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Subject: The government wants your advices on biofuels

Letter 1: General suggestions on biofuels decision making

Letter 2: Out-of-the-box solution for the bio-economy

To Whom It May Concern,

I really appreciate this opportunity to express my opinions on biofuels. I did it several times by publishing papers in scientific journals and am happy to send my opinions to the right administrative. As a new USA citizen, I would like to do my best to help the USA establish the reviving bioeconomy and regain No. 1 manufacturing nation position in the world. In Letter One, I will introduce myself and provide some suggestions about biofuels policy making. In Letter Two, I will present an out-of-the-box solution to the bioeconomy and how to re-shape the future bioeconomy.

First, let me introduce myself. I am an associate professor with tenure of Biological Systems Engineering Department of Virginia Tech. (With protection of tenure, I dare to speak my opinion openly.) I have received my degrees of Biochemical Engineering Bachelor and Master (China) and Ph.D. (Dartmouth College, USA). I have worked on biofuels since 1997, under supervision of biofuels pioneers Profs Lee Lynd and Charles Wyman. I think that I am qualified for making some comments and suggestions due to numerous reasons: (1) long-time training and studies in this field, (2) the broadest research topics in biofuels field as a single PI in the USA from pretreatment, cellulase engineering, consolidated bioprocessing bug development, metabolic engineering, synthetic biology, water conservation, food and feed production, and energy efficiency analysis, (3) different education and cultural backgrounds so that I can find out some blind spots, which most persons are ignoring, (4) a good record in biofuels R&D based on publications, grants, citations, and awards, (5) a brave and insightful thinker, who dare stand out to criticize non-sense biofuels R&D projects openly, and (6) an amateur historian, especially in science and technology. To partially support my claims: I am listing several of my achievements in R&D and their commercialization:

- (1) Discovering a new metabolic pathway for *Clostridium thermocellum* and validated technological feasibility of consolidated bioprocessing (CBP) concept. As a result, the DOE biomass program accepted it as an ultra-low production platform for cellulosic ethanol in 2006. Now the DOE Bioenergy Science Center and Mascoma are working on this direction. Mascoma will go to IPO by the end of this year. This work was mainly done by me, along with my Ph.D. advisor Lee Lynd.

- (2) Invented a cellulose-solvent and organic solvent-based lignocellulose fractionation (COSLIF), when I was an assistant professor at Virginia Tech. Now this technology has been licensed to Optafuel Co, which has a 25 MM investment for building a pilot plant in South Virginia.
- (3) Founded a biofuels start-up company – Gate Fuels Inc. It is funded by NSF SBIR I and BioMethodes Co.
- (4) Achieved the most energy efficiency way for the generation of hydrogen from renewable sugars. I am a receipt of Air Force Young Investigator Award (2008). Now Shell GameChange program is funding our efforts in commercializing this process (Note: *This technology is the most important technological breakthrough in the future bioeconomy. Please see my second letter. Its importance at least equals that of ammonia synthesis*).
- (5) Accomplished low-cost conversion of non-food cellulose to edible starch. This technology is under negotiation with a Chinese animal feed producer. We would solve the problem of feeding the world.

Second, history always teaches us a lot and it repeats itself in different forms. Recalling the successful story of making atomic bombs in the USA and China. The USA case tells us that **we need good leaders** (e.g., J Robert Oppenheim), who are quick to learn new things, are good communicators, are open to different opinions, dare to make decisions, do not think too much of his personal interests, and believe that national interests are beyond personal interests. Based on my observation, most USA biofuels leaders do not have such quality. Some famous biofuels scientists are leading the USA to wrong directions due to their personal interests (job security, money, and fame). As a result, it could kill the bright future of biofuels. The Chinese case tells us that (1) big democracy in science and technology is a must to avoid possible wrong directions (i.e., everyone has a chance to doubt or criticize research plan openly) and (2) concentration of limited money for to the best and well-analyzed projects and then achieving the goals within the shortest time. My suggestion is open debate and open discussion (it is not enough to do it in scientific journals). In this new system, any persons regardless of his ranking, university, and education background have a chance to raise his doubts or challenge established or leading scientists; such leading scientists must have their responsibilities to address such doubts openly. We need several round open debates until the doubts have been addressed clearly and openly. We may introduce open scientific and technological competitions like American Idol. **We need big democracy in S&T. We need dual-way evaluation and feedback rather than one-way judgment. Successful scientists in their fields do not mean that they are experts in another field.** (Note: there are so many instant biofuels experts. In reality, they know little.)

Third, we need biofuels leaders with great visions plus doable technology plans. Only vision cannot solve practical energy problems. Otherwise, science fiction writers might be best leaders. In reality, so many energy leaders are doing things like science fiction writers do. They may have right visions but they do not know how to do it. Day dream plans will waste tax-payer money and results in wrong decisions. My vision is to replace crude oil with renewable sugar when we can increase biomass energy utilization efficiency. Also, we have provide very detailed technical solutions as shown in the below papers.

