torque, rev. : Revolution, Pb : Brake Power, bmep : Brake Mean Effective Pressure BSFC : Brake Specific Fuel Consumption, bth h : Thermal Efficiency, CR : Compression Ratio, AFR : Air-Fuel Ratio, EGR : Exhaust Gas Recirculation, rpm : Revolutions Per Minute, CATIA : Computer Aided Three-dimensional Interactive Application, V : Volt, A : Ampere, CCM : Cubic Centimeters per Minute, SLM : Standard Liters per Minute, DC : Direct Current, AC : Alternating Current mF : Micro Farad, MOSFET : Metal Oxide Semiconductor Field Effect Transistor, PWM : Pulse Width Modulation, f : Frequency, MAP : Manifold Absolute Pressure, ADC: Analog to Digital Converter, DAC: Digital to analog converter, PLC: Programmable Logic Controller, STP: Standard temperature and pressure: 298.15 K, 101.325 kPa

HHO A VIABLE MEANS OR REDUCING EMISSIONS

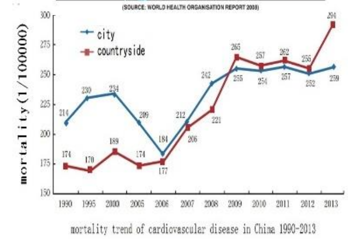
Introduction

Many business people will tell you that the problem with dependence on any non-renewable energy source such as fossil fuels is that it has no sustainability and thus in the long term it is a strategically bad plan. At best such efforts are a race, the dash for the cash until such resources run dry. We in the U.S. have, never the less, chosen fossil fuels as our main source of energy. We use it in a spectrum that ranges from the creating of electricity to traveling the world. We even use it to make our drinking glasses, shopping bags and plastics of all sorts. Unfortunately, too often we dismiss evidence linking climate change and air pollution to fossil fuel consumption. These changes have been so gradual that many believe them not to be true. Further, many are blinded to these changes purposely in order to keep the "common comforts" of life. Though many people today deny any change in the climate this is a documented truth. Cars and the pollution from cars are the single greatest polluter in our nation's cities (Tekin & Çavuşoğlu, 1997). It is hard to imagine that as little as 100 years ago electric power and the internal combustion engine (ICE) was rarely even heard of. Auto pollution comes from by-products of the combustion of fossil fuel (exhaust) and from the vapor of the fuel itself. Since this combustion is not perfect an automobile emits several types of pollutants. These are: Hydrocarbons (HC)--unburned fuel, Nitrogen oxides NOx—under high-pressure combustion nitrogen and oxygen create various NOx. Like hydrocarbons, these interfere with the formation of ozone and contribute to acid rain. Carbon Monoxide CO—CO is a product of the incomplete combustion of fossil fuels; when inhaled CO reduces the flow of oxygen in the bloodstream, this is very dangerous, especially to persons with heart disease. Carbon Dioxide CO_2—Th EPA views this compound as a product of a perfect combustion, though not threatening to humans CO_2 is a contributor to Global Warming as a greenhouse gas (EPA, 1994). Gasoline and diesel fuels are



mixtures of HC (Hydro Carbons), compounds which contain hydrogen and carbon atoms. Smog is proportional to the amount of HCs present in the exhaust. Many things in an engine can produce HCs such as advanced timing, or a bad catalytic converter though we cannot see it as CO_2 a colorless and odorless which makes this gas a killer. NOx (Nitrogen Oxides) are also very harmful to humans and contribute to smog, greenhouse effects, acid rain, and form toxic compounds which are also toxic to humans; because of this maximum limits on NOx emissions are continually being reduced (Walsh, 2001)(Bowman, 1992). NOx, HC's and CO top the list as the worst offenders for health and smog (Musmar, 2011). Catalytic converters introduced in 1975 significantly reduced hydrocarbon and carbon monoxide emissions, however, lead inactivates the catalyst is catalytic converters so oil companies had no choice but to once again remove lead from fuel. Today normal petrol combustion has the following emissions: Carbon monoxide 1-2% of volume, HC <.25% of volume, Nitrogen 71% of volume, CO_2 14% of volume, water vapor 12% of volume, NOx <.25% of volume, SOx < .03% of volume (Rajeshkumar et al, 2016).

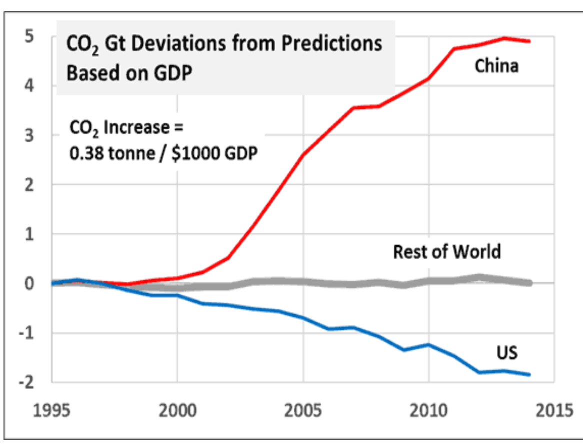
The EPA (Environmental Protection Agency) functions under The "Clean Air Act" of 1970 to regulate motor vehicles. This has led to devices to manage the exhaust caused by burning fossil fuels. The first regulation was through engine design, next the catalytic converter, mentioned above, to burn off HCs and CO, the Oxygen Sensor to help prevent combustion problems and finally the Exhaust Gas Recirculation (EGR) to manage NOx (EPA, 1994). By slowing down the combustion rate the EGR system is able to lower NO and NO. Emissions and Greenhouse Gasses come from many sources as viewed by the chart to the right which was published by the EPA. We see that the production of electricity is the biggest offender in total not just in cities which is followed by transportation and then industry. According to Harper 2007, electricity is produced mainly by fossil fuels, coal and



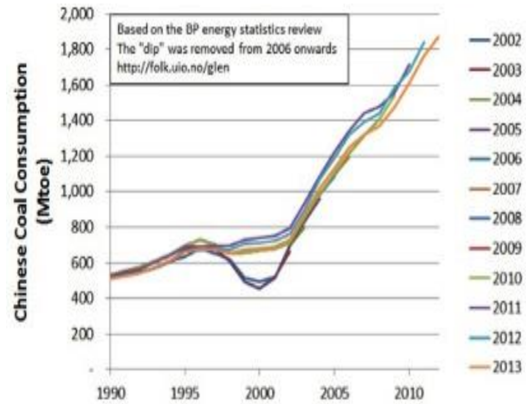
natural gas being the most widely used, on the other hand, in transportation gasoline and diesel are the most used fossil fuel. Reportedly fossil fuel accounts for approx. 90% of our energy consumption. If this is the case and in light of Industrialization and technology growth which have spurned growth in population and economy we can expect an even larger demand for fossil fuels, which will create a greater production of Emissions and Greenhouse Gases. We find this to be an unending circle. It is evident since fossil fuels cause damage to human life and the environment this cycle must be dealt with (Venkataraman and Elango, 1998). As a result of this fact fossil fuel-based energy sources are facing increasing pressure on a host of environmental fronts, including a serious challenge for coal to meet the greenhouse gas reduction targets, but we are not likely to do enough in time to curve expected damages we must come up with more ways to curb emission and greenhouse gas production (Herzog et al., 2006).

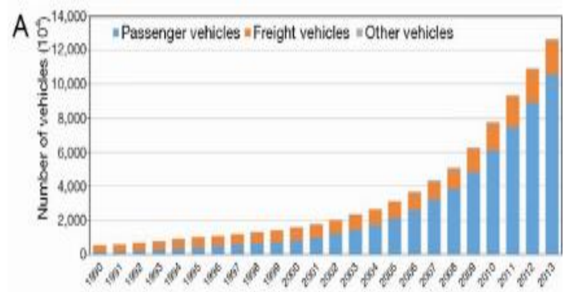
Intro – Problem

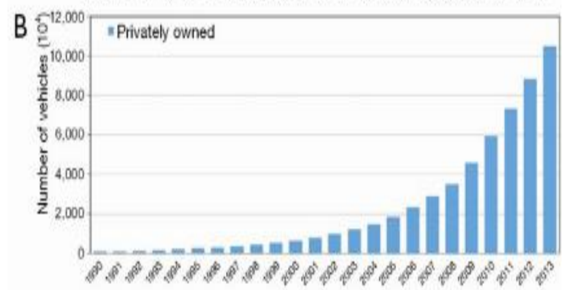
Recent changes in the world's economy afford us an opportunity to see our end if we stay on this current course. Global warming and emissions are a real-world problem faced by the scientific

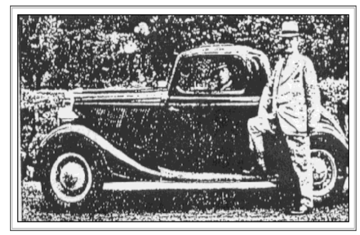


community. China provides us with the best evidence to date of the negative effects we can expect if we continue in fossil fuel dependency. China used to have the lowest heart disease rate in the world. It also enjoyed the cleanest air quality, however, with China's industrial revolution we see an increase in coal-based electric plants. The industrial revolution in China is being driven by the conversion of fossil fuels to energy just like here in the U.S. As a result, of the short time frame and exorbitant growth we can view China as a petri dish showing the end result of an economy based on fossil fuels. Though there seem to be correlations with the increase of fossil fuel use and greenhouse gas, the more worrisome evidence in the last ten years is that this fossil fuel revolution also correlates with an increase in heart disease--a percentage in China that now leads the world. Further, China's air quality is also reported among the worst in the world. Most residents of Chinese cities brag on the model of air purifier in their homes. Schools are closed, businesses and mass transportation stop due to dangerous parts per million counts. There is no doubt, we can no longer ignore these facts. We must move away from fossil fuels. However, if this is not reason enough there is that fact that countries not having these resources are facing continual energy crises. The use of fossil fuels has led to several environmental problems such as reduction carbon energy sources, water pollution, and habitat destruction, air pollution, heart disease, and energy crisis in the poorer countries around the world. Meanwhile, CO_2 levels are still climbing and the greenhouse effect is growing as a function of burnt fuel along with increased acid rain which will no doubt create new problems to deal with (Durairai et al.,2012). All these are big problems with our current source of fuel, however not our biggest. Our biggest hurdle will be the implementation of alternative fuels sources and the reduction of control by those in control of oil.









Many other sources of fuel for the ICE are readily available. I even found one that shows how wood gas can be used to run any ICE (Wyer, 1905). Articles of people using many forms of biomass to operate an ICE are available now. One interesting video on YouTube that explains gasification pretty well states that his gasifier will run off anything other than glass, metal, or rocks (Kieth, 2012). I find it amazing that most have not heard of alternative fuel sources for ICE's. Operating an engine from grass clippings is totally possible yet we make movies about it like it is an impossibility. Here is a picture from the beginning of the century of a gasifier mounted on a truck which at that time were commercially available. Yet today this information is suppressed. Charles Nelson Pogue made headlines in 1933 by driving his 1932 Ford (to the right) about 200 miles on a single gallon of gas. After a demonstration conducted by the Ford Motor Company in Winnipeg-the Pogue Carb went into production. However, this required White Gas. White Gas is gasoline which contains no additives- one of the crucial factors for these carbonators to run efficiently. When oil companies found this out they began to add lead to the production gasoline. This rendered Pogue's carburetor as inefficient and unusable. Unfortunately not long after this Pogue was found dead. Once more Shell Oil completed tests in 1975 that resulted in an opal getting an astounding 350 mpg by using the vapors of heated fuel to run a car (Shell, 1975), the same technology Pogue used. Amazingly all these tests were done on a private closed track with the results never being made known to the public. As a boy I recall Stanford University doing an experiment that included just re-porting a carburetor. The results, if I remember correctly, where an astounding 60mpg. Most of today's hybrids do not even come close to that. Later when the catalytic converter made the addition of lead a problem oil companies easily removed the lead since now the Pogue carb was successfully reported as a myth. The man who patented the first AC Motor, the technology that runs cellphone towers, and invented the production of alternating current was Nicola Tesla (Tesla, 1889). At that time Mr. Tesla envisioned to supply the world with free power, but J.P. Morgan pulled funding because it had no meter and could not make money. Later Edison using Tesla patents began equipping everyone with Tesla's AC current through wires funded by, you guessed it, J.P. Morgan. J.P. Morgan was the founder of Morgan/Chase bank. Every time one pays the power bill one should remember that bill is brought to you by Chase Morgan Bank. We were warned about such monopolizing of power by President Eisenhower who warned against the Military Industrial Complex (MIC). It is when a corporation becomes large that the population becomes in service to them. Eisenhower feared incoming John F. Kennedy would not have the wisdom to withstand the pressures brought by such a complex or corporation (MedHursta, 2009). When Kennedy gave his great speech in which he said, "I look forward to a great future for America - a future in which our country will match its military strength with our moral restraint"--shortly thereafter Kennedy was killed. This is our first foreseen hurdle. The powers at be won't allow a change away from fossil fuels without a fight. Walter Adam in his article points not to the MIC but to Giant Corporation as the dominator and controller of all economic environments. He points out they will operate outside of the law being immunized from all oversight (Adams, 1968). According to Dr. Steven Greer who produced the movies "Sirius" and "The Disclosure Project," these are one in the same. Even our government becomes a pawn with such giants of finance which use their power to prevent change.

Who are these giants of corporation? Reportedly Bank of America owns Exxon oil, Wells Fargo owns Chevron oil, J.P. Morgan/Chase owns Shell Oil, and Citi-Bank owns Arco, Bp, and Tesoro oil, and all these together own the Federal Reserve—that is correct the U.S. does not own the Federal Reserve. Here forward these are known as the four horsemen. The MIC is the biggest customer of the four horsemen and this is our biggest issue to overcome today. Though we know that the burning of fossil fuels correlates with climate change, poor air quality, sickness, and death, we have not the influence individually or economically to do much about it. These four horseman trade trillions of dollars monthly, an amount equal to or exceeding our national Annual Gross Product. As a result, nations, governments, and peoples are enslaved to their domination and have little or no recourse. These companies have proved that they have little concern for anything that creates opposition to their own economic security. How many lives have been lost in the procurement of power and money by oil spills, mass killings, and whole areas of forest being devastated, not to mention the small threat of a simple inventor mysteriously disappearing. It seems if any one government or person rocks the boat they can expect to be silenced by whatever means necessary, like Mr. Pogue, President Kennedy, and Tesla.

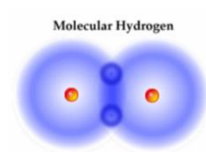
Problem Summation

To recap, by looking at China and the EPA we see that we must move from fossil fuels to reduce negative emission, climate change, poor air quality, and to save lives. However, those that form the upper tier of the banking and oil industries are in direct opposition to this and in times past subverted any attempt. As a result, we will have to start small and work with the situation. We must come up with something that will lower emissions while still using the fossil fuels until those in opposition allow a retiring of fossil fuels or the depletion of fossil fuel occurs if we are to make any headway at all.

Intro - Various forms of energy

"Energy is a quantity that can be assigned to every particle, object and system of objects as a consequence of the state of that particle, object or system" (Harper, 2007). Kinetic, potential, thermal, gravitational, sound, elastic, light and electromagnetic energies are all different forms of energy. The production of energy is important in all areas of the economy. The world's economy runs on the sale of energy in one form or another. To add to this, per capita, energy consumption is directly related to our standard of living (Vader and Joshi, 2005). Currently being researched by science are alternative energy sources such as solar, wind, biogas/biomass, tidal, geothermal, fuel cell, hydrogen energy, small hydropower, etc. (Alias, 2005). This paper will focus on Hydrogen as (HHO) and Electric as a way of reducing emissions while allowing the four horsemen to retain power by not moving entirely from fossil fuels. Biofuels, however, can be made from vegetable oils, animal fats or algae and is commonly referred to as Biodiesel, an alternative diesel fuel. These are renewable biological sources that are normally biodegradable and non-toxic. Biomass is a bio-source of H_2 and water that is burnable through a gasifier. This is the best alternative in my opinion as humans generally pay to get rid of all our biomass so why not make fuel from it. Electricity is both a power that can be produced cleanly and used cleanly. All these can have low emission profiles and be environmentally beneficial (Krawczyk, 1996). However, due to these characteristics, researchers are focusing much attention on hydrogen as an alternative fuel in ICEs and biomass is a great source of hydrogen (Saravanan & Nagarajan, 2008).

