Commercialization Plan

1. What is the product and what does it do?
   a.) Provide a clear description of the product or service
   Our final out-of-the-door product will be hydrocarbons specifically, gasoline, diesel and aviation fuel derived from biomass, agricultural waste and municipal waste. It is our intent to make use of the abundant biomass resources available within the state of Florida and Georgia for the purpose of producing a clean, green, continuous and sustainable supply of liquid hydrocarbon-based fuels. The overall process is based on conventional Fischer-Tropsch (FT) Synthesis, originally based on coal feed-stocks, invented in the 1920s in Germany. Biomass generated liquid hydrocarbon fuels via FT is only possible due to creative innovations in gasifier, catalyst, reactor and process design.

   b.) Explain the features of the product or service
   One of the major hurdles in the successful commercialization of biomass derived synthetic fuel is the cost associated with distilling the liquid hydrocarbons into gasoline, diesel, aviation fuel and waxes. This effort puts an upward pressure on the final price of the liquid fuel. Our proprietary technology efficiently converts biomass into synthetic liquid fuel with an overall efficiency (biomass to liquid hydrocarbons) of 18% to 20%- almost 63% higher than conventional biomass derived synthetic fuels. In addition, our fuels have 30 times less sulfur as currently mandated by EPA and put no pressure on food prices. Most importantly, our proprietary catalyst is tunable to selectively produce any cut of liquid hydrocarbon desired, thus enabling us to reduce the cost of the final product substantially.

2. How is the product unique and innovative?
   At present Fischer Tropsch technology is being used commercially in South Africa (Sasol), Middle East (Oryx) and Malaysia (Shell Bintulu). However, all these units are either based on iron catalyst or use coal or natural gas as raw material. Biomass is not a homogeneous feed-stock, nor is the current state-of-the-art catalytic systems tunable and selective.

   a.) Describe how it is different or innovative from what exists in market today?
   Our technology is flexible as it is designed keeping in view biomass as the raw material. The gasifier design can support a wide variety of biomass; this concept has not yet been exploited commercially. Resultant biomass derived gas has minimum contaminants, causing little to no stress on the downstream catalytic reactor. The engineered eggshell catalyst, in itself, is an exceedingly innovative concept that overcomes mass transfer limitations inherent with conventional reactor designs. Production of long chain hydrocarbons in FT synthesis is rate limited due to the accessibility of active catalytic I sites for diffusion of carbon monoxide. The tunable thickness of active catalytic surface area ensures that enough active sites are available for desired, highly selective hydrocarbon chain growth. In this way the required petroleum cut is obtained without any additional unit operations. Such a design has not been explored or exploited commercially as yet. Conventional reactors provide waxy product and additional unit operations are required to obtain the desired fractions.

   Additionally, the specific reactor design that we offer eliminates current heat transfer issues. FT synthesis is a highly exothermic process, if the evolved heat is not removed; catalytic sintering, decay and attrition are the net result. This problem has been a major stumbling block for commercial reactors and must be operated far below full capacity. We offer an innovative mixing of inert heat sink and catalyst along with inter-compartmentalization. Such a combination results in effective heat removal in the absence of an external cooling jacket.

   b.) Describe new features and functions it offers that currently aren’t unavailable.
   FT technology is very flexible in raw material utilization. We intend to put biomass, especially agricultural waste (wood, bagasse) and municipal waste i.e. RDF (refused derived fuel) to use. This technology will not only contribute in energy independence from foreign imports but will also aid in environment preservation by reducing landfill and carbon foot print.

   At present, FT synthesis uses coal and natural gas as the raw material and iron as the catalyst. However, our process is based on a cobalt silica supported eggshell design. Cobalt has a higher affinity towards long-chain paraffinic product than iron and shows far less attrition, thus being more suitable for the production of desired liquid fuel fractions and a longer catalytic active life (without the requirement of additional refinement). In addition, iron-based catalysts produce carbon dioxide as a byproduct while cobalt-based systems produce mostly water as a by-product thus, a greener, more sustainable, benign process.

