“Measuring the Associated Costs of Converting MSU’s Student/Public Transit System to CNG”

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Introduction

Overview

The dire economic times in America, market conditions, financial market perplexities, and the state of capital markets have ushered in a new responsibility of governance. Federal, State, and local governments have begun exploring new fiscal mechanisms of reducing costs and creating new streams of revenue sources to compensate for the heightened levels of trepidation regarding the United States financial markets and oil dependency. Government agencies have also begun using the regulatory apparatuses provided to them by Congress to ensure that there is a reduction in pollution and a clean and healthy environment. If there is a moment to muse the commonality between costs and a healthy environment, one could veraciously infer that a reduction in costs could potentially be on the horizon if both are pursued. Nevertheless, President Obama and his administration have made a commitment to be global leaders in energy efficiency, reducing carbon emissions and protecting future generations. As research suggests, there is an inundate amount of natural gas available domestically and it has been deemed a secure source of energy with minimal adverse environmental effects. In the study, Strengthening Our Economy: The Untapped U.S. Oil and Gas Resources, the revered firm ICF International discovered that America's array of oil and natural gas resources—if extracted—could generate more than $1.7 trillion in government revenue and create roughly 160,000 new jobs. [1] The Energy Information Administration projected in its Annual Energy Outlook Report in 2011 that

[1] Strengthening Our Economy: The Untapped U.S. Oil and Gas Resources. Prepared for: American Petroleum Institue. Researched conducted by: ICF International. Accessed at: http://www.api.org/Newsroom/upload/Access_Study_Final_Report_12_8_08.pdf

the natural gas demand in the United States could exceed 26.55 trillion cubic feet by the year 2035, a 16 percent increase over the projected demands in 2009. [2] As climate change legislation continues to grow and a demand for low-carbon fuels permeate in congressional discourse, the demand for natural gas will continue to increase. As technological advances are discovered and utilized accordingly, greater efficiency will be achieved in the natural gas process: extraction, treatment and transport, and combustion in boilers and turbines to generate electricity.

Goals of the Capstone Project

The steadily increase in demand for natural gas, its harmless effect on the environment—in comparisons with other energy sources—and its potential to generate new revenue is the impetus behind our capstone group electing to delve into the nuances of natural gas—that is, assessing the feasibility of converting **Mississippi State University Student/Public Transit Fleet to Compressed Natural Gas (CNG)**. In assessing the feasibility of converting MSU's Transit System, it will be of great pertinence for this research study to briefly provide a synopsis of other alternative natural gas sources (such as LNG) and why CNG is most feasible for conversion—if at all. This research will illustrate the various predicted costs that would come from conversion of MSU's bus transit system to compressed natural gas (CNG). In doing this research, available data will be synthesized from MSU's transportation department on the transit system, including but perhaps not limited to: number of vehicles, miles traveled, gas costs, maintenance costs and schedule, and vehicle turnover. The expected costs of the initial conversion and costs for purchases of future vehicles, which include the CNG system, will be analyzed. The cost of infrastructure will be thoroughly examined including: the amount of pumps that may be needed to meet MSU's needs, the onetime cost of building the pumps, the

[2] The natural gas demand analysis relies on forecasts from the EIA's Annual Energy Outlook 2011. Accessed at: http://www.eia.gov/forecasts/aeo/index.cfm

maintenance costs, any public/private pairing costs that may be found, and the costs associated with efficiently running this system. This research project will also include an analysis of the performance of these vehicles once they have become equipped with the new CNG system to illustrate the cost as compared to the expected cost of non-conversion, including the expected differences in savings from the cheaper CNG fuel.

Lastly, the methods section of this research document will fully explain how the capstone group has come to understand the costs of the conversion and trend analysis that were undertaken to predict any potential savings. An illustration will be provided for where or how the numbers were produced. In addition to a breakdown of the methods, a snapshot will be transcribed of the findings and a lucid written understanding of the proposal as the capstone group come to discover it. Moreover, there will be an illustration—governmental and non-governmental sources—of any findings associated with promotion, branding, and/or funding that could be sought with implementation of "green" technologies. The capstone group's hope is that this project will provide useful information for this institution of higher learning should administrators seek to understand more about the implementation of this sort of conversion, and serve as a model/framework should other institutions of similar demography seek to gain greater understanding of how to research cost of conversion of their own transit systems.

Literature Review

History of Natural Gas

The inquiry that often persists in both public and private settings: Why Natural Gas? Why is there such high demand for a fossil fuel that was discovered in 1821 by William Hart, who is considered by many to be the "father of natural gas?" [3] In order to fully understand the trajectory of the demand that now exists today, it is important that a written soliloquy provide a snapshot of the impediments that existed years ago with natural gas and how technology have opened gateways to new opportunities and exploration within the natural gas industry.

When natural gas was first discovered and the Fredonia Gas Light Company was founded, it was used mostly as a source of light. One of the major impediments behind natural gas being restricted to just being used as a source of light was that there existed no pipeline infrastructure that could be used as a transportation apparatus. The 19th century era was extremely vital in the progression and discovery of new technologies regarding the use of natural gas. Electricity arrival in the 19th century allowed producers of natural gas to explore new ways to use the product—natural gas lights were able to convert to electric lights. The discovery that played an integral role in engineering the natural gas industry down a new path in the 19th century was the construction of the pipeline. While this pipeline was rudimentary by any standard in today's society, it was the catalyst for the efficient transportation system of natural gas employed today. After the Second World War, the industry experienced advancements in welding techniques and pipe rolling mechanisms, which increased the pipelines' efficiency and durability. After the war, thousands of pipelines were constructed in the United States. Now that

[3] William Hart dug the first well in Fredonia, New York and after noticing gas bubbles dug a 27-foot well. He started the first American natural gas company: Fredonia Gas Light Company. Information retrieved at: www.naturalgas.org

a reliable transportation system existed for natural gas, this enabled the discovery of new uses for natural gas: heating homes, water heaters, ovens, and many other home appliances. The transportation infrastructure contributed greatly to the popularity of natural gas on several deferent fronts—like making it much easier to obtain. [4]

Before there can be a thorough understanding of the strides the natural gas industry has experienced since the 19th century, it is important that this research show the history of regulatory mechanisms employed by federal agencies and how less regulation created an environment conducive to healthy competition and market based prices. The first regulation occurred in 1938 when the United States government intervened in the natural gas industry because of the potential for the formation of a monopoly. If history served as an indicator, the United States government was afraid of the corruption and abuses that could permeate the industry as a result of the industry monopolizing—such as, but not limited to, unreasonable high prices. While regulatory mechanisms create an environment indicative of accountability, one of the major problems that are persistent in too many regulatory mechanisms is that they tend to decrease competition and create too much "red tape." During the 70s and 80s, the natural gas industry endured a number of gas shortages and price irregularities, indicating that something may have to be changed to ensure the vitality and robustness of the industry. Because of the problems the regulations caused, the United States government decided to move toward less regulation, which in turn, they hoped, would create competition, ensure fair market prices, and help the natural gas industry through the process of amelioration. The natural gas market today is regulated by the Federal Energy Regulatory Commission (FERC). According to the information

[4] Information is courtesy of: naturalgas.org. It is an educational website covering an array of topics related to the natural gas industry. The information provided is designed to provide students with a comprehensive outlook on all topics related to the natural gas industry.

provided by the natural gas information center, the industry is competitive; there aren't any strict regulations, and efficiency and technological advances have improved and increased astronomically. [5]

[5] Information is courtesy of: naturalgas.org. It is an educational website covering an array of topics related to the natural gas industry. The information provided is designed to provide students with a comprehensive outlook on all topics related to the natural gas industry.

History of Energy In Mississippi

When the oil and gas industry was discovered in Mississippi in 1903, it created opportunities for expansion in the infrastructure that strived off of agriculture (Phillips, 2013). Gas and oil helped bring increases in state revenue, job opportunities, and incentives for capital investors to assist in building the capacity for a new industry to be productive and efficient. However, this roadmap to success was not an easy task. Innovators faced barriers that included but were not limited to, 1) securing capital investments to initiate this development, 2) environmental and regulatory risk that the industry was subject to on an international, national, state, and local government intervention; and 3) unforeseen economic market conditions that stemmed from political and social influences to the rate of adoption for the industry (Phillips, 2013).

Currently, the emergence of natural gas and renewable resources are being encouraged to be utilized to reduce greenhouse gas emissions. It is just as important to understand how past developments and future expansion of new energy efficient opportunities will play a role in shaping the political, social, and economical structures of the state. While gas and diesel has dominated as the primary source in the energy sector, we must take into consideration its vulnerability of supply and demand market conditions that are contingent factors that rely heavily upon uncertainties that are unpredictable, especially for heavy duty fleets (Phillips, 2013). The volatility of economic constraints of petroleum has also led to the exploration of natural gas and renewable energy resource alternatives for fuel usage.

In Mississippi, finding shale gas is becoming of great interest to promoting the use of natural gas to circumvent the supply and demand of petroleum. Just as gasoline found its imprint within the roots of Mississippi soil, so has shale natural gas. Shale gas was found and has emerged during the development of new drilling technologies during the early 21st century (Phillips, 2013). New technologies that have developed over time are what have led to the development and utilization of other natural resources and natural gases. One impetus for drilling from a social and environmental perspective is that it does warrant a decrease in coal burning (Phillips, 2013). In comparison the development of the oil and gas industry, in Mississippi, it has also embarked upon the same challenges of creating a productive and efficient infrastructure for natural gas (Phillips, 2013). However, the future for the dependency on petroleum to reduce greenhouse gas emission relies heavily on the development of new infrastructures that will allow for practical conversion strategies to alternative fuel usage.

While Liquefied Natural Gas (LNG), propane, and Compressed Natural Gas (CNG) have all been considered viable alternatives, for the scope of our research we will focus on the utilization of CNG. For one CNG stations outnumber LNG stations. This information is critical in regards to refueling purposes. LNG vehicles and its conversion costs are much higher than CNG vehicles and conversion costs, the payback in terms of fuel cost is more rapid in heavy-duty fleets than a passenger vehicle because of the higher number of miles travelled per year and the much lower fuel mileage, which increases the potential fuel cost savings. Again, to get a substantial return economically, politically, and socially, building coalitions is a vital tool to strategize for successfully implementing building a sustainable infrastructure. Due to the lack of information available for an infrastructure such as Mississippi State University to convert heavy-duty fleet diesel vehicles to natural gas, the remainder the information gathered will rely heavily on a study that focuses on fuel cost saving and conversion considerations of Municipal fleets in Mississippi as well as various other sources.

In regards to building a sustainable and efficient infrastructure in Mississippi, three requirements must be met to ensure success. Members of both the public and private sector must be willing to work together and be willing to be change agents, diesel fuel must remain significantly higher than price of a Diesel gallon equivalent (DGE) of compressed natural, and a substantial number capital investments must be secured and gas providers discovered to assist in building an infrastructure (Breen, 2013). If prices of oil and gas were to ever decrease, it would convolute the need to convert to renewable resources or CNG. However with the trending data of rising natural gas prices, this factor doesn't pose a pressing barrier that halts this innovation from finding its mark in the Mississippi economy; thus in a State where more than 5 billion gallons of fuel are used each year in the Mississippi economy (Gasoline makes up 85%, diesel both on-road and off-road – makes up 14%. Aviation and jet fuel account for the remaining 1%.) it will be imperative to find ways to utilize alternative fuels to ensure the longevity of the oil and gas industry (Bryant, 2012).

Bryant, P. (2012). EnergyWorks: Mississippi's Energy Roadmap. Retrieved 2 April 2014. Retrieved from http://www.governorbryant.com/wp-content/uploads/2012/10/Energy-Works-Roadmap-Final.pdf

Breen, J.D.,Burke, J., & Riley, F. A. (2013, June 1). Converting Municipal Fleets to Compressed Natural Gas (CNG): Fuel Cost Savings and Conversion Considerations.*Mississippi State University- Stennis Government Institute Homepage*. Retrieved April 16, 2014, from http://www.sig.msstate.edu/sites/default/files/documents/CNG_Web_Final.pdf

Phillips, J. (2013, June 1). A Basic Overview of Oil & Gas Industry In Mississippi. *EFDMSystems.org*.Retrieved April 16, 2014, from http://efdsystems.org/pdf/Final_Overview_of_the_Oil_and_Gas_Industry.pdf

Natural Gas and its Nuances

The natural gas industry has seen exponential growth since it was first discovered during the 19th century, especially involving the production process. However, it is important before expounding on the advances in production processes that natural gas be given its due process regarding accurately defining what it is, its many components, and how it is a fuel that meets the demands of 21st century clean energy policies. Natural gas is considered one of the three major fossil fuels (coal and petroleum being the other two) used to generate energy. It is formed when layers of buried plants and animals are exposed to intense heat and pressure over a thousand years. It consists of methane and many other hydrocarbon compounds. Natural gas is odorless and colorless. It is combusted to generate electricity, which in turns enable the stored energy to be transferred into usable power. (Stroup 2013).