Intro - Hydrogen energy



Though H_2 has been looked at as an alternative because it enhances engine efficiency and produces less pollution (Boretti, 2010), the expenses to include this in manufacturing is too high (White et al, 2006). H_2 can be produced from electrolysis of water, coal gasification, from biomass, and solar photoelectrolysis (Saravanan and Nagarajan, 2008). However, though H_2 is one of the most common elements in the universe it is rarely found in nature by itself. Using H_2 can theoretically extend the lean limit—the least amount necessary to combust-- of a fuel mixture. This is done simply by adding a small amount of hydrogen to a liquid or gaseous fossil fuel. In turn, a more complete combustion occurs which improves efficiency and decreases NOx (Jingding et al., 1998)(Stebar and Parks, 1974). To add to this, during ultra-lean operation NO_x formation rates are so low that engine out emissions are near zero **(**Das, 1991). On the other hand, there are several problems with using H_2 alone as a fuel, foremost of which is the cost of production as we mentioned but there is another way to burn H_2.

Intro - Brown's Gas

Brown's Gas is a mixed form of H_2 and O_2 that is easily produced at a fraction of the cost of producing pure H_2. Brown's Gas has a few aliases: Hydroxy, HHO, and H_2O_2 to name a few. Basically, it is the vapor from the water after electrolysis. Scientifically, Hydroxy Gas (Brown's Gas) is a mixture of monoatomic and diatomic hydrogen and oxygen referred to as "Electrically Expanded Water (EEW)" or "Santilli Magnecules". Brown's Gas has a cool flame of about 130°C yet is able to melt just about anything. Although the flame is cool Brown's Gas can fuse brick, steel, sublimate tungsten, glaze quarts, and neutralize nuclear waste and burns with a clean flame. It uses no atmospheric oxygen and creates only pure water as its combustion product. (Michrowski, 1993). This gas cannot be stored safely it is very volatile and highly explosive at standard temperatures and pressures when mixed with air (Cameron, 2012). As a result, the forming and implementation must be done without ever storing or pressurizing the gas, i.e., it must be used as it is produced. This necessitates the need for a production unit or--HHO cell--for every application. When water is electrolyzed (when an electric current is passed through) Rydberg Clusters may be formed. Clusters of hydrogen and oxygen including water molecules in the "highly energized trigonal-by pyramidal geometry, monatomic and diatomic hydrogen, free electrons and oxygen" (Eckman, 2010). Rydberg clusters are in solids and liquids and are very stable for hours. In the case of HHO or Brown's Gas, these clusters have shown a lifespan of about 10 hours (Santilli, 2006). These clusters make use of the hydrogen bond which is a relatively weak bond when compared to the covalent bond (Mccarthy, 2008).

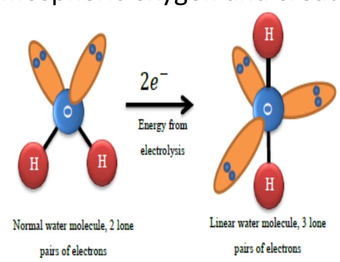


Figure 1: Rydberg clusters containing water molecules with highly energized electrons, but unenergized nuclei[4].

Intro - HHO Cells

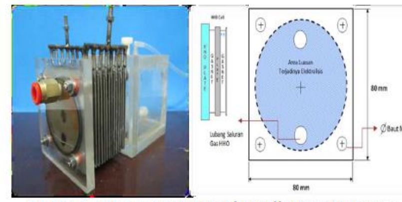


Figure 3. HHO gas Generator dry Cell type a.Generator construction b.Electrodes area

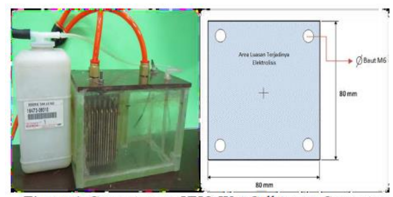


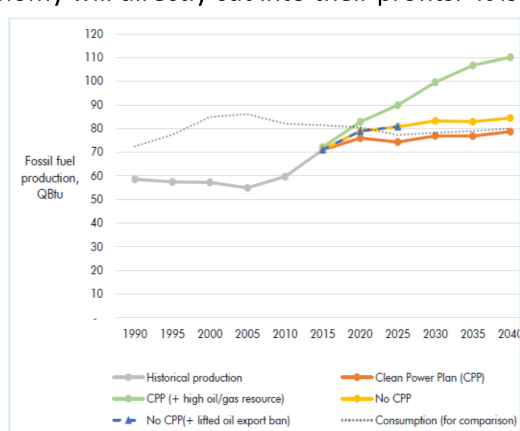
Figure 4. Generator gas HHO Wet Cell type a.Generator

There are two types of HHO cells currently. The Dry Cell, where only the center of the plates have an electrolyte, and the Wet Cell, where the entirety of the plates are submerged. The advantages for the dry cell are; the water is less, generated heat is smaller due to the circulation between cell and reservoir and easy access for testing plate voltages. The electric current used is also smaller because less of the power is converted into heat. The plate usage is only 60% versus 100% in a wet cell.

The Wet Cell is a generator with the electrodes fully immersed in the electrolyte. The advantages of the wet cell are; gas production has more quantity, the flow is stable, construction and maintenance are easier (Bambagn et al., 2016).

Intro - Stakeholders

Since HHO production is not centralized, and storage is dangerous, it cannot be metered and monopolized. As a result, such technology will be in the offense to the four horseman stakeholders because they cannot sell it. To add the increase in fuel economy will directly cut into their profits. It is Tesla's dilemma all over again. Since the population at large is our other stakeholder let us hope that we have better luck than him. Remember Tesla died bankrupt and alone in a small apartment after all his patents were stolen and used for profit, although, his science is still changing the world today, after all, who does not have a



cell phone? My only solution to this problem is that the changes be small. Unable to address the first foreseen problem more than that, we will concentrate on the other foreseen problems. Stockholm Environment institute suggests we might begin by simply limiting the amount of permitted fossil fuel licenses we allow. In their declaration that avoiding dangerous climate change requires a rapid transition away from fossil fuels and that a full phase-out of global fossil fuel consumption – particularly coal and oil—will have to be completed within the next 50 years (Rogelj et al, 2015). This report shows a tentative reduction in CO_2 emission by simply limiting the permitted extractions of fossil fuels. Under such a policy coal production in the U.S. would steadily decline. To add to this oil and gas extraction would drop as well. They conclude by stating that the phasing out of federal leases for fossil fuel extraction would reduce global CO_2 emissions by 100 million tons per year. These findings suggest that policy-makers should give greater attention to slowing down the permitting of expansion of fossil fuel extractions. However, fossil fuel expansion is at an all-time high and are only moving upwards (Rystad, 2015). Our current scheme of investing in fossil fuel expansion will lock us in the long-term making it impossible to recover from the effects of the effects of a fossil fuel based economy (Erickson et al. 2015).

Intro - Internal Combustion Fundamentals.

The engine used mostly powered by burning fossil fuel is the Internal Combustion Engine (ICE). These come in two main models the spark ignition (SI) known as a gasoline engine, and the compression-ignition (CI) engine known as the diesel engine. Each of these come in a range of styles and types. The four stroke, the two-stroke, and rotary are among these types; the stroke is defined as how many times the piston travels up and down in one cycle. We will be dealing with the four stroke models mostly to help us understand engine fundamentals (Kahraman, 2005; Haywood, 1998). The following pictures are from Haywood, 1998.

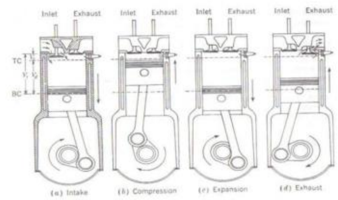


Figure 3.1. Cross-section schematic of a four stroke SI engine (Heywood, 1998)

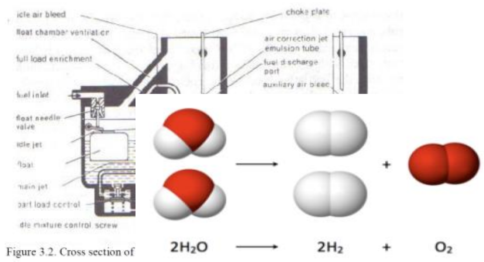


Figure 3.2. Cross section of

Figure 1. Decomposition of water molecules into HHO Gas

The picture on the left references the four stroke per cycle engine and the picture on the right has two typical types for fuel carburetion. Basically, fuel travels through the carburetor or injector to the cylinder on the intake down stroke. The fuel is compressed on the following compression upstroke. Combustion occurs either due to spark on SI engines of compression on CI engines which pushes the piston down on the combustion stroke and the leftovers are evacuated on the last upstroke called the exhaust stroke. Then the process repeats (Haywood, 1998). In our literature reviews, engine torque will normally be measured with a dynamometer. The engines output shaft is coupled to the dynamometer much like a transmission is to an auto. Then torque coefficient is found using an equation.

P (kW) = 2p w (rev / s) ´ T (Nm) x 10-3 brake mean effective pressure (bmep).

where,

$$bmep\ (kPa) = \frac{P_b\ (kW)\ \times\ n_r\ x\ 10^3}{V_d\ (dm^3)\ \times\ \omega\ (rev/s)}$$

When doing the math it is found that a perfect energy conversion is not attainable. The best that is found is about 96% (Kahraman, 2005; Haywood, 1998; Yilmaz, 2010).

Intro - Electrons, Water, and Conductivity

Water H_2O is a compound that is most important in life. Because of this, I am against using water hydrolysis as a formal means of producing power. I much prefer reclamation and the Recycling of Biomass and human and animal waste as the formal means of producing H_2, HHO, Methane, or other usable sources of fuel. However, that being said, let the research go on. Water consists of a compound of 2 molecules hydrogen (H_2)and one molecule Oxygen. When separated we have $2H_2O$ -> $2H_2$+ O_2. Since this is so simple and lite, compared to the much heavier petroleum, we have a much greater bang for the buck. Water can be turned into HHO gas through electrolysis (Durairai et al, 2012). Hydrogen has a calorific value of 120MJ/kg, a value that is much greater than gasoline, diesel or natural gas (Verhelst, 2009). Electrolysis is achieved by passing an electric current through two electrodes submerged in water. Electrolysis occurs when DC electron flows from a cathode to the anode via an electrolytic solution (Bureau, 2011). However, this produces heat so to reduce heat often an electrolyte is used as a catalyst. A bubbler unit must be used to prevent flashback. Hydrogen at or above 2500psi can easily lead to a blast. Using DC current the electrodes have two poles; a positive--the anode, and negative--the cathode. The following reactions are found:

Base equilibrium reaction:

Cathode (Reduction) $2H_2O(l)+2e^- \rightarrow H_2(g)+2OH^-(aq)$

Anode (Oxidation) $4OH^-(aq) \rightarrow O_2(g)+2H_2O(l)+4e^-$

Overall reaction $2H_2O(l) \rightarrow 2H_2(g)+O_2(g)$

Acid equilibrium reaction:

Cathode (reduction) $2H^+ (aq) + 2e^- \rightarrow H_2 (aq)$

Anode (Oxidation) $2H_2O (l) \rightarrow O_2 (g) +4H^+ (aq) +4e^-$

With all this, the hydrolysis of water is easily done.

(Bambagn et al, 2016).

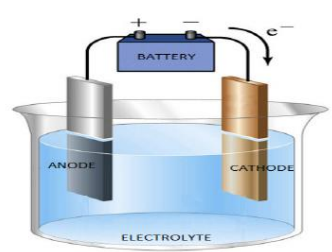


Figure 2. Schematic hydrolysis process of water

Intro - Bio Diesel

Biodiesel is diesel fuel made from vegetable oils, animal fats, recycled restaurant greases, algae, and other biomass. It is normally safe, biodegradable, and produces fewer air pollutants than petroleum-based diesel. Biodiesel can be used in its pure form or blended with petroleum diesel. Bio Diesel production Transesterification can be performed by continuous or batch systems. It is a process where vegetable oil or other biomass is reacted with alcohol or methanol and is catalyzed by bases, acids or enzymes to form esters and glycerol. The viscosity of the oil is changed to something that is very close to petroleum diesel (Durairai et al, 2012). Drop in replacement for diesel or CI engine of biodiesel with HHO is thought to be a valid alternative for the workhorses of our nation.

Literature Review

The papers in the following literature review offer answers to the many initial hurdles. Some of the reviews will be of a smaller nature and are just for answering specific questions, while others will be presented more extensively as to provide template information and background for further exploration. Both results in support of and against the hypothesis that HHO offers an acceptable alternative fuel source will be reviewed. In reviewing this literature I am looking for answers to the following questions. 1. Can H_2 burn in an engine? 2. Is it real--can one produce a burnable form of H_2 from water easily and cheaply? 3. Does HHO have significant data supporting the decrease of auto emission to warrant further study? 4. Is it true that one can build and HHO cell at little cost?

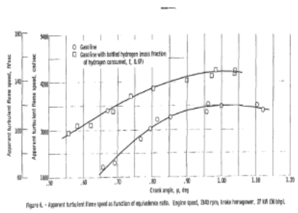
Q. Can H_2 burn in an engine?

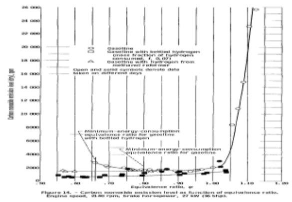
Rudolf A. Erren *made hydrogen-fueled engines in the 1920s* including trucks and buses. Allies of World found a submarine and even torpedoes converted by Erren to hydrogen power (Erren and Campbell, 1933). Since drinkable water is the exhaust hydrogen and oxygen as fuel they have been considered for the submarine since the end of the world wars (King and Rand, 1955).

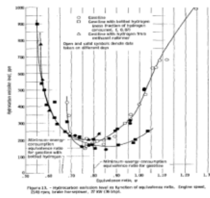
Robert Zweig *converted a pickup truck to run on H_2*. It still operates and can be seen at The American Hydrogen Association where it is displayed in public exhibits (Zweig, 1992).

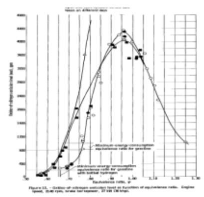
NASA, in 1977, did an experiment using a multi-cylinder engine to *extend the efficient lean operating range of gasoline by adding hydrogen*. It was hypothesized that the lean mixture –ratio combustion in internal combustion engines-- has the potential of producing low emissions and higher efficiency for several reasons. This list is directly out of their paper: 1. Excess oxygen in the charge further oxidizes unburned hydrocarbons and carbon monoxide. 2. Excess oxygen lowers the peak combustion temperatures, which inhibits the formation of oxides of nitrogen. 3. The lower combustion temperatures increase the mixture specific heat ratio by decreasing the net dissociation losses. 4. As the specific heat ratio increases, the cycle thermal efficiency also increases, the cycle thermal efficiency also increases which gives the potential for better fuel economy. NOx is produced by high combustion engines. Lee and Brehob indicated slightly increased hydrocarbon emissions will come from higher compression ratios. It is believed that a 10% increase in efficiency is possible (Lee and Brehob, 1971). In order to provide a basis for comparison, the engine was operated with varying amounts of hydrogen to gasoline ratios. Torque was measured at 55mph.

