The Browning of Green Technology: Getting Greener than Green

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ABSTRACT

We present pros and cons of corn-based ethanol production in energy policy and provide direction for improvements to current energy policy to account for the shortcomings of both fossil-fuel energy and green technologies. Corn-based ethanol has been promoted as a panacea for America's thirst for cheap and easy liquid energy. Yet, this supposed cure for low-mileage woes is quickly showing itself as yet another symptom of the deep-rooted problems United States' energy policy. Fuels based on feed stocks, particularly corn, soy or other food products, are not only insufficient to solve the problems intended to be fixed, but they also can lead to even more intractable problems. While discussions generally revolve around food price inflation, farmland degradation and increased difficulties in adopting necessary fuel efficiency improvement, we suggest including the Principles of Energy Conservation and an understanding of Nonlinear Dynamics in the exchange.

Keywords: biofuel, bioethanol, nonlinear dynamics, conservation, renewable energy

1. INTRODUCTION

The drive to expand the world's fuel supply has led to a broad expansion of efforts to produce fuels from renewable resources. Prominent among these is ethanol produced from food crops such as corn and sugar cane. Many governments, including that of the United States via the Energy Policy Act of 2005, have instituted programs to increase biofuel production. However, renewable energy sources are showing growing signs that they are not what they seem. Indeed, chinks in the armor of alternative energy sources from renewable supplies are appearing in the literature and news at an alarming rate. Just in the area of ethanol production from corn, many concerns exist:

- Using corn to produce ethanol increases food prices worldwide.
- The energy balance of ethanol production does not justify its use.
- Corn production increases lead to environmental degradation.
- Corn-derived ethanol does not resolve the issue of global warming.

While all of these concerns were foreseen, little in the form of permanent resolution to these issues has developed. The purpose of this paper is to review issues related to methods and elements of alternative energy policies which the authors feel have been inappropriately absent from the literature.[1] Several points provide context.

- No current form of energy currently is capable of replacing fossil fuels as the sole energy source of worldwide economies.
- Global warming and other effects of elevated atmospheric carbon dioxide levels can cause radical changes to weather patterns and other environmental conditions within the foreseeable future.
- Energy demand is unlikely to be reduced to any level that results in reducing the effects of energy shortages or of global warming.
- Emerging economies, such as those of India and China, potentially require ever larger infusions of energy to meet economic demands in those countries.
- Energy use and its side effects are global issues.

In this light, we suggest that two significant factors related to energy production and consumption are under-represented in the global discussion: 1.) the Principles of Energy Conservation and 2.) an understanding of the role of Nonlinear Dynamics in energy systems. The following is a brief argument for their inclusion in the paradigm.

2. CONSERVATION OF ENERGY

Elementary physics teaches that the principle of energy conservation provides that energy is neither created nor destroyed; it only changes form: potential to kinetic, chemical to electric, or the like. A simplified view of photosynthesis provides an excellent example of an efficient and semi-closed energy system. In photosynthesis[2], carbon dioxide and water react chemically when exposed to photons of appropriate energy levels within a plant cell. The reaction ultimately results in the production of sugar and oxygen. Respiration, conversely, is seen as the reaction of sugar and oxygen to produce carbon dioxide, water, and energy. The energy cycle includes the kinetic energy of the transiting photon, potential energy stored in the sugar, and the return of the potential energy to a useable, kinetic form in the metabolism or other burning of the sugar. Critically, while the carbon dioxide and water are cyclical in the process, the energy itself is dissipated. The energy originally in the photon is not returned to photonic state.

While we do not assert that principles of energy conservation relate directly to the mechanics or conceptualization of bioethanol production, there are appropriate comparisons that should be considered when debating the benefits of renewable energy sources.

