Company and Product Review

Accelergy TerraSync BioFertilizer – An Economically Attractive Approach for Crop Production, Soil Reclamation and CO2 Mitigation

By Trang Cao, October 2017

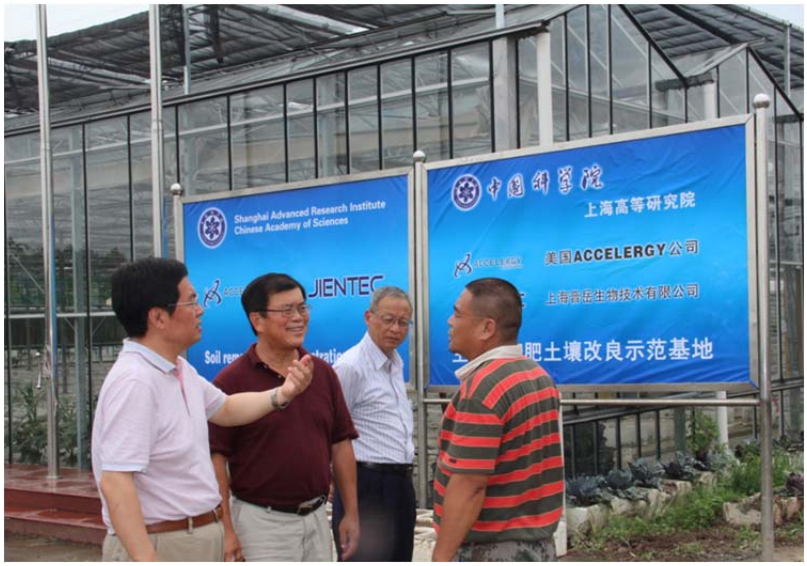
Accelergy TerraSync™ CO2 Capture and Utilization (CCU) Technology.

Synthetic fuels (XTL– CTL, BTL and GTL), cement production, aluminum production and fossil based electric power production technologies are inherently carbon inefficient, and require CO2 to be captured and either sequestered or utilized in order to reduce their carbon footprint to acceptable levels. Accelergy and its alliance partners have developed TerraSync™ CCU, a novel system for capture and utilization of process derived CO2, together with process waste water and waste heat (from gasification, coal to ammonia/urea and/or coal liquefaction or combustion processes) to produce selected strains of blue green algae for use as a nitrogen fixation component of BioFertilizer. This approach has been evaluated with the US DOE where greenhouse studies have shown the benefits of using algae based fertilizer as a supplement to conventional ammonia or urea based systems. Recent studies with Nexant, Bechtel and the Chinese EPC firm TCC show that this option is able to economically use CO2 while simultaneously reducing the overall GHG footprint of associated CO2 emitting facilities. TerraSync™ effectively allows one to economically produce synthetic fuels or electric power from coal and other carbon based feedstocks, with an overall carbon neutral or carbon negative footprint via the terrestrial sequestration of CO2.

TerraSync™ is also unique in its ability to not only offset carbon footprint for any process in which it's included, but also in the ability to produce high performance BioFertilizer with corresponding crop yield, oily or distressed soil reclamation and environmental benefits. In addition, when compared to other CO2 mitigation options, our approach uses significantly less land that straight Biomass to Liquids approaches and is much more efficient and lower cost that geologic sequestration options that require 25% added energy and lead to cost-doubling (or more) per unit of power generated or ton of CO2 mitigated.

Field tests at their partners labs in Shanghai have demonstrated the efficacy of TerraSync™ BioFertilizer in production of various crops with typical 15-25% yield improvements over conventional fertilizer based systems.