According to the article, “The State of Natural Gas,” there are many variables that play a role in natural gas being considered the fossil fuel that is capable of meeting the demands of clean energy policies championed by the Obama Administration. Research indicates that it is the cleanest and, compared to other hydrocarbon energy sources, it has high energy conversion efficiencies (Economides &Wood 2009). There has been a recent push toward reducing greenhouse emissions, especially carbon dioxide, which has led to the promotion of less harmful fossil fuels. The burning of natural gas produces nitrogen oxide and carbon dioxide; however, it is in lower quantities compared to burning oil and coal. Natural gas is so important because it is the only source of energy that can cost-effectively reduce the global carbon intensity by reducing the carbon dioxide emissions (3). Another reason why natural gas is so feasible in meeting those demands is its versatility while being able to maintain high levels of efficiency. Natural gas, as Economides and Wood suggests, can be used drive combined-cycle turbines and provide fuel for vehicles at high levels of efficiency (3). In essence, natural gas role has increased in being suitable to meets the world's energy needs, in-large because of its opulence, flexibility, and its clean burning nature.

Michael, J. & Wood, D. (2009). The State of Natural Gas. *Journal of Natural Gas, Science, and Engineering*. (1) 1-13.

Stroup, L. (2013). Natural Gas. Salem Press Encyclopedia. Cambridge, MA.

<u>Natural Gas Production Process and the Impact of New Methods</u>

The opulence of natural gas and the clean energy nature of it have led to new technologies in the realm of exploration, extraction, processing (treatment), and transport. Research shows that during the early days of the natural gas industry, it was an arduous and sometimes daunting task of locating underground petroleum and natural gas deposits. The obsolete techniques of locating these gas deposits consisted of searching the surface to identify any evidence of these underground formations. Industry extractors would also look for any seepages of oil or gas emitted from underground before they could accurately have an idea of where the deposits might be. More devastating to the obsolete methods of identifying natural gas deposits, the procedures were gravely inefficient—proving to be very costly—yielding undesirable results. The demand in fossil fuel energy allowed for innovative technological explorations; thus, there was an increase seen in the success rate of locating natural gas reservoirs. [6]

[6] Information is courtesy of: naturalgas.org. It is an educational website covering an array of topics related to the natural gas industry. The information provided is designed to provide students with a comprehensive outlook on all topics related to the natural gas industry.

Exploration

Exploration techniques and methods are vast; therefore, this section will show the correlation between where the industry once was and how technology has increased the innovative measures to exploring for these fossil fuels. History has shown and still suggests today that the process of extracting natural gas and petroleum deposits is convoluted because of the complexity of searching for something thousands of feet below the ground. The exploration process, in the 1800s, began with geologists extensively examining the surface of the earth to determine the areas to determine where these deposits might exist. However, the industry increases in technological advances and other revolutions have equipped geologists with more tools for exploration. A major breakthrough in the industry came through the basic use of seismology.[7] This device allowed geologists to locate sounds and vibrations that occur during earthquakes. The process of using onshore seismology involves artificially creating seismic waves, and its reflection is picked up by equipment called geophones[8] embedded under the ground. This date is then transmitted to a seismic recording truck and used for in-depth interpretation by geologists and the like. Another method of exploration is the use of gravimeters, where geologists measure the variations in the Earth's gravitational field. Nevertheless, the most important innovations in the history of the exploration of natural gas is the use of computers to compile and assemble the geological data gathered—enhancing the

[7] Is the study of how energy in the form of seismic waves moves through the Earth's crust and interacts differently with various undergrounds formations.

[8] Sensitive piece of equipment used for onshore seismology. To look further: naturalgas.org.

veracity of interpretation—into a map of the underground where drilling is being conducted. This innovative computer technology is commonly referred to as CAEX, computer assisted exploration. The computers have allowed for the compilation of seismic data being collected from the field; increase both the content and the reliability of the data being compiled. Because of the breakthrough in computer-aided exploration, there have been various techniques developed: 2-D Seismic Imaging, 3-D Seismic Imaging, and 4-D Seismic Imaging. According to recent data, 4-D imaging has resulted in recovery rates of 65 to 70 percent. [9]

[9] Information courtesy of Natural Gas Informational Website. Naturalgas.org

Extraction

The natural gas industry new technologies have been the driving force behind the inundate amount of innovative techniques designed to increase efficiency and ultimately decrease the cost. When determining rather or not to extract from a specific location, it depends on many variables: including, but not limited to, the economic potential of the natural gas reservoir. The placement of the drill site depends upon many factors: nature of the potential shale formation, characteristics of the subsurface geology, and depth and size of the target deposit. Before drilling can take place, the drilling company must first make sure that they have met all the legal requirements to drill in that specific area—involves securing permits and establishing legal agreements to extract and sell. Extraction of natural gas can take place either onshore or offshore. There are two types of onshore drilling: cable tool drilling and horizontal drilling. Cable tool drillings is the process of raising and dropping a heavy metal bit into the ground. This mechanism is usually used for shallow, low pressure formations. There have been innovations made in the process of cable tool drilling that have greatly increased the efficiency and range of this mechanism. These innovations include, but not limited to, the use of steam power. Horizontal drilling flexibility allows for the extraction of natural gas that was previously not feasible. The horizontal drill on the surface resembles that of a vertical well but once it's in the ground it runs parallel to the natural gas formation. As a result of the advancements in horizontal drillings in shale basins, the natural gas sources have been diversified. Horizontal drilling also uses a technique known as hydraulic fracturing[10].

Drilling offshore poses a number of different challenges because it occurs hundreds of miles away from the nearest landmass. Drilling at sea can create impediments because the sea floor is sometimes thousands of feet below sea level; therefore, an artificial drilling platform must be constructed. This platform can take many forms depending on the attributes of the well to be drilled, including the depths of the drilling target. The subsea drilling template is the most vital piece of equipment used in offshore drilling. Essentially, it connects the underwater well site to the drilling platform. Also, a blowout preventer is installed on the sea floor, preventing any oil or gas seepages out into the water. [11]

[10] Information courtesy of Natural Gas Informational Website. Naturalgas.org
[11] Information courtesy of Natural Gas Informational Website. Naturalgas.org

Processing

Natural gas produced at the wellhead contains containments and natural gas liquids that must be processed—that is, cleaned before it can be transported at high-pressures and long-distances through pipelines to be consumed by the public. To avoid operational problems, pipeline deterioration, or pipeline rupture, natural gas must be processed to be within certain specific gravities, pressures, Btu content range (British Thermal Units), and the appropriate water content levels. The processing of natural gas begins at the wellhead. Both oil and natural gas are often time found together in the same reservoir. The natural gas that is produced from oil wells is typically classified as either “associated-dissolved” or “non-associated dissolved.” Associated classification means that the natural gas is associated or dissolved in crude oil, vice versa for the other classification. The processing of wellhead natural gas can be very complex, especially when trying to ensure that it is of pipeline-quality. This process involves the removing of oil, water, and elements such as sulfur, helium, and carbon dioxide, and natural gas liquids. In addition to that process, there must be the installation of scrubbers; primarily used to remove sand and other large-particle impurities. The wells are connected to downstream facilities, in which the small-diameter pipes connect to the initial processing/treating facilities. The processing of natural gas falls under seven stages: gas-oil separators, condensate separator, dehydration, contaminant removal, nitrogen extraction, methane separation, and fractionation. [12]

Transportation

The movement of natural gas in the most efficient and effective way requires and extensive and elaborate transportation system. The transportation system is comprised of a network of pipelines, which is designed to quickly and efficiently transport natural gas to areas of high demand. The transportation route is comprised of three major pipelines: the gathering system, the interstate pipeline system, and the distribution system. Pipelines fall under to forms of characterization: interstate or intrastate. Interstate system resembles that of the interstate highway system in America. These types of pipelines are able to carry natural gas across state boundaries and in some cases across the country. On the other hand, intrastate pipelines only carry natural gas within a particular state. The pipeline network is extremely complex and capable of transporting natural gas across the entire country. The natural gas being transported through these pipelines travel at very high pressures. The pipelines are comprised of many components as well to ensure efficiency and reliability. Of these important components are the transmission pipes, used to gather and distribute the natural gas, typically coming in different measures depending on the functions. Also, to ensure that the natural gas remains pressurized as it travels through an interstate pipeline, compression of the natural gas is required which is done

[12] Natural Gas Processing: The Crucial Link Between Natural Gas Production and Its Transportation to Market. Accessed at: http://www.eia.gov/pub/oil_gas/natural_gas/feature_articles/2006/ngprocess/ngprocess.pdf

by compressor stations—40 to 100 mile intervals along the pipeline. Metering stations are placed along the pipeline to reduce its volume and push the natural gas through the pipe. The pipelines are made-up of vales that operate in the form of gateways; they allow the natural gas to flow freely and can be used to stop gas flow along a particular section of the pipe. The pipelines are equipped with sophisticated control systems to monitor the gas throughout its travel to ensure that the customers receive the delivery in a timely fashion. [13]

Why Compressed Natural Gas? Why Not LNG, or LPG?

It is extremely important that nations diversify their energy supply so they are less reliant on one energy providers or source, in that an adequate energy supply is vital to national economic development. Fossil fuels are advantageous because they are comprised of properties that allow them to store and deliver large quantities of energy more effectively that many other alternative energies. (Wood et. al 2009)

Compressed Natural Gas is made by compressing natural gas to less than 1% of its volume at standard atmospheric pressure. CNG is both odorless and tasteless. CNG is somewhat flammable, but the range of flammability is very narrow. Compressed Natural Gas poses no adverse threat to land or water, as in some toxic form. Unlike gasoline, CNG disperses rapidly. Compressed Natural Gas costs about 50% less than gasoline or diesel, have 90% fewer emissions than gasoline, and there is an inundate supply of it in America. [14] From a practical perspective as in relation to its feasibility in the transportation system, there are more compressed natural gas filling stations; it is easier to pump and to store.

[13] How Natural Gas is Transported. Accessed at: http://www.spectraenergy.com/Natural-Gas-101/Transporting-Natural-Gas/

[14] CNG NOW. WHAT IS CNG? Accessed at: http://www.cngnow.com/what-is-cng/Pages/default.aspx

Liquefied Natural Gas is made up of mostly methane. The liquefaction process requires the removal of non-methane components like carbon dioxide and water. LNG takes up les space than other natural gases, which makes it easier to transport and store than natural gas. It can be stored either below or above ground. LNG is also much easier to transport over long distances. However, LNG operations are capital intensive. The upfront costs are massive for construction of liquefaction facilities, purchasing complex-designed LNG ships for transportation, and regasification facilities. However, the primary component of LNG is methane which is considered to be a greenhouse gas because when released it increases carbon levels in the atmosphere. LNG is considered to be a more energy-dense fuel than CNG (truck can travel further on one tank), but it is 260 degrees Fahrenheit which requires it to be stored in heavily insulated tanks. When a vehicle is not running, the tanks will automatically release evaporating LNG—hence, pure methane into the air.[15]

Liquefied Petroleum Gas (LPG) is a clean-burning fossil fuel that is often used to power internal combustion engines. It produces significantly lower amounts of harmful emissions in the atmosphere and the greenhouse gas carbon dioxide. It is typically less expensive than gasoline, and does not have adverse effects on the performance of the vehicle. LPG isn't readily available and the consumer will not be able to travel as many miles on a tank of fuel. LPG is comprised of properties that make it very dangerous to handle. LPG must also have sturdy and cylinder tanks for storage purpose. There have been many documented cases of LPG cylinders explosions that have resulted in seriously bodily arm and property damage. It is also more expensive than CNG and gasoline. When LPG is used in vehicles, the life of the engine is shortened drastically—due

[15] Should Natural Gas-Powered Cars Run on CNG, LNG, or Gasoline? Christopher, Helman 2013. Business source Complete

to the lack of combustive properties. It is also not safe to be used in vehicles operating on rough terrain and mountain roads. [16]

Growth of CNG Sector

One of the driving forces behind CNG increased demand is the cost benefit it offers in comparison to other alternative fuels. Because of the commitment to decrease America's reliance on gasoline, companies have begun to look toward alternative fuel use. CNG's growth can be attributed not only to the need to decrease America's reliance on petrol but also it provides a costly efficient option, as oppose too many other alternative fuel sources. The United States implementation of initiatives and programs are available to states to help assist with the costs associated with purchasing NGVs etc. Currently, only 34 states have at least one CNG fueling station but are expected to continue increasing as states pursue more efficient methods of transportation. While the market has shown much promise, there are many impediments that states have encountered—such as: insufficient fueling stations, high costs of developing CNG based infrastructure, enormous operational costs, and the high cost of conversion [17]

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[16] Information accessed at U.S Department of Energy Office of Transportation and Air Quality. Accessed at: https://www.fueleconomy.gov/feg/lpg.shtml

[17] Compressed Natural Gas Market: Global Industry Analysis, Size, Share, Growth, Trends, and Forecast..