The Earth, in most respects, is a closed energy system. Most energy systems people use are single-use, or one-direction sources[3]. Petroleum and coal can be combusted only once, for example. The same may be said for sources such as wind and biomass, which differ from fossil fuels only in that new supplies are made available. It may be said that the only real sources of new energy on Earth are solar and tidal. These energy sources have the theoretical capability of supplying enough energy for all human activities. Further, the conversion of solar and tidal energy into usable forms would have only a minute impact on the resource. The inability to power the world by solar or tidal energy stems from having immature technology for energy conversion and an insufficient infrastructure. More importantly, there appears to be a lack of institutional and governmental acceptance that all other energy forms on Earth are one directional and finite, creating a need to develop energy policy within the confines of a generally closed system. In other words, conservation of energy dictates that there is only so much energy *in situ* on Earth, stored generally in some form of potential energy. New supplies of energy to the Earth are the only long-term solutions to energy issues. Bioethanol production, we suggest, has been approached by governments and producers as something it is not. The resulting problems and shortcomings of bioethanol were foreseeable when viewed in a proper energy paradigm.

While bioethanol production has elements of renewability about it, the inclusion of energy conservation principles should be applied to distinguish the renewable and non-renewable elements more effectively than current energy balance assessments. For example, an ideal bioethanol system could be defined as one in which all energy input is derived directly from solar energy. Its impact could then be defined in terms of its environmental costs (i.e. increased farmland, fertilization or other requirements). The benefits of bioethanol production would then be determinable by its ability to capture, store and use solar energy minus its capture, containment, distribution, and remediation costs.

This could easily be modified for any energy system. At the very least, energy sources should be described in terms of the efficiencies by which sources are convertible into usable forms, but with full regard that these systems are closed or partially closed systems. The proper calculation of the energy balance for fuel production must be recognized as a major issue to be resolved for energy policy as a whole[4]. Given the singular direction most forms of energy take, conservation of energy principles provide a proper yet broad accounting of the energy balance of corn to ethanol and other energy production systems.

This is not a call to end ethanol production or other renewable energy initiatives. It is merely recognition that a better understanding of this energy system is needed. The proper measure of an alternative energy system, such as corn-to-ethanol, is properly viewed in terms of whether the system has an overall positive or negative energy balance in light of the Earth's status as a generally closed system. Where the alternative energy system uses only energy sources already in place on Earth, it would be seen as a negative energy source. Where the alternative energy system has the ability to take advantage of external energy input to the Earth, such as solar or tidal energy, the system is potentially able to provide a positive energy balance.

In either case, the measure of the system must also account for efficiencies of the operations used to convert a raw or natural energy source into one people can use. This measure clearly would have the ability to identify the benefits of an alternative energy system. It is, of course, not the final determination.

3. NONLINEAR DYNAMICS

While nonlinear dynamics may describe many types of systems, there are likewise a number of ways to describe nonlinear systems. A starting point in this

Clean Technology 2008, www.ct-si.org, ISBN 978-1-4200-8502-0

discussion should be the Lotka-Volterra model of competition[5] described by coupled, partial differential equations. Examined in Strogatz's rabbits-and-sheep model[6], it is argued that competitors for scarce resources can create an inherently unstable system that threatens the existence of at least one of the species. To understand quickly the nature of a simple unstable system, imagine an inverted pendulum (or perhaps a pencil balanced vertically above one's fingertip). Mathematically speaking, this position is a balance point for the system; however, it is inherently unstable. Without constant monitoring and rebalancing, the pendulum or pencil will fall. Thoughtfully understood, nonlinear systems have the ability to model the complex interactions of participants acting both independently and interactively.

Ethanol production from corn has significant elements that identify it as a competitive system. Although production has increased, corn production is and must be finite. Forces with competing interests seek significant access to that finite resource, putting pressure on the corn market. There is no amount of corn that can be grown to satisfy fully the demands of the competitors without causing a significant negative impact on other environmental systems. The competitive system has a tendency toward instability, and at some point, at least one side competing for the resources will be unable to obtain sufficient supplies to meet its needs. This will threaten that competitor's survival.

These factors depict a nonlinear system that can be modeled by the Lotka-Volterra equations. The interplay of competing forces and limited supply create a dynamic in which luck, skill, momentum and competitive edge can result in the proliferation of one competitor and the extinction or decimation of the other.

Similar competitive forces can be seen in other energy systems, such as in the interplay between developed and developing economies. For example, it is well known that the United States, with approximately 5 percent of the world's population uses about 25 percent of its energy resources. China and India, each with over 16 percent of the world's population, are experiencing rapid industrial growth. With energy resources remaining roughly finite, capped in part by the need to limit carbon output, competition for such finite energy sources can create widespread instabilities. As the wealth of other nations increases, the competition will grow keener and will, of necessity, create instabilities poorly modeled with linear mathematics. Yet based on our review of the literature, there is little that describes the nonlinear aspects of the system.

