Appendix B: Technical Projection Tables

Table B-1: Biomass Volume and Price Projections through 2030

Feedstock Category	Feedstock Resource	2013 SOT	2017 Projection	2022 Projection	2030 Projection
		MM Dry Tons			
Agricultural Residues	Corn Stover	73.0	126.5	181.4	209.0
	What Straw	15.4	23.7	30.0	39.4
Energy Crops	Herbaceous Energy Crops	-	12.7	45.1	70.6
	Woody Energy Crops	-	-	11.7	25.8
Forest Residues	Pulpwood	8.9	6.0	13.1	40.1
	Logging Residues and Fuel Treatments	54.4	54.7	58.9	64.0
	Other Forestland Removals	2.2	1.8	2.4	2.7
	Urban and Mill Wood Wastes	26.1	26.2	28.5	31.5
Totals (MM Dry Tons/Year)		**179.9**	**251.7**	**371.1**	**483.0**
Average Price to Reactor (2011$/Dry Ton)		**$ 102**	**$ 80**	**$ 80**	**$ 80**

Table B-2: Algal Lipid Upgrading Supply and Logistics Key Process and Cost Metrics*

Algal Lipids Upgrading	Processing Area Cost Contributions and Key Technical Parameters					
Process Concept: Open Pond, Wet Solvent-Based Lipid Extraction	**Metric**	**2010 Baseline**	**2014 Projection**		**2018 Projection**	**2022 Projection**
Total Algal Feedstock Cost	$/GGE Algal Oil	**$18.22**	**$13.13**		**$6.30**	**$3.27**
Production Cost	$/GGE Algal Oil	**$15.60**	**$11.18**		**$5.17**	**$2.63**
Harvest Cost	$/GGE Algal Oil	**$2.99**	**$2.52**		**$1.65**	**$0.67**
Preprocessing Cost	$/GGE Algal Oil	**$1.72**	**$1.56**		**$1.11**	**$0.77**
Recycle/Coproduct Credit	$/GGE Algal Oil	**-$2.08**	**-$2.14**		**-$1.63**	**-$0.80**
Yields						
Gross Biomass Production	Ton AFDW/Acre-Year	19	29		37	44
Net Extracted Algal Oil Yield	Gallons/Acre-Year	1,040	1,580		2,500	5,260
Production						
Total Cost Contribution	$/AFDW Ton	$916.20	$656.47		$384.48	$343.19
Capital Cost Contribution	$/AFDW Ton	$650.89	$436.34		$207.46	$174.54
Operating Cost Contribution	$/AFDW Ton	$265.31	$220.13		$177.02	$168.65
Algal Productivity (Annual Average)	Gram/Square Meter-Day	13.2	20		25	30
Lipid Content	Dry wt%	25%	25%		30%	50%
Aggregate Pond Area per Facility	Hectare	4,050	4,050		4,050	4,050
Operating Days per Year	Days	330	330		330	330
Concentration at Harvest	Gram/Liter	0.5	0.5		0.5	0.5
Harvest						
Total Cost Contribution	$/AFDW Ton	$175.39	$148.27		$123.10	$87.21
Capital Cost Contribution	$/AFDW Ton	$71.57	$59.62		$47.28	$30.13
Operating Cost Contribution	$/AFDW Ton	$103.83	$88.65		$75.82	$57.08
Gross Harvesting Efficiency	%	77%	85%		90%	95%
Net Harvesting Efficiency	%	95%	95%		95%	95%
Final Concentration	Gram/Liter	200	200		200	200
Harvesting Capex	$/Million Gallon of Culture per Day from Cultivation	$169,000	$152,100		$126,750	$84,500
Harvesting Opex	$/Million Gallon of Culture from Cultivation	$88	$79		$66	$44
Preprocessing						
Total Cost Contribution	$/GGE Algal Oil	$1.72	$1.56		$1.11	$0.77
Capital Cost Contribution	$/GGE Algal Oil	$0.88	$0.84		$0.58	$0.27
Operating Cost Contribution	$/GGE Algal Oil	$0.84	$0.72		$0.53	$0.51
Net Extraction Efficiency	%	86%	86%		90%	95%
Flow Rate from Harvesting to Preprocessing	Gallon/Minute Harvested Slurry @200 Grams/Liter	471	715		893	1071
Extraction CAPEX	$/[Ton Algal Biomass/Day to Extraction]	$36,500	$32,900		$27,400	$18,300
Extraction OPEX	$/Ton Algal Biomass to Extraction	$12	$11		$9	$6
Recycle/Coproduct Savings						
Net Cost Savings	$/GGE Algal Oil	-$2.08	-$2.14		-$1.63	-$0.80
N Recycle	Gram N/Kilogram of Algae	57	57		57	57
P Recycle	Gram P/Kilogram of Algae	4	4		4	4
CO_2 Recycle	Gram CO_2/Gram Algae Grown	0.71	0.71		0.64	0.39
Digestate Coproduct Credit	$/GGE Algal Oil	-$0.05	-$0.05		-$0.04	-$0.02
Internal Power Generation (e.g. Reduction in Purchased Grid Power)	Kilowatt Hour/Kilogram of Algae	0.60	0.60		0.54	0.33

* Davis, et. al. (2012). Renewable Diesel from Algal Lipids: An Integrated Baseline for Cost, Emissions, and Resource Potential from a Harmonized Model. Available at: http://greet.es.anl.gov/publication-algae-harmonization-2012.