Intro to Clean Coalitions, Policies, and Branding

This section of the paper will discuss the cost of present fleet infrastructures to convert to alternative fuels (specifically Compressed Natural Gas aka "CNG"), describe price trend data, and introduce the SMART system here at Mississippi State University (MSU). However, before proceeding to describe the importance of converting current transit diesel systems into a sustainable low-carbon fleet, this capstone project will attempt to get an understanding of how alternative fuels have impacted policy approaches to address the need for finding innovative ways to reduce greenhouse emissions in the United States. Efforts to reduce greenhouse gas (GHG) emissions have evolved into policy frameworks nationwide that have incorporated a goal to reduce GHG by 80% by the year 2050 (AMCE, 2014). Current examples of successful implementation to convert heavy-duty vehicles with CNG include the Clean City programs such as Virginia's James Madison University recent attempt. While Mississippi does provide a plan, this research project will assist in the attempt to describe the impact of conversion. Thus, considering the capacity of the infrastructure, deciding on a slow-fill or time-filled pump, and building a strong private-public partnership to accomplish conversion of the SMART system into CNG from diesel will be imperative when moving forward on the final decision to do so.

One of the key factors to understand when specifically describing MSU's heavy-duty fleet and converting the current system to CNG is that the state of Mississippi has a regional contact that will assist them in the efforts of establishing Clean Cities Coalitions (CCC) from the local level, but none are currently participating. The CCC is an opportunity for State and Local stakeholders to take advantage of networking, funding, and other similar incentives to promote energy efficiency efforts provided by the federal government (DOE, 2014). Also, this project must take into account that the institutions planning to expand and convert to CNG are quite different from other alternative fuel conversion efforts (DOE, 2014). Thus, providing a market will accrue high upfront costs to build a capacity for conversion. These costs will be contingent upon competition within the market within a specific geographical location and its jurisdiction, fuel costs, and, and maintenance of the fleet.

According to the Mississippi Development Authority (MDA) over 66 percent of the petroleum consumed in the U.S. imported from other countries; the State of Mississippi is aggressively promoting oil conservation and the use of alternative, domestic fuels for everyday fuel consumption (MDA, 2013). In lieu of MDA's efforts, Mississippi State University has also committed to the utilization of fossil fuel alternatives. MDA and MSU have been working together along with the Department of Energy (DOE) and others to reduce energy intensity within Southeast Region of the United States the past few years; which has ultimately led to encourage the State's local coalitions to be established to sustain funding, develop strategic plans, and frameworks to guide cities in strengthening their competitive edge within the energy sector.

American Society of Mechanical Engineers. (2009). ASME General Positions on Statement: Techonology and Policy Recommendations and Goals for Reducing Carbon Dioxide Emissions in the Energy Sector. Retrieved 1 April 2014. Retrieved from : http://files.asme.org/asmeorg/NewsPublicPolicy/GovRelations/PositionStatements/17971.pdf

Mississippi Development Authority. (2013). Clean Cities. Retrieved April 16, 2014, from http://www.mississippi.org/energy/clean-energy/clean-cities/

U.S. Department of Energy. (2014). Clean Cities: Coalitions. Retrieved 15 April 2014. Retrieved from :http://www1.eere.energy.gov/cleancities/coalitions.html

Clean Cities Coalition

As afore mentioned, establishing a comprehensive plan to develop a partnership among members of the public and private sector is essential to the success of conversion to fossil fuels. According to Clark (2006), "Public-private partnerships, known as ''civic markets ''can create and provide ''funds'' such as public bonds along with private sector innovation and markets on the regional, state and national levels" (294). Hence, without these civic markets, it will be difficult to sustain a project to this magnitude. Especially one in which there is not a very high number of vehicles to convert. Thus, to achieve a successful conversion according to Alfonso-Conde et al. (2007) "Such an arrangement involves the investment of private risk capital to design, finance, construct, operate and maintain a project for public use for a specific term, generally around 20–30 years, during which the private provider collects revenues from the users of the facility" (335). This arrangement of a civic market is described by the by Department of Energy as the CCC.

The CCC is a program in which coalitions from the local level come together to advance the nation's economic, environmental, and energy security by way of reducing the use of conventional petroleum in transportation (DOE, 2014). These coalitions help to develop networks from the state and local level to accomplish these goals by providing the framework for decision-makers and identifying funding opportunities to sustain these projects. While the name of the coalition may sound innovative, the existences of such partnerships date back to the late 1980s and early 1990s.

In 1988, there were two laws that were amended to encourage the production and use of alternative fuel vehicles and the reduction of vehicle emissions; 1) Alternative Motor Fuels Act of 1988 and 2) Clean Air Act of 1990 (DOE, 2014). These two amendments led to the development of the Alternative Fuels Data Center in 1991 which was collected, analyzed, and distributed data used to evaluate alternative fuels and vehicles (DOE, 2014). Subsequently, the Energy Policy Act of 1992 was enacted and required certain vehicle fleets to acquire Alternative Fuel Vehicles. Thus, leading to the development of the Clean Cities in 1993 that provided informational, technical, and financial resources to the Energy Policy Act of 1992 that regulated fleets and voluntary adopters of alternative fuels and vehicles (DOE, 2014).

Since the Energy Policy Act of 1992, there have been three more key federal statutes that have led to the development of new energy demands. In 1998, the Energy Conservation Act was amended and awarded tax incentives for fleets to meet the standard compliance for the use of biodiesel blends; In 2005, the Energy Policy Act was enacted to establish a way for covered fleets under the Energy Conservation Reauthorization Act to reduce petroleum consumption in lieu of acquiring Alternative Fuel Vehicles; and in 2007, the Energy Independence and Security Act directed the DOE to allocate credits for some electric drive vehicles through (DOE, 2014). Hence, the assumption is that establishing a strong Clean Cities Coalition within a municipality has many benefits.

In fact, according to the DOE website, CCC's have saved more than 5 billion gallons of petroleum since its inception in 1993 (DOE, 2014). With all the networking opportunities, training sessions, analyzing data, and other facets offered; the benefits appear to have been very effective in the past 20 years. In particular, James Madison University in the Virginia Clean Cities Coalition serves as a prime example of the success the network has to offer. The Virginia CCC has saved approximately $400,000 in fuel cost, which is about $200,000 annually, and have saved just shy of 300k of diesel fuel in the past 3 years since they have converted to natural gas (Clean Cities, 2014). The City of Richmond was able to purchase 25 new refuse trucks and build a time-fill station with 13 pumps to accommodate the investment. One of the positive benefits from this investment was the access that the public had to the pumps. This is something to consider when trying to promote and brand this conversion in the transportation infrastructure. While this is a snapshot of the use of refuse trucks, this case study correlates with MSU's current situation because refuse trucks in comparison to shuttle buses are very similar. The success of The Virginia CCC relied heavily on federal incentives and credits; however relying on federal incentives alone may possibly be detrimental when trying to achieve a sustainable from of a transportation infrastructure.

In 2010, a study was conducted by the National Renewable Energy Laboratory to understand the determining factors for converting heavy-duty fleets over to CNG. The study utilized seven different scenarios to capture the long-term cost-effectiveness, more-consistent operational costs, increased energy security, reduced greenhouse gas emissions, reduced local air pollution, and reduced noise pollution (Johnson, 2010). For the scope of this project we will focus primarily on the municipal fleets from the study and the scenario that utilizes 30 transit buses averaging a life span of 15 years (this also includes a total mileage average of 35,286, a total miles per gallon average of 3.27 in Diesel, a CNG miles per gallon average of 3.02; with a year to year incremental cost of $50,502). According to Johnson (2010) municipal fleets were well suited for conversion, not only because their primary goal was to improve residential life, but also because they drive circular routes that enable refueling at the same station (4).

When considering to convert or not to convert, a coalition (if established) must take into account three important indicators to allow stakeholders involved in the decision making process to know if a CNG conversion project makes sense. These three indicators include the Net Present Value (NPV), the Rate of Returns (RORs), and the Payback Period of the project (Johnson, 2010). First, the Net Present value is the upfront costs needed to begin the project. Decision makers usually consider the equipment necessary to begin the conversion process, the full operations of the process (which includes all infrastructure costs), the cost of fueling, and any other future costs that might accrue of the life of the project. The initial investment is most likely to be the highest cost at any given time during the life of the project. Thus, considering how much you are willing to front will determine whether or not to begin the conversion process. For the scope of this project, we will focus on the funds needed to invest in an infrastructure for transit buses.

The next indicator to consider is going to be the ROR. This indicator is usually determined by the investors of the project. Investors usually consider the desired annual rate of return which usually includes the incremental costs over the projects timeline. They often compare and contrast similar projects to invest in to see whether or not the conversion project is feasible and possibly profitable. According to Johnson (2010), a 6% annual rate of return is pretty good (10).

Lastly, the payback period is an indicator in which investors want to know how long it will take and at what time during the project they will either a) break even, or b) begin to see a profit from their investment. To calculate the payback period, investors often utilize the discount rate of the Net Present Value to determine this period. The payback period can take effect in three different forms. The size of the fleet can also be a contingent factor in regards to determining the payback period. It can either take effect in a stable, progressive, or risk-aversed fleet. Hence, the larger the fleet the faster the payback period is likely to take place; however, if the fleet doesn't exceed the amount of 30 or more vehicles, the payback period may occur slower than usual (7 years or less is the average payback period for a fleet size of this magnitude) (Johnson, 2010).

Put into perspective, the group understands that funding a project to this magnitude is going to be what determines the success or failure of any CNG conversion projects; however, there are several avenues to explore when searching for monies to fund such projects. The federal government provides both grant and loan opportunities to aid in the start-up as well as the sustaining period of a CNG conversion project. They also provide tax credits. According to Johnson (2010), these tax credits serve as incentives for capital investors, and are intended to reduce the overall cost of installing the CNG refueling station, to purchase the CNG vehicles, and to purchase CNG (8). Municipal government entities are encouraged to take advantage of these credits. For the building or conversion of a refueling station, The Alternative Fuel Infrastructure Tax Credit is available to reimburse 50% of the cost of installing a CNG station, up to $50,000; and for the purchasing of vehicles the Alternative Motor Vehicle Credit provides a tax credit equal to 80% of the incremental cost of a CNG vehicle, to a maximum of $32,000 per vehicle (Johnson, 2010; pg. 8). Other funding opportunities are available to public and private partnerships on the federal and state level. These funding opportunities serve as a viable tool and can be utilized in many different ways such as educating the public, training, the workforce, and providing other opportunities to expand the growth of an infrastructure.

In 2013, Mississippi began to pave the way for public monies to fund parties interested in adding value to the utilization of alternative fuels in the forms of processing, converting, and storing. Programs such as the *Alternative Fuel Vehicle Revolving Loan Program*, *Rebate and on Research and Development Costs* and the *Energy Structure Revolving Loan Fund* were products from the Energy Policy Act of 2005 which mandated States to require funding opportunities to meet the energy demands of the United States. The *Alternative Fuel Vehicle Revolving Loan Program* provided zero-interest loans for public school districts and municipalities with funding to cover 100 percent of the incremental cost of purchasing alternative fuel vehicles (AFVs) and related systems or of converting existing vehicles to accept alternative fuels, whether propane gas, compressed natural gas or liquefied natural gas (House Bill 1685, 2013).

The *Energy Structure Revolving Loan Fund* is a Mississippi statute that provides communities with a low financing tool to partner with companies that invest more than $50 million in an economic development project (MDA, 2013). These aforementioned tools also assist public institutions such as Mississippi State to acquire *rebate and on research and Development Costs. Rebates and on Research and Development Costs* is included in a law that allow companies looking to tap into the wealth of energy expertise and resources available at Mississippi research institutions with a 25 percent rebate of the total research costs. This law will assist companies looking to tap into the wealth of energy expertise and resources available in Mississippi's research institutions (Mississippi House Bill 826, 2013). These funds are provided through the SMART (Strengthening Mississippi Academic Research Through) Business Act.

