CAAF/09-IP/7
2/11/09
English only

CONFERENCE ON AVIATION AND ALTERNATIVE FUELS

Rio de Janeiro, Brazil, 16 to 18 November 2009

Agenda Item 1: Environmental sustainability and interdependencies

FULLY INTEGRATION BETWEEN MULTIPLE RENEWABLE SOURCES TO BENEFIT FROM SYMBIOSES[1]

(Presented by Brazil)

1. INTRODUCTION

1.1 The feedstock production relates to microalgal science and engineering topic areas, included biology, feedstock production in patented raceways, processing and the conversion processes; the acquisition and/or capture, use and recycling of resources, such as CO_2, nutrients and others; the potential setting with reference to sustainability, environmental impacts, logistics, Net Energy Gain (NEG), jobs creation and specific training; the interface to other renewable energy technologies.

2. FEEDSTOCK PRODUCTION: SCOPE AND METHODOLOGY

2.1 The first step is to select the best areas to locate the feedstock production and also the conversion plants site. A roadmap must be set. This plan feedstock production experimental site (P-I) and the commercial production facility setting is in Maranhao and Piaui, two Brazilian States placed in an Tropical region near the Equator (roughly between 2° S and 5°S). Maranhao is bigger than Italy and a little smaller than Germany; Piaui is bigger than Great Britain.

2.2 The main reasons for such choice relates to: a) the key parameters which will influence the rate of microorganisms photosynthesis and growth conditions such as small temperature variation both during day and night, in the range of 20 to 32°C, within 12 to 16 hours of light per day, all-year-round and an average daily radiation between 5,33kwh/m2 and 5,55kwh/m2 equal to 19,98 MJ/m2 (high solar intensity (>250 W), with high PAR (>40%)); b) the water, nutrients, CO_2 nearby availability; c) The area is not exploitable for food production; d) the logistics, environmental impacts and Net Energy Gain (NEG).

2.3 The prototype P-I could be implemented between 2010 and 2012 and shall demonstrate the raceways proprietary patented technology viability. The large-scale implementation timeline is

[1] The ideas and propositions expressed in this paper are the result of ongoing research by Coppe – Alberto Luiz Coimbra Institute – Graduate School and Research in Engineering. The information presented in this paper is subject to change pending the final results.

intended between 2012 and 2020. The conversion plants site shall be implemented in Itaqui (Maranhao), which nearby port may operate very-large tankers and is closer to Europe (4.143 nautical miles from Rotterdam), to the USA (3.355 nm from New Orleans) and to Panama Canal (2.483 nm) than any other Brazilian port. The ships may use Pure Vegetable Oil as an alternative to heavy fuel.

Microalgae's key attribute (beneficial reuse of CO2) must be fully exploited. If the facility intends to produce fuel, it may not be workable its implementation at the CO2 point source emitters where no NEG or sustainability would be attained concerning the logistics, the water stress, the energy demand, et cetera.

2.4 The logistics role is extremely important regarding the NEG and sustainability. The P-I may not be sustainable since the input and output shall employ the transportation system already in place. The commercial scale feedstock production shall stand on a modular concept and the conversion plant shall consider pipelines implementation, the use of rivers for nutrients transportation, raceways under automated controls; how the workers will be housed, fed, trained and transported to the production sites must be considered. Each raceway will need Implementation Crews, Operation Personnel, Maintenance People, Conversion Technical Staff, Anti-Contamination Rapid Response Teams, Post-Graduate and Master Students, Researchers, Engineers, Back-office Staff, Security, Electrical and Plumber Technicians, Telemetry and Digital Responsible Personnel and so on. These people must be trained, must live nearby (far-away at least 10 km from the facilities) and the transportation from and to work must be provided by flex-fuel equipment. The workforce training through the Brazilian National Training Workforce Services (SENAI, SESI, SENAC) and involved Universities is likely. The commercial stage first-phase (5.020.000 raceways) may employ tens of thousands of workers. The transportation system must be put in place and shall use ethanol or biodiesel from Babassu and Palm feedstock (large scale production in the area).