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With respect to the design of catalyst, till today all available catalyst designs are not tunable toward a desired hydrocarbon product (one catalyst for one type of product). Our catalyst has been engineered to be tunable via variation in the thickness of egg-shell giving rise to a highly selective product. One can narrow the selectivity to a fine degree which results in no additional unit operations (e.g., distillation) being required for refining the raw product. This is a huge saving in plant fixed and operating cost.

c.) Describe benefits the target customer will receive as a result of the features or functions.
Our FTS technology offers carbon credit for the end users because of the reduction in carbon dioxide production as compare to conventional technology. This will have a positive impact on the stock price of this commodity.

The eggshell catalyst is product specific; there is huge savings in operating cost because of less downstream equipments for product refining. Lab results indicate absence of aromatics and alcohols in the final product; a clean fuel will thus enhance the performance of engine.

Almost all FTS reactors face the issue of downstream wax accumulations which is very difficult resolve. With this technology there is little to no chance of facing this issue, reducing the plant downtime because of reactor problems. The reactor design is suitable to take care of heat transfer issues, thus the reactor can be operated at optimal conditions giving higher conversion. We hope that linear scaling up of this reactor will preserve all good qualities it offers at bench scale.

3. Who are the first customers and what are they like?
The advantage in using our catalyst is that it can selectively convert synthesis gas (H\textsubscript{2}: CO) to gasoline, diesel or aviation (jet) fuel with very little processing. Thus, this tailored catalyst makes biomass-to-liquid (BTL) plants very efficient and competitive while providing the opportunity to select the cut of the final product.

a.) Provide a description of the customer or industry segment profile of what drives the typical customer (in the segment) toward their product/service.
Our initial target market is the Department of Defense (Air Force). The Air Force has a goal to obtain half of its fuel used in the continental US from renewable sources by the year 2016 [1]. We intend to provide a clean, continuous, reliable and domestic supply of NATO JP-8 (Jet Propellant-8) grade, the highest of its kind, produced via biomass using our proprietary gasifier, catalyst and reactor designs.

Liquid fuel is a strategic resource that has significant security, economic and geo-strategic implications. DOD’s fuel consumption varies from year to year in response to changes in missions and the tempo of operations. In FY 2000, fuel costs represented 1.2% of the total DOD spending, but by FY 2008 fuel costs had risen to 3% [2]. The Defense Energy Support Center (DESC), under the command of Defense Logistics Agency (DLA), has the mission of purchasing fuel for all DOD services and agencies, both in continental US and outside US. The Air Force and the Army represent the primary consumers of JP-8 fuel whereas the Navy consumes JP-5. The majority of DESC’s bulk fuel purchases are for JP-8 jet fuel, which has ranged from 60 to 74 million barrels annually. A September 2009 report published by the Congressional Research Services indicated that in FY 2008 the DOD’s purchases for JP-8 fuel totaled 62.5 million barrels at $3.13 per gallon [3]. According to the same report, the DOD spent almost $18 billion on acquiring fuels in FY 2008. With the ongoing operations in Iraq and Afghanistan to support the ground operations, the DOD’s demand for JP-8 jet fuel will continue to go up and will only put upward pressure on reaching the target of obtaining 50% of its fuel supply from renewable sources by 2016.

4. What unmet need does the product address in the market?
At present, the DESC purchases their supply of jet fuel from the open market by typically awarding fuel contracts for a period of one year. They use fixed price contracts with economic price adjustments. Over the last few years, prices paid for military specification JP8 jet fuel have exceeded the price of commercial equivalent fuel. This is not necessarily in the best interest of national security, in that, the DOD is dependent on foreign sources of oil for its jet fuel supplies and is exposed to the price variations in the market. Also, in 2007 the Energy Independence and Security Act was brought into effect by the Bush administration. It was to move the US towards greater energy independence and security, to increase the production of clean renewable fuels, to promote research on and deploy green house gas capture and storage options. In the light of this act of 2007, recent legislation directs DOD to consider using alternative fuel to meet its need. Since almost 73% of the total fuel purchased by the DOD in 2008 was jet fuel [2], and to fulfill the mandate of using fuels from renewable sources the Air Force’s need is addressed by our clean synthetic fuel made from biomass.