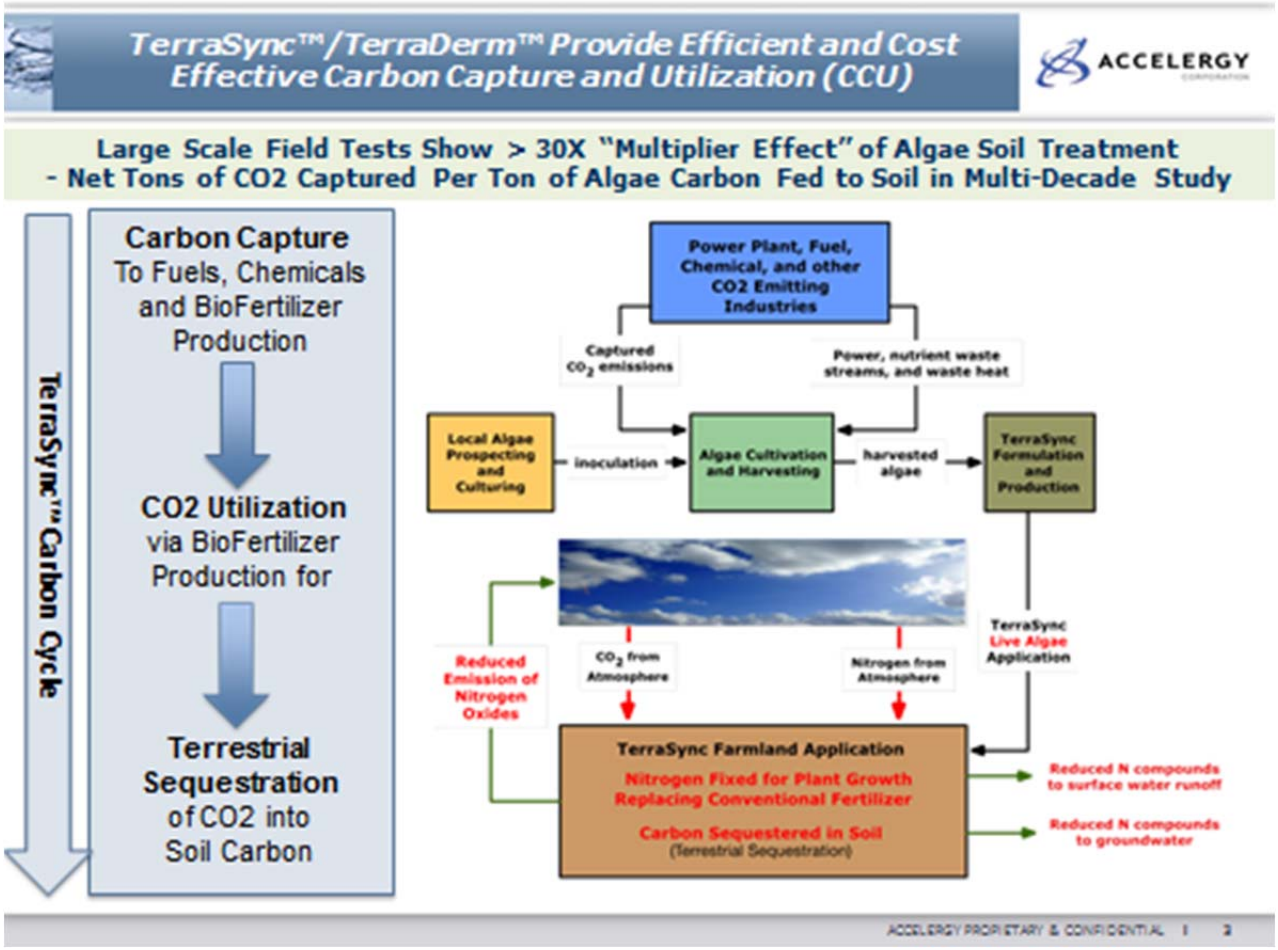
Accelergy Chinese Academy of Science Jientec Facility on Chongming Island



Larger scale demonstration is being planned as part of the US China Joint efforts on Carbon Capture and Utilization- and as follow-up to the recent workshop organized by US Ambassador to China, Max Baucus. Accelergy has been in contact with the US DOE and Office of Indian Energy Affairs and is looking forward to advancing a project proposal with the Crow Nation near Billings MT. The current plan calls for direct collaboration between the US DOE – Chinese Academy of Science and Accelergy and its subcontractors at Bechtel. We have been working with our partners at Bechtel to identify other locations for full scale commercial projects, including potential operations in Mozambique, Namibia, Botswana and Tanzania.

Why TerraSync is Unique: In order to produce clean fuels or power while simultaneously reducing carbon footprint of a facility with a conventional algae based approach, essentially all the CO_2 emitted from a facility must be captured and converted into algal biomass, and subsequently used in a way that does not readmit CO_2 to the

atmosphere. **For a conventional operating facility with 100,000-350,000 MT per year of CO_2 output, one would require an algae farm of about 1000 to 3,500 acres for full carbon offset (assuming an average algae farm can convert 100 MT per acre per year of CO_2 to algae).**



Almost all conventional uses of algal biomass readmit some or all of the carbon captured in algae cultivation back into the atmosphere; this is true for biofuels, animal feed, or combustion of algal biomass. In general, because carbon captured by the algae used for fuel, etc. provides a second economic good, less total carbon ends up in the atmosphere. The exception to this is a use of the algal biomass that actually results in sequestration of the carbon, such as terrestrial sequestration – i.e. long term storage of the carbon in soil.