2.5 The environmental impacts must be anticipated and mitigated. The genetic modified organisms (GMO) and the water after been used in the cultivation systems could impact the environment. The strains and water will be contained in what is usually called Recirculation Aquaculture System (RAS), which is an almost closed culture system that is considered environmentally friendly. After been used, all the water shall pass-through Stabilization Lagoons, where it will be filtrate by Halophytes and Macroalgae, such as *Glaciaria.* The resulting water will come back to the raceways, and the process is continuous.

2.6 Due to high risk of contamination the feedstock production shall take place 300km from the shore line, although using Ocean water to fill up the raceways. Other than the desired saline microalgae shall not be able to contaminate the production vis-à-vis the remoteness; at the same time, continental microalgae (which grow in potable water) shall not survive in a saline medium. In case of any raceway contamination, specially designed trucks will take care of the culture medium and transport it to facilities where it will be incinerated at high temperatures. Saline GMOs must never come to shore line. Pipelines for saline and aquifer water, culture medium, oil, slurry, biomass and the output shall be put in place, nutrients shall be transported through rivers such as Parnaiba and the raceways implementation bits and pieces shall be carried via the existing railroad. The environmental impacts must be dealt with.

2.7 The highest NEG and sustainability may be reached if the following settings occur: a) the electric power can be provided by biogenic gas (LD CH4) which will be captured in the hydro reservoirs where it is released as methane. It may be possible to generate 18.529 GWh (2112 MW) in Tucurui alone. High efficient (70%) gas-turbines shall supply the electric power by the existing transmission lines to fulfill the demand driven by: the pumping systems which must be used in the pipelines systems; the biomass drying (the removal of 1 kg H2O by drying requires more than 800 Kcal of energy and in order to minimizing energetic costs, no drying is necessary prior to lipids extraction for algae slurry); the conversion technologies facilities which run at high temperatures (750°-1,500° F); the workforce itself.

2.8 The hydrocracking process largely depends on the nature of the feedstock and the relative rates of the two competing reactions, hydrogenation and cracking under a wide range of very high pressures (1,000-2,000 psi) and fairly high temperatures (750°-1,500° F), in the presence of hydrogen and special catalysts (green chemistry concerning the reduced amount of waste generated). The hydrogen may be extracted from the sea water via wind powered electrolysis in Maranhao (The coastline shows winds of at least 7.0 m per second frequently reaching the mark of 9.0 m per second) and Piaui. Brazilian Northeast region wind potential is estimated to be 73.000 MW).

It requires the fully integration between multiple renewable sources to benefit from symbioses and in order to allow any output production to be sustainable, scalable, cost-effective and to multiply each one NEG. In other words, the interface to other renewable energy technologies such as presented turns out to be the main point so as to getting the highest sustainability.

2.9 Another step is outlining the research priorities required to achieving the targets given the current state of algal development, the prototype purpose and future commercial projected dimension. The aimed experimental results shall prove that certain microorganisms cultivated under those conditions are able: to acclimate to irradiance values as high as about 2000 μmol m-2 s-1; to prove a biomass concentration ranging between 1.2 to 2.2 g L–1, which results in a net productivity of about 0.5 g L–1 d–1 corresponding to a biomass yield of 32.5 g m–2 d–1 (based on the large-scale surface area of the cultivation system); to produce substantial amounts (e.g. 35% dry cell weight) of triacylglyceride (TAG) accumulation under photo-oxidative stress, nutrient limitation, high pH and cell cycle inhibition or other adverse environmental conditions. All raceways shall employ proprietary patented technology.

