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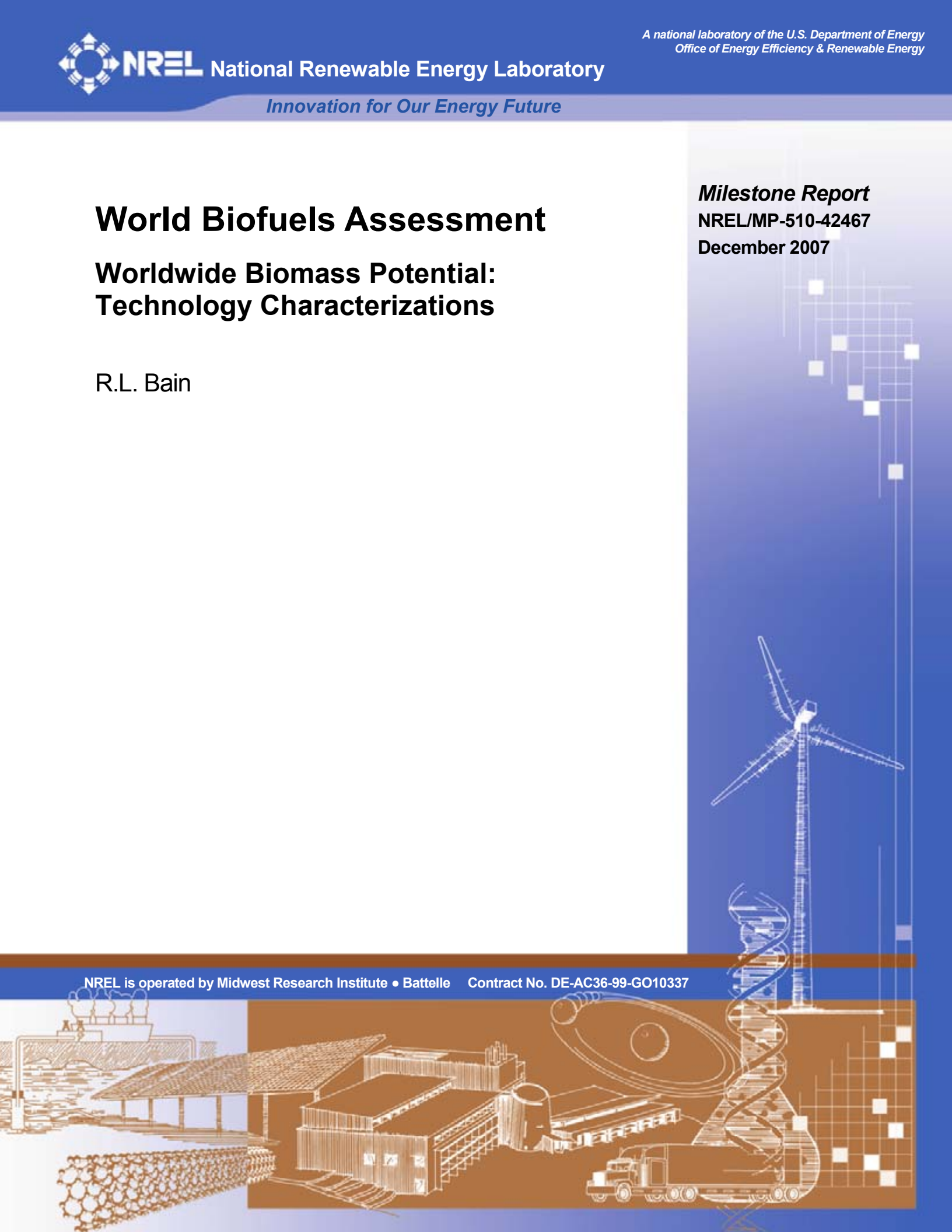
World Biofuels Assessment