Alfonso-Conde, A., Brown, C. & Rojo-Suarez, J.(2007). Public Private Partnerships: Incentives, Risk Transfer and Real Options. Review of Financial Economics 16 (2007) 335–349. Published by Elseiver Ltd. Received 10 March 2005; accepted 9 March 2007. Retrieved from www.elsevier.com/locate/econbase

Clark, W & Eisenberg, L (2008). Agile Sustainable Communities: On-Site Renewable Energy Generation. Unities Policy Vol. 16. Published by: Elsevier Ltd. 2008. Science Direct Database. DOI: 10.1016/j.jup.2008.01.009. Retrieved From: journal homepage: www.elsevier.com/locate/jup

Johnson, C. U.S Department of Energy, National Renewable Energy Laboratory. (2010). *Business case for compressed natural gas in municipal fleets* (Task No. FC08.0032). Retrieved from Alliance for Sustainable Energy website: www.nrel.gov.

Mississippi Development Authority. (2013). Clean Cities. Retrieved April 16, 2014, from http://www.mississippi.org/energy/clean-energy/clean-cities/

Mississippi Legislature. (2013). "MISSISSIPPI GOVERNMENTAL ENTITIES NATURAL GAS VEHICLES REVOLVING LOAN FUND"Retrieved 3 April 2014. Retrieved from http://billstatus.ls.state.ms.us/documents/2013/html/HB/1600-1699/HB1685IN.htm

Mississippi Legislature. (2013). "STRENGTHENING MISSISSIPPI ACADEMIC RESEARCH THROUGH BUSINESS ACT"Retrieved 3 April 2014. Retrieved from http://billstatus.ls.state.ms.us/documents/2013/html/HB/0800-0899/HB0826PS.htm

U.S. Department of Energy. (2014). Clean Cities: Coalitions. Retrieved 15 April 2014. Retrieved from :http://www1.eere.energy.gov/cleancities/coalitions.html

Disadvantages of A Conversion Project

Unfortunately, federal and state funding can only cover so much of a project; especially during the development stages of these projects. According to Johnson (2010) as stated, "when the incremental costs is greater than $40,000 government incentives do not help much, thus requiring a great help from the private sector to invest in the project" (16). This suggest that although civic markets are increasing, there is still a lack of capital investment which is leaving public institutions such as Mississippi State University to not only foot the cost for funding conversion projects (promoting R&D programs), but they are also left with doing most of the leg work.

Mississippi is currently not associated with the DOE's CCC program. Although the state is advocating for these actions to actually take place, no research is available to prove otherwise. Hence since there are no partnerships suggests that there are less opportunities to network for educating the public to know what's going on, less opportunities to seek capital investments, and less support to create public policy to strengthen the efforts of making Mississippi a global competitor in the energy field.

Johnson, C. U.S Department of Energy, National Renewable Energy Laboratory. (2010). *Business case for compressed natural gas in municipal fleets* (Task No. FC08.0032). Retrieved from Alliance for Sustainable Energy website: www.nrel.gov.

Potential Branding Efforts

Moving forward, when conversion projects to this magnitude are considered, research has suggested the promotion of civic markets. These civic markets can act as change agents in diffusion networks to ensure that constituents are aware of the benefits and consequences of utilizing alternative fuels. These civic markets can educate, train individuals, obtain funding, and do other things necessary to pursue the applicability of building the capacity for conversion projects. Civic markets that have established clean city programs are making even greater impacts within their communities; as well as society as a whole. According to DOEs Clean Cities Website (2014), "More than 228 million people (74% of the total U.S. population) live inside the boundaries of CCCs, and coordinate the work of almost 18,000 stakeholders nationwide." Therefore, it is our observation that establishing CCCs will impact future policy decisions, securing capital investments for the lifetime of a conversion project, and being able to effectively utilize state and federal funds.

Educating stakeholders is key. All communities are impacted to future energy decisions. When trying to garner support for a project of this magnitude, a municipal government must also consider the opinion of the public. Often time, when making decisions such as this one to convert or maintain current system, the public's opinion is often lacking. It has been statistically proven that the public values and morals support the conservation of energy whether they are liberal or conservative about their political ideals (Cleveland, 2004). Recent studies have also shown that a political ideal from the public's opinion has not changed over the last ten years. In fact, statistical data collected by Southeastern College suggest that the public supports conserving energy versus continuing to drill for oil (Cleveland, 2004).

In fact respondents in Cleveland's (2004) case study were asked about their perception regarding conservation of energy and whether they believed "protection of the environment should be given priority, even at the risk of curbing economic growth, or economic growth should be given priority, even if the environment suffers to some extent." (pg. 7) By wide and consistent margins from 1984 to 2000, the polls showed a strong public preference for environmental protection. Support for environmental protection ranged from 61 to 71%, whereas the number giving priority to economic growth ranged from only 19 to 32% and was only 28% when the question was last asked in April 2000.

Being informed about policy and advocating for policy change will also be a component in which CCCs will be tasked with identifying and encouraging the buy-in of other stakeholders if a conversion project were ever considered to be implemented at Mississippi State University. Although many times policy is enacted to encourage progress, it sometimes is not diffused; thus causing individuals, public institutions, businesses or other stakeholders to be uniformed about benefits that are provided if they choose to become participants of research and development projects. According to Bryant (2012) before the SMART Business Act, the state's R&D tax credit was underutilized and needed revamping to become more attractive and better structured (pg. 25). Now with a clearer objective to provide rebates and defray payments for the private sector, the new piece of legislation is more visible and provides the incentive for capital investors to finance conversion projects.

Lastly, CCCs provide the opportunity to identify funding across the board on a federal and state level. The MDA continues to try and build such partnerships as they have been known to do in the past. MDA's Energy & Natural Resources Division adopted a three-part strategy to increase the number of local government fleets choosing to adopt alternative fuel vehicles: advancing alternative fuel vehicles as a viable choice for fleet operators, developing public interest in and acceptance of alternative fuels, strengthening local coalitions. Other parties interested in participating in a conversion project may be more inclined to do so with such support from the State level (MDA, 2013).

When funding providers issue Notice of Funding Opportunities and receive Request for Proposals, they often look at the performance at the institution, individual, or other individuals interested in receiving funding prior to their request. Hence, many times their decision on awarding funding (and how much funding they provide) is contingent upon the support and performance provided thus far. Thus, the necessity to build strong coalitions with individuals, businesses, or public institutions of diverse expertise is essential to being awarded grant funding.

In regards to branding this innovation, we consider following Rogers (2003) theory of diffusing this technological advance through interpersonal and mass media communication channels. This includes educating stakeholders (via brochures distributed through the community or social media to invite them to public meetings for understanding of the pros and cons of CNG conversion), persuading them to buy into the innovation, collecting quantitative and qualitative data to understand the communities perception, implementing a comprehensive plan to ensure that the 3 indicators aforementioned are considered when deciding to convert transit systems to CNG are both practical and affordable; and seeking ways to re-invent the program so that future efforts to improve it will be understood and a strategic plan to handle upcoming complexities and uncertainties have a framework to be dissolved quickly (Rogers, 2003). To ensure its success giving this campaign to advocate for support from other stakeholders, we consider giving it a crafty name that relates to the efforts to convert MSU's transit system to CNG. We believe that a crafty name gives the innovation creativity and aids in garnering support for a successful conversion.

Bryant, P. (2012). EnergyWorks: Mississippi's Energy Roadmap. Retrieved 2 April 2014. Retrieved from http://www.governorbryant.com/wp-content/uploads/2012/10/Energy-Works-Roadmap-Final.pdf

Cleveland, C. (2004). C. Cleveland (Ed.), *Public Reaction to Energy, Overview*. Elsevier, Inc.

Mississippi Development Authority. (2013). Clean Cities. Retrieved April 16, 2014, from http://www.mississippi.org/energy/clean-energy/clean-cities/

Rodgers, E. (2003). *Diffusion of Innovation*, 5th ed. NY: The Free Press.

U.S. Department of Energy. (2014). Clean Cities: Coalitions. Retrieved 15 April 2014. Retrieved from :http://www1.eere.energy.gov/cleancities/coalitions.html

Introduction the SMART system

At the beginning of the 2014 Spring Semester, Mississippi State University introduced a new innovation to its campus transit system. The Starkville-Mississippi State University Area Rapid Transit (S.M.A.R.T) is an expansion of an earlier shuttle system that primarily focused on the MSU campus comprised of a total of 32 buses (Steinberg, 2014). Used for a number of different University initiatives (including campus tours), the SMART system will serve as the impetus to convert the heavy-duty vehicle fleet from diesel to Compressed Natural Gas). This is due to the freshness of the vehicles and their relative advantage of a longer life expectancy versus the older shuttle system.

Before moving forward, we will attempt to highlight what the SMART system is, where it derived from, and the reason for considering the possible conversion of these heavy-duty vehicles from diesel to CNG. The SMART system is an Intelligent Transportation System (ITS) that has integrated advanced communication technologies into MSU's transportation structure and vehicles to improve the safety of them, and attempts to enhance the mobility of those who choose to utilize it (RITA, 2014). It allows citizens of Starkville to access bus routes online, which provides accurate live bus maps; as well as schedules, and other pertinent information that may be beneficial to those who wish to make use of the shuttle. Anyone in the City of Starkville can utilize this innovation free of charge, and it allows them to travel to and from campus to other access points across the city.

The SMART system derived from a federal program that was established under the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) which was to research, develop, and operationally test Intelligent Transportation Systems (ITS) and to promote their implementation (RITA, 2009). Funds were obtained from the Mississippi Department of Transportation in 2012, and were awarded to Mississippi State University to aid in the development of the transits expansion. Unlike other no-cost, reliable and sustainable forms of transportations utilized on college campuses funded by the city, a private contractor or both; MSU is operating this system independently (Steinberg, 2014).

In our efforts, we considered investigating the SMART system because of its correlation with fuel savings, possible reduction in Greenhouse Gas Emissions (GHGs), and the possible benefits of the stakeholders involved in meeting the new energy demands and changing to more sustainable ones with the possibility of converting the heavy-duty vehicle fleet from diesel to CNG. Indeed fuel savings, traffic congestion, and vehicle costs were primary benefits of the SMART system; however, implementing it could also establish a marketplace and infrastructure that translates into greater economic productivity, administrative cost savings, and profits from the institutions perspective (RITA, 2009). This notion has the possibility of creating new jobs, increasing the efficiency of the transit system by providing real time data, and the possibility of new research and development (R&D) programs. Thus, this innovation could possibly result in the development of new applications and services in the future.

This project hopes to identify ways for these new developments to transform from the SMART system. The successful conversion of our heavy-duty fleet vehicles relies upon the ability of an infrastructure to build the capacity to be fully operational. Members from the university, city government officials, state and federal government officials, and other parties of interest (including individuals and companies from the private sector) must be able to work together to develop an effective and comprehensive framework to promote a clean, renewable, and healthy future for society in Mississippi (Clark, 2006). With the consumption of petroleum so high in the United States, it will be necessary to consider alternatives in the near future in case of limitations in the use of the nation's natural resources to prevent global warning. Thus, the use of alternative fossil fuels is paramount to meet the new demands to reach energy efficiency sustainable independence in the United States.

In 2012, Governor Phil Bryant of Mississippi signed the Energy Works landmark piece of legislation that attempts to be the roadmap to establishing the state as a global competitor for energy efficiency. The aim of this specific piece of legislation is to meet the country's energy demands by encouraging R&D programs to expand the State's energy capacity by way of infrastructure, finding strategic ways to capitalize from the competitive advantages the State has to offer through transportation and distribution of energy resources, and finding ways for the State to be more energy efficient (Bryant, 2012). Through these efforts, public and private partnerships will be a key component to ensuring that this roadmap to energy efficiency is practical and sufficient for Mississippi's goal of being a leader in the growing field.

Currently, 80% of the research being conducted in the State of Mississippi is publicly funded, which means that in order for the State to be competitive in regards to technological advances in the energy field the private sector will aid in sustaining more R&D programs and job opportunities in the energy field (Bryant, 2012). This means having more opportunities for workforce development and opportunities for the future children of Mississippi to stay rather than leave in search of such career opportunities. Hence, finding the necessary incentives to promote more civic markets will be imperative for meeting the new energy demands. According to Bryant (2012), “Patents are one measure of R&D driven innovation— indicative of a novel finding or technology. Data for 2001 through 2011, however, show that Mississippi produced only 17 patents in the energy realm over the course of the recent decade, with one company (SmartSynch) accounting for 7 out of the 17” (pg.24).