This is the source of concern. The nature of such competitive models is such that they do not allow the peaceful coexistence of the competing parties. Consider, for example, that nature does not tend to allow the coexistence to two dominant predators in a single location. There is a dominant predator and there are then the niche predators. There is anecdotal evidence of this in human systems, such as seen in the bankruptcies of many airline companies following deregulation in the 1980s, or on a larger scale in the difficulty in maintaining hegemony in social systems or by world powers.

It is equally important to understand and account for the magnitude of the forces that come into play in competitive systems. While the forces that act upon competitive systems generally act slowly and smoothly over long periods of time, there is often—and perhaps inevitably—the potential for forces to reach a level at which it is not possible to undo the changes to come. Consider the following two topical examples:

Global change resulting from an impact by a meteorite is a statistically small danger, but it is of enough concern that governments seek to prevent it. However, the only meaningful impact humans can have on a meteor on a collision course with Earth is when it is identified many, perhaps hundreds of years before impact. With a long lead time, it is theorized that humans might have the ability to impose a series of small forces on a large object, thereby deflecting it slightly and leaving it a near miss instead of a civilization destroyer. Were a meteor discovered only once it is close to Earth, there are no forces controlled by humans capable of changing the direction of a large object moving at orbital speeds.

A similar example is known in global warming issues. Global warming is seen to advance slowly, but in many ways may reach tipping points which may cause global disasters. The collapse of global ice sheets or a disruption of the Gulf Stream each have the ability to impose forces on world systems and which humans have no significant capability of undoing. Adaptation may come from a long, slow change, but once on the path for rapid change, there is no realistic way to undo, deflect, or alter the forces at play.

The reality of the dynamics of competitive systems—the critical factor that tends toward extinction or the assumption of a niche role—is that they are inherently unstable. Stability is not imposed naturally and, in fact, is a mathematical impossibility. Instead, quasi-stability may be prolonged through prudent regulation of the system, but it is never guaranteed. Regulation here would involve the constant monitoring and constant reassessment of the system as a whole in light of the necessary competitive forces. Regulations are usually not created for the sake of regulation itself, but strictly to preserve the significant needs of the competitors. This certainly would be controversial, but controversy is an insufficient reason for allowing the preservation of dangerous instability.

4. CONCLUSION

Previous paradigms for energy systems, such as ethanol production, have adequately encompassed the dynamics of the systems without regard for the fundamental principle of energy conservation and without inclusion of the perspective provided by nonlinear analysis. However, the complexity and urgency of the energy discussion have reached the point that demands their inclusion into the paradigm. The starting point may be just in seeing that energy systems are not getting easier to understand, nor are they stabilizing. At every turn, new issues and problems arise with every proposed solution.

The Principle of Energy Conservation carries with it the gravitas of a fundamental law of nature, imposed equally on fuel sources, people and the environment. Nonlinear dynamics has the ability to begin to account for the highly competitive nature of the forces acting upon human and natural systems.

Properly brought into the discussions on energy production and use, these elements will provide far better insight and planning capabilities than currently had and can help to prevent preventable instabilities.

[1] References for statements and assertions made herein are available upon request.

[2] The common, simplified version of photosynthesis is described.

[3] One might suppose a truly ideal energy system would be one which efficiently collects the end products of combustion and in a process of "artificial photosynthesis," efficiently converts solar energy and the end products back into a fuel source.

[4] At the least, this would allow a better comparison of the merits ethanol production. Where some assert the energy balance of oil is 9 to 1 and corn ethanol is roughly 2 to 1, oil is wholly non-renewable where corn is somewhat renewable. From another perspective, however, both involve carbon emissions. We see most discussions of renewable sources as taking only a perspective of the whole argument. It is clear that these "slices" of the argument are insufficient and do not properly account for energy conservation.

[5] An excellent reference for Lotka-Volterra systems is Strogatz, Steven H., Nonlinear Dynamics and Chaos, Westview Press, 1994. See in particular Section 6.4.

[6] Ibid.

Clean Technology 2008, www.ct-si.org, ISBN 978-1-4200-8502-0