Accelergy Corporation is a leader in this sector because of the uniqueness and versatility of technology portfolio. Accelergy provides direct access to world-recognized algae research and development (R&D) and processing facilities and to industry leading technology for conversion of coal and other fossil feedstocks to clean low carbon fuels or power. This allows Accelergy to deliver an innovative solution in the shortest timeframe and to minimize large cost investments that would be needed to reach a state of useful commercial readiness. Accelergy brings an elegant and proven algae processing system to bear – of which when fully integrated into customer operations – has the ability to offer multiple operational benefits across environmental and energy needs. Accelergy's CCU process, TerraSync, works via capturing carbon from CO_2 in algal biomass and production and use of biofertilizer for terrestrial sequestration of the carbon (i.e., additional CO_2 is captured from the atmosphere and sequestered in soil in the normal course of product use in crop production or soil reclamation, therefore this is an effective carbon offsetting mechanism for an even larger quantity of CO_2 than was generated at the source facility). **The total amount of land required for the algae biofertilizer process is about 1/10th that required for the conventional approach used in cultivation of algae for carbon mitigation; the same carbon mitigation outcome requires only 90-350 acres of algae farm for the cases noted above. In an average location, this can amount to significantly reduced investment (80-90% lower- in average cases several hundred million dollars lower) in the CCU facility.** The reduced land use and corresponding reduced water use are also critical factors that help make TerraSync the preferred algae carbon mitigation solution.

Accelergy's terrestrial sequestration approach to produce and use algae as a biofertilizer and also as a soil amendment to reclaim distressed soil in conjunction with coal to liquid fuels production is a unique capability that will dramatically change the way in which CO_2 mitigation is approached.

Accelergy Alliance Strategic Partnerships:

Algenol: offers state of the art algae identification – closed photobioreactor technology for production and isolation of cyanobacteria in commercial scale configurations.

Bechtel: provides industry leading engineering procurement and construction capabilities; and project execution capabilities globally.

Dr. Russell Chianelli: UTEP (who previously served as ExxonMobil's Chief Scientist in the successful deployment of bioremediation technology for the Exxon Valdez, Alaska oil spill clean-up program) provides scientific and technology deployment expertise for projects involving oily or contaminated soil clean up.

Mapleton Agri Biotec: offers microbial fertilizer formulation and production technology that has been deployed globally.

Global Thermostat: provides Accelergy with access to CO2 "air-capture" technology with modular integrated systems for capture and production of high purity CO2 from a range of industry sources, including from air, when low grade waste heat is available.

Shanghai Advanced Research Institute (SARI) – Chinese Academy of Science: SARI has been working with Accelergy since 2007 on various aspects of carbon capture and utilization and is responsible for all the research & development, and related scale up efforts, on this program in China. SARI has not only developed state of the art R&D capabilities in its Shanghai campus, but also oversees together with the Jientec firm our large scale field test program on Chongming Island. The results from these large scale field tests have confirmed independent studies conducted for Accelergy by Montana State University Agricultural Department and the Pennsylvania State University Agricultural Science Department in State College PA.

Useful Feedstocks for TerraSync Production: Waste CO2 streams from coal gasifiers or natural gas reformers; fossil based power production; heavy oil refineries, waste water containing N and S contaminants; bio-waste with K, P, Mg, Ca and low grade waste heat. Air can also be used as a source of CO2 when we employ Global Thermostat's CCU adsorbers – and recent studies have shown that it is possible to capture CO2 from air at total CO2 costs of $10-25 USD per ton.

Products: fully formulated BioFertilizer as a complementary soil treatment additive to be used with traditional ammonia or urea based fertilizer; "time release" nutrient production function via the photosynthetic action of blue green algae that continues to perform in nitrogen fixation after application. Soil amendments for stabilization of arid soil or distressed soil – demonstrated in Inner Mongolia Kubuqi Desert stabilization program, or for reclamation of salty soil for crop production.

Recent Developments: launched full scale demonstration programs in the Gobi Desert with a Chinese industry group and on Chongming Island with the Chinese Academy of Science and industry partners to produce food crops on salty soil along China's eastern shore; and with US based projects launched in Pennsylvania and Montana in conjunction with coal conversion or coal to power operations. Full scale commercial operations planned for 2016+ in MT. Accelergy is seeking industry partners to advance this option globally with primary CO2 sources from coal power or CTL production – and we are currently in discussions with Bechtel in the US and TCC in China.

Accelergy TerraSync Business Opportunity:

Accelergy has been developing several commercial project opportunities to advance the TerraSync concept and to help reduce or eliminate the overall carbon footprint of fossil based electric power production and in synthetic fuels production while simultaneously reclaiming distressed soil. In these cases, Ecomana is able to economically

