Energy Balance With Cellulosic Biofuels[1]

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Limited potential of grain-based biofuels to provide energy-efficient alternatives to substitute for fossil fuels paved the way for the cellulosic-based biofuels. However, a factor often ignored in evaluating alternative energy sources is net addition to the energy balance, compared to the total energy developed. This study addresses the issue of a net energy ratio (NER) for cellulosic feedstock for energy and its consequent impact on the cost per gallon of biofuel.

In this paper, NER was estimated to evaluate the efficiency of two cellulosic feedstocks primarily proposed to produce biofuels. The NER provides an estimate of the amount of energy required in ethanol equivalents to produce a gallon of ethanol. The biomass crop production data analyzed from McLaughlin (2011) resulted in a NER of 3.96 and 3.32 for Switch Grass (SG) and High Energy Sorghum (HES), respectively. These results are slightly higher than the 3.0 NER for SG estimated by McLaughlin and Walsh (1998). The difference is primarily attributed to the energy associated with the secondary inputs, which is not considered in the current analysis due to the outdated nature of the data. However, recent studies indicate a 7.0 NER for SG (Schemer et al. 2008), an estimate believed to be impacted by regional differences as well as differences in production activities used to grow, harvest, and process feedstocks.

Although SG and HES are considered potential alternative energy feedstocks based on the energy return estimates, the pressing policy issues and related discussions/debates should also include net addition of fuel supply to the economy and the cost per net gallon of ethanol to evaluate the net competitiveness of the biofuels to the existing fossil fuels in providing energy security to the U.S. Results (Table 1) indicate that to produce 30 million gallons of ethanol using SG, input energy equivalent to 7.57 million gallons of ethanol is required (footnote "c" of the table 1), thus resulting in a net production of only 22.42 million gallons of ethanol. Similarly, evaluation of the policy scenario targeting production of 16 billion gallons of cellulosic biofuels (the existing biofuel mandate under the Renewable Fuel Standard program), resulted in a net production of only 11.95 and 11.18 billion gallons of ethanol using SG and HES, respectively. Often, the energy required that goes into production and conversion of feedstock are ignored, leaving the impression that more fuel is added to the energy supply than actually occurs. However, the current analysis suggests that only 70 percent of the proposed biofuel production mandates are added to the net energy supply after accounting for the energy embedded in the biofuel crop production inputs.

[1] This is one of three essays that comprise the dissertation of Dr. Adusumilli (2012).

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Table 1. Summary of the feedstock production costs, net amount of biofuel produced, and the cost per gallon of ethanol accounting for the net energy ratio estimates

	Switch Grass	**High Energy Sorghum**
Desired Ethanol Production (gallons)[a]	30,000,000	30,000,000
Production Costs ($/year), to Supply Feedstock to Meet the Desired Ethanol Production[a]	$35,300,000	$63,700,000
Conversion Costs of Biomass to Ethanol, conversion cost of producing 30-million gallons ($1.715/gal) [b]	$51,467,594	$51,467,594
Net Energy Ratio[c]	3.96	3.32
Net Biofuel Production (gallons)[d]	22,424,242	20,963,855
Ethanol Feedstock Cost ($/gallon)[e]	$ 1.17	$ 2.12
Adjusted Cost of Ethanol ($/gallon)[f]	$ 3.87	$ 5.49

[a] Source: McLaughlin (2011a).
[b] Source: Pimental and Patzek (2005)
[c] Refer to Adusumilli (2012) to identify the Net Energy Ratio.
[d] Net Biofuel Production Using SG: (30,000,000/3.96 = 7,575,758; 30,000,000 – 7,575,758 = 22,424,242); for HES: (30,000,000/3.32 = 9,036,144; 30,000,000 – 9,036,144 = 20,963,855)
[e] 35,300,000/30,000,000 = $1.17; similar estimation for HES.
[f] (51,467,594 + 35,300,000)/22,424,242 = $3.87; similar estimation is performed for HES.

Accounting for the 3.96 NER of SG and the conversion costs, the total cost of production per gallon of ethanol increased to $3.87, which is substantially higher than the $2.00 per gallon production cost of gasoline (U.S. Census Bureau 2005). HES estimates are interpreted in a similar manner. These results suggest that cellulosic ethanol produced from SG and HES remain at a disadvantage compared to conventional fuels due to higher cost per gallon which in early 2013 were $2.87 per gallon not including any taxes (U.S. Energy Information Administration, 2013). These results (i.e., adjusted per gallon cost of ethanol at $3.87 (SG) and $5.49 (HES)) suggest that cost of production of cellulosic biofuels is not at a level to make them competitive with gasoline, as indicated by Bracmort et al. (2010) as one of the potential challenges of renewable fuels. Moreover, the cost per gallon of ethanol estimated in this study is higher than the National Renewable Energy Laboratory's (2007) estimate of $2.40 per gallon to produce and convert cellulosic feedstock to ethanol, renewing concerns of critics regarding the potential of cellulosic biofuels as a viable alternative to U.S energy demand.

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All of these factors confirm that estimation of NER provides valuable information to evaluate the potential of biofuels as alternative source of energy. Although energy return estimation is only one of the assessment metrics, broader impact-based metrics are required to provide information to the decision makers regarding other critical issues. While the government continues to support ethanol development to enhance energy security, attention must be given to develop a strategic plan to promote biofuels, accounting for the potential concerns at local, regional, and national levels.

Limitations

Some of the limitations associated with the current analysis of estimation of energy return of biomass-based ethanol include:

- The current analysis omits any energy required to produce machinery, farm equipment, conversion facilities, and other related capital factors, as the energy estimates associated with these inputs is dated. Availability of contemporary energy estimates for these inputs would allow for development of a more comprehensive energy estimate for cellulosic biofuels.

- Limited to no information was available regarding the co-products associated with biomass crops. As a result, no energy or value was assigned to the co-products in the NER estimation of biomass ethanol, thereby underestimating the benefits of biomass ethanol.

- Geographical variation can have large impacts on energy estimates of the biofuel system. The current estimate of NER of biomass ethanol that utilizes biomass crop production data from Middle Gulf Coast, Edna-Ganado, Texas area is not readily transferable to a more general region.]
- Not considered is the issue of form, where the demand for a mobile fuel may justify added costs. The value of having mobile fuels may override many of the impacts described in this study. However, it is important to consider the potential of an alternative fuel not only from an economic perspective but also from an energy perspective. Often times, however, economic approaches are distorted by government intervention through subsidies, tariffs, and other institutional forces.

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