Building the capacity to promote these partnerships will also aid in the economic advantage of having such a comprehensive infrastructure. There are only a few companies that are in the current market to manufacture, convert, and process natural resources. These companies such as NGV Solutions, the Stennis Space Center, the Northeast Mississippi Natural Gas District, and Jackson Waste Management add value in sustaining resources; however, they are too far and wide to be able to do so for the entire state (Breen, 2013). Therefore, expanding Mississippi’s infrastructure by creating jobs may serve as an impetus to promote more capital investments to give a much stronger economic advantage for the state in the energy sector. Indeed, Mississippi already has a great economic edge over other states in regards to its access to fifteen waterway ports (many which serve as a host to storing and transporting natural gas through Mississippi, which could possibly allow the State to serve as a hub for the transportation and distribution of natural gas, and give it more sources of revenue in the near future (Bryant, 2012).

Bryant, P. (2012). EnergyWorks: Mississippi's Energy Roadmap. Retrieved 2 April 2014. Retrieved from http://www.governorbryant.com/wp-content/uploads/2012/10/Energy-Works-Roadmap-Final.pdf

Breen, J.D.,Burke, J., & Riley, F. A. (2013, June 1). Converting Municipal Fleets to Compressed Natural Gas (CNG): Fuel Cost Savings and Conversion Considerations.*Mississippi State University- Stennis Government Institute Homepage*. Retrieved April 16, 2014, from http://www.sig.msstate.edu/sites/default/files/documents/CNG_Web_Final.pdf

Clark, W & Eisenberg, L (2008). Agile Sustainable Communities: On-Site Renewable Energy Generation. Unities Policy Vol. 16. Published by: Elsevier Ltd. 2008. Science Direct Database. DOI: 10.1016/j.jup.2008.01.009. Retrieved From: journal homepage: www.elsevier.com/locate/jup

Steinberg, Sasha. (2014). S.M.A.R.T shuttle system gains increase in riders. Mississippi State University Office of Public Affairs: News Bureau. Published 7 Feb 2014. Retrieved on 2 April 2014. Retrieved from http://www.msstate.edu/web/media/detail.php?id=6475

U.S. Department of Transportation Research and Innovative Technology Administration.(2009). Investment Opportunities for Managing Transportation Performance through Technology. Published 16 Jan 2009. Retrieved on 2 April 2014. Retrieved from: http://www.its.dot.gov/press/2009/transportation_tech.htm#sthash.HT7CBhwa.dpuf

U.S. Department of Transportation Research and Innovative Technology Administration.(2014) About ITS. List of Frequently Asked Questions. Retrieved 9 April 2014. Retrieved from http://www.its.dot.gov/faqs.htm

CNG vs. Diesel Emissions and Health Considerations

Environmental Benefits

The environmental benefits of buses fueled by compressed natural gas are important to discuss in the evaluation of the project. Greenhouse emissions have been a primary concern for policymakers. Climate change has brought a growing interest into environmental policy. Traffic-related emissions are considered to be a major contributor to the level of air pollutants in metropolitan areas (Hallquist et. al 2013). Heavy-duty vehicles are responsible for a high level of pollutants. The health impact of converting transit systems to CNG should also be considered in the analysis.

There are several implications for high level of air pollutants. One of the main factors of greenhouse emissions is the impact on global warming. The comparison of compressed natural gas to conventional diesel demonstrates the benefits of CNG conversion. The emission of particle mass from compressed natural gas buses is significantly more advantageous than conventional diesel buses. CNG buses emit a higher number of particles during acceleration, but the size of these particles is smaller than those emitted by diesel-fuelled buses (Hallquist et al., 2013). Acceleration is important for transit systems, because of the constant stops made by buses for passengers.

There are several emission factors that are used to measure environmental impacts of different transit systems. Particulate matter, nitrogen oxides, and sulfur dioxide are the components of emissions considered (Cohen, 2005). Differences in emission levels of compressed natural gas and conventional diesel offer a comparative analysis of the benefits of each fuel system. “Criteria pollutants” are designated by the Clean Air Act. Under the Clean Air Act, the United States Environmental Protection Agency (EPA) is required to set National Ambient Air Quality Standards. The guidelines set by the EPA create criteria for health and environmental standards (epa.gov/air/criteria.html).

There are two categories created by the EPA for particulate pollutions, which are “inhalable coarse particles” and “fine particles”. “Inhalable coarse particles” are measured from 2.5 to 10 micrometers. “Fine particles” are measured as 2.5 micrometers or smaller. “Fine particles” are common in gaseous pollutants, such as smoke and haze. These two categories are the most important to the EPA, because they are considered to be the easiest to enter into a person’s body. Most regulations are designed around these forms of pollutants, due to the associated hazards (www.epa.gov/airquality/particlepollution/).

The EPA has created several rules and programs to help reduce vehicle emissions. The 2007 Clean Diesel Trucks and Buses Rule enforced standards for a cleaner system of heavy-duty trucks in the United States. The Tier 2 Vehicle Emission Standards and Gasoline Sulfur Program established standards for emissions in passenger vehicles. The EPA has planned to create new standards that will enforce stricter means of emission reductions (www.epa.gov/airquality/particlepolution/reducing.html). As rules and programs continue to be proposed, it is important to pursue new methods of maintaining environmental standards set by the EPA. CNG conversion provides several environmental and public health benefits through a growing field.

Primary and secondary standards within the Clean Air Act distinguish the importance of improving emission regulation for the public good. Primary standards encompass the requirements for public health, while secondary standards focus on the environmental aspects of regulation (www.epa.gov/air/criteria.html). The continuation of environmental policymaking creates many incentives for creating a transit system that maintains the standards for emission control. New technologies, such as compressed natural gas, provide ways for accomplishing the goals established through legislation.

New studies have offered the foundation for methods of overcoming the increase in air pollutants. It is important to understand the need for innovative efforts within the public sector. The exposure of air pollutants to agriculture and infrastructure is an issue that requires regulatory standards.

Cohen, J. T. (2005). Diesel vs. Compressed Natural Gas for School Buses: A Cost Effectiveness Evaluation of Alternative Fuels. *Energy Policy, 33*(13), 1709-1722.

Hallquist, A. M., Jerksjo, M., Fallgren, H., Westerlund, J., &Sjodin, A. (2013). Particle and Gaseous Emissions form Individual Diesel and CNG Buses. *Atmospheric Chemistry and Physics*, *13*(10), 5337-5350.

National Ambient Air Quality Standards (NAAQS). www.epa.gov/air/criteria.html

Particle Matter (PM). www.epa.gov/airquality/particlepollution

Particle Pollution and Your Health. www.airnow.gov/index.cfm?action=particle_health.page1#1

Health Impacts

The health impact of emissions is measured through quality adjusted life years (QALYs). Differences in the health impact of CNG-fueled and diesel-fueled buses are important in the study. Developments in technology have shown damages to public health. Particulate matter, nitrogen oxides, and sulfur dioxide are considered major contributors to health issues, such as asthma, cardiovascular disease, and lung cancer (Cohen, 2005). Particulate matter is considered to be liquid and solid forms of pollutants within the air. The health impact of these pollutants is primarily associated with lung problems and potential complications within the bloodstream. Long-term and short-term health risks vary among areas that have higher levels of particulate matter within the air (http://www.airnow.gov/index.cfm?action=particle_health.page1#1)

Increasing health risks and environmental damages have led to escalating involvement of the United States Environmental Protection Agency (EPA).

CNG systems reduce the amount of particulate matters and nitrogen oxides, but the data indicates that upstream activities do not allow for reductions in sulfur dioxide (Cohen, 2005). One of the most important benefits of CNG in operation is the reduction in particulate matter. However, a majority of the particles emitted from CNG buses are more volatile than diesel-fueled buses. Essentially, more volatile particles evaporate into the atmosphere at a quicker rate. This can be a hazard in transit systems that conduct several bus stops. The rate of acceleration can increase the number of emitted particles, which tends to be an issue for transit systems (Hallquist et al., 2013).

Annually, CNG transit systems within the study reduce health damages by 3.9 QALYs. This is considered within an urban area (Cohen, 2005). The reduction in QALYs is contingent upon the fleet size of the transit system. The difference in transit systems creates difficulties for a consistency in available data. Most research must be based on assumptions, due to the inconsistency in data collection. Mileage is another measurable factor that may vary among transit systems. Regarding the data collected in the study, CNG conversion in transit systems is beneficial to public health and reduction of environmental. The reduction of QALYs should increase as mileage increases (Cohen, 2005).

Data suggests that emissions of nitrogen oxides are possibly unstable overtime for CNG transit systems. It is not certain if maintenance of vehicles could limit the increase in emissions of nitrogen oxides. The limit of data is an issue that has been problematic for researchers to determine how CNG vehicles will stabilize overtime. Vehicle maintenance is important to garner the best results. A further analysis of CNG buses would be necessary to make conclusions of the benefits of CNG conversions. The energy consumption of buses within transit systems is relatively higher than typical vehicles, which indicates higher level of emissions (Cohen, 2005). The need for CNG conversions is imminent as the levels of emissions continue to increase overtime.

Cohen, J. T. (2005). Diesel vs. Compressed Natural Gas for School Buses: A Cost Effectiveness Evaluation of Alternative Fuels. *Energy Policy, 33*(13), 1709-1722.

Hallquist, A. M., Jerksjo, M., Fallgren, H., Westerlund, J., &Sjodin, A. (2013). Particle and Gaseous Emissions form Individual Diesel and CNG Buses. *Atmospheric Chemistry and Physics, 13*(10), 5337-5350.

Particle Pollution and Your Health. www.airnow.gov/index.cfm?action=particle_health.page1#1

Vehicle Infrastructure and Maintenance Costs

Given the change in cost associated with the production of CNG vehicles and the growth of that market, CNG vehicle costs for conversion and new vehicle cost vary quite a bit. In converting these vehicles over to CNG there are several aspects that must be considered. These include age of the vehicle being converted, engine type, size of tank, systems controls, and a host of other considerations. While going into each and every aspect would require someone with much more technical expertise than we have, we can look at a host of expected costs for conversions as well as the incremental cost of adding new vehicles that run on CNG vs. Diesel.

One estimate puts the cost of conversion for heavy-fleet vehicles around 40K per vehicle[1]. In another estimate, a company Omnitek which specializes in this sort of conversion states that the cost can be done for “as little as $6000 to $12,000” dollars per vehicle[2]. There is great variability that comes with these sorts of conversion and the data available is often time contingent to location and availability of a company that does the conversion. That is why we decided to use three tiers when analyzing the cost of conversion for these types of vehicles which include high being 40K, average 30K, and low being 20k per vehicle converted. We believe it is safe to assume that the initial conversion of the 12 new vehicles will probably fall in that range.

The incremental cost associated with purchasing future vehicles also is reported on at vast differences. One study found the incremental cost of purchasing a new CNG vehicle to be around 50K[3]. Yet another analysis has the incremental cost at around 12K[4]. In Public Solutions Group’s analysis they have the figure for a new vehicle running CNG to cost between 40K and 60K more than the a conventional diesel engine[5]. A fourth analysis puts the difference in cost between 16K and 80K depending on type of bus purchased[6]. Given these vast differences in costs it can be assumed that a range similar to conversion cost can be extrapolated with the 20K, 30K, and 40K per vehicle cost being fairly consistent as the price can be seen trending downward as this technology becomes wider spread.

Maintenance costs for CNG vs Diesel vehicles also vary quite a bit. Some estimates have the maintenance costs holding even for the two types of fuels[1]. Other estimates have a $.04/mile increase for the CNG vehicle[7]. In an *Environment, Science, and Technology* article the maintenance cost of CNG over conventional diesel is approximately $.30/mile[8]. Given this vast difference of maintenance cost of CNG vehicles vs Diesel vehicles we will assume a low value of $0.00, an average of $0.15/mile, and a high of $0.30/mile. While these are just rough estimates based on interpretation of other's findings we feel confident that these costs are reflective of expected results.