- Zhang Y-HP, Mielenz JR. 2011. Renewable hydrogen carrier -- carbohydrate: constructing the carbon-neutral carbohydrate economy. *Energies* 4:254-275.

- Zhang Y-HP. 2009. A sweet out-of-the-box solution to the hydrogen economy: is the sugar-powered car science fiction? *Energy Environ. Sci.* 2(2):272-282.
- Zhang Y-HP. 2011. Simpler is better: high-yield and potential low-cost biofuels production through cell-free synthetic pathway biotransformation (SyPaB). *ACS Catal.* 1:998-1009.

According to our analysis, the USA has enough biomass resource to replace all oil used in the transportation sector.

- Huang WD, Zhang Y-HP. 2011. Energy efficiency analysis: biomass-to-wheel efficiency related with biofuels production, fuel distribution, and powertrain systems. *PLoS One* 6(7):e22113.

To my knowledge, Germany and Chinese Governments are supporting this new direction, opened by me. **My worry is that the USA invention does not mean the USA innovation, if we do not take action now.**

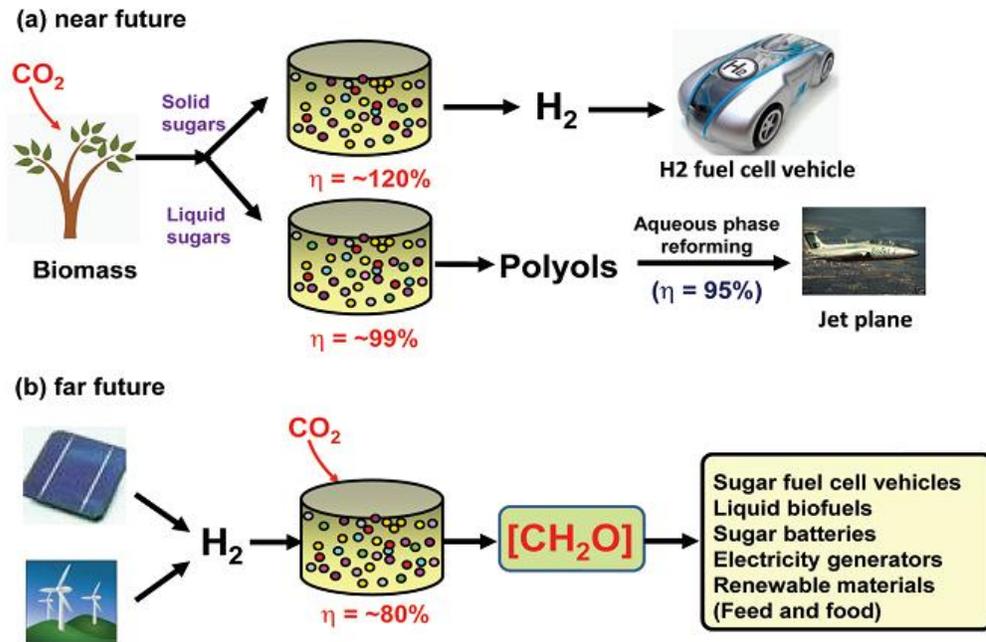


Figure 1. Different biofuels scenarios based on plant biomass through natural photosynthesis (near future) and starch produced by artificial photosynthesis (far future).

Fourth, we must search for the clarity of the bioeconomy R&D. *Not every possibility is worth testing.* Like Tobacco company's doing (studies that tobacco may not be bad to health in 1960-1970s), some oil companies (e.g., Exxon Mobile) are misleading biofuels directions on purpose. We need refocus on our biofuels directions. I summarize several key points:

1. Economic goals of biofuel R&D projects must be finished within a defined timeframe with numerous clear and hidden constraints plus political and geographic concerns;
2. Thermodynamics (energy conversion efficiency based on mass balance and energy balance) determines economics in the long term;

3. Energy efficiency analysis is simpler and more transparent than life cycle analysis and process economic analysis;
4. R&D can drastically decrease production costs but cannot break the limits set by thermodynamics, energetics, and physical and chemical properties of materials;
5. Not every biofuels possibility deserves more research. Muddy water strategy would delay biofuels' wide implementation or even kill biofuels' future;
6. Moore's law does not work in the energy field for both energy efficiencies and production costs due to the above-mentioned limits; and
7. Renewable energy sources could eventually replace most non-renewable fossil fuel sources, but this transition would take at least a half century.

Fifth, do not fund any big biofuels projects. The DOE Bioenergy Centers and USDA CAP projects cannot work. Funding big biofuels project must have a condition that these projects must pass through thorough open debates and examination.

Sixth, capping federal grants to any single researcher, e.g., one million dollars per year. We need encourage competition. Most times top scientists do not guide postdocs or students because they do not know technical details. Fundamental researchers cannot spend too much tax-payer money. For applied research, scientists should raise their grants or funding from private sources.

I appreciate your interests and reading. If you have any question, please feel free to contact me via email at biofuels@vt.edu, or by telephone, at 01-540-231-7414.

Yours sincerely



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