The results indicated that flame Speed was increased significantly. In leaner mixtures mixing hydrogen with gasoline reduced emissions favorably even NOx was reduced by a factor of 19, however, engine performance reduced also. At the useable performance settings, the NOx values actually increased. At an idle Hydrocarbon are slightly higher and Carbon Monoxide dropped. It should be noted that JPL conducted similar experiments with the same results. Please refer to the data in the graphs. The conclusion of the review, positive, H_2 can burn in an engine (Lee and Brehob, 1971)









Q. Is it real--can one produce a burnable form of H_2 from water easily and cheaply?

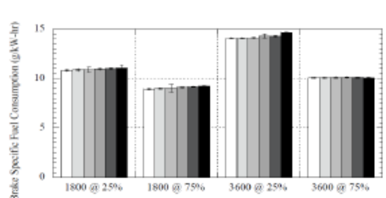
Two different researchers have shown that HHO can reduce diesel consumption (Yilmaz, 2010) (Bari, 2010). However, another team found a reduction in engine efficiency (Birtas, 2011). As a result, the University of Southern Queensland attempted to *validate the effects of onboard HHO addition on fuel economy and emissions in a 28kW diesel generator*. The results, HHO was shown to increase diesel consumption proportional to the rate of injection – up to a 5.2% increase at 55% load with 6L/min of HHO addition. The addition of water and HHO reduced Oxides of nitrogen (NOx) emissions up to 11.8%. It was found that the thermal losses in the engine stage would outweigh the economy gains from onboard HHO addition. To accurately automate and data-log the experiment an industrial control system was used.

Review,

Adnan et al found gaseous hydrogen injection rate of 20L/min at standard temperature and pressure (STP) doubled oxides of nitrogen (NOx) emission. Also due to the amount of current used in this experiment the generator is left with only about 29% of the engine's power available for useful work, this dramatically increasing diesel consumption (Adnan et al, 2009). The Bose and Maji experiments supported these findings and showed NOx emissions increased 70% and 90% at 20% and 40% load respectively due to hydrogen injection. The efficiency of the diesel engine increased due to the increased lean limit and flame speed due to the properties of hydrogen combustion (Bose, Maji, 2009). Lilik tested the effects of smaller ratios of hydrogen injection shown in

Table 1: Change in NOx emissions and BSFC on a 2.5L turbo diesel at 1800r/min

Parameter	2.5% FE H_2 25% Load	2.5% FE H_2 75% Load	5% FE H_2 25% Load	5% FE H_2 75% Load
NO	-16.9%	-3.4%	-24.2%	-5.4%
NO_2	+53.3%	+72.1%	+68%	+87.1%
BSFC	+0.3%	+0.4%	+0.6%	+0.6%



Brake specific fuel consumption of the four modes tested, with □ 0%, ■ 2.5%, ■ 5%, ■ 7.5%, ■ 10% and ■ 15% hydrogen substitution on an energy basis.

Figure 2: Brake specific fuel consumption for a 2.5L turbo diesel engine, courtesy Lilik [9].

Table 1. H_2 had a negative impact. The hydrogen injection in the turbo diesel engine had the opposite effect on diesel consumption showing a decrease in fuel economy (Lilik, 2010).

It was felt that a small rate of water injection could offset cylinder temperatures created from hydrogen and therefore reduce NOx emissions. As a result, Yilmaz et al injected small rates of HHO instead of H_2 into a diesel engine. Experiments performed showed positive results in improving the fuel efficiency of the engines. Tauzia et al compared the effects of EGR and water injection. This was more effective for reducing NOx emissions. NOx was reduced by 50%. Either water injection alone or onboard HHO addition alone both appear to reduce fuel economy of the diesel engines (Tauzia et al, 2010). Cameron found that there are no reliable indicators that onboard HHO has the potential to decrease diesel fuel consumption in a naturally aspirated generator based on the literature reviewed. The problem seemed to be the amount of energy it took to make the HHO was offsetting the contributing factors. He further found that HHO needs to be produced onboard and on-demand and factors of fuel and efficiency are connected to the water content in HHO and added water injection.

Template and design

A sodium hydroxide salt solution was used for an electrolyzer. A dry cell design with dead plates for higher voltage electrolysis was manufactured to perform an experiment to prove the effects of onboard HHO and water addition to diesel generators to enhance performance. A PLC system was used for the sake of repeatability. The key results of the test include HHO additions, water injection, and generator load along with the diesel fuel consumption and total NOx emissions. The plates in the electrolyzer are set up the same as in a car battery. The end plates were supplied *12.5-14V DC* resulting *in a 2.08V to 2.33V* drop across each successive plate in the electrolyzer. The total amperage rating was *18A connected in series and 30A electrolyzers connected in series*. Water was pumped in at 10% of the fuel consumption, it then was converted to steam and injected into the intake. A voltage over the potential of typically *0.6V above the 1.48V* thermo-neutral voltage is required for any significant current o flow at STP. This is due to a low reaction rate, the activation energy barrier, electrical resistance of the electrolyte and electrodes, and bubble formation (Zeng, Zhang, 2010).

Final Results,

HHO on-demand did not reduce diesel consumption. As the rate of HHO production increased so did the energy required to run the electrolyzer, resulting in a net loss. HHO and water injection reduced NOx between 1.3% and 11.8%. At 30% engine load, NOx was most affected by HHO injection, when combined with water injection there was a total reduction of 11.8% NOx emissions.

Table 6: Energy requirements for on-board electrolysis

H2-O2 (l/min)	RMS Voltage	RMS Current	Electrical Power	Energy of production	Thermal efficiency
2	242.0V	2.1A	513W	4.27Wh/L	50.5%
4	239.9V	3.9A	943W	3.93Wh/L	55.0%
6	237.7V	6.0A	1426W	3.96Wh/L	54.5%

Financial Analysis,

<u>No</u> financial feasibility

The problems found here point toward the amount of electricity it takes to produce enough HHO respectively reported as being 120W Electrolysis and 43W Electrolysis (Cameron, 2012). However, the gains of the water injection to alleviate the problem of high NOx is a great find. Also noted it the design of the HHO Cell. Please refer to the appendix for the Cameron Data Tables.

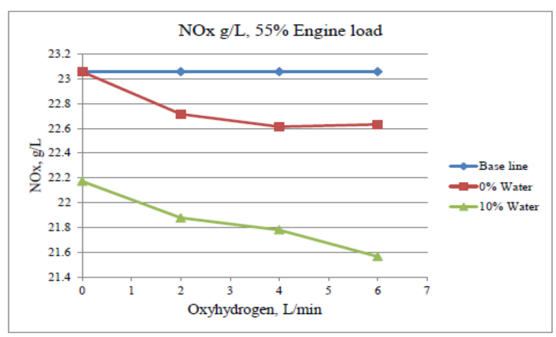


Figure 24: The effects of HHO and water injection on NOx at 55% engine load.

Q. Does HHO have significant data supporting the decrease of auto emission to warrant further study?

Stebar and Parks investigated the effects of hydrogen-supplementation and a very low NOx and CO emissions were achieved. Also, significant thermal efficiency improvements resulted from the extension beyond isooctane lean limit operation (Stebar and Parks, 1974).

Masood et al test results showed that the *hydrogen–diesel co-fueling solved the drawback of lean operation* of hydrocarbon fuels such as diesel. This reduced misfires, improved emissions, performance and fuel economy (Masood et al., 2006).

Ji and Wang studied hydrogen–gasoline mixtures in engines and concluded that wide flammability and fast burning velocity of hydrogen yielded reduced CO and HC emissions at idle and lean conditions (Wang, Ji 2009).

Rajeshkumar et al in this paper *introduced four methods to reduce the exhaust emissions.* 1. Adding additives. 2. HHO technology 3. Charcoal absorption to reduce the CO, HC and 4. A NaOH silencer to reduce more than two-thirds or carbon dioxide. The result showed fossil fuel was much nearer to complete combustion which intern ensures that there are no unburned hydrocarbons. Oxidation of the partially oxidized carbon i.e. CO was also more completely oxidized CO_2 (Rajeshkumar et al, 2016).

Masood et al studies found that though power output of an engine was 20% more than for a gasoline engine and 42% more when using a carburetor. Studies further suggested this will lead to *higher NOx emissions for injection of* H_2 *alone* (Masood et al., 2007).

However, Jingding studies have shown that if mixtures are made lean and spark timing is retarded *NOx can be reduced below the current standards for emissions* (Jingding, 1998).

Bambagn et al manufactured a PWM to control temperature. Instead of water injection to cool the cylinder, it was thought that Pulse width modulation temperatures might be controlled better. A PWM is an electronic circuit that is able to regulate current input by quickly turning the current on and off. This duty cycle and frequency can be set and adjusted (Ghiffari, 2013). One goal is to keep the Cell below 60° C (Musmar et al, 2011). The objective of this study is to see if these advantages remained with original engine specifications. A Dry Cell HHO device was used and optimization of PWM was done by varying the duty cycle of pulse width modulation i.e. 20%, 40%, 80%, and 100%. A venturi style mechanism mounted intake was used to port HHO. Measured was the effects of HHO gas on the performance and the temperature of the Cell. The results show optimum performance is generated by a PWM system with a 40% duty cycle. Documented increase BMEP, thermal efficiency, engine torque, power. The thermal efficiency increased respectively to 2.27%, 2.76%, and 3.05% while the performance increased by 6.55%, 7.65%, and 15.50%. The electrolyte used is an alkaline solution of KOH. The HHO Gas generator is composed of two basic components. Tube generator and a power source (battery). A Dry cell type generator with a separated bubbler and water fill (Bambagn et al, 2016).

The Performance parameters (taken directly from the study) (Bambagn et al, 2016).

1. Generator Power Input. The Formulation to find the input power is P=VxI. Watts=volts x amps.
2. HHO Gas production= measured by a gas flow meter.
3. Specific Energy Input defined as the amount of energy required to process the electrolysis of water in kjoule to produce 1kg of HHO gas.
4. Generator efficiency, the ratio of useful energy to the energy supplied to the system.
5. Generator HHO Temperature
6. The PWM system. PWM is an electronic circuit to control the amount of electric current that enters the equipment and to avoid excessive power dissipation in the battery. Also, Voltage is regulated by percentage of pulse width to the period of a square signal in the form of a periodic voltage applied to the motor as a power source. PWM signal can be constructed using analog methods using op-amp circuit or by using a digital method that could be affected by the resolution of the PWM itself. PWM

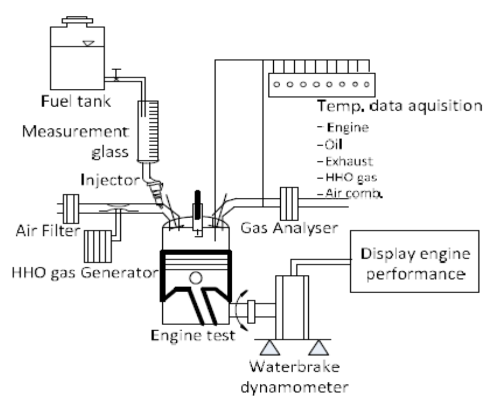


Fig. 7. Schematic diagram of the experimental setup

electronic circuits can be made using a 555 timer ic or IC LM324N. Timer IC is one type of timer that has the ability PWM controller with pulse width control features 0 to 100%. Mosfet drivers are needed to the use of PWM.

Bambagn Results

Generator temp was maintained at 60 ° C. Application of HHO gas generator in point above on standard ignition timing engine produce in an increase of performance such as torque, power, BMEP and thermal efficiency respectively of 2.27%, 2.76%, and 3.05% and decrease of bsfc 7.76% (Bambagn et al, 2016).

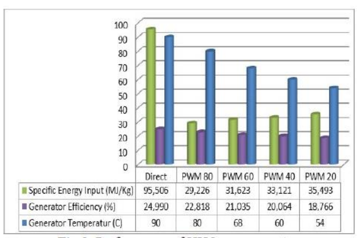


Fig.8. Performance of HHO gas generator

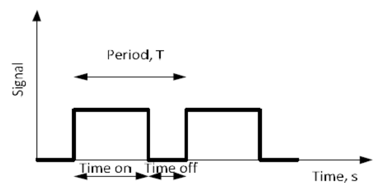


Figure 5. Duty cycle of pwm system

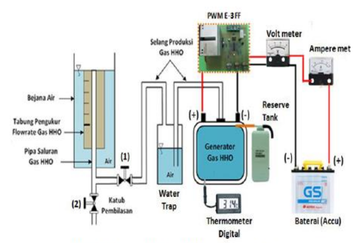


Fig 6. Assembly of HHO gas generator

Yimaz et al at Mutah University *showed that a mixture of HHO, air, and gasoline cause a reduction in emission pollutants and enhancement in engine efficiency*. Emission of NO and NOx were reduced by an astounding 50%. Moreover, carbon monoxide concentrations were reduced by 20%. While fuel consumption was reduced by 20-30% (Yimaz et al, 2010).

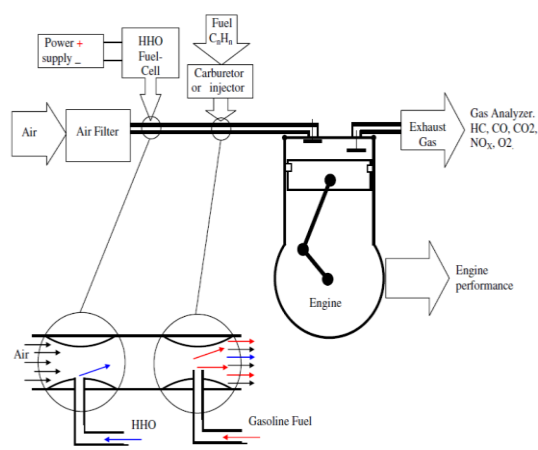
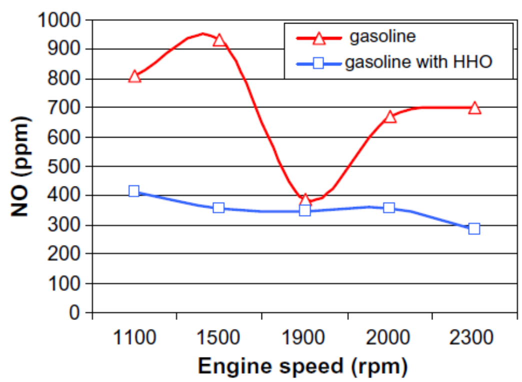
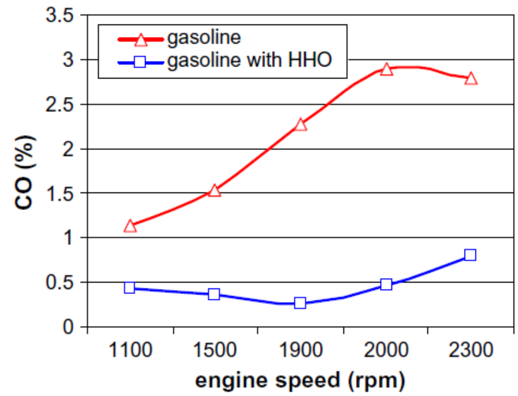


Fig. 2. Schematic experimental setup.

Template and design,





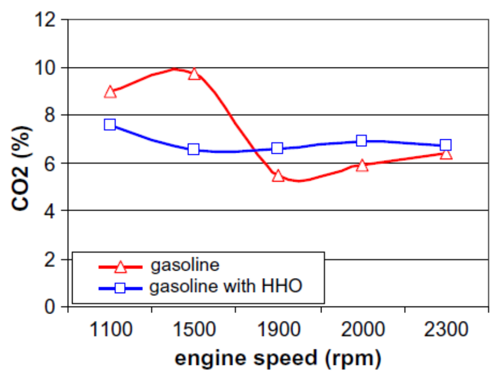


Fig. 8. Variation of carbon dioxide concentration in the exhaust with engine speed.