2.10 The P-I projected yield at 32,5 gr/m²/day/35% lipids results in an oil production rate from the raceway system of 11.37 gm−2 d−1, or 39.82 toe ha−1 yr−1. The prototype projected size is a nominal (not considering down timing) 10,000 tons of oil equivalent (toe) lipids production in a State-of-the-art facility occupying a 251 ha raceway area. Assuming 100% extraction efficiency, this is equivalent to 68.400 barrels of oil equivalent (boe) a year, or 2,863,771 gallons or 10.839.374 litters for extracted oil only. The dry biomass is projected to be 14,78 gm−2 d−1 or 53,97 tons ha-1 yr-1 which, at an energy content of 20 GJ/tone, is equivalent to 1079 GJ ha−1 yr−1 which is equivalent to 6.130 toe yr-1 or 1,761,319 gallons yr-1 or 6,666,591 litters. In other words, assuming 73 downtime days, the expected total production (including lipids and biomass equivalent) is 55,905 litters ha-1 yr-1 or 14,770 gallons ha-1 yr-1 or 5,977 gallons acre-1 yr-1. The prototype I (a time frame of 12 months may be required to the construction period, between 2010/2011) shall produce an estimated 3,707,295 gallons of oil equivalent a year by 2011-2012. The water needs are over 6.000.000m3 to fill-up and to complete after evaporation and percolation. Circa 50.000 ton of CO2 will be needed, and shall be nearby available, as well as the nutrients demand and the work force requests shall be evaluated.

2.11 This is likely due to the huge hydrographic basins near Maranhao, such as Tocantins-Araguaia (13.799 m³/s or 7,7% Brazilian potential), where the actual demand is 78,3 m³/s. There are also huge saline aquifer systems in Piaui, which are not suitable for agricultural purposes or for drinking, like the Parnaiba (330.000 km^2, potential offer estimated as 9.030 $x10^6$ m3/year).

2.12 The project aims to use alternative means of cultivation, such as recycling and use of natural occurring nutrients because a new large scale demand for microalgae must NOT result in fertilizer shortages: 1 - intensive use of manure, brackish water and production water from the huge cattle farming nearby, which can mitigate the adverse impact from livestock in the climate change; II - for nutrients, there are opportunities to use run-off fertilizers from soy bean cropland in river waters and estuarine systems in the Maranhao; III - availability of N and P adsorbed on suspended solids in turbid waters of the Amazon River; IV – make use of the basic catalysis process resulting K2PO4 as microalgae macronutrients;

2.13 The commercial-scale feasibility will require huge CO_2 quantities, as carbon is a key requirement. Actually three steel plants are been planned to be implemented in St. Louis, Maranhao, and the target output is 22.5 million tons in the timeline between 2010-2015, which equals to 70% of Brazilian production. On average, 1.7 tons of carbon dioxide are emitted for every ton of steel produced. In this case, it is equivalent to almost 40 million ton of CO_2 emission each year that could supply large scale microalgae production. Carbon dioxide pipelines must be implemented to link the Steel Industries and the microalgae feedstock production.

2.14 The data from international experiences and the P-I completion shall validate the commercial feasibility and identify the risks associated to large-scale feedstock production and bio-fuel conversion. A scale-up to 251.000 ha, on a par with 5.020.000 raceways shall be considered. The water needs would reach 6 billion m3 plus (due to evaporation and percolation), and the CO_2 needs would be circa 50 million ton yr-1, which can be viable in the region at little or no cost.

2.15 The output can reach 3,7 billion gallons of oil equivalent a year by 2020 (equals almost to 20% US, 4 times Brazilian or all American Airlines consumption in 2005), corresponding to 242.000 barrels a day/365 days. It is possibly workable a 1 barrel ha-1 day-1. As a comparison, Sapphire Energy predicts 1.4 billion as possible world production approximately in 2020. The output would increase dramatically when and proviso achieving a possible target near or @ 50 gr/m²/day/50% lipids.

The scale-up to other target levels is reliant on the availability of all inputs included renewable energy sources. The CO_2 sourcing may become the main constraint issue, although it shall be affordably imported from Europe and USA due to the proximity to Maranhao. Potentially, raceways occupying 753.000 ha could be located in the area, and @ 32,5 gr/m²/day/35% lipids, at least 12 billion gallon could be feasible to produce.

