Cellulosic Biofuels: Expert Views on Prospects for Advancement: Supplementary Material

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Abstract

In this supplementary material we provide details on our cost analysis and present tables summarizing the assessment results

Keywords: Biofuels; Technology R&D; Uncertainty; Environmental policy

1 Introduction

This paper contains supplementary material for "Cellulosic Biofuels: Expert Views on Prospects for Advancement" by Erin Baker and Jeffrey Keisler. The first section provides details about our cost analysis. The second section presents tables summarizing the assessment results.

2 Cost Analysis

In this section we present an example cost analysis, in order to compare the different technological paths most directly. There are two key parts to the cost analysis. The first is the capital and processing costs. We have specified these in our surveys in terms of a per-gallon cost for the specified end product. In this section we will translate each of these to a cost per gallon of gasoline equivalent. The second part is the feedstock cost. Each technology is associated with an efficiency. This, along with the underlying cost of the feedstock will determine the feedstock portion of the cost. We will assume that the feedstock is switchgrass and the cost is \$70/ton [1].[1] Please note that the actual cost of feedstock will vary, and will be at least partially dependent on the success of biofuels technologies and on the strength of climate change policies. Thus, the costs we present here should not be compared against non-biofuel costs, or against other biofuel estimates using a different assumption about feedstock cost. These estimates are useful for comparing our technologies against each other.

We start by calculating the cost per gge of switchgrass, assuming 100% of the energy in switchgrass is harnessed. We then convert that depending on the efficiency assumption of the technology. We use an energy content for switchgrass of 15.9 million btu/ton,[2] and assume that a gallon of gasoline has 115,000 btu. The cost of switchgrass per gge is then

$$\frac{70\$/ton}{15.9 \text{ million btu/ton}} 115,000 btu/gge = \$0.51/gge \tag{1}$$

To find the cost per gge, C, for each of the paths, we divide \$0.51 by the efficiency, E, and add the capital and processing cost per gallon of fuel, P, multiplied by a conversion factor v for diesel or ethanol, to convert into gge:

$$C = \frac{0.51}{E} + P * v \tag{2}$$

Table 1 highlights the values of E, P, and v for each of the paths.

Path	fuel	E	P	v	C
pyrolysis	gasoline	40%	1	1	2.27
liquefaction	gasoline	40%	1.5	1	2.77
A-P processing	diesel	40%	1.5	.88	2.60
gasification	ethanol	50%	1	1.52	2.53
gasification	diesel	55%	1.5	.88	2.25
Fermentation	ethanol	–	1	1.52	2.79

Table 1: Cost per gge

For the fermentation path, however, the efficiency was specified in a different manner, as 320 Liters of ethanol per ton of feedstock. We can convert this into a cost per gge:

$$\frac{70\$}{ton} * \frac{ton}{320L} * \frac{3.79L}{gal} * \frac{1.52gal}{gge} = 1.26\$/gge \tag{3}$$

[1] This is a central number assuming a yield of 4 tons per acre.

[2] Based on data from [2].

The processing cost was specified as \$1/gallon of ethanol, and so the total cost is:

$$1.26 + 1 * 1.52 = 2.79\$/gge \tag{4}$$

In summary, we see that the endpoints specified by the experts are all in the same neighborhood, and are very close to DOE targets. For example, DOE reports a target cost of ethanol from corn stover as \$0.82/gallon of ethanol and efficiency of 90 gal/ton [3]. Using our assumptions this is a gge of \$2.43, a bit more optimistic than our endpoint of \$2.79. The key difference between the values is in the cost of fermentation. Their target for gasification was again \$0.82/gal of ethanol and efficiency of 70 gal/ton, giving a total gge of \$2.77, a bit less optimistic than ours [3]. The key difference in this case is our very optimistic endpoint for efficiency.

3 Probability Tables

	Hydrolysis			Pyrolysis		Liquefaction		Gasification		
Funding Trajectory	No	Low	High	Low	High	Low	High	Low	Medium	High
Ex. 1	#N/A	25%	66%	75%	100%	5%	50%	8%	100%	100%
Ex. 2	10%	25%	90%							
Ex. 3	8%	18%	50%							
Ex. 4	#N/A	5%	80%	100%	100%	75%	75%	5%	50%	50%
Ex. 5	30%	40%	50%	80%	90%	47%	60%			
Ex. 6	70%	70%	80%	25%	70%	20%	40%	20%	40%	N/A
Ex. 7	15%	25%	45%	35%	93%	35%	80%	15%	75%	95%
Average	27%	30%	66%	63%	91%	36%	61%	12%	66%	82%

Table 2: Elicitation Results for First Stage Technologies

	Aqueous Phase		Fermentation		
Funding Trajectory	Low	High	Low	Medium	High
Ex. 1	15%	50%	66%	50%	66%
Ex. 2	1%	50%	95%	95%	95%
Ex. 3	8%	45%	100%	100%	100%
Ex. 4	5%	50%	5%	25%	25%
Ex. 5	60%	75%	72%	72%	72%
Ex. 6	95%		90%	90%	90%
Ex. 7	30%	75%	20%	40%	60%
Average	31%	58%	64%	67%	73%

Table 3: Elicitation Results for the second stage of hydrolysis paths

	Refine bio-oil		Refine bio-crude	
Funding Trajectory	Low	High	Low	High
Ex. 1	50%	90%	50%	90%
Ex. 2				
Ex. 3				
Ex. 4	5%	90%	5%	90%
Ex. 5	85%	93%	87%	95%
Ex. 6				
Ex. 7	20%	60%	40%	95%
Average	40%	83%	46%	93%

Table 4: Elicitation Results for the second stage of STP paths

	Syngas to Diesel		Syngas to Ethanol	
Funding Trajectory	Low	High	Low	High
Ex. 1	90%	90%	20%	30%
Ex. 2				
Ex. 3				
Ex. 4	5%	10%	5%	13%
Ex. 5	85%	86%	85%	86%
Ex. 6				
Ex. 5	20%	40%	40%	60%
Average	50%	57%	38%	47%

Table 5: Elicitation Results for the second stage of gasification paths

References

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[3] U.S. Department of Energy. Biomass multi-year program plan, 2009.