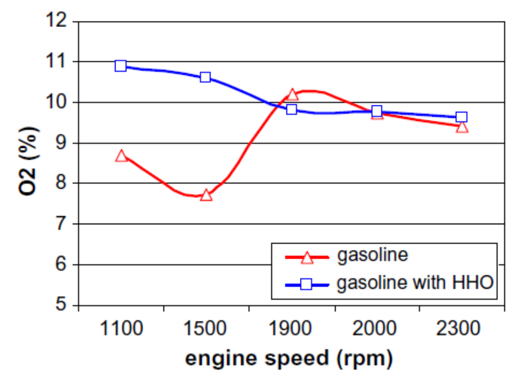


Fig. 7. Variation of oxygen concentration in the exhaust with engine speed.

The fuel cell used in this research is basically an electrolyte cell which decomposes water into HHO. The heat generated is due to the electrolysis process so a sodium bicarbonate is added to accelerate the decomposition. HHO has a caloric value three times that of gasoline. Plates of stainless steel are used to prevent degradation. The effect of adding HHO gas to the air/fuel mixture on the carbon monoxide concentration is presented, in fig 4. Using a blend of HHO gas reduces the presence of CO. The conclusion from the study shows that HHO cell may be integrated easily with existing engine systems. Further, that the combustion efficiency has been enhanced when HHO gas has been introduced, consequently reducing fuel consumption. Concentrations of nitrogen oxide have been reduced by 50%. Carbon dioxide has been reduced to 20%. NOx concertation was reduced to about 54%. Finally, HC concentrations were highly affected by the engine speed and the presence of HHO (Yimaz et al, 2010).

Q. Is it true that one can build and HHO cell at little cost?

Cunningham et al made researches *on methods and apparatus for enhancing combustion* in an ICE through electrolysis and produced hydrogen along with oxygen yielding an enhanced combustion at low engine loads for all types of engines (Cunningham et al, 1992).

Ammar A presents work in *the design of a device attached to the engine to integrate an HHO production system with the gasoline engine*. He states this device can be easily installed in any engine compartment.

Review,

Studies at Mutah University include the reduction of cylinder liner wear, the filtration process, fuel mixing processes, as well as the introduction of the HHO fuel cell (FC). In the theoretical background, in “Properties of hydrogen” Momirlan *elaborated upon the hydrogen H_2 technology*, economics and the environmental impact on the world at the end of the 20th century. In the 21st century studies have been centering on browns gas or HHO (Momirlan, Veziroglu, 2002).

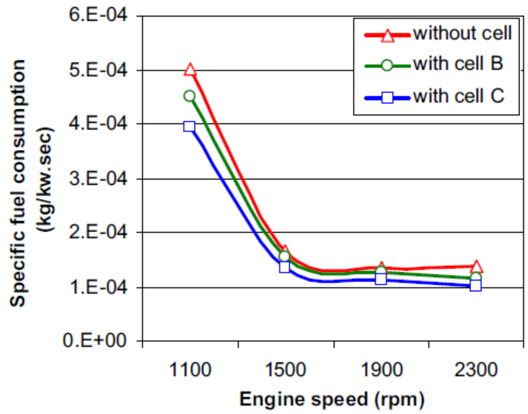
Dunn in his paper talked about how the decisions made today will likely determine which countries and companies *seize the enormous political power and economic prizes* associated with the hydrogen age now dawning (Dunn, 2002).

Schulti et al done studies on acceptance, risk perception and customer satisfaction gave suggestions on *how to use marketing methods*, education projects, and product exposure in order to attain the successful introduction of hydrogen as an alternative fuel (Schulti et al., 2004).

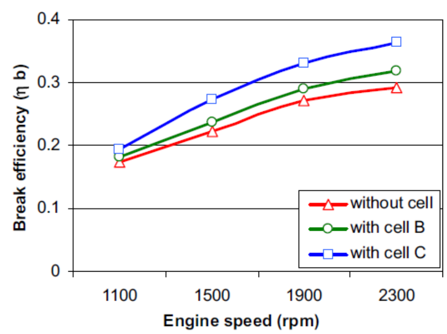
Hekkert et al discuss the role of governments in the transition to hydrogen (Hekkert et al., 2005).

Template and Design,

The type cells used in this experiment was a Wet Cell filled with water and *sodium bicarbonate*. Two cells were constructed being the same type with different configurations FCb and FCc. Cell FCc is half the dimension of cell b, with an electrode placed closer.

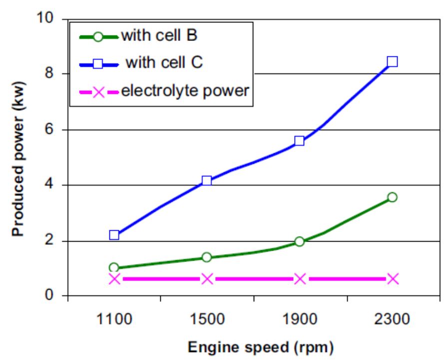


Results: (the list is taken directly from the study).



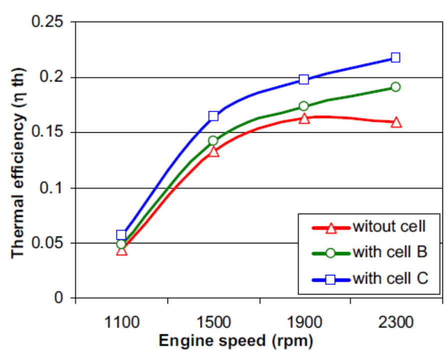
An increase in efficiency of about 3% for cell b and 8% for cell c.

1. Fuel consumption was reduced especially with cell c.
2. fig 10 shows a reduction in exhaust gasses this leads to better combustion and cleaner gas
3. Increased power.



Conclusions

1. The use of HHO in gasoline engines enhances combustion efficiency, consequently reducing fuel consumption and thereby decreasing pollution.
2. The optimal size of the FC is when the service area of an electrolyte needed to generate sufficient amount of HHO is twenty times that of the piston surface area. Also, the volume of water needed in the cell is about one and a half that of the engine capacity.



The FC which can be used in simple, easily constructed, and easily integrated with existing engines at low costs, about 15 dollars per cylinder. How does design affect production?

(Ammar, 2010).

HHO with Diesel Design

Durairai et al wrote a paper dealing with *bio-diesel and HHO gas from hydrolysis*. This report states that the using of water powered biodiesel results in a substantial reduction in emission. Preheating the air improves the thermal efficiency. This is a strange finding since most CI engines make use of an intercooler to cool the air and prevent run away. The main focus deals with implementation of oxy-hydrogen as a duel fuel with biodiesel (Durairai et al, 2012).

Biodiesel

Biodiesel is a clean burning mono-alkyl ester-based fuel very close the consistency of fossil-based diesel but is made from renewable sources such as vegetable oils and animal fats.

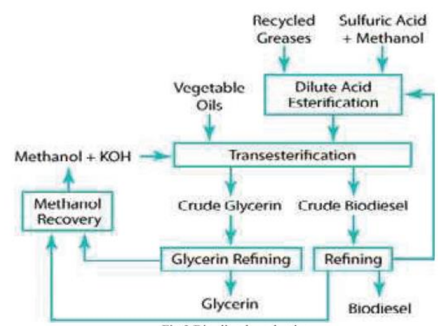


Fig.2.Bio-diesel production

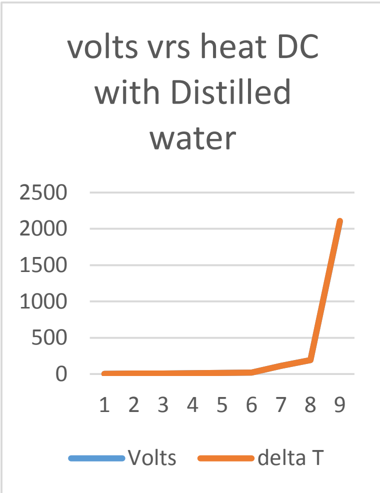
Findings. (list is taken directly from original paper) (Durairai et al, 2012).The HHO/Bio-diesel shows evidence of producing low emissions and higher thermal efficiency.

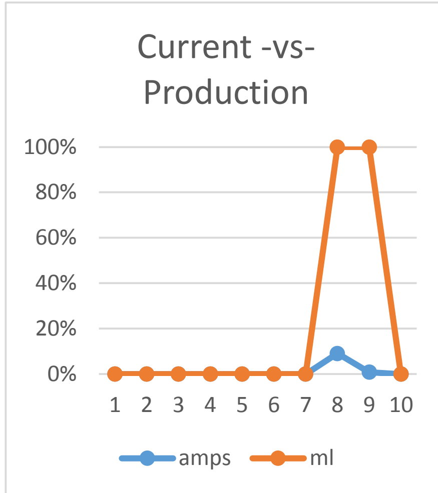
1. Reduces the formation of unburned hydrocarbons and reduces the unburned fuel in the combustion chamber.
2. Due to this the combustion process will be done in an efficient manner and the hydrogen is four times highly effective when compared to ordinary fuels.
3. Due to this it will increase the combustion reaction and lead to an increase in efficiency and torque, and horsepower.

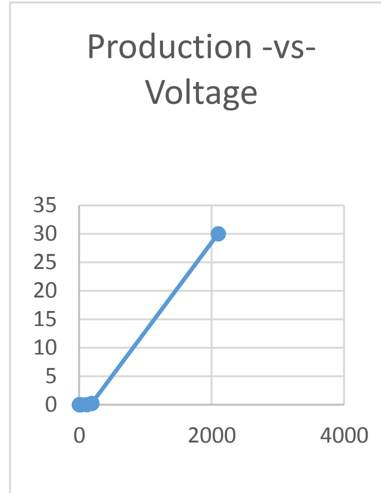
4. The HHO compounds will be used to reduce the formation of CO2 and CO and other harmful compounds produced in the engine and increase in mileage and performance of the engine.
5. Heat energy is recovered from the exhaust gasses which causes lower heat addition, thus improving engine thermal efficiency.
6. NOx emission is reduced with the exhaust heat recovery system. Higher inlet air temperature is caused the lower ignition delay, which is responsible for lower NOx formation with air preheating. Uniform or better combustion will occur due to the pre-heating of inlet air, which also causes lower engine noise.
7. Due to better evaporation and shorter ignition delay, there is less fuel adhering to the combustion chamber wall and therefore a small amount of fuel accumulated in the combustion chamber before ignition is started which may produce low NOx emission as well as low noise vibration.

Literature Review and Experimental Conclusions

Studies show that concentrations of nitrogen oxide have been reduced by up to 50% or more. Carbon monoxide has been reduced to 20% or more to add to this CO_2 was shown to be reduced greatly. It seems the main problem with this technology is the amount of electricity it seems to take to make it have a net gain. These problems were addressed in by my experiments. I found it possible to use a variable frequency wave and drop the current draw to 0 amps. This means it is possible to produce HHO with a very little electrical current draw. Further, in my findings it was determined that the voltage that an auto engine charging system operates at is the worst voltage range to operate an HHO cell. At these ranges excessive heat and current draw were present. Voltages above 20 volts work much better. However, higher voltages are better for production but should be used in concert with a PWM or some other frequency controller to prevent heat accumulation and excessive current draw. Having dealt with any drawback we now will look at HHO as a viable fossil fuel additive in reducing Emissions and Greenhouse Gases. Here are the results from my experiments the data table are given in the appendix.

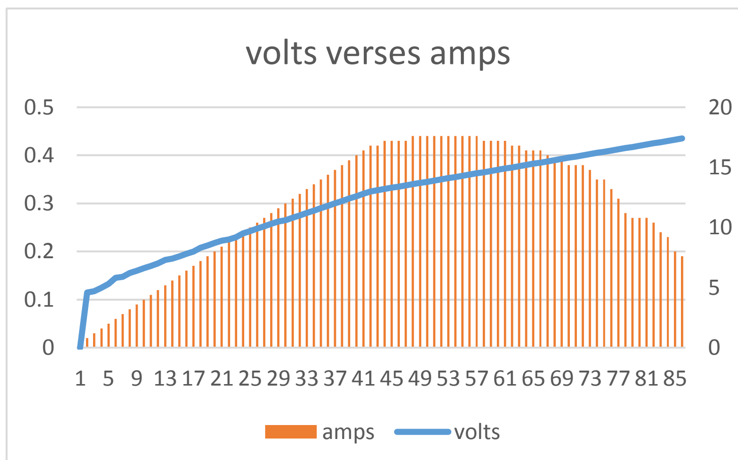




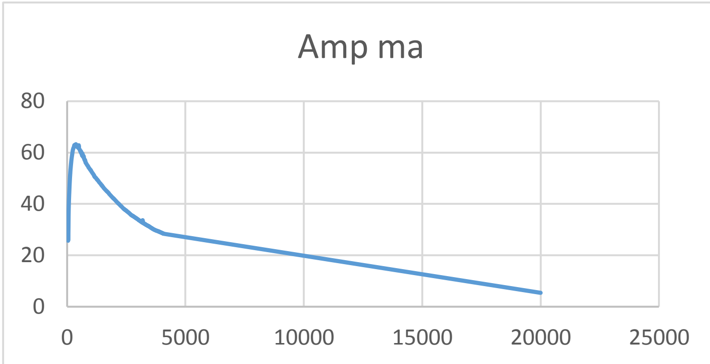


Appendix (A): (Morse, 2016).

Results From Voltage Versus Amp Review: Appendix B. As stated above it was found that the greatest draw on a power source is from 12 to 16 volts which are what the range is for the standard auto charging system. The graph indicates that at some voltage greater than 20 volts it may be possible to have a low current drain.

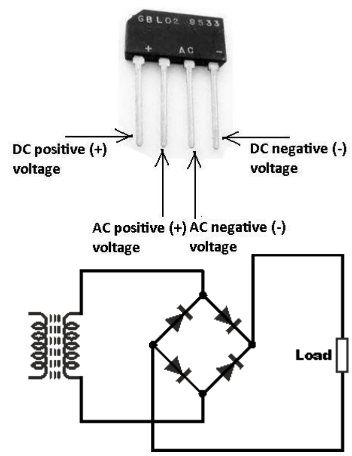


The use of an audio amp to provide an A.C. signal at the resonant frequency of the cell. The resonance frequency is found by recording the metal of the cell after being struck. Then the file is analyzed with an audio frequency analyzer to determine resonant frequencies. The resonance frequencies are found to be 46.7. 53, and 127 Hz. A signal from a frequency generator was running through an audio amplifier, in this way an alternating current at the desired frequency was obtained. These tests show that as the frequency current draw dropped to zero while still producing HHO gas.

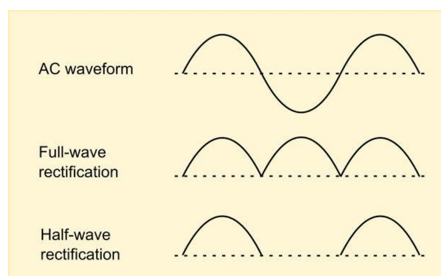


Appendix (E) (Morse, 2016).

Audio Signal through a full wave rectifier.



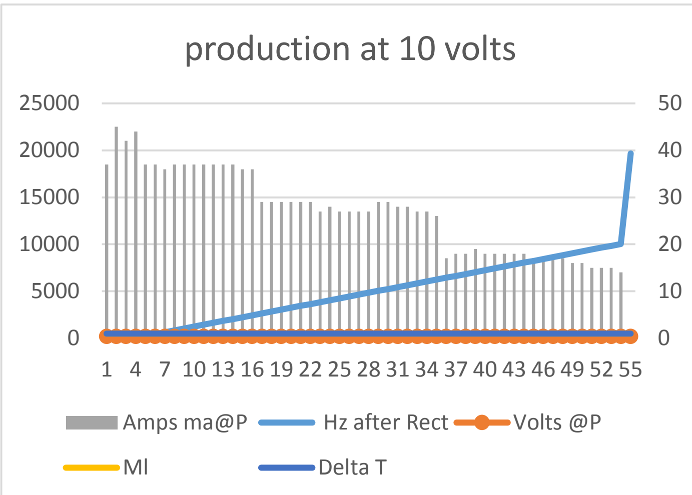
A full wave rectifier if a diode bridge that in essence splits the positive and negative portions of the alternating wave. It then inverts the negative portion to positive. The end result is a positively charged pulse at twice the frequency rate.