Worldwide Biomass Potential: Technology Characterizations

R.L. Bain

Milestone Report
NREL/MP-510-42467
December 2007



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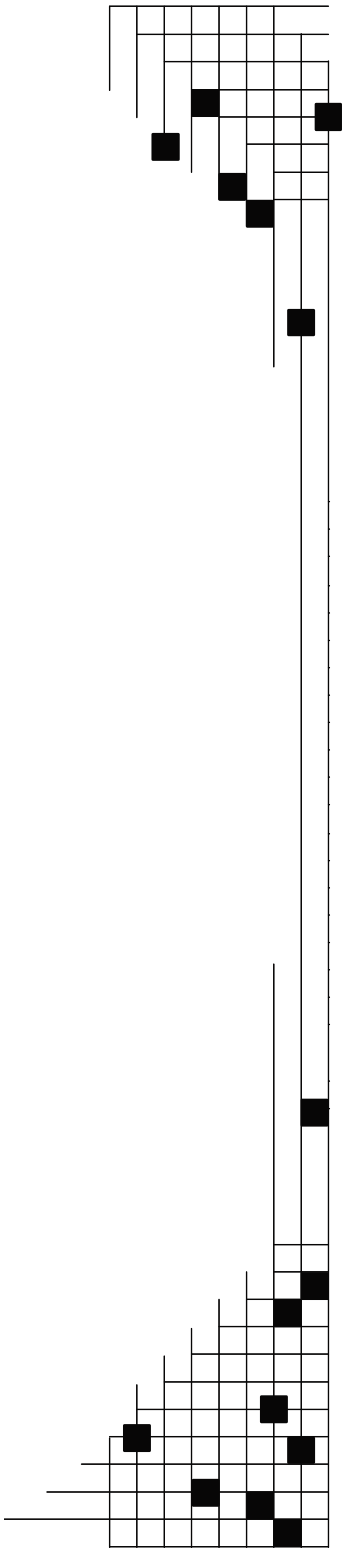
Prepared under Task No. BB076810



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Abstract

A joint EERE-PI project was completed to estimate the worldwide potential to produce and transport ethanol and other biofuels, with an emphasis on the 5 year and 10 year potential for biofuels supply to the United States. The project included four specific tasks: 1) identify the range of countries to be included in the study, 2) assess the resource potential for production of ethanol from sugar and starch-based feedstocks, and biodiesel, 3) assess the resource potential for production of other biofuels, including lignocellulosic ethanol, pyrolysis oil, and renewable diesel, and 4) integrate results into the MARKAL energy policy model. The project team included DOE (Policy and International and the Office of the Biomass Program), Oak Ridge National Laboratory (feedstock supply curves), the National Renewable Energy Laboratory (conversion technology characterizations), and Brookhaven National Laboratory (MARKAL analysis).

The NREL portion of this study was primarily concerned with estimating the plant gate price (PGP) of liquid biofuels (corn and wheat dry mill ethanol, cellulosic ethanol, biodiesel, renewable diesel, and pyrolytic fuel oil) from selected biomass feedstocks for countries included in the study using representative existing and developing technologies. A methodology for comparing costs between countries was developed. Plant sizes studies ranged from 25 MM GPY to 100 MM GPY. The results of the technology characterizations (capital costs, operating costs, plant gate prices) are presented in 2005 U.S. dollars and include estimates of comparative costs in each country.

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Acronyms

AFUDC	Allowance for funds during construction
BC	Biochemical
BLS	Bureau of Labor Statistics
BNL	Brookhaven National Laboratory
bu	Bushel
CCM	Capital cost multiplier
CEPCI	Chemical Engineering plant cost index
COP	Cost of product
DCFROR	Discounted cash flow rate of return
DDG	Distillers dried grains
DFC	Direct fixed capital
DE	Domestic equipment
DOE	United States Department of Energy
FAME	Fatty acid methyl ester
GPM	Gross processing margin
GPY	Gallons per year
IE	Imported equipment
ISBL	Inside battery limits
kWh	Kilowatt hour
LC	Labor costs
LCM	Labor cost multiplier
LPM	Labor productivity multiplier
LRM	Labor rate multiplier
MACRS	Modified accelerated cost recovery system depreciation
MARKAL	MARKal ALlocation; a mathematical model of the energy system of one or several regions that provides a technology-rich basis for estimating energy dynamics of a multi-period horizon
MM	Million
MMT	Million metric tonnes
NREL	National Renewable Energy Laboratory

