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Climate hope is not dead! In accordance with QER’s inclusion of climate change impact on energy policies, we reviewed climate status and policy publications released over the past 18 months. These documents paint a gloomy picture of climate change with highly uncertain outcomes and a policy structure that has failed to achieve agreement on how to effectively move forward on climate change after twenty-five years of trying.

The silver lining buried in the thousands of climate change pages comes form James Hansen, the former head of NASA’s Goddard Institute for Space Studies and one of the world’s foremost climate experts. In his 2014 paper (jhansen 2014) he lays-out a science and fact based strategy that holds out the potential and possibility of reversing the melting of the world’s ice sheets and glaciers, especially in the Arctic, global warming’s ominous sentinel of things to come. But only if we act now!

Adopting ice melt reversal as the goal of energy and climate policies could turn the legacy of this generation from one of perceived recklessness and inaction leading to despair and possible catastrophe; to one of science, fact-based hope and historic achievement. We could monitor the progress towards achieving the goal from planet vital signs as recently published in Nature by David G.Victor and Charles F. Kennel.

Best of all, seriously moving in this direction would inspire hope in young people who are near certain to live through and have to endure some of global warming’s harshest impacts if we continue current strategies or policy stagnation.

In this submission, we strongly urge QER to introduce and consider the reverse-the-ice-melt goal in upgrading ST& D infrastructure and energy polices. We introduce new infrastructure and energy transition technologies to advance progress towards this goal as well a mechanism to assure a near and long term flow of energy transition and sustainability technologies to energy and materials markets.

***Climate Review***

We reviewed NCA 3 US Climates Assessment, IPCC AR5 and related documents and summaries, IEA publications related to climate and combustion of fossil fuels, IEA Technology Roadmap, and the latest World Energy Outlooks. Further, we reviewed the work and assessments of independent scientists and climate experts. We focused on several major issues including ice melt status in the Cryosphere, recent events in the Arctic and climate responses to CO2 emissions that impact the rate of climate change. We explored the potential of reaching an irreversible, major, climate tipping point with disastrous results —a near certain possibility recognized by institutional and independent scientists.

***Expected Greater Climate Action —Limits on Fossil Energy Supply***

Most recent climate assessments agree that maintaining a planet somewhat similar to the one we now live in requires limiting CO2, emissions to 565 billion tons CO2 (~129 GtC) between 2007and 2049; plus reducing atmospheric carbon concentration to 350ppm or lower with CO2 reduction actions beginning now and continuing until climate stability is achieved. Reaching these CO2 reduction goals requires major cuts in CO2 and methane emissions near term.

Limits on fossil fuel use under climate change mandates will reduce the volume of fossil fuels that can be burned and WEO projects a rapid decline in production of non-conventional oil and gas in approximately 10 years. These oil and gas losses could be replaced with liquid renewable fuel production and greater efficiency in oil markets.

Most all recent climate and energy related publications stress that moreenergy research development and demonstration “RD&D” is essential to achieving this century’s climate goals while maintaining energy supplies. Although we agree on this issue, our priorities focus more on application to markets of independently developed market-ready or near-ready technologies. We urge DOE/QER to support adding market application and market entry to the RD&D list of essential investments to be made –and fund such activities.

The greatest opportunity for near term reductions of CO2 emissions with a high degree of certainty lies in global oil markets. The core technologies discussed below open major oil markets to greater efficiency and clean renewable fuels. They also provide for high volume domestic production of clean renewable fuels and new materials.

***Oil Market Challenges*** Under current climate policies, according to IEA’s WEO 2013, world oil consumption will increase from the current 89 million barrels (bbls)/day to 112 million bbls/day forcing 52.94 million tons of CO2 into the atmosphere daily in 2035. This amounts to 19.3 ***billion*** tons of CO2 per year from 1.72 ***Trillion*** USG of oil. The lower carbon emissions climate scenarios now under consideration still increase daily world oil consumption well over an unacceptable 100 million bbls per day in 2035.

ICEs inefficiently consume 70% of world oil; and there are well over a billion of these engines operating worldwide every day. They consume approximately 63 million barrels of oil per day (2.65 ***billion*** US gallons) ***emitting an estimated 23.3 mega tons of CO2 daily and 10.7 billion tons of CO2 per year.*** WEO attributes the growth in oil consumption to growth in international diesel fuel markets.

The THA/AHN collaboration accesses a wide range of proven energy transition technologies that can enter oil markets with greater efficiency and high volume domestic production of clean renewable fuels (The “Core Technologies”).

**Expanded Liquid Fuel Options –Government’s Role**

**Relevant Select QER Questions**: What is the potential for TS & D infrastructure changes to enable alternative lower-carbon, more energy efficient energy production?

What alternative policies, technologies, and investment solutions would most effectively achieve our emissions and resilience goals?