Table B-3: Unit Operation Cost Contribution Estimates (2011$) and Technical Projections for Thermochemical Conversion to Gasoline and Diesel Baseline Process Concept[1]

(Process Concept: Wood Energy Crop, Fast Pyrolysis, Bio-Oil Upgrading, Fuel Finishing)

Processing Area Cost Contributions & Key Technical Parameters	Metric	2009 SOT	2010 SOT	2011 SOT	2012 SOT	2013 SOT		2014 Projected	2015 Projected	2016 Projected	2017 Projected
Conversion Contribution	$/gal gasoline blendstock	$12.40	$9.22	$7.32	$6.20	$4.51		$4.02	$3.63	$2.96	$2.44
	$/gal diesel blendstock	$13.03	$9.69	$7.69	$6.52	$5.01		$4.46	$4.03	$3.29	$2.70
Conversion Contribution, Combined Blendstocks	$/GGE	$12.02	$8.94	$7.10	$6.02	$4.59		$4.09	$3.69	$3.01	$2.47
Programmatic Target	$/GGE	$3	$3	$3	$3	$3		$3	$3	$3	$3
Combined Fuel Selling Price	$/GGE	$13.40	$10.27	$8.26	$7.04	$5.60					$3.39
Production Gasoline Blendstock	mm gallons/yr	30	30	30	30	29		29	29	29	29
Production Diesel Blendstock	mm gallons/yr	23	23	23	23	32		32	32	32	32
Yield Combined Blendstocks	GGE/dry U.S. ton	78	78	78	78	87		87	87	87	87
Yield Combined Blendstocks	mmBTU/dry U.S. ton	9	9	9	9	10		10	10	10	10
Natural Gas Usage	scf/dry U.S. ton	1,115	1,115	1,115	1,115	1,685		1,685	1,685	1,685	1,685
Feedstock											
Total Cost Contribution	$/GGE fuel	$1.38	$1.33	$1.17	$1.03	$1.01					$0.92
Capital Cost Contribution	$/GGE fuel	$0.00	$0.00	$0.00	$0.00	$0.00					$0.00
Operating Cost Contribution	$/GGE fuel	$1.38	$1.33	$1.17	$1.03	$1.01					$0.92
Feedstock Cost	$/dry US ton	$106.92	$102.96	$90.57	$79.71	$88.10					$80.00
Fast Pyrolysis											
Total Cost Contribution	$/GGE fuel	$0.97	$0.93	$0.91	$0.90	$0.78		$0.78	$0.77	$0.76	$0.76
Capital Cost Contribution	$/GGE fuel	$0.82	$0.79	$0.76	$0.75	$0.66		$0.65	$0.65	$0.65	$0.64
Operating Cost Contribution	$/GGE fuel	$0.15	$0.15	$0.15	$0.15	$0.12		$0.12	$0.12	$0.12	$0.11
Pyrolysis Oil Yield (dry)	lb organics/lb dry wood	0.60	0.60	0.60	0.60	0.62		0.62	0.62	0.62	0.62

[1] Jones, S. et al. "Process Design and Economics for the Conversion of Lignocellulosic Biomass to Hydrocarbon Fuels: Fast Pyrolysis and Hydrotreating Bio-Oil Pathway." PNNL-23053. (2013). Richland, WA: Pacific Northwest National Laboratory. http://www.pnnl.gov/main/publications/external/technical_reports/PNNL-23053.pdf.

Processing Area Cost Contributions & Key Technical Parameters	Metric	2009 SOT	2010 SOT	2011 SOT	2012 SOT	2013 SOT		2014 Projected	2015 Projected	2016 Projected	2017 Projected
Upgrading to Stable Oil via Multi-Step Hydrodeoxygenation/Hydrocracking											
Total Cost Contribution	$/GGE fuel	$10.07	$7.05	$5.23	$4.17	$2.88		$2.39	$2.01	$1.35	$0.95
Capital Cost Contribution	$/GGE fuel	$0.71	$0.68	$0.66	$0.65	$0.59		$0.57	$0.51	$0.45	$0.42
Operating Cost Contribution	$/GGE fuel	$9.36	$6.37	$4.57	$3.52	$2.29		$1.82	$1.50	$0.90	$0.52
Annual Upgrading Catalyst Cost, mm$/year	WHSV,[2] number of reactors, catalyst replacement rate, and $/lb	512	344	243	184	130		100	80	43	19.4
Upgraded Oil Carbon Efficiency on Pyrolysis Oil	wt%	65%	65%	65%	65%	68%		68%	68%	68%	68%
Fuel Finishing to Gasoline and Diesel via Hydrocracking and Distillation											
Total Cost Contribution	$/GGE fuel	$0.25	$0.24	$0.24	$0.24	$0.25		$0.25	$0.24	$0.24	$0.14
Capital Cost Contribution	$/GGE fuel	$0.16	$0.15	$0.15	$0.15	$0.16		$0.16	$0.16	$0.16	$0.07
Operating Cost Contribution	$/GGE fuel	$0.09	$0.09	$0.09	$0.09	$0.09		$0.09	$0.08	$0.08	$0.07
Balance of Plant											
Total Cost Contribution	$/GGE fuel	$0.74	$0.72	$0.71	$0.71	$0.68		$0.68	$0.67	$0.66	$0.63
Capital Cost Contribution	$/GGE fuel	$0.36	$0.34	$0.33	$0.33	$0.29		$0.29	$0.29	$0.29	$0.29
Operating Cost Contribution	$/GGE fuel	$0.38	$0.38	$0.38	$0.38	$0.39		$0.38	$0.38	$0.37	$0.34
Models: Case References		2009 SOT 090913	2010 SOT 090913	2012 SOT 090913	2012 SOT 090913	2013 SOT 122013		2014 P 122013	2015 P 123013	2016 P 123013	2017 P 093013