OBP	DOE Office of the Biomass Program
ORNL	Oak Ridge National Laboratory
OSBL	Outside battery limits
PCMI	Imported equipment multiplication factor
PCML	Local material multiplication factor
PC	Purchased equipment cost
PGP	Plant gate price
PI	DOE Policy and International Program
POX	Partial oxidation
SL	Straight line depreciation
TC	Thermochemical
TCC	Total capital cost
TIC	Total installed capital
TPI	Total plant investment
USD	United States dollars
VAT	Value added tax

Technology Characterizations–Executive Summary

The overall objective of the joint EERE-PI project is to estimate the worldwide potential to produce and transport ethanol and other biofuels, with an emphasis on the 5 year and 10 year potential for biofuels supply to the United States. The project identifies four specific tasks:

- Task 1: Identify the range of countries to be included in the study
- Task 2: Assess the resource potential for production of ethanol from sugar and starch-based feedstocks, and biodiesel.
- Task 3: Assess the resource potential for production of other biofuels, including lignocellulosic ethanol, pyrolysis oil, and renewable diesel.
- Task 4: Integrate results into the MARKAL energy policy model

The project team includes DOE (Policy and International [PI] and the Office of the Biomass Program [OBP]), Oak Ridge National Laboratory (feedstock supply curves), the National Renewable Energy Laboratory (conversion technology characterizations), and Brookhaven National Laboratory (MARKAL analysis).

The NREL portion of this study is primarily concerned with estimating the plant gate price (PGP) of liquid biofuels from selected biomass feedstocks for countries included in the study using representative existing and developing technologies. The results of the technology characterizations are presented in 2005 U.S. dollars and include estimates of comparative capital and operating costs in each country.

The countries of interest selected by the project team for the study are:

- The United States
- Argentina
- Brazil
- Canada
- The Caribbean Basin
- China
- Colombia
- India
- Mexico

Supply curves in the years 2012, 2017, 2027 have been developed by Oak Ridge (ORNL 2007) for the following feedstocks: sugar cane, corn, soybeans, palm oil, bagasse, agricultural residues (corn stover and wheat straw), and woody/perennial materials. In some cases where data are not available, the ORNL feedstock prices represent single point values.

NREL has estimated PGPs for ethanol from corn dry mills, ethanol from sugar cane mills, ethanol from wheat mills, ethanol from biochemical conversion of lignocellulosic feedstocks, ethanol from thermochemical conversion of lignocellulosic feedstocks, residual fuel oil from pyrolysis of lignocellulosic feedstocks, biodiesel from soybeans, renewable diesel from soybeans, and biodiesel from palm oil.

While USA feedstock supply curve estimation is outside the scope of the present ORNL study, selected USA feedstock costs were used as a check on the reasonableness of the

models developed. Although one complete PGP set of curves was developed (sugar cane ethanol in Brazil, Figure 1), the PGP comparisons presented in this section are based on a single feedstock cost (price at 50% of 2017 potential supply or single point value if a supply curve isn't available) for each country. Selected costs for sugar, starch and fatty acid feedstocks are given in Table 1, and costs of lignocellulosic feedstocks are given in Table 2.