How does penetration of various new technologies impact oil, gas, electricity, and fueling TS&D infrastructure?

***The Core Technologies.***

The Core Technologies are backed by over 40 years and 600 person years of invention, research, development, and demonstration, as well as 130 issued US patents, 70 more in the patent pipeline, and a network with skills, know-how, and additional patentable inventions. Most of these materials and energy technologies are at or near application ready but need the resources and policies required to apply them to energy and materials markets.

***Oil Market Access Technologies:*** The retrofitable precision spark injection (PSI) system and the thermochemical regeneration (TCR) system work together to increase ICE efficiency by as much as 30% and consequently cut GHG emissions by the same 30%. The PSI/TCR open the internal combustion engine (ICE) to a wide range of fuel selections including renewable fuels and hydrogen. Collectively, these two technologies are referred to as the Firewater System or just Firewater. (Please see technical paper in Appendix I and appropriate patents referenced in Appendix II). Further, technical details available under appropriate non-disclosure agreements.

***The PSI System****:* The Thermochemical Regeneration System (“TCR” ) described below delivers a regenerated fast, clean burning, fuel to the PSI fuel injector system. The PSI system injects the fuel into the engine’s combustion chamber through a spark that insures positive ignition as the fuel enters the combustion chamber. The positive ignition, the hydrogen character of the regenerated fuel and the fast burn enable a higher heat release than the original fuel delivers and they reduce heat losses to the cooler cylinder walls, pistons, valves and head transferring this normally wasted energy to powering the pistons downward movement. The PSI system increases fuel efficiency by approximately 5%. The spark injection feature applies to use on diesel engines as well as gasoline fueled engines. When retrofitted to an engine together with the TCR, the engine will be able to efficiently utilize most any spark ignitable fuels including renewable fuels, hydrogen and Metrol® fuels. These fuels are described later in this document.

***The TCR”) System****:* The retrofittable TCR unit has multiple applications. In diesel engines it receives alternative, renewable or traditional fuels and rejected (waste) energy from the engine powers regeneration of the incoming fuel This result in a clean fast burning, hydrogen characterized fuel that enables a greater heat release to the combustion chamber. (See ICE and materials patent references in Annex II).

***Metrol® Fuel Production and Preemptive CO2 Capture***Metrol ®fuels are a family of fuel blends made from CO2 and N2 extracted from the air and hydrogen. CO2 can also be captured from stacks of facilities that burn fossil fuels and used as a source of carbon to make Metrol® fuels and new materials. Preemptive carbon removal:

xC + O2 🡪 CO2

Hydrogen produced from an abundant range of substances that either rot or burn and other substances containing carbon and hydrogen are anaerobically disassociated in an endothermic process to provide separate supplies of hydrogen and carbon

CxHy + Heat 🡪xC + .5yH2

CH4 + Heat🡪C + 2H2

Each ton of collected carbon (that does not burn) preemptively prevents formation of 3.66 tons of carbon dioxide.

The co-produced hydrogen is combined with air (particularly the CO2 and N2 in the air) to form Metrol® liquids that replace fossil fuels and ***that can be transported in conventional pipelines stored in gasoline, diesel fuel, LP and natural gas fuel tanks***. An example of a completely carbon-free fuel constituent of Metrol® blends is ammonia (NH3) or ammonium hydroxide (NH3OH). Another fuel blend constituent is urea, and other blends include fuel alcohols -- all of which are made from hydrogen and air and are therefore renewable for as long as the air contains CO2. and N2.

Metrol fuels are "net-hydrogen" because they are made from hydrogen and air and when used they emit water and cleaner air. In engine operation heat rejected by the coolant and/or by the exhaust gases release pressurized hydrogen from the Metrol fuel and deliver it to the engine. The hydrogen fueled engine can produce more power when needed, last longer with less maintenance, and actually clean the air that is utilized to produce the Metrol® fuel that passes through the combustion chamber.

In applications where Metrol® fuels replace fossil fuels they produce negative CO2 emissions. The renewable Metrol® fuel powers the engine without carbon emissions and the carbon extracted from the air leaves the atmosphere minus the carbon extracted from it.

In stationary applications such as industrial parks, ports, power plant sites, and rail yards, the captured carbon can be utilized to produce new materials. These materials are stronger than steel, lighter than aluminum, more conductive than copper, long lived, recyclable, and re-deployable. Materials production yields renewable hydrogen as a byproduct.

The best place to make metrol® fuel is in industrial parks that produce carbon enhanced products ranging from diamonds to semiconductors to asphalt.

Making durable goods and equipment from the new materials keeps the carbon out of the atmosphere. Further, When these new materials are used to reinforce wind and other forms of renewable energy they increase the energy output of these facilities for as long as they operate and extends their useful lives --a far better use than burning the carbon once and having to deal with its aftermath of climate warming CO2.

