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OPINION

Practical limitations and recognizing hype

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Large swaths of the public lack a basic understanding of energy issues. This fact, coupled with a desire for a miracle that will mitigate energy and environmental concerns, makes clean energy an area ripe for hype. Many technologies are described that are possible, yet will never be practical. As scientists and engineers we must do better job explaining the difference. Practical limitations were ignored as the development of cellulosic ethanol rode a wave of optimism and hype earlier in this decade. It is now clear that cellulosic ethanol is not delivering on the promises made. Scientists and engineers will continue to show us what is possible. We must focus our efforts in energy on those technologies that can also be practical.

I was at a social event recently where a colleague announced that she was going to purchase the new solar powered Prius.[1] It became clear to me at that moment that lack of understanding about energy issues in the U.S. is a serious problem. This was an intelligent person telling me something that I know is impossible. The despair in my response was a complete shock to her. I told her that the solar energy falling on a car the size of the Prius would never allow it to practically operate. The solar energy simply isn't sufficient to power a car. I was talking with an intelligent and articulate co-worker, employed by a technology company. She works in a business function, but likely has a technical degree lurking in her past. Yet, she has no understanding of very fundamental concepts of energy.

I have come to believe that large swaths of the public also lack a basic understanding of energy issues. They also want to believe that a miracle will happen so that our life styles won't have to change for us to improve the environment and reduce energy use, especially petroleum use. They also believe the hype. Ads that show the Prius now has solar cells don't really highlight that they are only used to power a fan to keep the car cool on particularly sunny days. The ads, some wishful extrapolation and a lack of thermodynamic understanding pushed my coworker to conclude she'd be driving with only solar power.

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It is completely impractical to think that a passenger car could be operated by just the sunlight falling on it. Clouds and nightfall require that batteries store power while parked to have any hope of propelling a car with solar energy. Such an arrangement is certainly possible, but likely not particularly practical. Photovoltaic cells that would cover a Prius can only be counted on to average about 0.5 kWh/day where I live in Michigan.[2] Collection by prudent parking and storage in efficient batteries would enable a 2011 Prius to travel about 3.5 miles per day.[3] Coating two square meters of the car's horizontal surface with solar cells would allow you to travel about 1300 miles per year. That is about 10% of the average miles put on a car in a year. The solar Prius would save 27 gallons of fuel, or about $110 per year with gas at $4/gallon.[4] In 10 years, the savings would pay for the solar cells.[5] Ten year paybacks are not particularly attractive propositions, certainly not by the by standards that American business operates. While it is possible to put solar cells on a car, it is not practical.

The distinction between possible and practical dominates my job. Controlling the R&D budget at Dow is a tremendous responsibility. We have earned the right to spend our R&D budget because we continue to deliver value to the corporation. We have to continue to earn that right by showing that our investment in R&D provides a return. It is not, and will never be, an entitlement. It is my job to see that the money is spent wisely. One of the main parts of my job is separating those opportunities that will create sustainable value from those opportunities that are fads. Fads are things that come and go without providing lasting value.

Technology fads dot the history of science. The scientific method relies on skepticism. New advances must always be greeted with both wonder and critical analysis. This was true for reanimation claims *via* galvanism in the 1800's, for claims that neutrinos moving faster than the speed of light today, and for many things in between. Fads develop when what is possible becomes confused with what is practical. Jet packs are clearly possible. As a boy, I saw movies showing them and I was convinced I'd be riding one by now. It turns out that they are not practical. I believe that the engineers working on the project got so enamored with proving that jetpacks were possible, they likely overlooked the obvious issues that make them impractical.

"The United States does not have to rely on oil to drive our economy and quality of life. We can replace much of our oil with biofuels—fuels made from plant materials grown by American farmers."[6] This is typical of statements made about biofuels early within the last decade (2002–2006) as momentum for biofuels was building. Concerns about energy security, rising energy prices, and climate change all fed into a desire by the public for a silver bullet. Biofuels were positioned as the solution that would not only solve the problems, but do so while maintaining or improving quality of life. These promises are largely unmet as we move into 2012. The approximately 6 million gallons of cellulosic ethanol available in 2011 are a far cry from the 250 million gallons mandated by the RFS in 2007.[7] I believe that the hype surrounding biofuels has caused many in the area to overlook obvious issues that make cellulosic ethanol impractical. Reports detailing what was possible came to be viewed as reports of what was practical.

Understanding why cellulosic ethanol has failed to live up to the hype can be found in the answer to four questions:

- how much biomass is available?
- how much will it cost?
- how much will the conversion technologies cost?
- how much more are we willing to pay for the resulting fuel?

The answer to these questions convinced me that cellulosic biofuels would not deliver the value that the hype around them promised.