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Furthermore, fuel derived from FT is free of any sulfur and nitrogen containing compounds as found in conventional jet fuel thus burning a lot cleaner. This has a huge environmental impact because it is sulfur- free; there are no sulfur dioxide or sulfuric acid aerosol emissions. Our synthetic FT fuel has several advantages over other bio-derived jet fuels such as ethanol, biodiesel etc. For example, the primary concern with the use of biodiesel is its low temperature properties; they have freezing points near 0 °C , much higher than the maximum freezing point of jet fuel, -40 °C. Ethanol has lower gravimetric energy content than our synthetic FT fuel and is more volatile as well. Additionally, the emissions from alcohol or biodiesel fueled turbine engines may have a potential cause for concern. When incompletely combusted, oxygenated fuels can emit aldehydes- their emissions are classified as hazardous air pollutants by US EPA.

Given the need of the Air Force to supplement their current fuel supply with renewable sources coupled with the independence from dependence on foreign sources for jet fuel and reduction in the carbon footprint provided by synthetic FT fuels, our product, with its inherent advantages, is perfectly aligned with goals of DOD in the near and far future.

5.) What is the estimated total size of the initial customer group? Will this segment be adequate to support the business associated with the product?

Several efforts by the Air Force are underway to test and certify synthetic FT fuels. In August 2007, the Air Force certified the B- 52 to use a 50/50 blend of synthetic fuel and currently tests are underway to certify the C-17, B-1, and F-22 for future use. In December 2007, a C-17 completed the first transcontinental flight using a synthetic fuel blend, and a B1 flew at supersonic speeds using a similar blend in March 2008 [1]. This encouragement from the Air Force to test and certify synthetic FT fuels is a positive sign for our product as it has a viable market that is waiting for its successful commercialization.

a.) Discuss the total size of the market segment (either in dollars or unit sales) along with its growth

The majority of DESC’s bulk fuel purchases are for JP-8 jet fuel, which has consistently ranged from 60 to 74 million barrels annually over the past decade (the equivalent of 165,000 to 200,000 barrels per day) [3]. The Air Force and the Army represent the primary consumers of JP-8. Also, from FY 2000 to FY 2008 the fuel expenditures increased from $3.6 billion to nearly $18 billion- almost a 500% increase [2]. Actual volumes purchased had increase by 30% over the same time. Given the air support provided by the Air Force to ground operations in Iraq and Afghanistan simultaneously, a conservative estimate of growth of demand for JP-8 jet fuel is 5% annually. Coupling this with the Air Force’s target to supplement their current supply with renewable sources, by 2016 we expect the synthetic FT jet fuel market to be anywhere between 30 to 50 million barrels annually and increase at a steady rate.

b.) Identify trends (e.g. growth, regulatory, consumer etc.) that will help sustain the market over time.

Currently, there is an unmet need to produce between 30 to 35 million barrels of synthetic FT fuel from renewable sources for the military and this will only continue to grow. Additionally, the regulations placed on getting approval for aviation fuel are very stringent and does not look favorable towards ethanol, biodiesel or cryogenic fuels. In fact, the only alternative fuel approved for aviation use is synthetic FT based fuel which can be blended with conventional jet fuel up to 50% by volume. In 2006, turbine engine manufacturers GE, Honeywell, Pratt &Whitney and Rolls Royce presented a consensus position at the Aviation Alternative Fuel Workshop; some of their conclusions were: (i). Kerosene based fuels are preferred option, (ii). Biofuel (derived from plant oil) presents major technical and logistical risks, (iii). the FT process provides opportunity to produce aviation fuel from biomass at lower risk and shorter timescales [4]. This is a key indicator that synthetic FT fuels have a legitimate opportunity to emerge as the only certified alternative fuel for aviation in the future unless biodiesel and ethanol can overcome their stability issues. Moreover, the consumer, in this case, the aviation industry and in particular the DOD is looking for a clean fuel with minimum to zero carbon footprint.