When these materials are applied to durable infrastructure equipment such as pipelines, utility poles, transmission and distribution lines or vehicles, vessels, rail cars, etc. they lighten them and extend their useful life. Perhaps most important as the durable new materials and goods enter major markets they sequester carbon for the useful life of the equipment and can be recycled or redeployed indefinitely creating a growing carbon sink with each application.

***ICE Applications, Fuel Use and Dollar Savings*** Applying the Firewater technologies to medium and large diesel engines in in ships, and power production cuts CO2 emissions and fuel consumption; and provides a payback of retrofitting costs in the very near term from fuel cost savings. Figure 1 below is an example of the fuel and CO2 emissions reductions that can be achieved with Firewater on a medium-large diesel engine in ship or power generation

*Fig. 1*

Line two of Figure 1 shows the fuel consumption and CO2 reductions the Fig. 1 engine can achieve with a Firewater retrofit operating on a mixture of diesel oil (DO) and heavy Fuel Oil (HFO), a typical mix of marine and off-shore power plants fuels. The second to last column titled *CO2 Reductions per Engine* shows a reduction of 57,048 annual tons of CO2 emissions from Firewater retrofitting. Fuel consumption savings equal 487 USG/hour and 3,798,600 USG/year on a typical 7800 hours annual operating schedule.

These reductions come from just the efficiency increase provided by the Firewater system. Additional CO2 reductions can be achieved by switching to natural gas due to its lower carbon concentration. Switching to no-carbon Metrol® fuel provides an emission reduction of 156,881tons/CO2 per year plus a CO2 credit equal in the amount of carbon removed from the air to make the Metrol® fuel. This credit assures negative CO2 emissions when operating a Fig. 1 engine on Metrol® fuels.

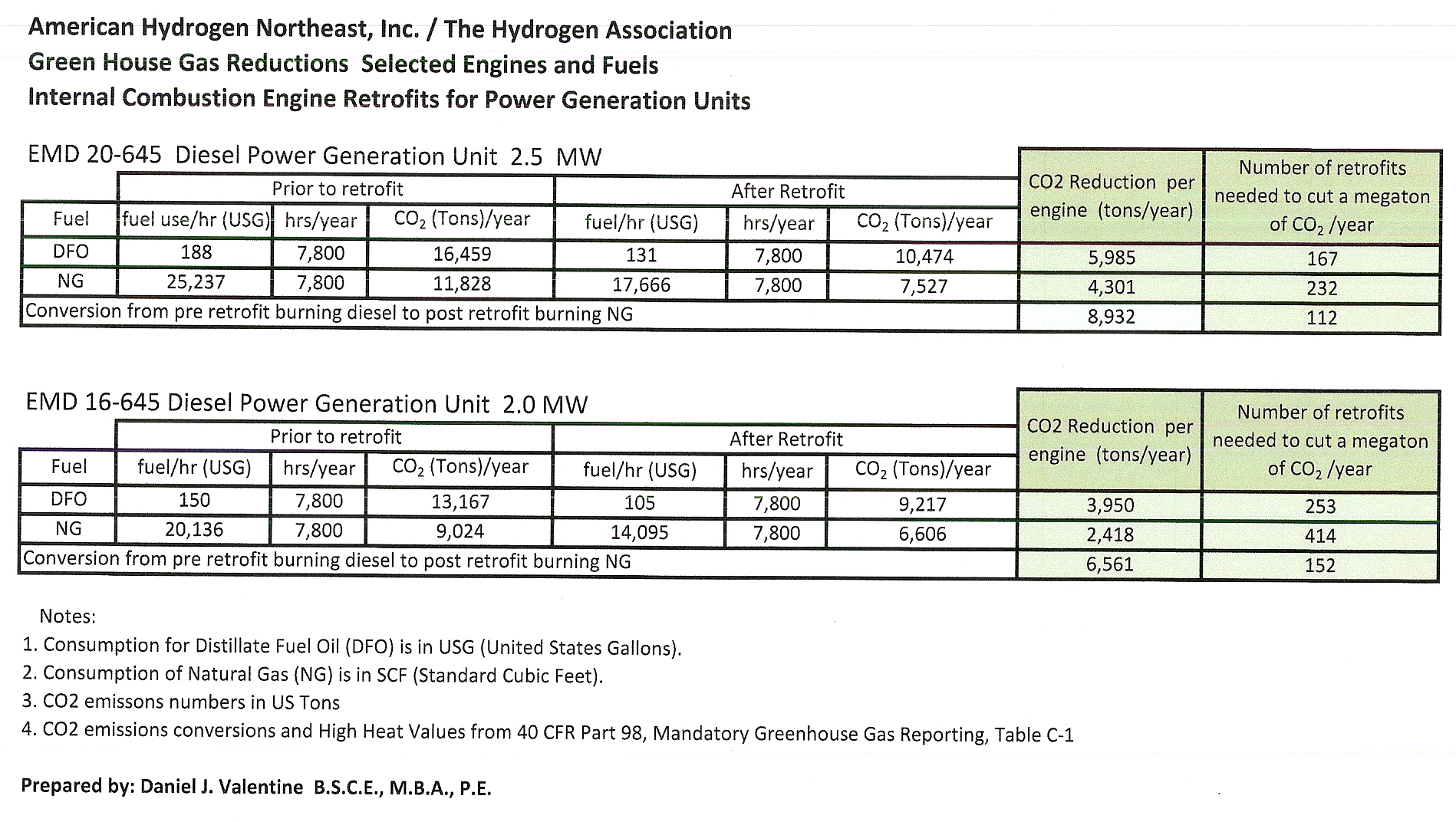
The last column is the number of engines in the Fig.1 required to annually reduce CO2 emissions by a million tons/year from just the efficiency increases. In the example, it takes 18 converted engines to cut a megaton of CO2 from annual engine emissions. When operating on Metrol® fuel, it takes just 6 Figure 1 engines to cut a megaton of CO2 emissions/year. A well serviced and maintained diesel engines can last 100 years and operate without GHG or other emissions emissions. ***It would take removing over 30,000 cars from service in the US to equal the CO2 emissions reductions achieved by retrofitting one Figure 1 engine.***