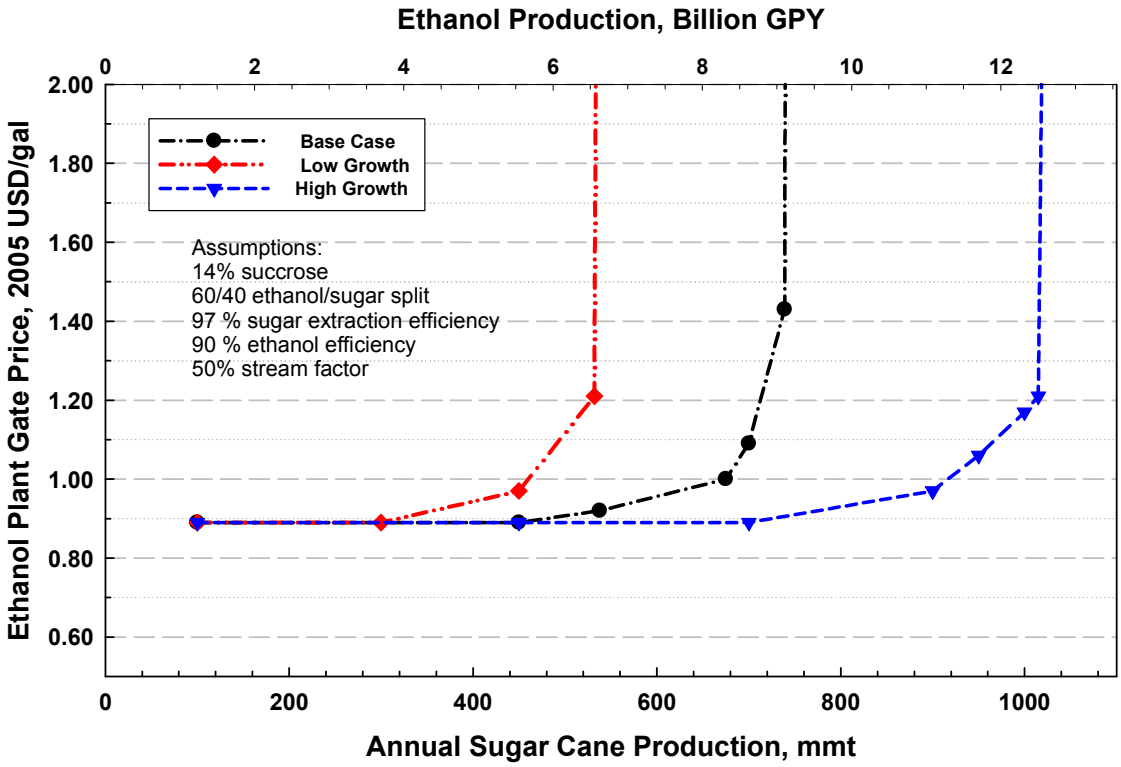


Figure 1. Plant gate prices for Brail 2017 sugar cane ethanol (based on 50 MMGPY plants): low, base, and high growth scenarios

Table 1. Selected non-lignocellulosic feedstock prices (calculated from ORNL 2007)

	Sugar Cane	Corn		Soy Beans		Wheat		Palm Oil
	$/ton	$/ton	$/bu	$/ton	$/bu	$/ton	$/bu	$/ton
USA	29.00	107.0	3.00	187.6	5.60	113.3	3.40	
Argentina	34.30	127.5	3.57	143.6	4.29	92.5	2.78	
Brazil	10.45	135.0	3.78	175.0	5.22			
Canada		86.0	2.41			102.0	3.06	
Caribbean Basin	15.00							275
Colombia	26.85							406
China	23.00	126.0	3.53	319.8	9.55	159.0	4.77	
India	15.00							
Mexico	29.00	130.0	3.64					

Table 2. Selected lignocellulosic feedstock prices (calculated from ORNL 2007)

Country	**Bagasse**	**Ag Residues**	**Woody /Perennial**
		(2005 USD/ST)	
USA	35.0	35.0	35.0
Argentina	9.1	47.2	47.2
Brazil	7.6	30.8	47.2
Canada	--	10.0	16.3-47.2 (31.8)
Caribbean Basin	7.6	14.5	47.2
China	9.1	28.1	47.2
Colombia	14.5	14.5	47.2
India	7.3	7.3	47.2
Mexico	15.4	47.2	47.2

Product yields used in the study are given in Table 3.

The technology evaluations are based on a "factor" analysis–an approximate method that uses factors to estimate the capital costs of process systems based on purchased cost. Multiplier factors are based on historical published values, and represent plus forty percent/minus ten percent estimates. In this study factored cost estimates developed in one country, typically the United States, need to be converted to costs in other countries. Since location multipliers are different for capital and labor, estimates of equipment/labor splits for the costing factors are used, based on discussions given in Valle-Riestra (1983).