c.) Discuss obstacles that may be encountered when trying to enter the market with this product/service (e.g. investment required, economies of scale, government regulations, environmental issues, customer loyalty etc.)

Setting up a FT synthesis plant is a capital-intensive endeavor but if economies of scale can be achieved, it will be a profitable venture. For example, the biggest FT plant in the world, based in Sasolburg, South Africa is completely paid for and is generating profits. The first step will be to successfully set up a small-scale pilot plant with an overall foot -print of .25 acres to generate a few barrels of JP-8 jet fuel and diesel every day and to have the fuel rigorously tested by the regulatory authorities for approval. However, to set up a commercially viable and profit generating BTL plant, we would have to
acquire a large enough land to house a medium-to-large size gasifier, several reactors, distillation columns and employ round-the-clock maintenance engineers to ensure smooth operation of the plant. Another key aspect of making this venture a profitable one is the un-interrupted supply of biomass. We’ve strategically decided to operate in northern part of Florida as this would give us access to the agricultural waste, most abundant in the region and to wood chips waste from southern part of Georgia and would reduce the burden of transportation. Another reason to locate in Florida is that we would have ready access to the Macdill Air Force base in Tampa and to be closer to Pensacola Air Force base for running test flights utilizing our JP-8 fuel.

6. What is the underlying technology for the product?
   a.) Describe the Technology and what it does (not how it works)
      Our product “eggshell” catalyst is developed using a novel process. It has “precise- control” of the weight loading of the active metal zone which selectively converts synthesis gas [H2; CO] to gasoline, diesel or jet fuel with very little separation. Moreover, the eggshell design reduces the cost of metal loading by approximately 50% over current technologies. The technology we offer, despite being unique, is very simplistic in design and cost effective as it makes use of readily available chemicals and wet chemistry techniques. The catalyst is flexible with regard to synthesis gas composition and is resistant to attrition and poisoning. Our reactor design takes care of the generated heat, reducing the risk of sintering and plugging due to carbon formation. Also the performance of reactor with regard to wax accumulation has been satisfactory ensuring successful ongoing operation.

   b.) Explain how the technology is being uniquely applied to solve the needs of target market
      Recent rise in the cost of liquid petroleum (from crude oil) has increased the demand of fuel production from alternate resources. According to the world energy handbook, from 2002 to 2030, there will be 60% rise in the world energy requirement. Most of this will be covered by the renewable resources. Our catalyst utilizes synthesis gas generated from biomass which is a renewable resource. By selectively converting this so called “Bio-syngas” to gasoline and diesel/aviation fuel, we are providing liquid fuel from an alternate environmental friendly method. At present, liquid fuel being produced requires repeated refining. End customer has to bear the operational cost of these additional processing. What we propose will not only utilize alternate energy resources, but will also reduce the operations and reactor downtime costs (during fuel production). All of these parameters will ensure customer’s access to cheap clean fuel.

7. What is the current state of the product?
   a.) Describe where the product is in the development phase
      Cobalt eggshell catalyst has been developed using precipitation technique. Optical microscopy has been used to confirm the thickness of egg shell zone. Extensive characterization techniques have been employed to confirm the properties of final product. These include X-ray photoelectron spectroscopy (XPS), X-ray diffraction (XRD), Chemisorption and physi-sorption techniques and IR spectroscopy.