The Firewater system also eliminates health-damaging carbon particulates and nearly eliminates NOx emissions. With Metrol® fuels the only emission is clean water.

***Engine Economics*** At a $2.58 cost per gallon of a diesel fuel/HFO mixture, the engine efficiency savings of 487/USG/hour equals fuel cost savings of $1256/hour and $9,800,388/ year. These large savings per engine enable the THA/AHN collaboration to generate net after tax revenues and reinvest them in further R, D, and applications to markets independent of depletable energy and materials competitors.

***More Firewater Diesel Applications*** The Firewater system economics are also attractive to small industrial/locomotive size engine owners in rail, harbor craft, push boats, tugs ferries and small power generation. Below in figure 2 is an example of the CO2 and fuel consumption reductions that a typical diesel engine in these markets can achieve with a Firewater retrofit. The chart assumes a 30% increase in fuel efficiency from Firewater.

Fig. 2.



Line one of the upper chart of Figure 2 shows the fuel consumption and CO2 reductions a typical Figure 2 engine can achieve with a Firewater retrofit when operating on diesel oil in a line haul locomotive, small ship, or power generation plant with 7800 annual average operating hours. DO is a typical fuel in these markets.

In this case, Firewater cuts CO2 emissions by 5,985-tons/annum and fuel consumption by 57 USG/hour and 444,600 USG/Year. When operating on Metrol fuel, the engine emits only water reducing CO2 emissions by 16,459 tons/year plus a credit for the amount of CO2 extracted form the air to make Metrol fuel.

***Engine Economics*** At $3.00/USG cost of diesel fuel engine owner save $1,333,800 per annum in fuel costs (444.600 USG x $3.00 = $1,333,800) providing a quick payback of retrofitting costs and reduced operating costs thereafter; a strong incentive to retrofit. The cleanup of toxic emissions further incentivizes engine owners. Firewater enables retrofitted engines to meet current and proposed EPA and international emissions standards.

Converting just one of these engines reduces CO2 emissions equal to taking 1,108 cars off the road.

US Class I railroads own and operate over 24,000 locomotives and there are ~100,000 operating worldwide. In the US there are roughly 9000 tug-size work vessels. As a rule, cargo ships have more than one propulsion engine and there are ~90,000 of them in operation. Both the rail and marine industries are actively seeking clean alternatives to diesel and HFO.

The point here is that increasing engine efficiency in these markets and opening these giant high polluting high GHG emitters, to clean renewable fuels could make a giant step towards climate safety while assuring an abundant energy supply ***without major T S & D changes.***

***Industry Economic Benefits***. Fuel costs make-up a significant percentage of rail, marine and power generation operating costs. Widespread application of Firewater systems in the heavy diesel engine market has the potential to make rail and marine industries more efficient and cleaner operating.

Expanding the application of Firewater technologies to diesel transport vehicles where a substantial portion of the increase in oil demand between now and 2035 arises. Entering these markets could begin as early as 2020 if funding for market applications is procured timely.

***Coal Market Alternative, DG/CHP, STD Cost Reductions***

**Relevant Select QER Questions for this Section:** What options or best practices for configuring TS&D systems to allow new technologies (Generation, end use, etc) to compete with one another?

How does penetration of various new alternative fuels and technologies impact oil, gas, electricity and fueling TS&D infrastructure?

How can and should TS&D systems be configured to enable more consumer choice?

