Direct Reduction of California's Carbon Dioxide Burden

Thorenco LLC

Methane Decomposition for Reduced Carbon Content Hydrogen-Enriched Natural Gas Industrial Fuel

Fuel for Reduced Emissions from Electric Power Generation, Transportation, and Heating Operations

"1% Proposal"

For 50% Carbon Gas Reduction

Introduction:

California's Cap and Trade program has commenced. Funds are available for innovation to reduce carbon dioxide emissions in California. 1% of the proceeds should be allocated in a continuing program to the development of an efficient industrial process that removes at least one half of the carbon from natural gas. The requested funding will support development of an industrial process to make a new natural gas-based fuel commercially available, a fuel that provides adequate process heat with reduced carbon dioxide emissions. Thorenco intends to integrate the underlying technologies to make the improved fuel commercially available. The new fuel will have a reduced emissions profile, a smaller carbon footprint because it will contain less carbon than natural gas.

Presently, natural gas is the cleanest industrial fuel available. It is used widely in California for electric power generation and space heating. Proven reserves of North American natural gas have increased over the last decade because shale gas and gas from tight formations can be now economically recovered and sold into the national pipeline network. Increased natural gas consumption is anticipated in California in upcoming years.

Natural gas is a low cost hydrocarbon fuel used in the power generation sector, the space heating sector and for certain industrial processes. Improving natural gas by lowering its carbon content is the goal and the technical solution proposed by Thorenco. The integration of the applicable

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technologies should be supported with appropriate investment from the California Air Resources Board.

Support for manufacturing facilities in Stockton, California will also be requested when the integration process is complete and after fabrication materials are selected and plans and specifications are computationally optimized.

Pipeline quality natural gas is amenable to processing to reduce its carbon content. Various methods of carbon separation methods exist and many have promise to enrich natural gas with hydrogen. Methane will be treated to separate its hydrogen from its carbon. The product, Processed Natural Gas (PNG) will have various grades: mixtures of methane with increasing hydrogen concentrations, from 50% and up.

Carbon extracted from natural gas could be used for other purposes: carbon fiber materials manufacturing, tire production, metallurgical applications to name three. Carbon could also be stockpiled pending sale or long term sequestration. Carbon is much less expensive to sequester on a long term basis than carbon dioxide because it is a solid and not a fugacious gas.

Processed Natural Gas (hydrogen enriched methane) will generate less carbon dioxide than unprocessed natural gas when it is burned. The energy costs of the process to remove at least one half of the carbon in methane are estimated to be approximately five to ten percent of the heat content of the produced hydrogen. The separations hardware involves manufacturing metal components and assembly of the electronics packages. No advanced or unknown technology is involved.

The idea is simple: treat natural gas to enrich it with cleaner burning hydrogen.

Abstract:

This proposal seeks funding to directly reduce carbon gas emissions by reducing the carbon content of natural gas used as fuel. Natural gas is used to power gas turbines that produce electricity, to provide heat for desalinization, as an input to make hydrogen for liquid transportation fuels, various petrochemical products and for heating purposes. The technology may also be advanced to provide high quality hydrogen for numerous industrial and commercial applications including transportation fuels.

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Concept:

Pipeline grade natural gas (NG) is processed in one or several successive methane decomposition (chemical) reactors to separate hydrogen from carbon in the natural gas feedstock. The separated (extracted) carbon is sold for industrial purposes and the hydrogen component in Processed Natural Gas (PNG) burns without the production of carbon dioxide. PNG is a cleaner burning fuel for all process heat applications: electricity production, potable water production, and ammonia production.

The process will generate hydrogen enriched methane and industrially marketable carbon black. When one half or more of the carbon in methane is removed from the NG feedstock, carbon dioxide emissions to the atmosphere are reduced by one half or more.

The economics of hydrogen consumption applications, will determine the level of hydrogen purity in the product gas. The process allows varying amounts of methane to remain in the hydrogen enriched fuel. The purity of the hydrogen needed for the application governs the number of process steps for hydrogen synthesis and thus its cost at the user level.

If a mixture of 50% hydrogen and 50% methane is satisfactory for the power generation purposes, the overall reduction in carbon dioxide production will be 50%. If pure hydrogen is needed for industrial applications, the fuel gas can be further refined by established methods to separate methane from hydrogen. By staging the process steps, the ratio of the hydrogen to methane in the final grade of the product gas can be increased and a higher value product provided.

Processed Natural Gas (PNG) can be furnished in grades from almost pure hydrogen to a desired mix of methane and hydrogen. Stripping the carbon from methane provides a productive pathway to reduce overall carbon gas emissions because so much methane is burned in California. The new processing steps provide a treatment for natural gas to deliver hydrogen mixed with methane to the fuel buyer's specifications.