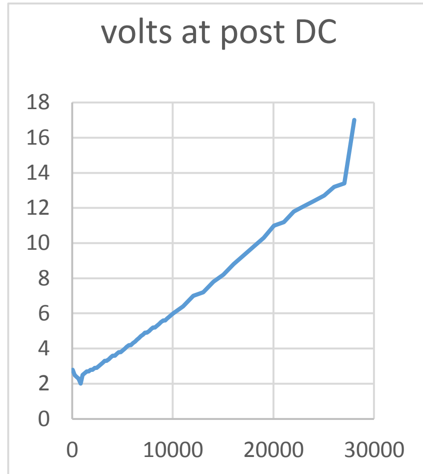


It is shown that the voltage value of the rectified audio signal follows the characteristics of the continuous d.c. voltages as shown in the Volts at the post-DC graph to the right. As a result, it is possible to find a frequency that will have a very small current draw using an audio signal rather than a PWM which may require advanced electronics.

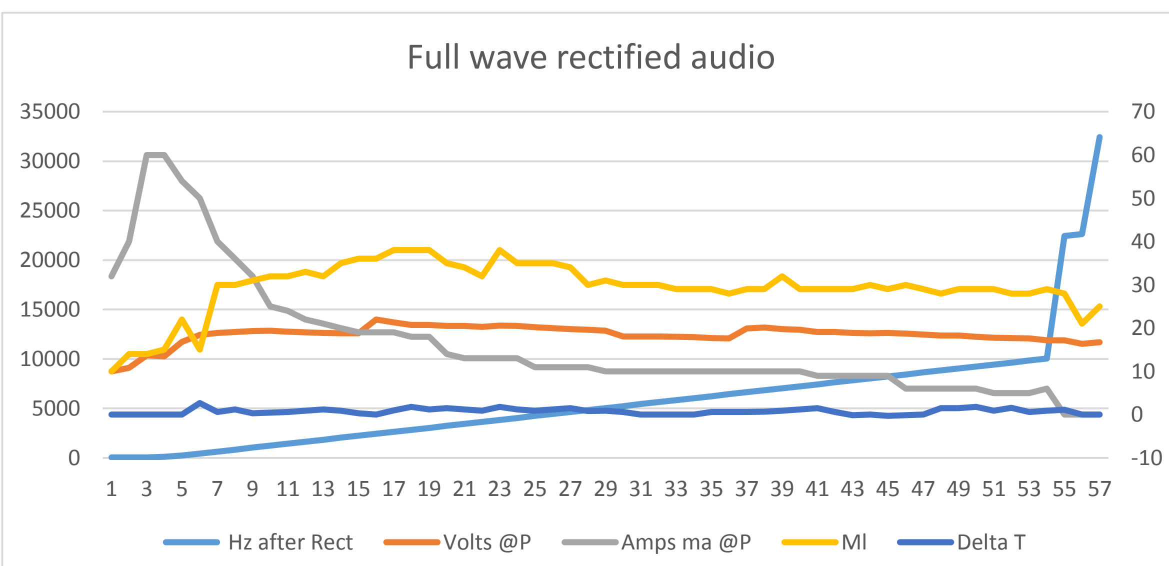
Results: Production and current results of using an audio signal through a full wave rectifier with the voltage held at 10 volts. Appendix (G).

Discussion on Experiments





It is shown that voltage seems to be the deciding factor on production. No matter what Hz the production value was stable at 7.5 mL per minute. An unexpected outcome is a drastic reduction in current needed. Current dropped to 50 milliamps or less, also it was noticed that at extremely high frequencies production remains the same but amperage draw drops to zero. This is very promising and greatly reduces the cost of producing HHO. However, 7.5 mL per minute is not enough production to



supply the need. Production and current results of using an audio signal through a full wave rectifier with only Hz being changed and voltage and amperage being the result of the given Hz. Appendix H (Morse, 2016). Again the results show that at 22440 Hz current draw drops to zero. While the production did reduce by 2 mL per minute this is an acceptable loss to have the net cost drop so radically. Delta T (temperature increase) is also lower at this point. The other alternative is to use a Pulse Width Modulator, and from our research, the current reduction can also be achieved.

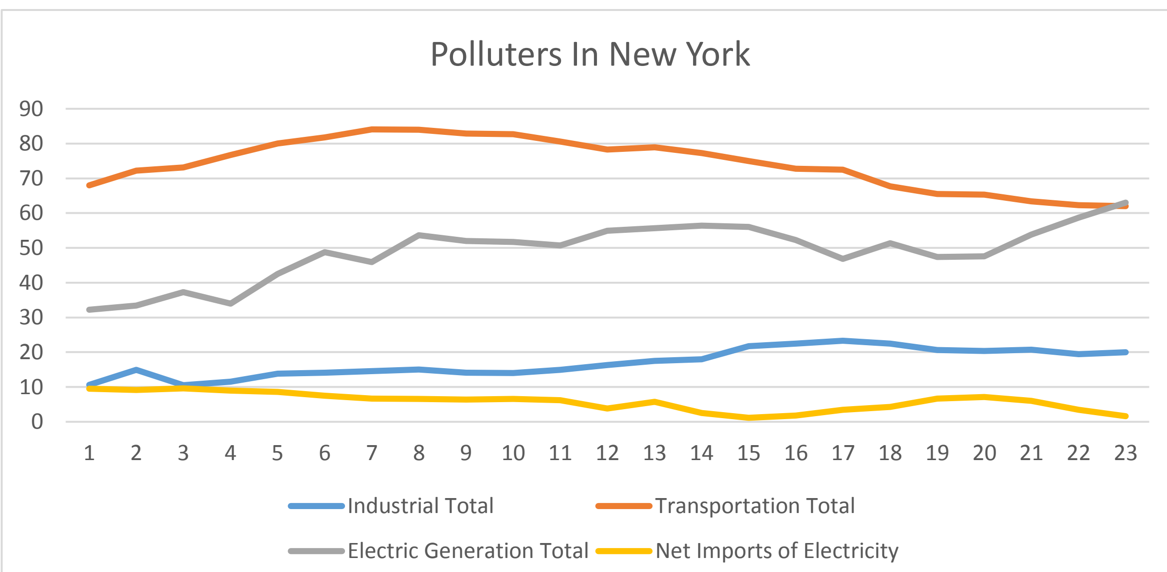
Literature Review Summation.

1. Yes H_2 and HHO can be burned in an engine. Erren and Campbell in 1920 were successful.
2. Yes HHO can be produced from electrolysis for little cost (Yull Brown patent, in 1977).
3. Though H_2 alone is not suitable as an alternative fuel source for a drop-in replacement, in the future it is still a viable alternative due to the weight to power ratio, however, engines design specifically for H_2 would have to be engineered, in the meantime HHO with the water content that it has will reduce all emissions and enhance power and torque when the fossil fuels are leaned out to accommodate for the HHO, with the addition of a control unit to control the flow rate into the intake for this reason more experimentation is advised Lee and Brehob in 1971 showed H_2 to be an insufficient drop in replacement for fossil fuel(Lee and Brehob, 1971).
4. Engineering an HHO cell seems to be inexpensive, in my tests I was able to build one for $20 (Morse, 2016).

Hypothesis

In this study and review, we looked at one of the enduring alternatives to gasoline and diesel. However, the idea, for now, is not to replace gasoline, nor improve mileage so drastically that it would warrant attention by those in opposition but to use it as an additive to reduce emission and provide some relief on the demand of fossil fuels. Hydrogen has been researched for a long time. We examined data from a NASA experiment with Hydrogen to see what effects on mileage and emission it will have when using it as an additive to common ICE fuels. Physical and environmental factors according to this and other studies were also reviewed. We showed that since water is present in HHO many of the problems concerning emissions were overcome. To add many studies mapped out reductions in all emissions. The problems of heat and current were overcome by the use of electrolyte, changing the voltage out of an auto charging system range, and changing the frequency to a pulse that causes a zero net current draw. This was shown to be applicable to CI and SI engines alike. Through this data, we believe that the hypothesis that HHO is a viable means of reducing emissions has been supported. Further, we will be taking data reported on a New York State site and converting that table data into graphs to show current emission measured then using data from the literature review as well as data from experimentation to show that HHO is a viable fossil fuel additive and can be used to lower emissions.

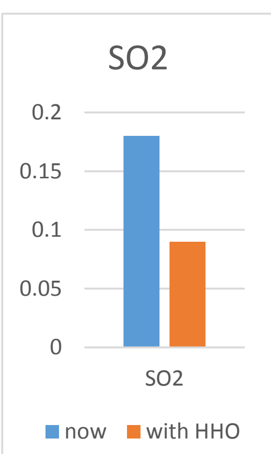
Data Table: Interpretations From the State of New York.

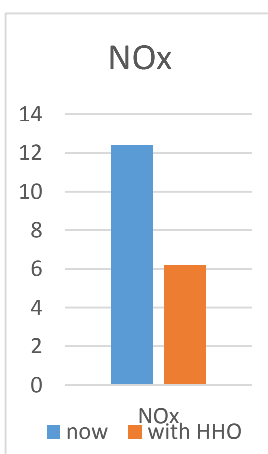


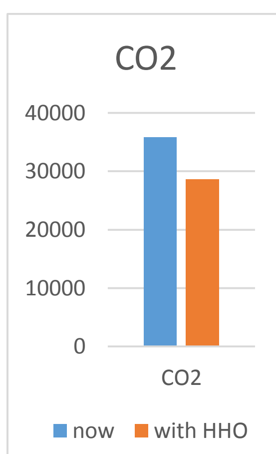
Final Analysis and Discussion

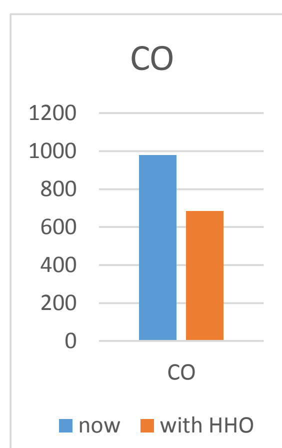
HHO has been looked at as an alternative additive to fossil fuels to help relieve the stresses caused by used of such fuels as well as hardships caused by the limitation of supply. Several questions were posed at the beginning of this paper and an effort has been made to determine if HHO is economically a real world alternative. Through the previous studies, we have found an answer to this question. It was found that in the Nasa Study that H_2 can burn in engines, usually needing the timing changed to function properly. It has further been shown in the Yilmaz literature review that HHO does significantly reduce all auto emissions while reducing fuel consumption. Yilmaz reported a 50% reduction in NOx, 20% in both CO and CO_2, also a small reduction in SO_2 all while reducing fuel consumption by 20-30%. Also found is that design does indeed affect production, and it is recommended that experiments in design continue. Researchers should continue the Cameron 2012 study with data table (Appendix G) supported the findings of the Yilmaz study but found that HHO was too expensive due to the power requirements at auto operating voltages.

As a result, a study was performed by varying the frequency and wavelength in an attempt to find optimal voltages and frequencies. By reviewing the data tables in Appendixes A-F it was found that the power requirements can be much reduced but using voltages above 30 volts, further, by employing a full wave rectifier is was found it was possible to have a cell produce efficient amounts of HHO while









having a 0 amp current draw. Please refer to the chart created on page 32. This relieves the constraint of the Cameron 2012 studies. Having removed all arguments against the HHO cell as a viable means of reducing emissions we will now look at the possible outcome of using such technology. A review of data from a data table given by the New York State website reveals that through the years 1990-2012 in the state New York transportation has been by far the greatest contributor of emissions. In the chart, we created from the data table (Appendix H) a chart was created to show just how much more of a contributor transportation was compare to other sources of emissions (page 34 chart 1). We see that transportation drawn in red was over double the amount until in 2012 it was matched by electric production from fossil fuels. Using the data from Buffalo N.Y. listen by the state website we can compare the possible reduction of emissions that might be obtained by implementation of the HHO cell in autos. The state data listed in Appendix H was compared with the Cameron Data listed in Appendix G. The four charts created on page 35 show the possible reduction of SO_2, NOx, CO_2, and CO. These are substantial. To add it is believed that reductions of implementing this technology in fossil burning electric plants might very well produce similar results.

Final Conclusions and Recommendations

Conclusions

1. Can H_2 burn in an engine? Yes

2. Is it real--can one produce a burnable form of H_2 from water easily? YES!

3. Does HHO have significant data supporting the decrease of auto emission? YES!

4. Is it true that one can build and HHO cell at little cost? YES!

5. How does design affect production? The design does affect production.

6. At what amperage and voltage values is a Cell likely to operate best at? Above 30 volts, the higher the better. Through manipulation of the waveform and frequency it is possible for an HHO cell to operate efficiently at a Zero amp current draw.
7. Does evidence support that the implementation will reduce emissions in major cities such as Buffalo N.Y. Yes, the data tables reveal that the main producer of emissions in N.Y. is transportation. Further, a comparison of the data from Buffalo N.Y. with the data from the Cameron 2012 shows a significant reduction of emissions is possible.

Recommendations

It is recommended to further experiments using PWM's and high voltages along with design modifications for the greatest possible production potential. Further, it is recommended cell design continue to be experimented with a D.C. pulse wave fully rectified. It is recommended that this technology should be distributed only on a temporary basis. On the other hand, since it can be produced cheaply, and has such great potential for immediate reduction of emissions as well as known greenhouse gases this technology should move to the forefront with governmental implementation on government ran transportations. It is noted that using water as a source of fuel is not really a good idea as it is the lifeblood of everything on the planet and thus this technology is only recommended for use in the short term. Once more recycling biomatter in a gasifier is just as efficient and as we have tons of this matter that we have to pay to get rid of, economically speaking, it just makes more sense. Grass clippings may be used as the alternative to fossil fuel. Biomass as fuel is a renewable as well as an efficient means of disposal. To make pellets from biomatter is an easy process and the gas is burnable in most vehicles especially CI engines. Until then the HHO is a ready and waiting drop in replacement for many fossil based engines and tools

References

Adams, Walter (1968) *The American Economic Review.* Vol. 58, No. 2, Papers and Proceedings of the Eightieth Annual Meeting of the American Economic Association (May, 1968), pp. 652-665 Published by: (URL: http://www.jstor.org/stable/1831851

Adnan, R.; Masjuki, H.; Mahlia, T. (2009) An experimental investigation of unmodified DI diesel engine with hydrogen addition. 2009, pp. 45-49.

Alias A. (2005) *Two Days National Seminar on Alternative Energy Resources.* August, 27-28, Thane, India.

Ammar A. Al-Rouson (2010) *Reduction of fuel consumption is gasoline engines by introducing HHO gas into intake manifold.* Department of Mechanical Engineering, Faculty of Engineering, Mutah University Mutah, Al-Karuk 61710 Jordan. 10 March 2010.

Antonia V.; Herzog, Timothy E.; Lipman, Daniel M. (2001) *Sources Report*. Encyclopedia of Life Support Systems Publication. University of California, Berkeley USA, 63 p. Laboratory (RAEL), URL: http://socrates.berkeley.edu/~rael

Bacon, F.T. (1960) *The high-pressure hydrogen-oxygen cell.* J Ind Eng Chem 1960;52(4):301-3

Bambagn, Sudaramanta; Sudjud, Darsopuspito; Djoko, Sungkono (2016) *Fuels, and Combustion Engineering Laboratory*. Department of Mechanical Engineering, Sepuluh Nopember Institute of Technology, Surabaya, Indonesia.