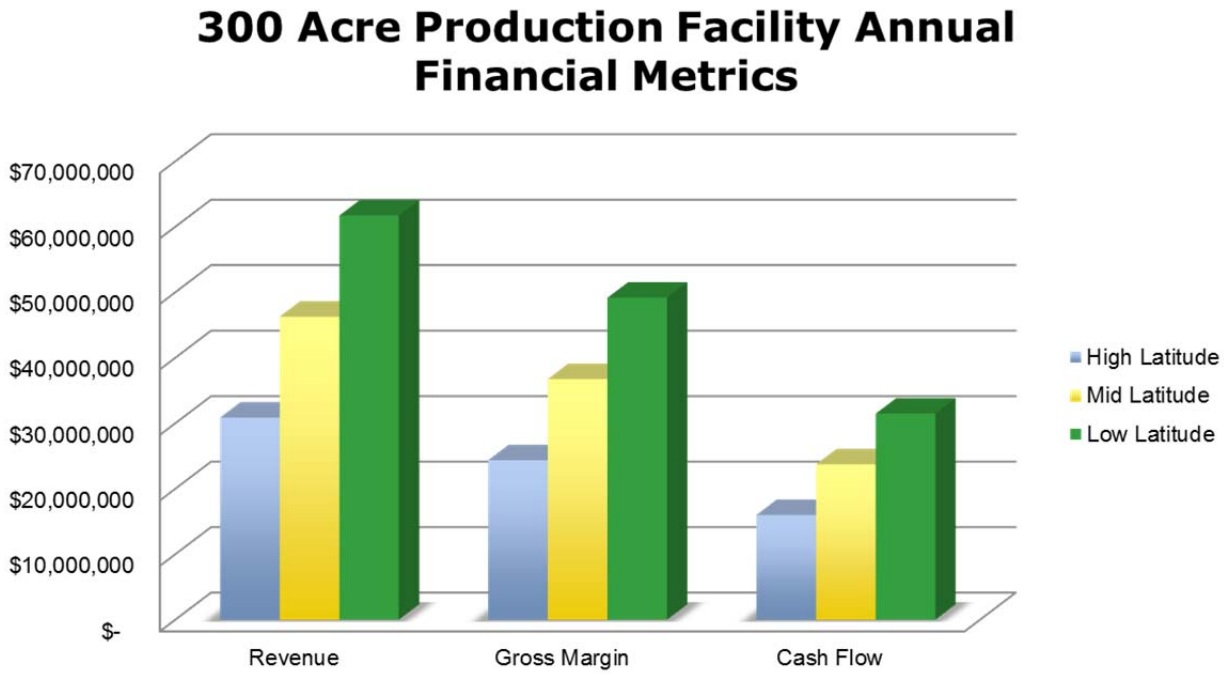
produce soil remediation agents from process derived CO2 and then by appropriate use of the BioFertilizer to re-establish the productivity of such soil for crop production.

The economics for such a facility are noted below for cases where algae production is done at a generic location in North America using open pond vs closed photobioreactor technology.

	Open pond	**PBR**
Yield		
Lipid production [MM gal/yr]	10.0	10.0
Diesel production [MM gal/yr]	9.3	9.3
Land Use:		
Pond/PBR Land Use [acre]	4,820	4,820
Total plant land required [acre]	7,190	7,190
Resource Assessment:		
Net makeup water demand [MM gal/yr][1]	10,000	3,000
-Water evaporated [gal/gal lipid]	570	250
-Water blowdown to treatment/discharge [gal/gal lipid]	430	50
Fresh CO2/ sugar demand [ton/yr][2]	145,000	145,000
Power coproduct [MM kwh/yr][3]	80	100
Naphtha coproduct [gal/yr]	340,000	340,000
System cost:		
Total capital cost (direct + indirect) [$MM]	$390	$990
Total Capital Cost Per Acre ($K)	$80	$206
Net operating cost [$MM/yr]	$37	$55
Algae BioFertilizer/Soil Amendment Production Cost ($/ton)	$300	$700+

Note: Recent studies indicate that TerraSync BioFertilizer can be economically sold at prices equal to or below those of conventional urea based fertilizer; and that comparative field tests indicate positive yield advantages on an equivalent fertilizer cost applied basis.

In this case, the algae produced from power plant or process derived CO2 is then combined with other components to produce a finished BioFertilizer formulation for use with specific crops. The overall economic performance from such a facility is attractive based on BioFertilizer production and sales alone, and does not require government or carbon market subsidies – which would only further serve to enhance overall economic attractiveness of the option. In recent studies we have shown that it is possible to totally eliminate the carbon footprint of a 500MW power plant a costs that are 60-70% lower than those for conventional carbon capture and physical sequestration (CCS), and without the 25+% parasitic energy load with CCS.



Year 4 Financials

Key Assumptions:

- **No value assigned to carbon credits**
- **Fertilizer sold at a 15% discount to current market prices**
- **Production facilities operational 11 months of the year**

Bibliography

The following documents are relevant to this work:

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10 U.S. Pat. No. 4,950,601 MacDonald, et al. The use of heterocystous blue-green ***algae*** as a fertilizer which fixes nitrogen.

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14. U.S. Pat. No. 3,958,364 Schneck, et al. 1976. The production of the flocculating polysaccharides by reducing the nitrogen concentration of the medium.