1. "Converting Municipal Feets to Compressed Natural Gass (CNG): Fuel Cost Savings and Conversion Consideration." J. Dallas Breen, James Burke, Frank A. Riley. (July 2013). *Stennis Institute* at Mississippi State University.
2. "Natural Gas vs Diesel." Jeff Carter. (April 2011). Points and Figures. Accessed at: http://pointsandfigures.com/2011/04/27/natural-gas-vs-diesel/
3. ."Business Case for Compressed Natural Gas in Municipal Fleets." Caley Johnson (June 2010). *National Renewable Energy Laboratory.* U.S. Dept. of Energy and Office of Energy Efficiency and Renewable Energy.
4. "Comparative Costs of 2010 Heavy-Duty Diesel and Natural Gas Technologies." Michael Jackson, Raymond Schubert, and Erin Kassoy (2005). *TIAX and NGVTF*.
5. "Hybrid-Diesel vs. CNG." Steven Richardson. (January 2013). *Public Solutions Group*.
6. "Clean Diesel versus CNG Buses: Cost, Air Quality, & Climate Impacts." Dana Lowell. (February 2012). *Strategic Environmental Consulting.*
7. "Reducing Transit Fleet Emissions Through Vehicle Retrofits, Replacements, and Usage Changes over Multiple Time Periods." Timon Stasko and Oliver Gao. (2010). *Transportation Research Part D.* (15) 254-262.
8. "Fuels for Urban Transit Buses: A Cost-Effective Analysis." Joshua Cohen, James Hammitt, Jonathan Levy. (2003) *Envirn. Sci. Technol*. (37) 1477-1484.

Fueling Station Infrastructure and Maintenance Cost

The first thing to note when trying to decide what the associative cost will be with a switch from diesel to CNG, when assessing the fueling station cost, is what the needs of the University transit system will be. Given that the initial conversion would probably only encompass about 12 to 15 buses there won't be a great need for infrastructure that can run a larger fleet (75-100 buses). There is however a need for fueling that can be done rather quickly (similar to the speed of a conventional diesel pump) and a station that can be adaptable to grow as the fleet brings in newer buses to cycle out the old.

There are really three major types of CNG fueling stations used in this sort of applicability. These are a Cascade Fast-Fill, a Buffer Fast-Fill, and a Time-Fill[1]. The Cascade Fast-Fill tends to be better with typical retail for random arrival so be able to have multiple compressors and operation throughout the day. The Time-Fill stations are a lower cost option but take several hours to fill and are better used with all night filling and are only good when vehicles return to the station every night to refill. Since the Universities vehicles can/will be coming all day and at some point there could be expansion to other vehicles the Buffer Fast-Fill station style is what would be recommended[1]. This station is the most frequent example used for transit buses and taxi services. They usually are comprised of a dryer (removes water vapor), compressor (creates appropriate pressure), buffer control panel (determines the flow of fuel), temperature compensation system (accounts for temperature differences to assess that the vehicle receives a full fill), and the dispensers (fill hoses).

The buffer fast-fill system that would meet the needs of MSU would be one with the gas dryer, two compressors, three large high pressure storage systems (tanks), and a two-hose fast-fill dispenser[1]. This type of setup would be able to fill "10 heavy-duty/20 DGE consecutively fueling in a 1-hour peak period"[1] and allow the University to be able to fill its fleet every evening or morning as needed as well as any randomly arriving light-duty vehicles that the University may find it beneficial to expand towards into the future. The costs associated with these types of systems vary.

In a publication produced at the Stennis Institute at Mississippi State University the authors found that a vast variety of prices can exist with these sorts of fast-fill stations[2]. They noted that the estimated cost can be anywhere between 400K and $1.7 million[2]. In the article cited previously about the recommended buffer fast-fill system, the cost of components is estimated at around 650K and the installation cost is estimated at around 350K bringing the total cost to 1 million[1]. In an additional article, “operation of 31 CNG vehicles required installation of 2 fueling facilities with a total cost of $400,000” (pg. 1716)[3]. This brings us to a conclusion that we can extrapolate three levels of facility cost being low (400K), average (750K), and high (1.1 million).

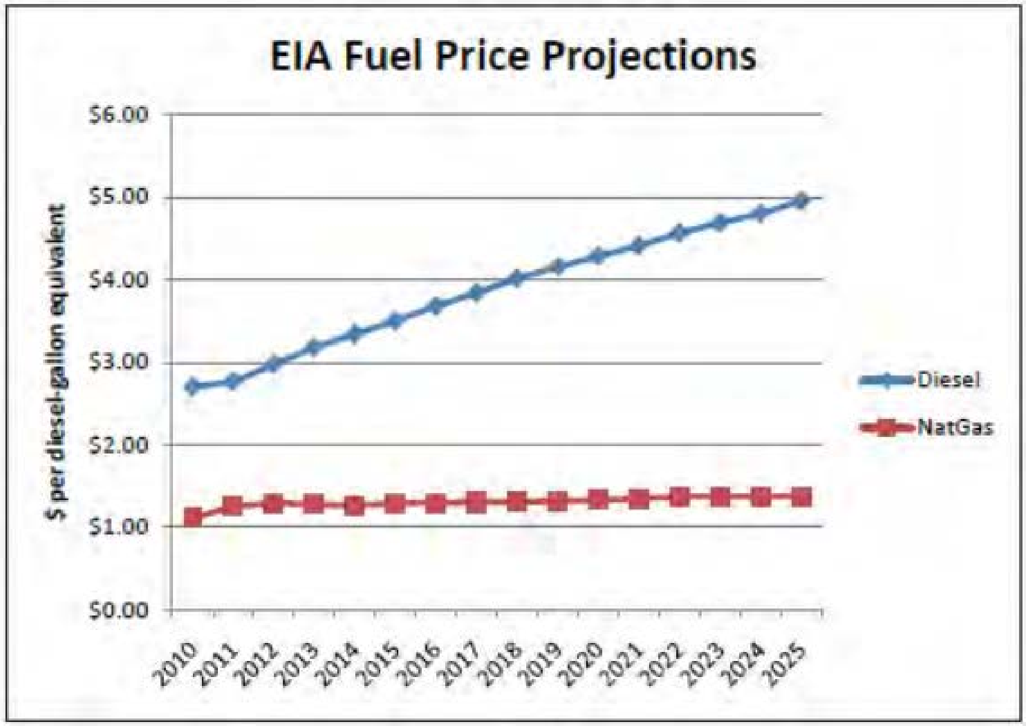
The maintenance cost for CNG stations also vary quite a bit. In one estimate the cost range from $950 per additional bus in low cost areas to between $1900 and $11,000 in high cost areas per bus[4]. In another study they found that average maintenance cost, including the cost of professional service to be between $205k/yr. (21 buses) and $292K/yr. (75 buses)[5]. A third study has the cost anywhere between 2.5K and 15K per month[6]. In yet another finding the cost of maintenance are approximately 1.5K per month on a quote from Richard Drake, P.E. and vice president of ET Environmental[7].

Given this vast array of prices for maintenance cost, we believe an extrapolation of cost can be on the low side being 25k/yr., the high being around 200K/yr., and an average being around 75K/yr. This is due to the fact that maintenance in Mississippi should be cheaper and can be done in house with proper training. While this is a simple and by no means exhaustive analysis of what it will actually cost there is quite a bit of room for variance.

1. "U.S. and Canadian Natural Gas Vehicle Market Analysis: Compressed Natural Gas Infrastructure." Prepared by TIAX for America's Natural Gas Alliance. (DATE!!!)
2. "Converting Municipal Feets to Compressed Natural Gass (CNG): Fuel Cost Savings and Conversion Consideration." J. Dallas Breen, James Burke, Frank A. Riley. (July 2013). *Stennis Institute* at Mississippi State University.
3. "Diesel vs. Compressed Natural Gas for School Buses: A Cost-Effectiveness evaluation of Alternative Fuels." Cohen, J. (2005). *Energy Policy*. (33). 1709-1722.
4. "Fuels for Urban Transit Buses: A Cost-Effective Analysis." Joshua Cohen, James Hammitt, Jonathan Levy. (2003) *Envirn. Sci. Technol*. (37) 1477-1484.
5. "Compressed Natural Gas Fuel Evaluation." Wave Transit. *Cape Fear Public Transportation Authority*. (September 2012).
6. "Business Case for Compressed Natural Gas in Municipal Fleets." Caley Johnson (June 2010). *National Renewable Energy Laboratory*. U.S. Dept. of Energy and Office of Energy Efficiency and Renewable Energy.
7. "Exploring the Total Cost of CNG." Shelley Mika. (April 2013) *Government Fleet.* Accessed at: http://www.government-fleet.com/article/print/story/2013/04/exploring-the-total-cost-of-cng.aspx.

Price Trend Data – CNG vs. Diesel

Over the past several years and predictably in the future we see a trend where Diesel prices are continually going up and CNG prices are predicted to be steadily low. See Table 1.



Source: US Energy Information Administration

When analyzing the cost savings associated with CNG vs. Diesel there are a few things to consider. Since there is a $0.50 commodities credit given to CNG providers for opening up their fueling stations to the public we will only hold for current commercial CNG prices, as we are not sure that the University is or would be willing to do that. In addition we used current Diesel prices which incorporate taxes. Since taxes in Mississippi on Diesel are roughly 42.4 cents per gallon, if the commodities credit were to be used on CNG it would basically wash out the taxes in the fuel cost[2].

The following table incorporates CNG prices for MS (1,000 ft.^{3}):

Show Data By: ◉ Data Series ○ Area	2008	2009	2010	2011	2012	2013
Commercial Price	12.48	9.48	8.75	7.99	7.38	7.60
Percentage of Total Commercial Deliveries included in Prices	90.4	91.0	90.6	89.8	89.0	89.1

Source: US Energy Information Administration

The following table incorporates Diesel prices in the Gulf States:

Show Data By: ◉ Product ○ Area	2008	2009	2010	2011	2012	2013
Diesel (On-Highway) - All Types	3.756	2.420	2.938	3.775	3.876	3.835
Ultra Low Sulfur (15 ppm and Under)	3.760	2.421	2.938	3.775	3.876	3.835

Source: US Energy Information Administration

Year	Cost of Diesel
2008	$ 3.76
2009	$ 2.41
2010	$ 2.94
2011	$ 3.78
2012	$ 3.88
2013	$ 3.84
Average = $ 3.43 Low = $ 2.41 High = $ 3.88	

To accurately analyze and incorporate CNG as compared to Diesel we must convert the cost of CNG to Diesel Gallons Equivalent (DGE). This equates the BTU's in the fuels in order to accurately be able to analyze the two fuels. The following table is that conversion.

Year	Commercial Cost per 1,000 Cubic Feet	1,000 Cubic Feet CNG to DGE Equation	$ DGE
2008	$ 12.48	$ 6.89	$ 1.81
2009	$ 9.48	$ 6.89	$ 1.38
2010	$ 8.75	$ 6.89	$ 1.27

2011	$ 7.99	$ 6.89	$ 1.16
2012	$ 7.38	$ 6.89	$ 1.07
2013	$ 7.60	$ 6.89	$ 1.10
Average = $ 1.30 Low = $ 1.07 High =$ 1.81			

As can clearly be seen the price of diesel over the past six years has trended up while the price of CNG has trended downward. This however is not the only step one must take when accurately comparing the mpg savings between the two fuels. While CNG can be converted to DGE based on BTUs, this is not an accurate reflection of how to compare the two fuels. CNG vehicles are actually less efficient than comparative diesel vehicles. The percentage is variable with some estimates in the 80% range and others in the 90% range for newer vehicles[1]. As this is the case we held the high, low, and average cost of CNG over the past six years and did an 80%, 85%, and 90% weighted cost to accurately compare the two fuels. (see chart below).

Cost Savings	80% Efficiency	85% Efficiency	90% Efficiency
Average (Avg. for both fuels)	$ 1.70	$ 1.81	$ 1.92
Low (Low Diesel, High CNG)	$ 0.48	$ 0.51	$ 0.54
High (High Diesel, Low CNG)	$ 2.25	$ 2.39	$ 2.53

Since this project is only seriously looking at converting only the newer fleet vehicles and the cost of additional vehicles we decided to just use the 85% efficiency numbers.

1. “Hybrid-Diesel vs. CNG.” Steven Richardson. (January 2013). *Public Solutions Group.*
2. “Diesel Taxes: Combined Local, State and Federal.” American Petroleum Institute. (April 2014). Accessed at: http://www.api.org/Oil-and-Natural-Gas-Overview/Industry-Economics/~/media/A375B82CC4184656A093C6168A1DD08E.pdf

Methods

Given the high variance with all of these numbers that are a result of differences in needs, sources, locations, times and a host of other reasons, we have decided to principally look at this analysis as if it were done on the averages of all variables. The following charts will illustrate the afore mentioned breakdowns of Station Costs and Maintenance, Vehicle Conversion Costs and Maintenance, and mpg Savings from CNG. As the initial conversion will likely be only the 12 buses and we cannot know the exact future growth of MSU's transit system, this would be the best way to assess the potential savings that MSU could expect if implemented today.