Biomass is not a concentrated resource. Widely distributed, it is low in both density and energy density. It is present almost everywhere, but never in amounts that rival fossil reserves. Transportation over long distances is impractical due to the low density. Multiple industries vie for what is actually a very limited resource. Lignocellulosic materials provide energy today through direct combustion. Approximately 4% of the annual U.S. electricity, the largest fraction of renewable power, is supplied from biomass. Clearly, you can make power or liquid transportation fuels, but there certainly isn't enough to significantly supply both. Electricity is the most valuable form of energy, as shown in Fig. 1 (*e.g.* electric ~$35/MM BTU *versus* ~$24/MM BTU for gasoline). In addition, turning biomass into electricity requires far less capital, thus, it generates a higher return. Even with these advantages it stuggles to compete with electricity generated from coal and natural gas because of the higher cost of the biomass on an energy basis. Turning biomass into transportation fuels require more capital, conservers less enthalpy and generates a less valued form of energy.

The common misconception is that biomass is inexpensive. There are indeed some supplies that are inexpensive, like beetle kill in the mountain west. Municipal solid waste, which averages over 50% lignocellulosic materials, has been targeted by some as a free or even negative cost raw material.[8] Being paid to take raw materials always improves the process economics, and it works so long as the raw material supplier doesn't notice that you're making money. Their excitement about paying you to take the raw materials generally wanes with your success. Inappropriate focus on these more opportunistic feedstocks adds to the hype by inaccurately presenting a picture that near free raw materials are widely available. The discussion must elevate to material supply commensurate with the transportation fuel demand. The opportunistic options simply cannot supply the amount required for significant biofuels production. Development of on-purpose bioenergy crops and use of agricultural wastes that today are not collected is required to meet the mandated fuel demand.[9] Studies examining the cost of production of energy crops and agricultural residues continue to move biomass prices higher.[10,11] Higher prices multiplied by the unit ratio for conversion to alcohol yields an overall raw material cost that is comparable to the corn ethanol. Raw materials cost for biofuels from cellulosics simply aren't lower than incumbent corn or fossil-based fuels. Additionally, many believe that simply reaching cost parity with market prices for fossil fuels is sufficient. Fig. 2 shows that parity is insufficient since other options still are present that will be exploited first and with higher financial returns.

The capital for biomass conversion is still projected to be, at a minimum, over double the capital requirement for today's starch and sugar-based technologies.[12] Current costs, as opposed to n^{th} plant projections, are even worse, frequently exceeding five times the cost. High capital cost with no significant raw material cost benefit does not create an advantaged position. The lack of a discernable advantage keeps capital from flowing into cellulosic opportunities and rightly so. Industry has an obligation to create a return on invested capital. Compelling financial opportunities in energy generally are awash in capital. The boom in shale gas occurred during the recent global recession, at a time when many cellulosic efforts failed to find financing. The clear value proposition created investment. Many proposals talk about how biofuels might reach cost parity with oil, but what they fail to understand is that cost parity is insufficient. Capital will flow to the lowest cost option. A gas to liquids plant can produce transporation fuels at lower cost than cellulosic ethanol.

How much more are we willing to pay? The answer resides more in social science than technology. Higher raw material cost plus higher capital means higher cost to the consumer. There is anecdotal evidence that can be offered on both sides of the argument for whether consumers will pay for green. Green power programs

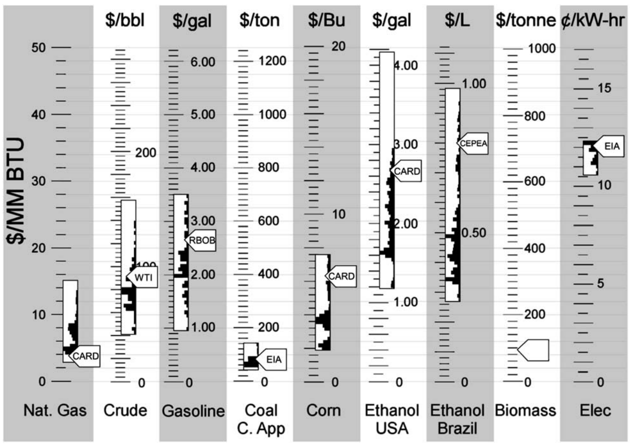

Fig. 1 Energy equivalent plot for common fuel sources. Liquid transportation fuels and electricity are the most valued energy. Biomass resources can be deployed in the production of electricity today using proven, commercial technology. Co-firing or pure biomass firing are both robust, proven technologies. Price indicators are for U.S. values from 4 November 2011. Histograms show historic pricing over the last 5 years, where available.[14]

have grown, and participation in some of the most popular programs is reported to be near 5%.[13] The reality is that green power supplies about 0.4% of total residential electricity production. These are opt-in programs where most U.S. consumers can choose to pay more for clean energy. Most don't. I don't see much evidence that consumers are willing to pay more for biofuels or for "green" chemical products.