Bambagn, Sudaramanta; Sudjud, Darsopuspito, Djoko, Sungkono (2016) *Application of dry cell HHO gas generator with pulse width modulation on spark ignition engine performance.* Fuels and Combustion Engineering Laboratory, Department of Mechanical Engineering, Sepuluh November Institute of Technology, Surabaya, Indonesia. Ijret International Journal of Research in Engineering and Technology, 2016.

Bari, S.; Esmaeil, M. M. (2010) *Effect of H2/O2 addition in increasing the thermal efficiency of a diesel engine*. Fuel, vol. 89, pp. 378-383, 2010.

Bell S.R.; Gupta, M. (1997) *Extension of The Lean Operating Limit For Natural Gas Fueling of a Spark Ignited Engine Using Hydrogen Blending*. Combustion Science and Technology, 123:23–48.

Benkataraman, B.; Elangoe, D. (1998) *Renewable Energy Sources*. Hindustan College of Engineering, Padur, India, 235 p.

Bhavesh, V.; Chauhan, M.E.; Rathod, Gaurav P.; Patel, Tushar M. (2016) *An Experimental Investigation of HHO Gas and Varying Compression Ratio on Emission Characteristics of Constant Speed Diesel Engine (CI)*. Indian Journal of Research Issue 4 April 2016 Patel Associate professors, L.D.R.P-ITR, Near KHA-5 Circle, Sector-15, Gandhinagar.

Bhardwaj. S.; Verma, A.S.; Sharma, S.K. (2014) *Effect of Browns gas on the performance of a four-stroke gasoline engine*. Int. Journal of Emerging Technology and Advanced Engineering (Online). Volume 4, Special Issue 1 Feb 2014

Birtas, A.; Voicu, I; Petcu, C.; Chiriac, R.; Apostolescu, N. (2011) *The effect of HRG gas addition on diesel engine combustion characteristics and exhaust emissions.* International Journal of Hydrogen Energy, vol. 36, pp. 12007-12014, 2011

Boretti, A.(2010) *Comparison of Fuel economies of high-efficiency diesel and hydrogen engines powering a compact car with a flywheel-based kinetic energy recovery system*, Int. Journal of Hydrogen Energy 35 (2010) 8417-8424

Bose, P.K.; Maji, D. (2009) *An experimental investigation on engine performance and emissions of a single cylinder diesel engine using hydrogen as inducted fuel and diesel as injected fuel with exhaust gas recirculation.* International Journal of Hydrogen Energy, vol. 34, pp. 4847-4854, 2009.

Bowman, C.T. (1992) *Control of combustion-generated nitrogen oxide emissions: technology driven by regulation.* 1992, pp. 859-878.

Brown, Yull. (1977), *A technique to generate HHO gas based on electrolysis process.* Brown Y. Brown's gas. United States Patent. US Patent 4014,777; March 28, 1978

Bureau of Agriculture, (2011) *Energy in Australia 2011*. D. of and E. a. T. Resources, Eds., ed. Canberra: Australian Bureau of Agriculture and Resource Economics and Sciences, 2011.

Cameron, R. (2012) *Surveying Effects of Onboard HHO and Water Injection in a Diesel Generator.* A dissertation submitted by Rick Cameron, University of Southern Queensland Faculty of Engineering and Submitted: October 2012.

Cunningham, J.E.; Goodenough, R. (1992) *Method and Apparatus for Enhancing Combustion in an Internal Combustion Engine through Electrolysis*. United States Patent, April, 21, 1992.

Das, L.M. (2002) *Near-Term Introduction of Hydrogen Engines For Automotive and Agriculture Application*. International Journal of Hydrogen Energy, 27:479–87.

Das, L.M. (1991) *Exhaust Emission Characterization of Hydrogen Operated Engine System: Nature of Pollutants and Their Control Techniques*. International Journal of Hydrogen Energy, 16:765–75.

Dunn, S. (2002) *Hydrogen futures toward a sustainable energy system*. Int. Journal of Hydrogen Energy 2002;27:235-64

Durairai, R.B.; Shanker, J.; Siva Sankar. M. (2012) *HHO Gas with Bio Diesel as a Dual Fuel with Air Preheating Technology.* SciVerse ScienceDirect. Procedia Engineering 38 2012 1112-1119 Faculty of Engineering and Technology, SRM University, Chennai India. Professor and Director Center for BioMedical Research, Arunai engineering college, Thirubanamalai, India. 2012 published by Elsevier LTD. Selection and/or peer-review under responsibility of Noorul Islam Centre for Higher Education

Eckman, C. (2006) *Plasma Orbital expansion of the electrons in water.* Proc. NPA, vol. 7, pp. 142-144, 2010.

EPA, Environmental Protection Agency (1994) *EPA 400-f-92-007 Fact Sheet* OMS-5 August, 1994 Automobile Emissions: An Overview.

Erickson, Peter; Lazarus, Michael (2016*) How would phasing out U.S. federal leases for fossil fuel extraction affect CO_2 emission and 2°C goals.* Stockholm Environment Institute working paper no. 2016-12 Stockholm Environment Institute – U.S. Center.

Erickson P.; Lazarus, M.; Tempest, K. (2015) *Carbon Lock-in from Fossil Fuel Supply Infrastructure*. SEI discussion brief. Stockholm Environment Institute. Seattle, WA, US. http://www.sei-internationsl.org/publications?pid=2805

Erren, R. A.; Campbell, W.H. (1933) *Hydrogen: A Commercial Fuel for Internal Combustion Engines and Other Purposes*. Journal of Inst. Fuel. 6:277-90.

Fanhua Ma; Mingyue Wang. (2010) *Performance and emission characteristic of a turbocharged spark-ignition hydrogen-enriched compressed natural gas with high hydrogen ratio.* Int. Journal of Hydrogen Energy 2010;356438-47

Ghiffari. Y.A.; Sungkono, D. (2013) *Study of HHO Gas Generator Characteristics Wet Cry Cell and Cell type with dimensions of 80x 80 mm with the addition of PWM E-3 FF (1 kHz)*. Pomits Engineering Journal Vol. 1 No. 1. (2013).

Harper, D. (2007) *Online Etymology Dictionary*. (Access date: 12 April 2010) http://www.etymonline.com/index.php?search=energy&searchmode=none

Hekkert, M.P.; Van-Giessel, J.F.;,Ros, M.; Wietschel, M.; Meeus, M.T.H. (2005) *The evolution of hydrogen research: is Germany heading for an early lock-in?* Int. Journal of Hydrogen Energy 2005;30:1045-52

Herzog, A.V.; Lipman T. E., Kammen D. M.; (2006) Renewable Energy

Haywood, J. B. (1998*) Internal Combustion Engine Fundamentals*. McGraw-Hill Publication. Massachusetts Institute of Technology, Boston, USA. 15-371.

Hoehn, F. W.; Parks, M. W. (1974) *Feasibility Demonstration of a Road Vehicle Fueled with Hydrogen-Enriched Gasoline*, Ninth Intersociety Energy Conversion Engineering Conference. Am, Soc. Mech. Eng., 1974, pp. 956-964

Hoehn, R. W.; Baisley, R. L.; and Dowdy, M. W. (1975) *Advantages in Ultra-lean Combustion Technology Using Hydrogen-Enriched Gasoline.* Tenth Intersociety Energy Conversion Engineering Conference. Inst. Electric. Electron. Eng., 1975, pp 1156-1164

Ijret International (2015) *Application of dry cell HHO gas generator with pulse width modulation on spark ignition engine performance*. Journal of Research in Engineering and Technology

Jingding, L.; Linsong, G.; Tianshen, D. (1998) *Formation and Restraint of Toxic Emissions in Hydrogen–Gasoline Mixture Fueled Engines*. International Journal of Hydrogen Energy, 23(10):971-5.

Kahraman, E. (2005) *Analysis of a Hydrogen-Fueled Internal Combustion Engine*. The Graduate School of Engineering and Sciences of İzmir Institute of Technology. M.Sc. Thesis 71 p.

Keith, Wayne (2012) Wood Gas Video Series. https://www.youtube.com/watch?v=_tA0stq9rjg

King, R. O.; Rand, M. (1955) *The Hydrogen Engine*. Canadian Journal of Technology.

Krawczyk, T. (1996) *Biodiesel– Alternative Fuel Makes Inroads but Hurdles Remain*. American Oil Chemists Society Second Edition.California, USA,

Lee, R. C. Brehob, W. (1971) *Effect of Compression Ratio, Mixture Strength, Spark Timing, and Coolant Temperature Upon Exhaust Emissions and Power*. SAE Paper 710832, Oct. 1971 NASA

Lee, R. C. Brehob, W. (1971) *Mechanisms of Pollutant Formation and Control from Automotive Sources.* SAE Paper 710483, June 1971 NASA

Lilik, G.K.; Zhang, H.J.; Herreros, M.D.; Haworth, C.; Boehman, A. L. (2010) *Hydrogen assisted diesel combustion.* International Journal of Hydrogen Energy, vol. 35, pp. 4382-4398, 2010.

Masood, M.; Ishraat, M. M.; Reddy, A. S. (2007) *Computational Combustion and Emission Analysis of Hydrogen–Diesel Blends with Experimental Verification*. International Journal of Hydrogen Energy,32:2539-47.

Masood, M.; Isharat, M.M.; Reddy, A.S. (2006) *Computational Combustion and Emission Analysis of Hydrogen–Diesel Blends with Experimental Verification*. International Journal of Hydrogen Energy, 32:2548-52.

MCcarthy J. (2008) *Hydrogen Study*. Stanford University. (Access date: 10 March, 2010) http://wwwformal.stanford.edu/jmc/progress/hydrogen.html

Medhursta, Martin J. (2009) *The Military-Industrial Complex and the New Industrial State.* Re-conceptualizing rhetorical history: Eisenhower's farewell address pages 195-218, Publishing models and article dates explained Published online: 05 Jun 2009.

Michrowski, A. (1993) *Anomalous Water Explained by Brown's Gas Research.* Planetary Association for Clean Energy Newsletter. 6 (4):10-11. 74 -- 1993. Yull Brown's Gas. Planet. Assoc. Clean Energy News, 6 (4):10- 11.

Millman, J.; Grabel, A. (1987*) Microelectronics*. Second Edition. McGraw-Hill Inc. Publication. New York, USA. 690 p.

Mohamed, M.; Kassaby, EL.; Yehia, A.; Eldrainy, Mohamed E.; Khidr, Kareen; Khidr, I.(2015) *Effect of hydroxy (HHO) gas addition on gasoline engine performance and emissions.* Alexandria University, Alexandria Engineering Journal. Mechanical Engineering Department, Faculty of Engineering, Alexandria University, Egypt. 8 June 2015. Faculty of Engineering, Alexandria University. Production and hosting by Elsevier B.V. This is an open access article under the CC BY-NC-ND License.

Momirlan ,M.; Veziroglu, TN. (2002) *Current status of hydrogen energy.* Renewable Sustainable Energy Rev. 2002;6:141-79

Morse, J (2016) HHO A Viable fossil fuel additive http://www.jefferymorse.net/wp-content/uploads/2016/08/Morse_J_Methods%20and%20Applications.pdf

Musmar, Sa'ed A.; Ammar A. Al-Rousan. (2011) *Effect of HHO gas on combustion emission in gasoline engines.* Department of Mechanical Engineering , Faculty of Engineering, Mutah University, Mutah, Al-Karak 61710, Jordan 16 Feb 2011

Pogue, (1962) *US Patent Pogue carb,* U.S. Pat. 2,025,798. CARBURETOR Filed Sept. 2'7, 1935 https://www.google.com/patents/US3049850

Rajaram, S. (2014) *Effectiveness of oxygen enriched hydrogen-HHO gas addition on direct injection diesel engine performance, emission, and combustion characteristics*. 18(1), 259-268.

Rajeshkumar G.; Rajapandian R.; Surendrakumar G.; Ananth Kumar P.; Vasanthanseelan S.; Senthil Ganesh A. (2016) *Experimental investigation of emission control in IC Engines By introducing various techniques.* Engineering & Technology in India www.engineeringand technologyinindia.com Vol 1:2 March 2016

Shell; Richard, Michael Graham (2008) 350mpg Shell Car. (Online). http://www.treehugger.com/cars/souped-down-1959-opel-t-1-gets-37659-mpg.html

Rogelj, J,; Schaeffer. M.; Meinshausen,M.; Knutti, R.; Alsomo, J.; Riahi, K.; and Hare, W. (2015). *Zero emission targets as long-term global goals for climate protection.* Environmental Research Letters. 10(10). 105007. DOI:10.1088/1748-9326/10/10/105007.

Rystad, Energy (2015). UCube, Version 1.18 Oslo. Norway. http://www.rystadenergy.com/Databases/UCube. Media

Sankar, T. (2014) *The effect of oxy-hydrogen (HHO) on the performance and emission characteristics of diesel and karanj in single cylinder four stroke diesel engine*. 2(1), 12-18

Santilli, R.M. (2006) *A new gaseous and combustible form of water.* International Journal of Hydrogen Energy, vol. 31, pp. 1113-1128, 2006.

Saravanan, N.; Nagarajan, G. (2008) *An Experimental Investigation of Hydrogen-Enriched Air Induction in a Diesel Engine System*. International Journal of Hydrogen Energy.

Schulti, I.; Hart, D.; Vorst, R. (2004) *Issues affecting the acceptance of hydrogen fuel.* Int. Journal of Hydrogen Energy, 2004;29:677-85

Sierens, R; Rosseel, E. (1995) *Sequential injection of gaseous fuels.* In: Proceeding of the 5th International Congress: the European automotive industry meets the challenges of the year 2000; 1995 June 21-23. Strasbourg: EAEC Congress; 1995. P. SIA 9506A03

Sierens, T.; Rosseel, E. (1998) *Variable composition hydrogen/natural gas mixtures for increased engine efficiency and decreased emissions*. In: Proceeding of the spring engine technology conference; FortLauderadale; 1998 April 26-29. ASME; 1998. P. 98-ICE-105.

Stebar, R.F.; Parks, F.B. (1974) *Emission Control with Lean Operation Using Hydrogen-Supplemented Fuel.* SAE Paper (Document No.740187).

Tauzia, X.; Maiboom, A.; Shah, S.R. (2010) *Experimental study of inlet manifold water injection on combustion and emissions of an automotive direct injection Diesel engine.* Energy, vol. 35, pp. 3628-3639, 2010.

Tekin, M.; Cavusoglu, Y. (1997) *Pollutant Formation and Its Control in Internal Combustion Engines*. 1st Automotive Technology Congress with International Participation, May, 26-30, Adana, Turkey.

Tesla, N. (1889) *Thermo-Magnetic Motor*. Patent 396,121, Specification forming part of Letters Patent No. 396,121, dated January 15, 1889. Application filed March 30, 1886. Serial No. 197,115.

Vader, N.V.; Joshi, V.A. (2005) *Wind Power Generation Technology*. Two Days National Seminar on Alternative Energy Resources. August, 27-28, Thane, India.

Venkataraman, B.; Elango, D. (1998) *Renewable Energy Sources*, Hindustan College of Engg, Padur-603 103 Tamil Nadu

Verhelst, S.; Wallner, T. (2009) *Hydrogen-fueled internal combustion engines*. Progress in Energy and Combustion Science 35 (2009) 490-527

Walsh, M. P. (2001) *Global Trends in Diesel Emissions Regulation-A 2001 Update.* SAE paper, pp. 01-0183, 2001.