These tables were created with the intention of providing a snapshot of potential future benefits of purchasing CNG vehicles so it starts with the initial 12 vehicles we assume should be converted and proceeds incrementally forward. In addition given that some of the findings in the literature review did point to higher cost we will provide a look at a 12 vehicle conversion that incorporates less savings on mpg (taxes withheld and 80% efficiency) as well as slightly higher conversion and infrastructure costs and maintenance to see what we think a low end estimate might produce.

This first chart is the Low Cost Per Additional Conversion:

Amount of Vehicles	Cost Per Additional Conversion (Low)	Total Cost of Conversion	Assumed Miles Traveled* (14,000/vehicle/year)
12	$ 20,000.00	$ 240,000.00	168,000.00
15	$ 20,000.00	$ 300,000.00	210,000.00

20	$ 20,000.00	$ 400,000.00	280,000.00
25	$ 20,000.00	$ 500,000.00	350,000.00
30	$ 20,000.00	$ 600,000.00	420,000.00
35	$ 20,000.00	$ 700,000.00	490,000.00
40	$ 20,000.00	$ 800,000.00	560,000.00
45	$ 20,000.00	$ 900,000.00	630,000.00
50	$ 20,000.00	$ 1,000,000.00	700,000.00

*based on a percentage of MSU Miles Traveled per year (30 current buses traveling an average of 35,000 miles per month = 420,000 miles per year).

The Next Chart is the Average Cost Per Additional Conversion (highlighted #'s are used for analysis):

Amount of Vehicles	Cost Per Additional Conversion (Average)	Total Cost of Conversion	Assumed Miles Traveled*
12	$ 30,000.00	$ 360,000.00	168,000.00
15	$ 30,000.00	$ 450,000.00	210,000.00

20	$ 30,000.00	$ 600,000.00	280,000.00
25	$ 30,000.00	$ 750,000.00	350,000.00
30	$ 30,000.00	$ 900,000.00	420,000.00
35	$ 30,000.00	$ 1,050,000.00	490,000.00
40	$ 30,000.00	$ 1,200,000.00	560,000.00
45	$ 30,000.00	$ 1,350,000.00	630,000.00
50	$ 30,000.00	$ 1,500,000.00	700,000.00

*based on a percentage of MSU Miles Traveled per year (30 current buses traveling an average of 35,000 miles per month = 420,000 miles per year).

The Next Chart is the High Cost Per Additional Conversion:

Amount of Vehicles	Cost Per Additional Conversion (High)	Total Cost of Conversion	Assumed Miles Traveled*
12	$ 40,000.00	$ 480,000.00	168,000.00
15	$ 40,000.00	$ 600,000.00	210,000.00

20	$ 40,000.00	$ 800,000.00	280,000.00
25	$ 40,000.00	$ 1,000,000.00	350,000.00
30	$ 40,000.00	$ 1,200,000.00	420,000.00
35	$ 40,000.00	$ 1,400,000.00	490,000.00
40	$ 40,000.00	$ 1,600,000.00	560,000.00
45	$ 40,000.00	$ 1,800,000.00	630,000.00
50	$ 40,000.00	$ 2,000,000.00	700,000.00

*based on a percentage of MSU Miles Traveled per year (30 current buses traveling an average of 35,000 miles per month = 420,000 miles per year).

This Chart Illustrates the Incremental Maintenance Cost/Vehicle/Mile (Highlighted fields will be used for analysis):

#	Incremental Maintenance Cost Low	Incremental Maintenance Cost/Mile High	Incremental Maintenance Cost/Mile Average
	$ -	$ 0.30	$ 0.15

1 2		$ 50,400.00	$ 25,200.00
1 5		$ 63,000.00	$ 31,500.00
2 0		$ 84,000.00	$ 42,000.00
2 5		$ 105,000.00	$ 52,500.00
3 0		$ 126,000.00	$ 63,000.00
3 5		$ 147,000.00	$ 73,500.00
4 0		$ 168,000.00	$ 84,000.00
4 5		$ 189,000.00	$ 94,500.00
5 0		$ 210,000.00	$ 105,000.00

This Chart Illustrates the various Fuel Station Infrastructure Costs and Annual Maintenance Costs (highlighted fields will be used):

Infrastructure Cost Average	Infrastructure Cost Low	Infrastructure Cost High
$ 750,000.00	$ 400,000.00	$ 1,100,000.00

Annual Cost of Maintenance Average	Annual Cost of Maintenance Low	Annual Cost of Maintenance High
$ 75,000.00	$ 20,000.00	$ 200,000.00

This Chart Illustrates the average cost savings in mpg CNG vs. Diesel:

#	Assumed Miles Traveled* (14,000/vehicle/year)	Low End Cost Savings MPG **	High End Cost Savings MPG**	Average Cost Savings MPG**
		$0.51	$2.39	$1.81
12	168,000.00	$ 85,680.00	$ 401,520.00	$ 304,080.00
15	210,000.00	$ 107,100.00	$ 501,900.00	$ 380,100.00
20	280,000.00	$ 142,800.00	$ 669,200.00	$ 506,800.00
25	350,000.00	$ 178,500.00	$ 836,500.00	$ 633,500.00
30	420,000.00	$ 214,200.00	$ 1,003,800.00	$ 760,200.00
35	490,000.00	$ 249,900.00	$ 1,171,100.00	$ 886,900.00
40	560,000.00	$ 285,600.00	$ 1,338,400.00	$ 1,013,600.00
45	630,000.00	$ 321,300.00	$ 1,505,700.00	$ 1,140,300.00
50	700,000.00	$ 357,000.00	$ 1,673,000.00	$ 1,267,000.00

** Based on Consumer Price Differences Over 6 year period for high, low, and average differences in Price. Also including an assumed 85% efficiency. (See Chart in *Price Trend Data*)

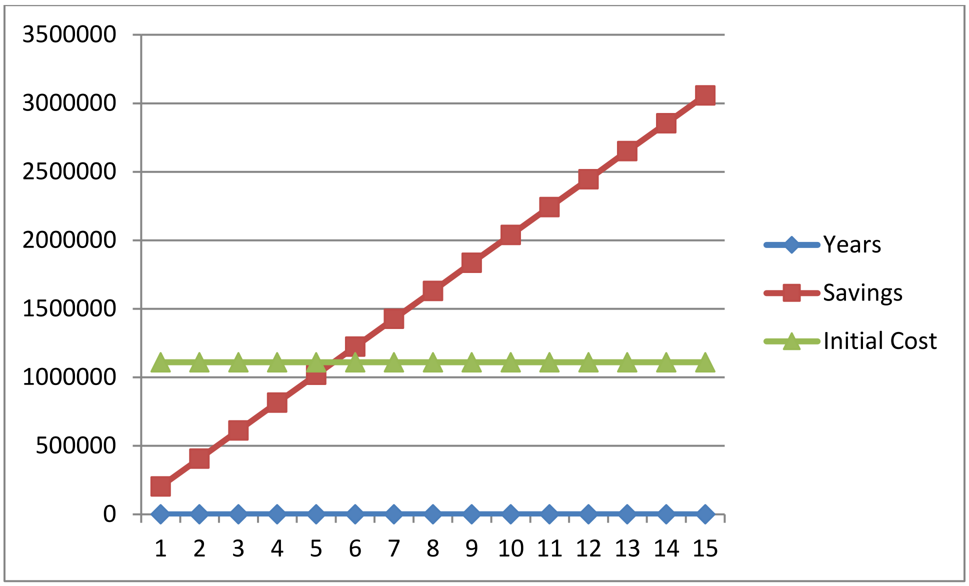
Findings and Interpretation

Cost Savings

The following chart, with accompanying breakdown of the methods used to measure the cost and savings, illustrates that somewhere between 5 and 6 years at 14,000 miles/vehicle/year the 12 converted transit buses can be expected to pay back the initial cost of conversion. This shows that over the life of the vehicles (assuming a 15 yr. turnover) the savings from this conversion could be as great as 2 million dollars.

<u>Average Savings Timeline</u>

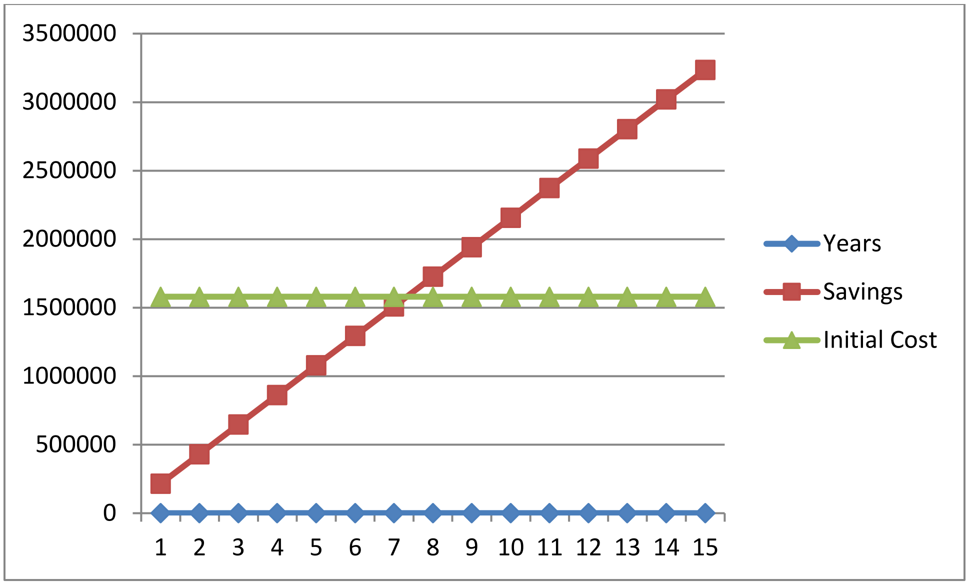
(Initial Cost = $750,000.00 Infrastructure Average + $360,000.00 Average Conversion for 12 Vehicles) (Savings = Average mpg Savings for 12 Vehicles $304,080.00 - $75,000.00 Average Annual Cost of Fueling Station Maintenance – $25,200.00 Average Incremental Maintenance Cost for 12 Vehicles)



Given that cost for conversion of these vehicles and infrastructure cost can be especially high in some cases we would also like to run another analysis, given the vast array of literature we have explored, as it may provide an even better or, potentially, more accurate insight into the potential cost/savings. In this review we will only look at the last two years of fuel prices and withhold diesel taxes and weight at 80% efficiency. We will also assume a high cost of vehicle conversion and a high cost of infrastructure. The fueling station maintenance cost and incremental maintenance cost will remain the same.

Hybrid Savings Timeline

(Initial Cost = $1,100,000.00 Infrastructure High + $480,000.00 High Conversion for 12 Vehicles) (Savings = Hybrid mpg Savings for 12 Vehicles {[(3.86 diesel average -.425taxes – 1.085 cng average)(.8o efficiency)]*(12*14,000mi./yr.)} of $315,840.00 - $75,000.00 Average Annual Cost of Fueling Station Maintenance – $25,200.00 Average Incremental Maintenance Cost for 12 Vehicles)



This chart illustrates that, even in the event of higher initial costs and fuel prices being more reflective of the current context, savings from a conversion of 12 vehicles can be seen in less than 8 years. This illustrates a savings over 15 years of approximately $1.6 million.

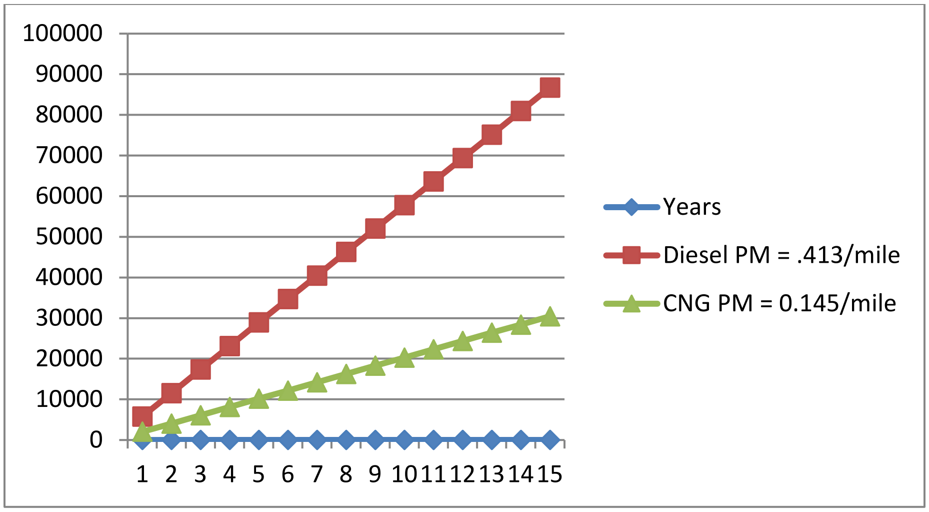
These two scenarios: the average and the hybrid model, illustrate quite well that savings for CNG conversion are certainly feasible and over a lifespan of 15 years are more than worth the considered investment. There are other considerations that must be looked at as well in order to properly understand the whole potential for CNG and how and why MSU might want to consider more vigorously converting its fleet going forward. These are the potentials for environmental impact.