Plant gate prices in other countries are converted to selected country costs using published conceptual equipment and labor cost estimating factors. Capital costs are divided into

domestic equipment and imported equipment. For imported equipment duty, freight, and Value Added Tax (VAT) are considered in determining a multiplication factor. A local material index is used for domestic equipment. Labor costs are based on USA costs, with labor rate multipliers and labor productivity multipliers. The factors, in combination with estimated equipment/labor percentages, are used to convert base case capital and operating costs to the specified country. Where factors are not available default values for imported materials (1), and depreciation schedule (10% straight line) are used.

Table 3. Technology characterization product yields

Product - Feedstock		Yield			
		gal tonne	Btu/gal	Btu/gal gasoline	gal Gasoline Equiv tonne
Ethanol - Corn (a)	[a]	112.2	84,100	124,238	76.0
Ethanol - Sugar Cane	*	13.6	84,100	124,238	9.2
Ethanol (TC) - Bagasse	**	88.3	84,100	124,238	59.8
Ethanol (TC) - Ag Residues	**	88.3	84,100	124,238	59.8
Ethanol (TC) - Wood/Perennials	**	88.3	84,100	124,238	59.8
Ethanol (BC) - Bagasse		98.9	84,100	124,238	66.9
Ethanol (BC) - Ag Residues		98.9	84,100	124,238	66.9
Ethanol (BC) - Wood/Perennials		98.9	84,100	124,238	66.9
Ethanol - Wheat	[b]	93.3	84,100	124,238	63.2
Biodiesel - Soybeans		49.8	129,500	124,238	51.9
Renewable Diesel - Soybeans		47.0	123,129	124,238	46.6
Pyrolytic Fuel Oil - Bagasse		151.0	83,600	124,238	101.6
Pyrolytic Fuel Oil - Ag Residues		151.0	83,600	124,238	101.6
Pyrolytic Fuel Oil - Wood/Perennials		151.0	83,600	124,238	101.6
Biodiesel - Palm Oil		270.0	129,500	124,238	281.4
Renewable Diesel - Palm Oil		255.3	123,129	124,238	253.0

[a] DDG = 0.33ton/ton corn
[b] DDG = 0.37 ton/ton wheat
*** at a 60/40 ethanol/sugar ratio**
*** * in addition, 15.4 gal/tonne higher alcohols (11.8 gal gasoline equivalents/tonne)**

Capital and operating cost estimates are based on published studies, performed over a period of time. For consistency all estimated are normalized to 2005 using the Chemical Engineering Plant Cost Index. The CEPCI is a standard cost index used to update cost estimates to a given year. It is made up of 41 Bureau of Labor Statistics (BLS) producer price indexes, 12 BLS labor cost indexes, and a calculated labor productivity multiplier. A summary of the capital costs are presented in Figure 4, expressed in terms of capital intensity. Capital intensity is the plant installed cost divided by the annual plant product capacity, assuming a 100 percent operating factor. As such, capital intensity incorporates plant size economies and process conversion efficiency. For the most part capital intensity is relatively constant for a given technology. The exceptions are Canada with higher than average capital intensity, and Mexico with lower than average capital intensity. The variations are due primarily to high construction labor costs in Canada and low construction labor costs in Mexico. The capital intensity of sugar cane ethanol is higher than corn ethanol because of the low capacity factor, 50%. Renewable diesel has low capital intensity because of the assumption of locating the process in a petroleum refinery where hydrogen can be purchased across the fence instead of investing in a hydrogen plant. Pyrolytic fuel oil capital intensity is low, but further upgrading will be needed to produce a transportation fuel.

Cellulosic ethanol processes are more capital intensive than corn and sugar ethanol processes, reflecting the additional processing needed to convert lignocellulosic feeds.