To what extent can demand response programs reduce the need for electricity generation and capacity?

***Firewater’s Role***Applying the Firewater engine technologies to distributed generation and small scale CHP opens a new pathway to clean energy competition in electricity markets. Firewater Systems increase engine efficiency and clean-up emissions with any fuel selection. Its fuel flexibility provides greater consumer choice and the potential to switch to renewable fuels and alternative fuels. When Metrol fuels become available in an area fuel costs decrease and only water vapor is emitted.

***Small-Scale DG/CHP*** can be backed up by relatively inexpensive electricity storage that supplies electricity when engine is shut down for maintenance or exchanged for overhauls eliminating the need for grid connection and utility capacity.

***DG/CHP combats global warming threats***. Closed loop cooling systems eliminate demand for high volumes of cooling water and the potential for shutdown or reduced power output during heat waves or droughts. Decentralizing power generation eliminates outages from transmission and distribution damage from fires, super storms, and other GW impacts on TS&D systems.

***Impact on TS&D*** In service areas where large-scale Metrol fuel production facilities are located gas distribution systems would be utilized to safely distribute hydrogen to DG engines using the technologies disclosed in US patent 8,313,556. Although no change in the current pipeline facilitates would be needed, regulators would have to assure access to the system.

***Financing Firewater equipped DG/CHP*.** QER pubs estimate that upgrading the ST&D electrical systems wiil cost two trillion dollars and this cost will be passed on to ratepayers. Investing in DG would bring financial benefits to ratepayers instead of higher costs. These benefits would incentivize ratepayers to switch advancing the transition to low and no carbon fuels. Reduced loads on TS&D would reduce the extent to which the grid would have to be upgraded and cut the estimated costs in proportion to the shift to DG. DG units could be sized and equipped to charge electric vehicles. The number of people who switch to DG/CHP would be the only limit the extent to which DG/CHP could reduce central system loads.

***Financing DG/CHP*** installations have numerous methods and benefits. Manufacturers of DG units, utilities, ratepayers and DG purchasers and or DG O&M companies could pay the cost of installation and get repaid from a portion of cost savings from switching to DG in much the same way as solar panels are being financed now in many instances.

Ratepayers who own their home or facility could borrow money at mortgage interest rates and repay the loans from ratepayer DG savings. Governments could provide low interests loans and secure the loans with a call on ratepayer savings. Financing along these lines avoids the cost of large credit instruments and the time consuming and expensive legal and permitting requirements and the regulatory delays of large-scale projects.

Shifting the burden of financing to a large number of credit-worthy individuals and businesses spreads and reduces the financial risks cuts the price tag utilities and governments would have to take on in major financings.

The 300 US power plants subject to flooding, sea level rise, storm surges or heat wave shut downs or reduced power outputs will not impact DG operations.

***Assuring a Supply of Competitive Energy Transition Technologies***

Most all recent climate and energy related publications assert that new energy technologies and more research, development, and demonstration “RD&D” are essential to achieving this century’s climate goals while maintaining energy supplies.

In this section we propose establishment of a center for applied research and development that assures a continuous supply of proven energy transition technologies to most all energy markets –for decades with outside funding after the initial capital infusion.

The THA/AHN collaboration project is based on the Core Technologies discussed in this submission and others available to the Collaboration. The Center’s mission is to apply and advance market-ready of near-market ready technologies and products to energy and materials markets in competition with fossil fuels and traditional materials.

Initial revenues are generated from the sales of Firewater equipment and later from new materials. Beyond this, we spin-off new companies equipped with market ready technologies and strong management teams. Alternatively, we license technologies to existing companies with established markets for the technology. Establishment and growth of the Center creates hundreds of jobs and multiple new companies continue job creation. We often hear that small business create the jobs; but new companies create the most!

The Collaboration is organized in such a way that AHN is required to reinvest net revenues after taxes in further R & D and applications of transitions technologies to energy markets. We refer to this project as the Golden Goose Center for Applied Energy Research and Development as the valuable energy eggs keep coming.

Reinvestment funds are substantial. For example, in the 5th year after funding, the AHN business plan financials project $717,359,750 in revenues and $249,071,115 in net after-tax earnings for reinvestment in energy transition R & D and market applications.

The impact of the Golden Goose Center on oil, gas markets is to speed-up injection of superior, competitive, climate-safe, products into oil, gas, coal and materials markets. ***The fuel we introduce can be transported in traditional pipelines, tanks, vehicles, vessels and stored in traditional tanks*** with little or no re-purposing. The impact on electricity TS&D is to incrementally shift reliance on traditional electricity transportation and distribution systems to on-site generation and pipeline or truck fuel delivery. Waste stream analysis of feedstocks for hydrogen and new materials production should be conducted and redirection of trash flows of materials most suitable for energy and materials production should be implemented. Collection and delivery systems may ned to be reorganized to supply ample feedstocks.