Environmental Emission Differences

In addition we also wanted to look at the potential environmental impact from a conversion such as this. Assuming the central measurements for emissions as provided in Cohen et. al (2003) and based on the 14,000 mile per vehicle measurement we can chart the expected emissions of CNG vs. Conventional Diesel (this will include both vehicle operation emissions and upstream emissions)[1]. The master data inputs follow as well as each category comparing CNG to Diesel.

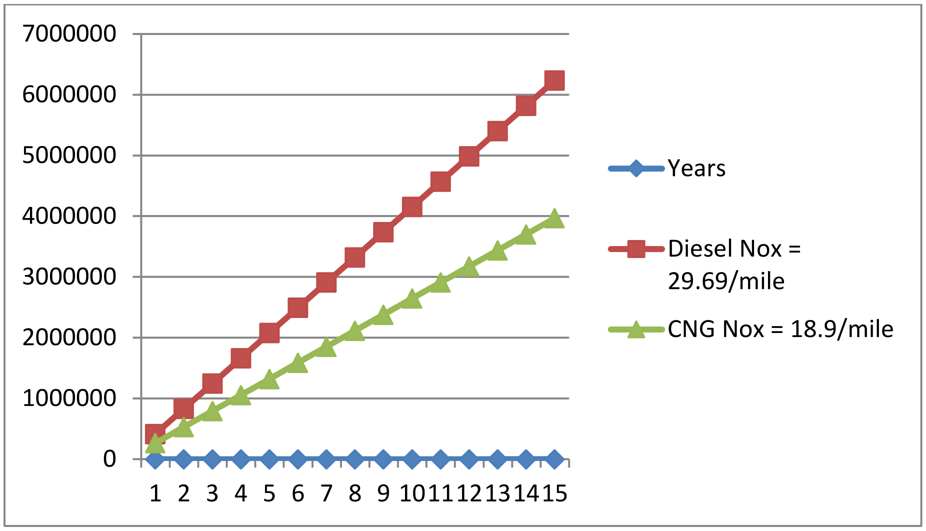
Years	Diesel CO_2	Diesel Nox	Diesel SO_2	Diesel PM	CNG CO_2	CNG Nox	CNG So_2	CNG PM
	3370/mile	29.69/mile	.84/mile	.413/mile	4030/mile	18.9/mile	0.83/mile	0.145/mile
1	47,180,000.00	415,660.00	11,760.00	5,782.00	56,420,000.00	264,600.00	11,620.00	2,030.00
2	94,360,000.00	831,320.00	23,520.00	11,564.00	112,840,000.00	529,200.00	23,240.00	4,060.00
3	141,540,000.00	1,246,980.00	35,280.00	17,346.00	169,260,000.00	793,800.00	34,860.00	6,090.00
4	188,720,000.00	1,662,640.00	47,040.00	23,128.00	225,680,000.00	1,058,400.00	46,480.00	8,120.00
5	235,900,000.00	2,078,300.00	58,800.00	28,910.00	282,100,000.00	1,323,000.00	58,100.00	10,150.00
6	283,080,000.00	2,493,960.00	70,560.00	34,692.00	338,520,000.00	1,587,600.00	69,720.00	12,180.00
7	330,260,000.00	2,909,620.00	82,320.00	40,474.00	394,940,000.00	1,852,200.00	81,340.00	14,210.00
8	377,440,000.00	3,325,280.00	94,080.00	46,256.00	451,360,000.00	2,116,800.00	92,960.00	16,240.00
9	424,620,000.00	3,740,940.00	105,840.00	52,038.00	507,780,000.00	2,381,400.00	104,580.00	18,270.00
10	471,800,000.00	4,156,600.00	117,600.00	57,820.00	564,200,000.00	2,646,000.00	116,200.00	20,300.00
11	518,980,000.00	4,572,260.00	129,360.00	63,602.00	620,620,000.00	2,910,600.00	127,820.00	22,330.00
12	566,160,000.00	4,987,920.00	141,120.00	69,384.00	677,040,000.00	3,175,200.00	139,440.00	24,360.00
13	613,340,000.00	5,403,580.00	152,880.00	75,166.00	733,460,000.00	3,439,800.00	151,060.00	26,390.00
14	660,520,000.00	5,819,240.00	164,640.00	80,948.00	789,880,000.00	3,704,400.00	162,680.00	28,420.00
15	707,700,000.00	6,234,900.00	176,400.00	86,730.00	846,300,000.00	3,969,000.00	174,300.00	30,450.00

The particulate matter or PM chart goes as follows (single vehicle/yr.)



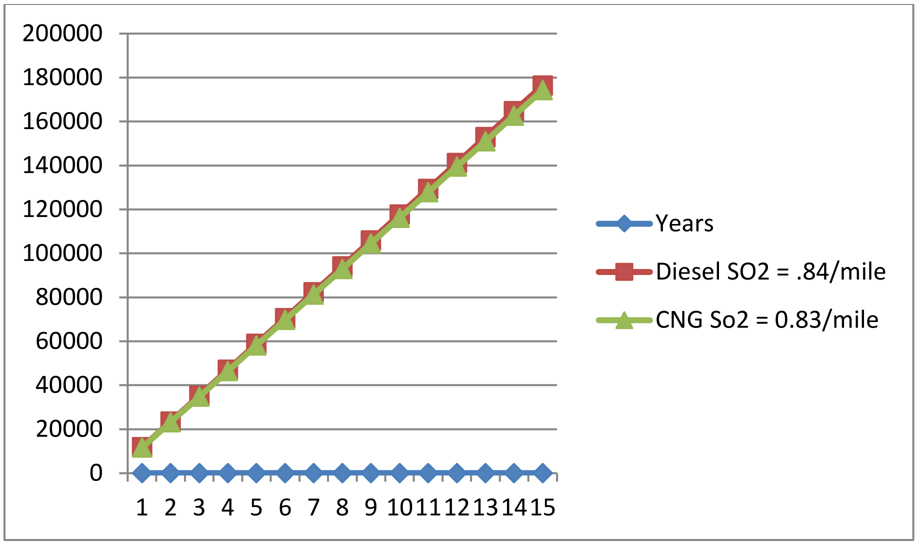
As one can see with an initial PM difference of 65% CNG vastly decreases the particulate matter over the lifespan of a single vehicle.

The Nitrous Oxide or NOx chart goes as follows (single vehicle/yr.)



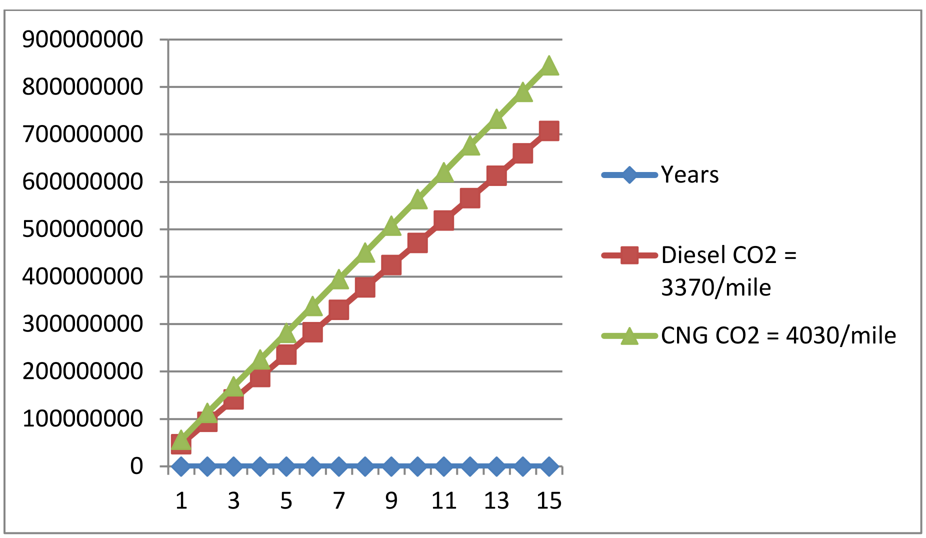
Given the fact that CNG cuts emissions of NOx by 36%, over the lifespan of a single vehicle this can be huge savings in the amount of NOx put into the environment.

The Sulfur Dioxide or SO2 chart goes as follows (single vehicle/yr.)



While CNG vehicles actually emit no SO2 in their operations the upstream emissions from the CNG processes produce more than Conventional Diesel[1]. The end result is almost equal emissions of SO2 from the two fuels.

The CO2 or carbon dioxide chart goes as follows (single vehicle/yr.)



Theoretically a DGE of CNG and conventional diesel should produce the same amount of Carbon Dioxide. However the upstream emissions for CNG increase the CO2 amount as well as the fact that CNG by DGE is less efficient than conventional diesel.

These charts illustrate that, while CNG produces less NOx and PM, it produces more CO_2. The environmental impacts would appear to be a wash, however, not all greenhouse gases or emissions are created equally. PM can tend to be carcinogenic and very bad for health and NOx can form ground level ozone or smog[1]. Therefore while the current big fuss is focused on reducing CO_2 there are very real environmental benefits to consider.

1. "Fuels for Urban Transit Buses: A Cost-Effective Analysis." Joshua Cohen, James Hammitt, Jonathan Levy. (2003) *Envirn. Sci. Technol.* (37) 1477-1484.

Recommendations, Considerations, and Conclusion

The United States of America has been at the forefront regarding many of the innovations that have changed the world and allowed for the pursuit of fiscal policies to reduce costs and increase efficiency from the federal government to local municipalities. These innovations that have allowed for the United States government to pursue cost-saving fiscal maneuvers are the result of federal policies that have been championed, such as that of reducing greenhouse emissions and creating a cleaner and healthier environment for future generations. The natural gas industry's vitality over the past decades have been instrumental in the United States being able to pursue initiatives at the national level to actively reduce costs and build capacity at all levels of government to decrease the United States dependency on petroleum and foreign imports. Compressed Natural Gas (CNG) has been viewed as the fossil fuel that is most suitable for transportation purposes on many different fronts: cheaper than other alternative sources of energy, market is not as volatile, more fillings stations than other alternative fuel sources, and it will increase the local economy by providing jobs and Research and Development Programs—only to name a few. There are many incentives and programs available to states to offset the substantial upfront costs to put the infrastructure in place; nevertheless, as this research has accurately shown, there are so many other factors that must be considered in order to pursue alternative fuel sources. Mississippi State University's Student/Public Transit System feasibility is a perfect example of the contingencies that have to be considered in determining whether CNG is the most viable energy source that will achieve the most cost-savings and efficiency output in the heavy-duty fleets.

Based on a thorough analysis of the Mississippi State University current heavy-duty fleet transportation system and the new innovative SMART system, the capstone group can conclude with great veracity that while a decision to convert to CNG is contingent upon many factors that fall under infrastructure costs, cost-savings, and the payback period of initial investment; there are many government programs that make the potential for conversion extremely attractive—such as: tax credits associated with infrastructure cost, tax credits available to offset conversion costs, public/private partnerships, and the opportunity to engage mechanical engineering students at MSU in some capstone oriented capacity to assist with infrastructure and maintenance objectives but also as a way for the students to give back to MSU and their community. The communication department here at MSU could assist with the promotion and branding of the investment project, while simultaneously gaining valuable work-related experience that will greatly enhance their career trajectory.

Overall we conclude that the findings for potential cost-savings illustrate a need to more actively consider and pursue looking into conversion of its heavy-fleet (transit) vehicles. Given the growth of this energy sector and the potentials it has for dramatic reductions in fuel budgets, more studies should look at expanding CNG conversion (especially once infrastructure is in place) to light-duty vehicles as well. CNG provides a clean, cheap, and domestic ability to reduce budgets, be environmentally sound, and reduce our dependency on foreign petroleum sources.