2.16 There are existing and emerging risks regarding to: The algal production is in the early stages, the complete process has not yet been sufficiently being developed at an industrial level and as result it may become difficult to implement such large scale production facilities, as never before has been through; The required new infrastructure build-up shall cope with time delays as the technical, economic, environmental and policy issues may also holdup the completion; The likely NEG may be partially achieved since the knowledge shall be acquired; There are multiple sector interdependencies that shall be difficult to address as a number of technological fields have to be developed, so as to achieving the mass production of microalgae as precursors of biomass and oil; Although they are technically feasible, Brazilian national institutions catalysis groups shall develop proprietary conversion technologies and it's worth noting that although HRJ technology has significant advantages over BTL concerning capital costs and energy efficiency, both must be simultaneous addressed since the former employs vegetable oil as bio fuel originator and the latter uses algae dry biomass as bio fuel precursor depending on the F-T process.

3. WHY BRAZIL? THE BIO POTENTIAL, THE TECHNOLOGIES & THE EXPERIENCE.

3.1 The lab scale shall by no means answer whether the scale-up is practical or the bio jet fuel price tag. As soon as possible, ICAO must identify the sites in the world where assured conditions are at hand. The ultimate Brazilian setting presents each and every one which is aligned to other environmental considerations. These conditions turn out to be the main point so as to getting the highest sustainability and Net Energy Gain. The bio jet fuel feedstock scale-up is unavoidably interconnected to other renewable energy sources availability in the same region where huge water, nutrients and CO2 accessibility shall be lasting, logistics implementation might be straightforward, workforce transportation system might employ ethanol or biodiesel and high solar intensity together with high PAR must prevail all year round. The sugar-cane business attests Brazilian former bio fuel scale-up know-how. Brazil also has the bio-potential to become a bio jet fuel practical exporter, to become energy independent and the first large country to become CO2 neutral.

4. ALFA CONSORTIUM & COPPE-UFRJ

4.1 The technology aggregator and main institution will be COPPE-UFRJ, leading other Brazilian and International bodies in a consortium (alfa consortium). These institutions shall be invited or already have been, such as INT (National Institute of Technology), IME (Military Engineering Institute), ITA (Aeronautics Technology Institute). Alfa consortium shall provide the R&D and implementation strategies, microalgae bio-prospection/development, raceways proprietary technologies, conversion technologies development, knowledge management and coordination; The Brazilian Army Command's Trompowsky Foundation may be responsible to implement the P-I engineering work and logistics; The States of Maranhao and Piaui shall be part of the project (Piaui's Environmental Department is already working). The roles and responsibilities as well as a timeline of actions shall eventually be identified.

4.2 Coppe and Centroclima proposed in September 2008 to establish the Brazilian National Institute of Microalgae Technology as a Source of Renewable Energy-IMA (Tender No. 15/2008 - MCT / CNPq / FNDCT / CAPES / FAPEMIG / FAPERJ /). It aims to develop new strategies and products to mitigate the GHGs emission, included the semi-arid region development in partnership with the PAN-Brazil - National Action Program of the Combating Desertification and Mitigating the Effects of Drought (MMA), the INT (National Institute of Technology - MCT), with several laboratories and / or departments of UFRJ, UERJ, UFMA, UFPI, FURG,UNESP, FIPERJ, and researchers from other institutions, such as IME, ITA, UCB, UnB, UFBA, UNICAMP, Agro Embrapa, Embrapa Genetic Resources, IOC-FIOCRUZ, MIT, Harvard Medical School, etc. The General Coordinator was Emilio Lebre La Rovere and Executive Coordinator M. Azevedo. The advisory board suggested was Ignacy Sachs (Ecole des Hautes Etudes en Science Sociales) and Jean Charles Hourcade (CIRED - Centre International de Recherche sur l'Environnement et le Développement).

4.3 **Coppe – Instituto Alberto Luiz Coimbra de Pós-graduação e Pesquisa de Engenharia** - Over four decades, Coppe has become the largest education and engineering research center in Latin America. It has 12 programs for post-graduate programs (MSc and PhD), has trained more than 11,500 teachers and doctors and now has 320 professors in exclusive dedication, 2,600 students and 350 employees, among researchers and technical and administrative staff. To meet the demands of its growing scientific research projects development it has 116 modern laboratories, which makes up the Brazilian largest engineering complex.

— END —