My concerns over cellulosic biofuels do not imply I believe we cannot make progress in energy. There are practical options to address the underlying environmental and energy concerns that prompt interest in biofuels. Many of these options rely on making practical improvements to materials and practical engineering improvements. Increasing the use of diesel (with new particulate filters) and high efficiency internal combustion engines combined with light weight materials can dramatically increase fuel efficiency in transportation. Wind and building integrated solar modules with high efficiency PV materials can supplement our electrical generation capability. Practical steps to reduce the cost of ownership and to improve efficiency can be made. More rigorous building codes and improved insulation can decrease the energy use to heat and cool buildings. Industry continues to decrease the energy and water required to produce the products society demands. Oil sands and shale gas offer the potential for significant quantities of relatively inexpensive energy. Some may argue that the externalities of fossil fuels are not adequately incorporated into our current financial analysis. Publicly held companies can only make decisions on the costs they incur, not on externalities. As we struggle with a national debt, the cost of health care and other pressing societal needs we must be rigorous in separating hype around energy from practical solutions that can improve our use of valuable energy resources.

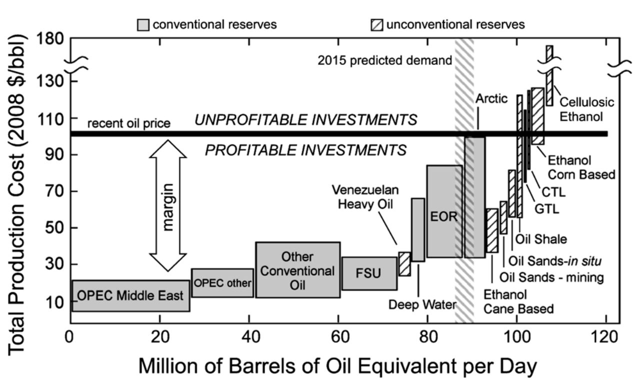

Fig. 2 Liquid transportation fuel options for 2022 based on DOE volume projections. Based upon cost for production, cellulosic technologies are more expensive than gas-to-liquidls (GTL) and coal-to-liquids (CTL) technologies. This is due both to scale limitations imposed by biomass and higher cost for the feedstock on an energy content basis. Investment will flow to these other options before investment in biofuels. Data from IEA, EIA, Booz Allen Hamilton, DOE Biomass Multiyear Program Plan April 2011, and Dow Analysis.

References

1 Prius is a trademark of Toyota.
2 This assumes a 600W cell and the NREL published data for available sunlight.
3 Google recently published the results of using a Prius and found 139.6 Wh/mile as the measured performance. From RechargeIT.org (www.google.org/recharge/).
4 Assumes 50 mpg, the published mileage for the Prius.
5 600W cells were priced at approximately $1000 by doing a web search.
6 *Growing Energy*, NRDC 2004.
7 The 2007 Energy Independence and Security Act (energy.senate.gov/public/_files/RL342941.pdf) and the EPA reductions of June 2011 are detailed in Bevill, Kris; "EPA cuts 2012 cellulosic biofuel target", Ethanol Producer Magazine, 21 June 2011.
8 As an example, see Fulcrum Biofuels S-1 filed on 22 September 2011.
9 DOE, Billion Ton Study Update, 14 August 2011, DOE-EE-0363.
10 NRC, Renewable Fuel Standard: Potential Economic and Environmental Effects of U.S. Biofuel Policy, 4 October 2011.
11 B. Mendell, A. Lang, T. Snydor, *Woody Biomass as a Forest Product*, Forisk Consulting, October 2011.
12 DOE EERE Biomass Multi-Year Program Plan 2010, 1 November 2010. Downloaded from http://www1.eere.energy.gov/biomass/pdfs/biomass_mypp_november2010.pdf; Product ID 4778.
13 NREL News Release NR-1910, 9 May 2011 reports 6 million MWh of green power purchases. The 2010 Electric Power Annual (published by the DOE Energy Information Agency) reports 1446 million MWh of residential purchases of electricity.
14 CARD indicates the Iowa State Center for Agricultural and Rural Development, WTI and RBOB pricing from NYMEX, EIA is the DOE Energy Information Agency and CEPEA is Centro De Estudos Avancandos Em Economia Aplicada. Histogram data from CARD is weekly close from March 2005. WTI and RBOB are monthly average from January 2006. EIA coal is weekly close from January 2006. EIA electricity is monthly retail average for residential customers from January 2009 to May 2010. Brazilian ethanol data is weekly close from January 2005.

