<u>“Answering Professor Smil”: A thought leadership project in conjunction with the World Bioenergy Association</u>

9-June-2017
Thomas Digby
Founder & CEO, Aljadix
thomas.digby@aljadix.com
www.aljadix.com

<u>Problem Scenario</u>

The bioenergy world is disappointed that cleantech media focuses on solar and wind power more than bioenergy. This is especially disappointing because we know that vast majority of world primary energy supply is bioenergy (10%) and fossil fuel (81%) whereas renewable electricity makes up less than 4% (even including hydro!) (IEA, 2016). If we are going to be serious about putting an end to King Petroleum, much more attention needs to be paid to renewably sourced bioenergy which can directly replace fossil fuels.

So why is the media reluctant to pay attention to our bioenergy solutions?

Answer: Because they are not scalable.

In my personal view, this is a situation where the media is correct.

Again, in my personal view, the legitimate technical basis for the scalability challenge is presented by Prof Vaclav Smil. You might have heard of Smil: He’s Bill Gates’s favourite author. (Gates says he has read every one of Smil’s 36 books (as of 2015).) And since 1983 Smil has been deeply skeptical about the use of biomass for bioenergy, recently stating that, if scaled with current technology, the environmental destruction would be “truly nightmarish” (Smil, Power Density, 2015).

This is not to say that there are no good business models inside the current technology. In fact, it is self-evident that there are excellent bioenergy models from feedstocks such as municipal solid waste (Fulcrum Bioenergy), waste vegetable and animal oils (Neste NexBTL, AltAir), sugar cane (*vis* Brazilian ethanol) and a variety of existing technologies which are proven to be environmentally and financially sustainable.

But Smil‘s point, and I believe the legitimate basis for lack of media enthusiasm, is that the current business models barely touch the requirement for bioenergy to even begin to replace fossil fuels. Let’s look at liquid hydrocarbon fuels. Biofuels currently provide 3% of liquid hydrocarbon fuels, while fossil petroleum provides the other 97%. Projected increases of biofuels to 2040 are not optimistic.   There is simply not enough land, water, nutrients, or free energy to produce a sustainable bioenergy feedstock to make a substantial dent in supply of renewable liquid hydrocarbons to replace fossil petroleum.

Smil's nightmare arrives when you recognize that massive scale up of existing biofuel technologies would lead to choking of ecosystems as wasted nutrients drain into watersheds and to carbon dioxide release due to inefficient processing of feedstocks and the destruction of forests as land requirements grow.

This is not to mention the "food versus fuel" problem leading to increased price of food crops due to competition for resources. Look at the recent report of the US Department of Energy – the 2016 Billion Ton Update - which supports a plan to replace (only) 50% of US liquid transportation fuels by 2040. This plan, while highly laudable, will make a heroic but ultimately modest contribution to solving the biofuel supply problem. It will require a massive logistical deployment across the US to achieve it and yet still leave King Petroleum on his throne.

Smil's hypothesis is not actually centered on the environmental problem of biofuels. It's a more fundamental thermodynamic concern. Smil's recent statement of his hypothesis (in Power Density, 2015, MIT Press) is that no biofuel technology achieves a viable Power Density (calculated as energy flux (or energy captured/produced) per unit of the Earth's surface) compared to other energy sources. Power Density measures the surface area required to provide a unit of energy. It includes all the surrounding area required for equipment, transport and processing. It also includes energy inputs required for production (nutrients may be converted to their energy cost for this calculation). Large dispersed resources like biofuels made from biomass, currently have low average Power Density of 0.3 W/m2 (watts per square meter). Electricity made from solar and wind have orders of magnitude higher Power Density, being 5 and 50 W/m2, respectively (though wind falls to 1 W/m2 if you include the spacing between turbines). Nuclear and fossil energy dominate, averaging 300 W/m2 (not including transmission lines) and 160 W/m2 (including pipelines), respectively.

It turns out that the Power Density of bioenergy is very low due to the heavy requirement for resources (land, water, fertilizer), the wasteful process by which these resources are used, and the fundamental thermodynamic observation that typical crops and forests absorb less than 1 % of incoming solar energy as they grow through photosynthesis.

We can put numbers to Smil's basic hypothesis. If all worldwide agricultural residues (after harvest) for a year were somehow collected and processed to biofuel (4 billion tonnes averaging 18 GJ/tonne (UN FAO, 2014)), totaling 72 PJ, it would not nearly suffice to replace the energy content of the hydrocarbon fuels we currently use, being 160 PJ (IEA, 2015)).

Or look at the problem from the other end: The current use of liquid fossil hydrocarbons is approximately 4.2 billion tonnes of carbon per year (ignoring solid coal for the time being). The corresponding amount of biomass feedstock in the best case most efficient scenario (assuming an unlikely 100% conversion of carbon atoms into combustible hydrocarbons) would require a minimum of 8.4 billion tonnes of biomass (biomass averages 50% carbon content). This biomass requirement is equal to the annual worldwide agricultural harvest including all the food we eat!

And let's look at nitrogen: if we needed to produce 8.4 billion tonnes of biomass, and the biomass contains an average of 5% nitrogen, we would require at least 420 megatonnes of nitrogen per year. This nitrogen requirement is almost 3 times the amount currently produced on an annual worldwide basis (156 mt/yr, FAO 2011).

The basic problem with Smil's analysis is not Smil.   He is certainly correct inside his framework. You can't get more energy out of a system than you put into it. (First law of thermodynamics). And at every processing step, some energy is lost (Second law of thermodynamics). Even media people can instinctually get this. It's an inconvenient truth but, in my view, better to face it squarely than to pretend it's not there

****

So let's take a look at this situation. Can nothing be done to answer Prof Smil?

This paper is presented on the expectation that challenges like Smil's are destined to be overcome, but only if not ignored. With creative thinking, patient attention to unravelling the strands of technical argument, and daring to re-assess our deeply ingrained cultural practices, it is my hope that those of us committed to the bioenergy field can answer Smil's objections and provide a path forward in bioenergy that will directly benefit all humanity.

It will take a team effort of individuals committed to testing solutions, relying on scientific principles, and minimizing judgmental/destructive evaluations as new ideas begin to take root.

In the end we will be exploring the fascinating potential of a highly scalable biofuel that answers the challenge of Prof Smil. I believe that to grasp this potential we must be willing to re-examine the well-known scalability problems of current biofuel technology, to base our judgement on trusted thermodynamic and engineering principles, and prepare to challenge our own perspectives on bioenergy.