Wang, S.; Ji, C.; Zhang, B.; Liu, X. (2014) *Realizing the part load control of a hydrogen-blended gasoline engine at the wide open throttle condition*. Int. Journal of Hydrogen Energy 39(2014) 7428-7436

Wang, S.; Ji, C. (2012) *Cyclic variation in a hydrogen-enriched spark-ignition gasoline engine under various operation conditions*. Int. Journal of Hydrogen Energy 37 (2012) 1112-1119

Wang, S.; Ji, C.; Zhang, B.; Liu, X. (2012) *Performance of a hydro-oxygen-blended gasoline engine at different hydrogen volume fractions in the hydro-oxygen*. Int. Journal of Hydrogen Energy 37 (2012) 13209-13218

Wang, S.; Ji, C.; Zhang, B. (2011) *Starting a spark-ignited engine with the gasoline-hydrogen mixture*. Int. Journal of Hydrogen Energy 36 (2011) 4461-4498

Wang, S.; Ji, C.; Zhang, B.; Zhang, J. (2011) *Comparison of the performance of a spark-ignited gasoline engine blended with hydrogen and hydrogen-oxygen mixtures*, Energy 36 (2011) 5832-5837

Wang, S.; Ji, C.; Zhang, B.; Zhang, J. (2011) *Improving the performance of a gasoline engine with the addition of hydrogen-oxygen mixtures*. Int. Journal of Hydrogen Energy 36(2011) 11164-11173

Wang, S.; Ji, C.; Zhang, B. (2010*) Effect of spark timing on the performance of a hybrid hydrogen-gasoline engine at lean conditions*, Int. Journal of Hydrogen Energy 35 (2010) 2203-2012.

Wang, S.; Ji, C. (2010) *Experimental study on combustion and emissions performance of a hybrid hydrogen-gasoline engine at lean burn limits*. Int. Journal of Hydrogen Energy 35 (2010) 1453-1462

Wang, S.; Ji, C. (2009) *Combustion And Emissions Performance of a Hybrid Hydrogen–Gasoline Engine at Idle and Lean Conditions.* International Journal of Hydrogen Energy, 35(1): 346-55.

Wang, S.; Ji, C. (2009) *Effect of hydrogen addition on combustion and emissions performance of a spark ignition gasoline engine at lean conditions*. Int. Journal of Hydrogen Energy 34 (2009) 7823-7834

White, C.M.; Steeper, T.T.; Lutz, A.E. (2006) *The hydrogen-fueled internal combustion engine: a technical review*, Int. J. Hydrogen Energy 31 (2006) 1292-1305

Widhiyanuriyawan, Denny (2016) 325999: *All other miscellaneous chemical product manufacturing.* 325998: *All Other Miscellaneous Chemical Product and Preparation Manufacturing.* 221210: *Natural Gas Distribution.* 325181: *Alkali and chlorine manufacturing.* 325180: *Other Basic Inorganic Chemical Manufacturing.* 325189: *All other basic inorganic chemical manufacturing.* Applied Mechanics & Materials; 2016, Vol. 836, p294-298, 5p (2016).

Wyer, Samuel S. (1906) *A Treatise on Producer- Gas and Gas producers*. American society mechanical engineers, Library of the University of California, Hill Publishing Company New York and London, The Engineering and Mining Journal, Power, American Machinist. 1907 http://www.driveonwood.com/static/media/uploads/pdf/treatise_on_producer_gas_and_gas_producers.pdf

Yilmaz, A.C., Ulundamar, E., Aydin, K (2010) *Effect of Hydroxy (HHO) gas addition on performance and exhaust emissions in compression ignition engines.* Int. Journal of Hydrogen Energy 2010;35:11366-72 http://doi.org/10.1016/j.jihydene.2010.07.040

Yilmaz, Ali Can (2010) *Design and application of Hydroxy HHO system.* Cukurova University Institute of Natural and Applied sciences MSc Thesis Ali Can Yilmaz. Department of Mechanical Engineering Adana, 2010 12-07-2010.

Yilmaz, A. C.; Uludamar, E.; Aydin, K. (2010) *Effect of hydroxy (HHO) gas addition on performance and exhaust emissions in compression ignition engines*. International Journal of Hydrogen Energy, vol. 35, pp. 11366-11372, 2010.

Zeng K. & Zhang, D. (2010) *Recent progress in alkaline water electrolysis for hydrogen production and applications.* Progress in Energy and Combustion Science, vol. 36, pp. 307-326, 2010.

Zweig, R. M. (1992) *Proceedings of the Ninth World Hydrogen Energy Conference.* October, 8-12, Paris, France.

Data Sources
http://folk.uio.no/glen Graphs and data for Emission is China
EPA.gov for Data concerning EPA
https://data.ny.gov For Emission Data in New York
http://jefferymorse.net for Data on my experiment

Appendix

Appendix A. D.C. Voltages in distilled water.

d.c.	Volts	amps	ml	by sight	minutes	delta T
	2	0	0	no	0	0
	5	0	0	no	0	0
	9	0	0	no	0	0
	12	0	0	no	0	0
	15	0	0	no	0	0
	20	0	0	no	0	0
	112	0	0	no	0	0
	190	0.02	2	yes	20	2
	2100	0.25	30	yes	2	10

Appendix B. D.C Volt versus Amps Comparison.

Volts:amps

0:0	4.6:0.02	4.7:0.03	5:0.04	5.3:0.05	5.8:0.06
5.9:0.07	6.2:0.08	6.4:0.09	6.6:0.1	6.8:0.11	7:0.12
7.3:0.13	7.4:0.14	7.6:0.15	7.8:0.16	8:0.17	8.3:0.18
8.5:0.19	8.7:0.2	8.9:0.21	9:0.22	9.2:0.23	9.5:0.24
9.7:0.25	9.9:0.26	10.1:0.27	10.3:0.28	10.5:0.29	10.6:0.3
10.8:0.31	11:0.32	11.2:0.33	11.4:0.34	11.6:0.35	11.8:0.36
12:0.37	12.2:0.38	12.4:0.39	12.6:0.4	12.8:0.41	13:0.42
13.1:0.42	13.2:0.43	13.3:0.43	13.4:0.43	13.5:0.43	13.6:0.44
13.7:0.44	13.8:0.44	13.9:0.44	14:0.44	14.1:0.44	14.2:0.44
14.3:0.44	14.4:0.44	14.5:0.44	14.6:0.43	14.7:0.43	14.8:0.43
14.9:0.43	15:0.42	15.1:0.42	15.2:0.41	15.3:0.41	15.4:0.41
15.5:0.4	15.6:0.39	15.7:0.39	15.8:0.38	15.9:0.38	16:0.38
16.1:0.37	16.2:0.35	16.3:0.35	16.4:0.33	16.5:0.31	16.6:0.28
16.7:0.27	16.8:0.27	16.9:0.27	17:0.26	17.1:0.24	17.2:0.23
17.3:0.2	17.4:0.19				

Appendix C. Audio Signal voltage and amperage with distilled water.

Hz	Amp ma	Volts	Hz	Amp ma	Volts	Hz	Amp ma	Volts	Hz	Amp ma	Volts
20	27.7	0.2	30	30	0.3	40	25.7	0.4	50	27.8	0.4
60	35.3	0.4	70	39.7	0.4	80	42.5	0.4	90	44.7	0.4
100	46.9	0.4	110	48.8	0.4	120	50.5	0.4	130	51.9	0.4
140	53.2	0.4	150	54.2	0.5	160	55.3	0.5	170	56.2	0.5
180	57.2	0.5	190	57.9	0.5	200	58.6	0.5	210	59.2	0.5
220	59.8	0.5	230	60.4	0.5	240	61	0.5	250	61.3	0.5

260	61.7	0.6	270	61.9	0.6	280	62.1	0.6	290	62.4	0.6
300	62.8	0.6	310	63	0.6	320	62.9	0.6	330	62.9	0.6
340	63	0.6	350	62.8	0.6	360	63.2	0.6	370	63.3	0.6
380	63.2	0.6	390	63	0.6	400	62.8	0.6	410	62.7	0.6
420	62.3	0.6	430	62.5	0.6	440	62.5	0.65	450	62	0.6
460	62.8	0.7	470	62.6	0.7	480	62.3	0.7	490	62.9	0.7
500	61.8	0.7	510	61.5	0.65	520	61.4	0.65	530	61.2	0.69
540	60.9	0.7	550	60.8	0.7	560	60.5	0.7	570	60.3	0.7
580	60.6	0.7	590	59.9	0.7	600	59.9	0.7	610	60.1	0.7
620	59.5	0.7	630	58.9	0.7	640	59	0.7	650	59.6	0.7
660	58.6	0.7	670	58.9	0.7	680	58.3	0.7	690	58.6	0.7
700	58.6	0.7	710	58	0.7	720	57.6	0.7	730	57.3	0.7
740	57.1	0.7	750	57	0.7	760	57.1	0.7	770	56.5	0.7
780	56.1	0.7	790	56.1	0.7	800	55.9	0.6	810	55.7	0.6
820	55.6	0.6	830	55.4	0.6	840	55.3	0.6	850	55.1	0.6
860	55	0.6	870	54.9	0.6	880	54.7	0.6	890	54.6	0.6
900	54.3	0.6	910	54.2	0.6	920	54.1	0.6	930	54	0.6
940	53.8	0.6	950	53.7	0.6	960	53.6	0.6	970	53.4	0.6
980	53.3	0.6	990	53.2	0.6	1000	53.2	0.6	1010	52.9	0.6
1020	52.8	0.6	1030	52.6	0.6	1040	52.5	0.6	1050	52.3	0.6
1060	52.2	0.6	1070	52.1	0.6	1080	51.9	0.6	1090	51.8	0.6
1100	51.7	0.6	1110	51.5	0.6	1120	51.4	0.6	1130	51.2	0.6
1140	50.9	0.65	1150	50.9	0.65	1160	50.7	0.69	1170	50.5	0.7
1180	50.4	0.7	1190	50.3	0.7	1200	50.3	0.7	1210	50.2	0.7
1220	50.1	0.7	1230	50	0.7	1240	49.8	0.7	1250	49.7	0.7
1260	49.5	0.7	1270	49.5	0.7	1280	49.4	0.7	1290	49.3	0.7
1300	49.2	0.7	1310	49.1	0.7	1320	48.9	0.7	1330	48.8	0.7
1340	48.7	0.7	1350	48.5	0.7	1360	48.4	0.7	1370	48.3	0.7
1380	48.2	0.7	1390	48.1	0.7	1400	48	0.7	1410	47.9	0.7
1420	47.8	0.7	1430	47.6	0.7	1440	47.5	0.7	1450	47.4	0.7
1460	47.2	0.7	1470	47.2	0.7	1480	47.1	0.7	1490	47	0.7
1500	46.8	0.7	1510	46.7	0.7	1520	46.6	0.7	1530	46.5	0.7
1540	46.3	0.7	1550	46.2	0.7	1560	46.1	0.7	1570	46	0.7
1580	45.9	0.7	1590	45.8	0.7	1600	45.7	0.7	1610	45.6	0.7
1620	45.5	0.7	1630	45.4	0.7	1640	45.3	0.7	1650	45.2	0.7
1660	45.1	0.7	1670	45	0.7	1680	44.9	0.7	1690	44.9	0.7
1700	44.8	0.7	1710	44.7	0.7	1720	44.6	0.7	1730	44.5	0.7
1740	44.4	0.7	1750	44.3	0.7	1760	44.2	0.7	1770	44	0.7
1780	43.9	0.7	1790	43.8	0.7	1800	43.7	0.7	1810	43.6	0.7
1820	43.5	0.7	1830	43.4	0.7	1840	43.3	0.7	1850	43.2	0.7
1860	43.1	0.7	1870	43	0.7	1880	42.9	0.7	1890	42.8	0.7
1900	42.7	0.7	1910	42.6	0.7	1920	42.5	0.7	1930	42.4	0.7
1940	42.3	0.7	1950	42.2	0.7	1960	42.2	0.7	1970	42.1	0.7
1980	42	0.7	1990	41.9	0.7	2000	41.8	0.7	2010	41.7	0.7
2020	41.6	0.7	2030	41.5	0.7	2040	41.4	0.7	2050	41.3	0.7
2060	41.2	0.7	2070	41.1	0.7	2080	41	0.7	2090	40.9	0.7
2100	40.8	0.7	2110	40.7	0.7	2120	40.6	0.7	2130	40.5	0.7
2140	40.4	0.7	2150	40.3	0.7	2160	40.2	0.7	2170	40.2	0.7

2180	40.1	0.7	2190	40	0.7	2200	39.9	0.7	2210	39.8	0.7
2220	39.7	0.7	2230	39.6	0.7	2240	39.5	0.7	2250	39.4	0.7
2260	39.3	0.7	2270	39.2	0.7	2280	39.2	0.7	2290	39.1	0.7
2300	39	0.7	2310	38.9	0.7	2320	38.8	0.7	2330	38.7	0.7
2340	38.6	0.7	2350	38.5	0.7	2360	38.4	0.7	2370	38.3	0.7
2380	38.2	0.7	2390	38.1	0.7	2400	38.1	0.7	2410	38	0.7
2420	37.9	0.7	2430	37.9	0.7	2440	37.8	0.7	2450	37.7	0.7
2460	37.6	0.7	2470	37.6	0.7	2480	37.5	0.7	2490	37.5	0.7
2500	37.4	0.7	2510	37.3	0.7	2520	37.2	0.7	2530	37.2	0.7
2540	37.1	0.7	2550	37	0.7	2560	36.9	0.7	2570	36.8	0.7
2580	36.8	0.7	2590	36.7	0.7	2600	36.6	0.7	2610	36.5	0.7
2620	36.5	0.7	2630	36.4	0.7	2640	36.3	0.7	2650	36.2	0.7
2660	36.1	0.7	2670	36	0.7	2680	35.9	0.7	2690	35.9	0.7
2700	35.8	0.7	2710	35.7	0.7	2720	35.6	0.7	2730	35.6	0.7
2740	35.5	0.7	2750	35.5	0.7	2760	35.4	0.7	2770	35.4	0.7
2780	35.3	0.7	2790	35.3	0.7	2800	35.2	0.7	2810	35.1	0.7
2820	35.1	0.7	2830	35	0.7	2840	34.9	0.7	2850	34.9	0.7
2860	34.8	0.7	2870	34.8	0.7	2880	34.7	0.7	2890	34.6	0.7
2900	34.6	0.7	2910	34.5	0.7	2920	34.4	0.7	2930	34.4	0.7
2940	34.3	0.75	2950	34.3	0.75	2960	34.2	0.75	2970	34.1	0.75
2980	34.1	0.75	2990	34	0.75	3000	33.9	0.75	3010	33.8	0.75
3020	33.8	0.75	3030	33.7	0.75	3040	33.6	0.75	3050	33.6	0.75
3060	33.5	0.75	3070	33.5	0.75	3080	33.4	0.75	3090	33.3	0.75
3100	33.3	0.75	3110	33.2	0.75	3120	33.1	0.75	3130	33.1	0.75
3140	33	0.75	3150	32.9	0.75	3160	32.8	0.75	3170	32.8	0.75
3180	32.8	0.75	3190	33.7	0.75	3200	32.7	0.75	3210	32.6	0.75
3220	32.6	0.75	3230	32.5	0.75	3240	32.4	0.75	3250	32.4	0.75
3260	32.3	0.75	3270	32.3	0.75	3280	32.2	0.75	3290	32.2	0.75
3300	32.1	0.75	3310	32.1	0.75	3320	32	0.75	3330	31.9	0.75
3340	31.9	0.75	3350	31.8	0.75	3360	31.8	0.75	3370	31.7	0.75
3380	31.7	0.75	3390	31.6	0.75	3400	31.6	0.75	3410	31.5	0.75
3420	31.5	0.75	3430	31.4	0.75	3440	31.4	0.75	3450	31.3	0.75
3460	31.3	0.75	3470	31.2	0.75	3480	31.2	0.75	3490	31.1	0.75
3500	31	0.75	3510	31	0.75	3520	30.9	0.75	3530	30.8	0.75
3540	30.8	0.75	3550	30.7	0.75	3560	30.7	0.75	3570	30.6	0.75
3580	30.5	0.75	3590	30.5	0.75	3600	30.4	0.75	3610	30.4	0.75
3620	30.3	0.75	3630	30.3	0.75	3640	30.2	0.75	3650	30.1	0.75
3660	30.1	0.75	3670	30	0.75	3680	30	0.75	3690	30	0.75
3700	29.9	0.75	3710	29.9	0.75	3720	29.8	0.75	3730	29.8	0.75
3740	29.7	0.75	3750	29.7	0.75	3760	29.7	0.75	3770	29.6	0.75
3780	29.6	0.75	3790	29.6	0.75	3800	29.5	0.75	3810	29.5	0.75
3820	29.5	0.75	3830	29.4	0.75	3840	29.4	0.75	3850	29.4	0.75
3860	29.3	0.75	3870	29.3	0.75	3880	29.2	0.75	3890	29.2	0.75
3900	29.2	0.75	3910	29.1	0.75	3920	29.1	0.75	3930	29	0.75
3940	29	0.75	3950	29	0.75	3960	28.9	0.75	3970	28.9	0.75
3980	28.8	0.75	3990	28.8	0.75	4000	28.8	0.75	4010	28.7	0.75
4020	28.7	0.75	4030	28.6	0.75	4040	28.6	0.75	4050	28.5	0.75
4060	28.5	0.75	4070	28.5	0.75	4080	28.4	0.75	20000	5.4	0.8