The Collaboration is seeking US $67 million over three years as an initial cash infusion. Compared to the cost of other items in energy transition infrastructure, the cost of funding is relatively small and it yields a high return in terms of providing an essential element of timely energy transition.

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NCA3 Climate change Impacts in the United States

Appendix I

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NEW HEAVY ENGINE TECHNOLOGIES

*CUT FUEL COST AND POLLUTION*

NEW TECHNOLOGY SUMMARIES AND TEST RESULTS

1. Computer-aided controls and components provide direct-injection and spark-ignition of traditional and alternative fuels in internal combustion engines. Called ***Precision Spark Injection*** or ***SparkInjection,*** this technology enhances energy conversion efficiency with hydrocarbon fuels and enables utilization of lower cost fuels1 including hydrogen, methane, and carbon monoxide regardless of octane or cetane rating. It provides full rated power production with gaseous fuels that produce far lower volumetric heating value than Diesel fuel. An adaptive electronic control monitors crankshaft acceleration, cylinder pressure, and rpm for purposes of minimizing fuel use through all duty cycles including start-up, idle control, acceleration, transient operation, and full-power development. Each fuel injection and ignition is monitored and adjusted to produce maximum torque within the selected duty cycle. The variables are timing of fuel injection, spark ignition, and amount of fuel injected. 1,2,3,4
2. **Thermo chemical regeneration** and/ or regenerative braking energy are utilized **or** combined in a system called “FireWater Thermochemical Regeneration” or “FireWater” to produce greater fuel values from hydrocarbon fuels and an oxygen donor such as methanol and or water. Heat recovered from the cooling and exhaust systems and/or regenerative braking electricity produce hydrogen from hydrocarbon fuels or water and convert hydrocarbons and a suitable oxygen donor by several endothermic steps including vaporization and formation of gaseous fuel species that yield greater energy upon combustion than the original hydrocarbon precursor fuel. 1,2,3,4,

Performance and efficiency tests that combined FireWater Thermochemical Regeneration and SparkInjection systems included engines that were

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converted from Diesel and from homogeneous-charge operation to direct injection and spark ignition. Diesel engines converted to FireWater operation with SparkInjection components developed as much power as provided with directly injected Diesel fuel. (Ordinarily conversion to hydrogen causes a power loss.)

SparkInjection of hydrogen-characterized fuel mixtures improved the thermal efficiency (based on fuel BTU injected) about 5% or more compared to previous operation on diesel fuel and enabled larger improvements provided by gaseous fuel constituents derived by thermochemical regeneration. Energy gained from thermochemical regeneration amounted to 20 to 25% greater heat release on combustion compared to hydrocarbon fuel feed stocks. In addition, exhaust emissions of particulates, hydrocarbons, and carbon monoxide were eliminated and oxides of nitrogen were reduced.

Dynamometer Tests of a Two-stroke engine follows and shows the potential for power and efficiency improvements on diesel engines and is representative of our broader experience applying these technologies to Diesel engines:

GM 2-71 DIESEL:

ENGINE: 4.25" Bore x 5" Stroke: 142 cu. in. displacement, 2-stroke; 2-Cylinder; 17:1 Compression Ratio; Normally aspirated.

At the manufacturer's recommended operating conditions,

this engine produced 48 HP at 1,800 RPM on Diesel fuel.

This engine could only produce about 32 HP using Diesel fuel injection and compression ignition to pilot ignition of natural gas, which was admitted (fumigated) along with air through the air intake system.

After conversion to FireWater SparkInjection operation this engine produced 48 HP at 1,800 RPM using methane, propane, methanol, or sulfur-free diesel fuel as the FireWater feedstock with net efficiency improvements ranging from about 20% to 32% compared to unconverted efficiency with conventional Diesel fuel operation.

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EFFICIENCY IMPROVEMENTS PROVIDE EMISSIONS REDUCTIONS:

1. The ignition delay of conventional diesel fuel comprised of a mixture of large-molecules as liquid-fuel constituents includes the time to evaporate and crack these molecules and then penetrate enough additional hot air to ignite. Small gaseous molecules (such as H2 and CO) have much less delay and eliminate particulate formation. The time to complete combustion of any fuel is a function of the heat release, availability of the oxidant, and degree to which the heat release is conserved. In order to equalize kinetic energy in a population of mixed mass molecules, small molecules have much higher velocities than large molecules. Small molecules like hydrogen travel faster, traverse greater distances, collide more often, and diffuse more rapidly than larger molecules at the same temperature. Hydrogen burns in a much wider range of air-fuel ratios than most hydrocarbons. This along with the higher heat release as hydrogen oxidizes is why hydrogen burns 5 to 10 times faster than hydrocarbon fuels.
2. Increased BMEP for improving specific power rating: One way to improve BMEP is to prepare fuel constituents that burn more rapidly to enable pressure development during the power stroke for reduced backwork during the compression stroke. Reversible theoretical cycle efficiency is not influenced by pressure, however practical cycle efficiency is greatly influenced by pressure because the greater the pressure the faster the combustion process and backwork and heat losses are reduced during compression in nonadiabatic positive-displacement engines.
3. Reaction rates for CxHy are generally much slower than for smaller H2 and CO molecules in which the surface to volume ratio of the small molecules are larger than for larger hydrocarbons. The first step of reacting carbon in a hydrocarbon is an endothermic reaction in which heat is required to release the hydrogen from the carbon in order for the carbon to be oxidized. Subsequently, the greater portion of heat released by hydrocarbon-sourced carbon combustion is from the step of carbon monoxide being oxidized to form carbon dioxide:

C + 0.5 O2 🡪 CO + 47,517 BTUs/Mole Equation 1

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CO + 0.5 O2 🡪 CO2 + 121,666 BTUs/Mole Equation 2

1. FireWater technology provides heat transfer from the cooling fluid and exhaust system for endothermic reactions to prepare free hydrogen and fully oxygenated carbon as carbon monoxide. This provides improved system efficiency, reduces maintenance and extends engine life because less heat is transferred from these fast burning fuels to the piston, rings, cylinder walls and valve assemblies.
2. In addition to hydrogen produced by regenerative braking, engine cooling jacket temperature is adequate to provide significant heat addition for endothermic thermochemical regeneration process steps. Exhaust gas temperatures are substantially adequate to add heat at higher temperatures to accomplish completion of endothermic reactions with hydrocarbon feed stocks including liquid and lower-cost gaseous fuels such as landfill methane as shown below:

CH4 + H2O + HEAT3  🡪 CO + 3H2 Equation 3

CO + 3H2 + 2O2 🡪 CO2 + 3H2O + HEAT4 Equation 4

CH4 + 2O2 🡪 CO2 + 2H2O + HEAT5 Equation 5

1. The heat of reaction at constant pressure of Equation 5 is -344,940 BTU/Mole. It is -103,968 BTU/Mole for 3 moles of Hydrogen = -311,904 BTU; and -121,666 BTU/Mole for combusting CO in Equation 4 for a total yield of -433,570 BTU. This is the lower heating value without any credit for the heat of condensation of 3 moles of water. Compared to Equation 5 it yields -88,630 BTU more energy than burning the methane directly. Thus, about 25% more combustion energy is delivered for production of work. Thermochemical regeneration does not require the new fuel species to be used at elevated temperature and the new species can regeneratively transfer heat to the thermochemical process for additional advantages in the FireWater technology.1,2,3,4
2. Such energy gains can be found in the regenerative nature of the

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FireWater process in which the endothermic reaction of Equation 3 produces two new chemical compounds. Engine waste heat is used to create new fuel molecules that release more energy than the original fuel. Commensurately the carbon is provided as a fully oxygenated fuel constituent to assure rapid and complete combustion without particulate formation typical to applications with Diesel fuel.

1. Additional improvements are derived from SparkInjection stratified-charge combustion of the hydrogen and carbon monoxide. SparkInjection technology solves the low-cetane ignition problem by providing precision spark ignition of fuel entering the combustion chamber and solves the low volumetric energy problem of gaseous fuels by enabling gas and vapor fuel delivery rates up to 3000 times greater than for liquid diesel fuel. Hydrogen burns much faster than hydrocarbons in a much wider range of fuel/air mixtures to allow the engine to operate more smoothly with later ignition, reduced heat losses during compression, and reduced backwork for greater BMEP per BTU of heat release. The engine that started with 40% efficiency can be converted and improved to 50% or more by using hydrogen characterized fuel mixtures that are produced by **thermochemical regeneration and/or** regenerative braking.
2. In a hypothetical engine with 40% efficiency, 100 BTUs of primary fuel could be thermo-chemically regenerated to provide addition of 20 to 25 BTUs. Heat rejected by the engine substantially provides the endothermic energy required and additional endothermic energy may be contributed by regenerative braking and/or partial oxidation. Such sources of endothermic energy are used to produce two new fuel species (CO and H2). These new species release up to 125 BTUs upon combustion compared to conventional operation with 100 BTU. Such an engine conversion could also gain an additional 5% or more in thermal efficiency from SparkInjection stratified-charge combustion principles and therefore the engine would require 20% to 30% less original feedstock fuel to produce the same amount of shaft work. 2,3,4,8
3. Reductions of carbon dioxide, hydrocarbons, particulates, and oxides of nitrogen are provided by:

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A) Reduced fuel consumption. Carbon dioxide and hydrocarbon emissions are reduced in accordance with thermal and corresponding fuel-efficiency improvements