      FTS reaction has been performed by loading optimized catalyst in the optimized reactor. Heat transfer issues have been successfully resolved. . Conversion and selectivity data has been obtained over the course of multiple runs. Condensable hydrocarbons have been analyzed in a gas chromatograph (GC) and infrared ATR (attenuated total reflectance) to confirm the presence of hydrocarbon cut and oxygenates (if there are any).

      The pilot plant reactor design has already been discussed; pressure drop calculations have been performed. Next plan is to model the reaction on MATLAB and COMSOL to assess material and energy balance across the system.

   b.) Identify the steps needed to get the prototype and how much it will cost
      Currently, having successfully developed and tested reactor operation at bench scale, our next step is to build a pilot scale unit for FTS process using our proprietary catalyst and reactor design. In order to realize this plan we wish to set up first a medium scale reactor and downstream separation (i.e. fractionating) equipment. Such a set up will provide us thermodynamic data and it will also corroborate our computer simulation results.

      All important a goal is to set up a pilot scale reactor based on the data obtained from the bench scale, medium scale reactors and computer simulations. We believe that above mentioned strategy will ensure our success. Apart from the reactor, there will be a gasification unit (in order to covert biomass to synthesis gas). Our plan is to utilize licensed third party gasification unit (Pearson Biomass Reformer). If all goes according to plan within the span of couple of years we will have a small
commercial plant with a capacity in the range of 25 to 150 tons/day dry biomass. To have an operational and optimized pilot plant, it would cost a total of $3 million of which about $1.8 million would be capital expenditures.

8. **What are the barriers to others entering the market?**
   a.) **Describe the status of patents, who owns them and the licensing terms.**
   There are two patents of interest to our company. One, U.S. Patent No: 7,375,142 issued May 2008, titled Process and apparatus for the production of useful products from carbonaceous feedstock. This patent is assigned to and owned by Stanley Pearson of Pearson Technology Inc., company with whom we are discussing the possibility of a joint venture. Through the joint venture, Pearson Technology Inc. will provide us an automated, fully operational, turn-key biomass gasifier for a substantially reduced cost in return for being the primary supplier of the biomass gasifier once we move into commercial scale production.

   Second, a pending patent application filed by and assigned to the University of South Florida (USF) with the opportunity to file internationally. We are currently negotiating a worldwide exclusive license for access to the process and composition of matter of the catalyst.

   b.) **Include discussion (if appropriate) of trade secrets, copyrights and trademarks.**
   We understand and appreciate that not all subject matter can and should be patented. To that end, our company possesses not only patent or patent pending intellectual property but also trade secrets for reactor designs, optimized performing conditions. We also possess invaluable know-how on handling of non-condensable matter, and distillation process that are very valuable. Finally, Tino Prado, P.E. of Prado Technology Corp. has proprietary know-how on F-T reactor design as well as the overall plant design strategy for an efficient and successful biomass to hydrocarbons plant.

   c.) **Describe any other unique knowledge or qualifications that will give market advantage to your team?**
   Another key element of our team is our relationship with Prado Technology Corp. We are currently in discussions with Tino Prado, P.E., the founder and chief executive of the company to merge with our company and advance this potential opportunity on biomass to liquid plant. Tino brings a wealth of experience in F-T plant designs. In fact, Tino Prado participated in the design of the biggest and commercially perhaps the most successful F-T plant in the world- SASOL, in the year 1975. To summarize, our relationship with Pearson Technology and Prado Technology Corp. and an exclusive license from USF has put us in a strong position to successfully set up a pilot plant and then graduate to build something bigger, better and more effective than Sasol within USA.

**References**

1.) **DOD Energy Security Task Force 2008**
2.) **DESC Fact Books 2008**
3.) **Congressional Research Service, Department of Defense Fuel Spending, Supply, Acquisition and Policy- Sept 2009**
4.) **Aviation Alternative Fuel Workshop, sponsored by ATA, AIA and FAA**