Appendix D. Audio Signal with Full Wave Rectifier, Voltages at Cell electrodes.
Hz: hz after full wave: volts at post DC

20	40	2.8:	120	240	2.5:	220	440	2.4:	320	640	2.3
420	840	2	520	1040	2.5	620	1240	2.6	720	1440	2.7
820	1640	2.7	920	1840	2.8	1020	2040	2.8	1120	2240	2.9
1220	2440	2.9	1320	2640	3	1420	2840	3.1	1520	3040	3.2
1620	3240	3.3	1720	3440	3.3	1820	3640	3.4	1920	3840	3.5
2020	4040	3.6	2120	4240	3.6	2220	4440	3.7	2320	4640	3.8
2420	4840	3.8	2520	5040	3.9	2620	5240	4	2720	5440	4.1
2820	5640	4.2	2920	5840	4.2	3020	6040	4.3	3120	6240	4.4
3220	6440	4.5	3320	6640	4.6	3420	6840	4.7	3520	7040	4.8
3620	7240	4.9	3720	7440	4.9	3820	7640	5	3920	7840	5.1
4020	8040	5.2	4120	8240	5.2	4220	8440	5.3	4320	8640	5.4
4420	8840	5.5	4520	9040	5.6	4620	9240	5.6	4720	9440	5.7
4820	9640	5.8	4920	9840	5.9	5020	10040	6	5520	11040	6.4
6020	12040	7	6520	13040	7.2	7020	14040	7.8	7520	15040	8.2
8020	16040	8.8	8520	17040	9.3	9020	18040	9.8	9520	19040	10.3
10020	20040	11	10520	21040	11.2	11020	22040	11.8	11520	23040	12.1
12020	24040	12.4	12520	25040	12.7	13020	26040	13.2	13520	27040	13.4
14020	28040	17									

Appendix E. Production and current results from an audio signal through a full wave rectifier. With voltage held at 10 Volts.

Hz from source	Hz after Rectifier	Volts @P	Amps @P	Ml	Delta T	Visual	Time
20	40	10	0.37	15	0	yes	2
23.5	47	10	0.45	15	0	yes	2
26.75	53.5	10	0.42	15	0	yes	2
63.75	127.5	10	0.44	16	0	yes	2
120	240	10	0.37	15	0.3	yes	2
220	440	10	0.37	15	0.3	yes	2
320	640	10	0.36	15	0	yes	2
420	840	10	0.37	15	-0.3	yes	2
520	1040	10	0.37	15	0.6	yes	2
620	1240	10	0.37	15	0.3	yes	2
720	1440	10	0.37	15	0	yes	2
820	1640	10	0.37	15	0	yes	2
920	1840	10	0.37	15	-0.3	yes	2
1020	2040	10	0.37	15	0	yes	2
1120	2240	10	0.36	15	0.6	yes	2
1220	2440	10	0.36	15	0	yes	2
1320	2640	10	0.29	15	0.3	yes	2
1420	2840	10	0.29	15	0	yes	2
1520	3040	10	0.29	15	0.3	yes	2
1620	3240	10	0.29	15	0	yes	2

1720	3440	10	0.29	15	0	yes	2
1820	3640	10	0.29	15	0.3	yes	2
1920	3840	10	0.27	15	0	yes	2
2020	4040	10	0.28	15	0	yes	2
2120	4240	10	0.27	15	0	yes	2
2220	4440	10	0.27	15	0	yes	2
2320	4640	10	0.27	15	0	yes	2
2420	4840	10	0.27	15	0	yes	2
2520	5040	10	0.29	15	0	yes	2
2620	5240	10	0.29	15	0	yes	2
2720	5440	10	0.28	15	0	yes	2
2820	5640	10	0.28	15	0.2	yes	2
2920	5840	10	0.27	15	0	yes	2
3020	6040	10	0.27	15	0	yes	2
3120	6240	10	0.26	15	0	yes	2
3220	6440	10	0.17	15	0	yes	2
3320	6640	10	0.18	15	0	yes	2
3420	6840	10	0.18	15	0	yes	2
3520	7040	10	0.19	15	0	yes	2
3620	7240	10	0.18	15	0	yes	2
3720	7440	10	0.18	15	-0.6	yes	2
3820	7640	10	0.18	15	0.4	yes	2
3920	7840	10	0.18	15	0	yes	2
4020	8040	10	0.18	15	0.9	yes	2
4120	8240	10	0.17	15	0.9	yes	2
4220	8440	10	0.17	15	0.2	yes	2
4320	8640	10	0.17	15	0	yes	2
4420	8840	10	0.17	15	0	yes	2
4520	9040	10	0.16	15	-0.2	yes	2
4620	9240	10	0.16	15	-0.3	yes	2
4720	9440	10	0.15	15	-0.3	yes	2
4820	9640	10	0.15	15	0	yes	2
4920	9840	10	0.15	15	0	yes	2
5020	10040	10	0.14	16	0	yes	2
9840	19680	10	0	16	0	yes	2

Appendix F. Production and current results from an audio signal through a full wave rectifier.

Hz from source	Hz after Rect	Volts @P	Amps ma @P	Ml	Delta T	Visual	Time
20	40	10	32	10	0	yes	1
23.5	47	10.8	40	14	0	yes	1
26.5	53	13.7	60	14	0	yes	1
63.75	127.5	13.5	60	15	0	yes	1

120	240	16.8	54	22	0	yes	1
220	440	18.4	50	15	2.7	yes	1
320	640	18.9	40	30	0.6	yes	1
420	840	19.1	36	30	1.2	yes	1
520	1040	19.3	32	31	0.3	yes	1
620	1240	19.4	25	32	0.5	yes	1
720	1440	19.2	24	32	0.6	yes	1
820	1640	19	22	33	0.9	yes	1
920	1840	18.9	21	32	1.2	yes	1
1020	2040	18.8	20	35	0.9	yes	1
1120	2240	18.8	19	36	0.3	yes	1
1220	2440	22	19	36	0	yes	1
1320	2640	21.3	19	38	1	yes	1
1420	2840	20.7	18	38	1.8	yes	1
1520	3040	20.7	18	38	1.2	yes	1
1620	3240	20.5	14	35	1.5	yes	1
1720	3440	20.5	13	34	1.2	yes	1
1820	3640	20.3	13	32	0.9	yes	1
1920	3840	20.6	13	38	1.8	yes	1
2020	4040	20.5	13	35	1.2	yes	1
2120	4240	20.2	11	35	0.9	yes	1
2220	4440	20	11	35	1.2	yes	1
2320	4640	19.8	11	34	1.5	yes	1
2420	4840	19.6	11	30	0.8	yes	1
2520	5040	19.4	10	31	0.9	yes	1
2620	5240	18.1	10	30	0.6	yes	1
2720	5440	18.1	10	30	0	yes	1
2820	5640	18.1	10	30	0	yes	1
2920	5840	18	10	29	0	yes	1
3020	6040	17.9	10	29	0	yes	1
3120	6240	17.7	10	29	0.6	yes	1
3220	6440	17.6	10	28	0.6	yes	1
3320	6640	19.9	10	29	0.6	yes	1
3420	6840	20.1	10	29	0.7	yes	1
3520	7040	19.8	10	32	0.9	yes	1
3620	7240	19.6	10	29	1.2	yes	1
3720	7440	19.1	9	29	1.5	yes	1
3820	7640	19.1	9	29	0.6	yes	1
3920	7840	18.9	9	29	-0.1	yes	1
4020	8040	18.8	9	30	0	yes	1
4120	8240	18.9	9	29	-0.3	yes	1
4220	8440	18.7	6	30	-0.1	yes	1
4320	8640	18.5	6	29	0	yes	1
4420	8840	18.3	6	28	1.5	yes	1
4520	9040	18.3	6	29	1.5	yes	1

4620	9240	18	6	29	1.8	yes	1
4720	9440	17.8	5	29	0.9	yes	1
4820	9640	17.7	5	28	1.6	yes	1
4920	9840	17.6	5	28	0.6	yes	1
5020	10040	17.2	6	29	0.9	yes	1
11220	22440	17.2	0	28	1.1	yes	1
11320	22640	16.4	0	21	0	yes	1
16220	32440	16.7	0	25	0	yes	1

Appendix G: Logged Data – Exhaust Emissions

Exhaust Emissions Data (Averaged)								
Load (kW)	Water	HHO (L/min)	CO(g/L)	O2(g/L)	NOx(g/L)	AFR(--)	LDA(--)	Eff(%)
9.91	0%	0	5.6	5728.1	17.33	47.4	3.3	99.6
9.91	0%	2	4.8	5724.0	16.80	47.4	3.3	99.6
9.91	0%	4	4.9	5773.7	16.29	47.7	3.3	99.6
9.91	0%	6	5.8	5783.5	15.91	47.7	3.3	99.5
9.91	10%	0	5.5	5723.8	17.11	47.4	3.3	99.6
9.91	10%	2	5.7	5723.4	16.43	47.4	3.3	99.5
9.91	10%	4	4.9	5789.2	15.66	47.8	3.3	99.6
9.91	10%	6	5.4	5796.0	15.28	47.8	3.3	99.5
19.1	0%	0	6.3	2578.5	23.06	29.3	2.0	99.6
19.1	0%	2	6.3	2614.3	22.72	29.5	2.0	99.6
19.1	0%	4	6.3	2619.8	22.61	29.6	2.0	99.6
19.1	0%	6	6.2	2621.1	22.63	29.6	2.0	99.6
19.1	10%	0	6.3	2546.4	22.17	29.1	2.0	99.6
19.1	10%	2	5.6	2553.9	21.88	29.2	2.0	99.6
19.1	10%	4	5.8	2562.9	21.78	29.2	2.0	99.6
19.1	10%	6	5.7	2563.0	21.56	29.2	2.0	99.6

On-board HHO Test						
HHO (L/min)	Load (kW)	Diesel (g/h)	EGT (C)	Water Injection	Relative humidity	IAT (K)
0.0	9.91	3430.0	216.7	0%	16.1	297.4
2.0	9.91	3488.4	223.3	0%	13.3	299.3
4.0	9.91	3543.5	229.7	0%	11.8	301.1
6.0	9.91	3623.1	236.4	0%	11.0	302.4
0.0	9.91	3393.9	228.0	10%	9.6	304.8
2.0	9.91	3470.8	231.3	10%	9.0	305.5
4.0	9.91	3555.0	234.5	10%	9.3	305.1
6.0	9.91	3639.0	238.6	10%	9.0	304.8
0.0	19.1	5173.5	324.5	0%	6.0	310.6
2.0	19.1	5277.8	329.3	0%	5.5	311.6
4.0	19.1	5365.3	335.8	0%	5.0	312.3
6.0	19.1	5466.3	342.5	0%	4.9	313.1
0.0	19.1	5205.3	332.2	10%	4.4	313.9
2.0	19.1	5309.3	335.2	10%	4.1	314.2
4.0	19.1	5391.4	339.4	10%	4.2	314.3
6.0	19.1	5507.9	345.0	10%	4.3	314.5

External Supplied HHO Test						
HHO (L/min)	Load (kW)	Diesel (g/h)	EGT (K)	Water Injection	Relative humidity	IAT (K)
0.0	9.91	3423.5	225.9	0%	8.6	303.9
2.0	9.91	3407.4	227.7	0%	8.0	305.3
4.0	9.91	3385.4	229.3	0%	7.6	306.5
6.0	9.91	3372.9	230.3	0%	6.9	307.3
0.0	9.91	3412.6	230.4	10%	6.8	307.6
2.0	9.91	3417.6	230.3	10%	7.3	306.8
4.0	9.91	3405.9	229.7	10%	7.3	306.8
6.0	9.91	3399.6	229.9	10%	7.4	307.0
0.0	19.1	5198.2	326.0	0%	4.4	313.4
2.0	19.1	5184.4	327.6	0%	3.5	315.3
4.0	19.1	5157.0	330.4	0%	2.9	317.3
6.0	19.1	5165.8	332.8	0%	3.0	317.8
0.0	19.1	5237.6	333.5	10%	3.0	317.0
2.0	19.1	5229.8	334.0	10%	3.3	316.8
4.0	19.1	5212.6	333.7	10%	3.1	317.0
6.0	19.1	5206.1	334.0	10%	3.3	317.0

Appendix H. New York State Data Emissions

https://data.ny.gov/Energy-Environment/Greenhouse-Gas-Emissions-From-Fuel-Combustion-Mill/djfn-trk4

Year	Residential Total	Commercial Total	Industrial Total	Transportation Total	Electric Generation Total	Net Imports of Electricity	Year Total
2012	30.7	21	10.6	68	32.2	9.5	171.9
2011	31.4	24.3	14.9	72.2	33.4	9.1	185.3
2010	32.2	25.1	10.5	73.1	37.3	9.6	187.8
2009	33.4	25.4	11.5	76.7	34	9	190.1
2008	35.1	25.8	13.8	80	42.5	8.6	205.9
2007	36.9	26.7	14.1	81.8	48.8	7.5	215.8
2006	33	25.4	14.6	84.1	45.9	6.7	209.9
2005	39.7	28.6	15	84	53.6	6.6	227.5
2004	38.8	34.8	14.1	82.9	52	6.4	228.9
2003	39.3	32.8	14	82.7	51.7	6.6	227.2
2002	36.7	31.1	14.9	80.6	50.7	6.2	220
2001	38.9	30.7	16.3	78.3	54.9	3.8	223
2000	40.2	32.2	17.5	78.9	55.7	5.7	230.1
1999	35.1	30.3	18	77.3	56.4	2.5	219.7
1998	32.4	27.8	21.7	75	56	1.1	214
1997	35.6	29.8	22.5	72.8	52.3	1.8	214.8
1996	37.2	27.9	23.3	72.5	46.8	3.4	211.2
1995	34.9	27	22.5	67.7	51.3	4.3	207.6
1994	35.9	27.8	20.6	65.5	47.4	6.7	203.9
1993	36.4	28.3	20.4	65.3	47.6	7.1	205
1992	36.8	27.4	20.7	63.4	53.8	6	208.2
1991	33.4	26.3	19.4	62.3	58.7	3.4	203.6
1990	34.2	26.5	20	62	63	1.6	207.3

New York State emissions Data
Data for Buffalo N.Y. https://data.ny.gov/Energy-Environment/Title-V-Emissions-Inventory-Beginning-2010/4ry5-tfin

2013 Erie Buffalo 9140200021 AURUBIS BUFFALO INC

SIC Code	VOC (tons)	NOx (tons)	CO (tons)	CO2 (tons)	Particulates (tons)	PM10 (tons)	PM2.5 (tons)
3351	15.46	12.43	978.18	35779.68	8.45	3.76	2.97

HAPS (tons)	SO2 (tons)			
0	0.18	"	Buffalo, NY	(42.887691, -78.879374)"