B) Conversion of fuel-sourced carbon to carbon monoxide eliminates hydro-carbon particulate emissions

C) Peak-combustion temperatures that cause formation of oxides of nitrogen can be eliminated by stratified-charge combustion of hydrogen-characterized fuel mixtures within surplus air according to an adaptive algorithm for the relative timing of fuel injection and plasma ignition events with respect to combustion chamber geometry, fuel penetration pattern, piston speed, BMEP requirement, and electronic monitoring of each combustion chamber temperature. 2,3,4,5,

The following references partially disclose confidential proprietary technologies for improving fuel efficiency along with greatly reducing or eliminating oxides of nitrogen and particulate emissions from heavy engines.

1) U.S. Patent **6,984,305** 5) U.S. Patent **8,297,254**

2) U.S. Patent **6,756,140** 6) U.S. Patent **8,147,599**

3) U.S. Patent **6,446,597** 7) U.S. Patent **8,313,556**

4) U.S. Patent **6,155,212** 8) U.S. Patent **8,528,519**

APPENDIX: Notes Regarding Cycle Efficiency:

Diesels incur greater friction and windage losses for equal horsepower at equal shaft speeds.

Diesels have greater heat losses from the combustion chamber during compression of unthrottled air through a higher compression ratio than homogeneous charge engines.

Diesels have reduced air utilization compared to homogeneous charge engines.

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Diesels overcome a theoretical cycle efficiency disadvantage compared to the "air standard analysis" of a positive displacement, spark- ignition Otto-cycle engine which is:

na = 1- (1/rc)0.4 Equation 6

The Diesel or "compression-ignition air standard analysis" is:

na = 1- (1/rc)0.4 (rd1.4-1)/(1.4(rd-1)) Equation 7

Where: na is efficiency,

rc is compression ratio, and

rd is volumetric expansion during constant-pressure combustion.

The theoretical air-standard Diesel efficiency is less than that of an Otto-cycle engine at equal compression ratios. The differences between the air-standard and actual cycles are so great, however, that it is instructive to instrument and operate actual engines to determine what is beneficial in matters of stratified-charge, preparation of small fuel molecular species, recovery of waste heat, air utilization and throttling. It is important to note that a practical requirement for utilizing higher compression ratios in Diesel engines is to achieve sufficient air heating by compression to evaporate and crack the fuel for ignition and thereafter to cause faster combustion after ignition.

SparkInjection of faster burning fuel constituents improves the stratified-charge advantages of Diesel engines to further provide much higher fuel efficiency than either conventional Diesel or homogeneous charge engines.

**Appendix II**

**The Core Technology Bundle and Patents**

AHN/THA available technologies: The AHN/THA project brings together a bundle of proven sustainability technologies invented and developed over the past forty years of research, development and application under the direction of Roy McAlister, the inventor of the core technology bundle mentioned above, the discoverer of graphene in the early1980s and the building of a full bundle of proven climate and earth friendly technologies that materially advance climate and economic sustainability on an economically feasible basis. McAlister is President and a director of THA and Chairman and Chief Science Officer of AHN.

McAlister holds 130 issued US patents and has 70 additional patents pending. Most of these patents are related to making a transition to a sustainable future including without limitation timely reduction of GHG emissions, increasing aftermarket and new ICE efficiency, co-production of new materials with a byproduct of hydrogen that can be sold at prices competitive with fossil fuels.

Patented examples of McAlister’s inventions show the breadth, depth, and developmental history and the latest McAlister technologies for new materials, ICE technologies for improved efficiency and heat recovery along with, manufacturing and tooling technologies to enable sustainable prosperity.

Examples of McAlister US patents:

**Internal Combustion Engine Technologies** -including efficiency & mfg. 8,297,254 B2; 8,529,519 B2; 8,255,768 B2; 8,091,528 B2; 8,091,528 B2; 8,074,625 B2; 7,628,137 B2; 6,756,140 B2; 6,446,597 B1; 6,155,212; 5,899,071; 8,394,852; 5,343,599; 4,243,779; 4,066,046; 3,980,061,

**Energy Storage, Transportation & Delivery**: 8,313,556; 8,147,599; 6,503,584 6,015,065;

**New Materials/Renewable Fuels**: 2011/0061383 A1; 8,192,852; 8,172,990; 8,147,599; US 8,075,750; US 8,075,749; 8,875,748; 6,984,305 4,714,513; 4,692.537; 4,488,540; 4,465,721; 4,458,087; 4,436,058; 4,433,557; 4,414,364; 4,401,105; 4,371,326; 4,350,663; 4,333,789; 4,319,871; 4,316,436; 4,313,427; 4,301,862; 4,300,971; 4,279,244; 4,271,103; 4,265,220; 4,261,338;