Carbon is separated from methane by thermo-chemo-electric methods. The separation takes place immediately before the fuel gas is delivered to the turbine (generating electric power) or to the chemical plant that synthesizes plastics, ammonia or other commodity petro-chemicals. Carbon black is stockpiled for sale to carbon consumers such as tire manufactures, or carbon fiber manufacturers. Hydrogen with a set percentage of residual methane is burned to power gas turbines or desalinization plants or in more purified form to supply industrial hydrogen applications.

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Background:

The integration of existing technologies improves attributes of natural gas as a fuel. When a percentage of the carbon in natural gas is removed, carbon dioxide emissions from its combustion will be reduced by the same percentage. PNG improves the quality of the electricity or other products produced from it because there are lower carbon gas emissions from its use. The amount of carbon in the feed gas is reduced, beneficially reducing the amounts of carbon dioxide discharged into the atmosphere.

California and other jurisdictions have imposed measures to control and reduce release of carbon dioxide to the atmosphere. The cost of discharging carbon dioxide is now quantified. Other jurisdictions may impose a carbon taxes or follow the cap and trade model. PNG will be a superior fuel to develop to provide electricity, fresh water or hydrogen for various applications. Because PNG consumption will generate less carbon dioxide than all the other fossil fuels, its use will eventually enjoy significant commercial advantage over all other fossil based fuels in the global market place.

It is foreseeable that in North America, PNG will become the fuel of choice for power generation, desalinization and for many industrial applications that use hydrogen as a feedstock. Now that new extraction technology has improved recovery of natural gas from shale and other "tight" formations in North America, proven reserves of natural gas are significantly higher than they were a decade ago. The national delivery and distribution system for natural gas exists and will be upgraded to transport more gas to market.

Carbon is separated from methane to provide an enriched hydrogen fuel for cleaner combustion and other industrial applications. PNG provides a good solution to upgrade low cost shale gas coming on stream. PNG is a cleaner burning fuel for electrical power generation. PNG has a smaller carbon foot print when used for the production of plastics, ammonia and various synthetic liquid fuels and specialty chemicals than NG has.

Details:

Disordered Carbon or Amorphous Carbon (DC/AC) is the best material to use as a catalyst in the decomposition of methane to make a commercial stream of fuel gas enriched with hydrogen to be delivered at the fuel intake manifold of the gas turbine generator. Graphite and ordered carbon is not appropriate for use as a catalyst. Activated charcoal is not the best choice. Various transition metals do not function over time as catalysts because carbon deposited on their surfaces from methane blocks their catalytic functions.

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Interestingly, amorphous carbon in the form of common carbon black (CB) emerges as the most attractive catalyst candidate. This material is produced during the decomposition of methane. Uniquely, the separations process generates its own catalyst.

Reactions proceed on CB (or other forms of DC/AC) where there are dislocations in the structure of the carbon particle. The process maximizes the continuous production of surface defects, dislocations and vacancies in the micro crystalline structure of the produced carbon particles. These dislocations provide the micro-environment for methane gas molecules to decompose into hydrogen and carbon: CH4 => C + 2H2.

Microwave energy acts on CB to heat it internally. Ultra sonic energy keeps the particles in motion. These two inputs efficiently deliver process heat and make active catalyst surfaces. Microwave radiation is used because it heats only the carbon particles which in turn heat the feed gas. Ultrasonic energy is used to control particle size and density. Direct current is added as well to provide additional energy to break chemical bonds in the molecules comprising the feed gas. Microwave energy and ultrasonic energy can be directed exclusively to the CB where it is absorbed efficiently. The energy delivered by microwave radiation to the catalyst grains becomes available to the hot spots where the dislocations capture hydrogen from methane in the first reaction of the stages of complete methane decomposition. The microwave energy applied to the CB and the direct current provided to the NG provide the major inputs to commence the decomposition cascade. Areas of high activity on the CB are occluded by carbon removed from methane but other areas of high activity are formed continuously. The proposed separator maximizes the population of dislocations in the CB matrix by taking advantage of doping carbon grains with selected particles that provide lattice discontinuities. Because of variation in size between the carbon atoms and selected atoms for doping, discontinuities are continuously generated.

The additional energy input is direct current. A system of brushes delivers direct current to the region where carbon particle density is the greatest. In this region arcing from the brushes excite the feed gas and assist hydrogen formation. Additionally, the methane feed stream is heated by the waste heat captured in the exhaust stream of the turbine. These three processes, microwave, ultra sonic and direct current keep the surfaces of the amorphous carbon particles chemically active continuing the process indefinitely.

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Conclusion

The representatives of the California Air Resources Board are expected to make investments that reduce carbon dioxide emissions in California. Thorenco submits a proposal to develop a basic method of treating methane to reduce its carbon content. When Processed Natural Gas is used as a fuel, carbon gas emissions will be reduced. The task is to integrate technologies to provide methane processing at the end of the delivery system. Methane can be processed to remove some and eventually all of the carbon it contains. This technology is appropriate for investment. Thorenco's proposal may be the only one that seeks to reduce carbon dioxide emissions by reducing the carbon content in a highly utilized fuel. The manufacturing of the separators will be done in Stockton, California.

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