For different plant sizes, capital and operating costs are scaled using a 0.7 default scaling factor or individual scaling factor where known (0.50 – 0.85). Peters and Timmerhaus (2003) state "It is often necessary to estimate the cost of a piece of equipment when no cost data are available for the particular size of operational capacity involved. Good results can be obtained by using the logarithmic relationship known as the 'six-tenths-factor rule,' if the new piece of equipment is similar to one of another capacity for which cost data are available. According to this rule, if the cost of a given unit at one capacity is known, the cost of a similar unit with X times the capacity of the first is approximately $(X)^{0.6}$ times the cost of the initial unit." Valle-Riesta (1983) states " A logical consequence of the 'sixth-tenths-factor' rule for characterizing the relationship between equipment capacity and cost is that a similar relationship should hold for the direct fixed capital of specific plants ... In point of fact, the capacity exponent for plants, on the average, turns out to be closer to 0.7."

Table 4. Process capital intensity, plant size — 100MM GPY

Product - Feed	USA	Argentina	Brazil	Canada	Caribbean Basin	China	Colombia	India	Mexico
	← 2005 USD/annual gal →								
Ethanol - Corn	0.49	0.52	0.50	0.63		0.54			0.39
Ethanol - Sugar Cane	1.11	1.19	1.14		1.25	1.22	1.11	1.19	0.89
Ethanol (TC) - Cellulosic	1.66	1.78	1.69	2.16	1.87	1.82	1.65	1.77	1.33
Ethanol (BC) - Cellulosic	1.66	1.78	1.69	2.16	1.87	1.82	1.65	1.77	1.33
Ethanol - Wheat	0.60	0.64		0.78		0.66			
Biodiesel - Soybeans	0.54	0.58	0.56			0.60	0.54		
Renewable Diesel - Soybeans	0.11	0.12	0.11			0.12	0.11		
Pyrolytic Fuel Oil - Cellulosic	0.32	0.37	0.35	0.45	0.39	0.38	0.34	0.37	0.28
Biodiesel - Palm Oil					0.61		0.54		

The feedstock costs and capital costs are used in a discounted cash flow analysis to estimate plant gate prices of products. The project and financial assumptions for the cash flow analyses are given in Table 5. The assumptions include 100% equity financing, a 10% return on equity, a 3-year permitting and construction period, a 20-year operating period, and 1.9% inflation (consistent with the DOE H2A model).

The feedstock costs (Tables 1 and 2), capital costs (derived from Table 3), process yields (Table 4), and financial factors (Table 5) are used to estimate plant gate prices, as shown in Table 6 for 100 MM GPY facilities. PGPs for corn dry mill ethanol vary from $1.05/gal in Canada to $1.53/gal in Brazil. Sugar cane ethanol ranges from $0.82 in Colombia to $1.66 in the United States, with Brazil estimated at $1.05/gal. Bagasse appears to be an attractive opportunity for cellulosic ethanol, with PGPs ranging from $0.54/gal in Brazil and Mexico to 0.65/gal in China. The USA bagasse ethanol number is high at $1.17/gal; however, there is no supply curve and a conservative high bagasse price was assumed, $35.00.ton. Biodiesel and renewable diesel prices are primarily a function of soybean prices (80-90% of total cost), and vary widely depending on the country, from $0.92/gal biodiesel in Argentina ($1.81/bu soybeans) to $3.42/gal biodiesel in China ($9.55/bu soybeans). Renewable diesel is incrementally higher than biodiesel, $0.06 – 0.19/gal; however renewable diesel has a non-quantified

advantage in cetane value (+30 to 50 cetane numbers) and in use in existing fuel blends and distribution systems. Pyrolytic fuel oil has attractive costs, $0.26 - $0.60/gal, but is not a transportation fuel; it's primarily role would be as a refinery feedstock. Upgrading costs and yields for pyrolysis-derived diesel and gasoline have not been estimated in this report.

Table 5. Project and financial assumptions

Factor	
Discount Rate	10%
Equity / Debt	100 / 0 %
Cost of Capital – for debt/equity sensitivity analysis	7%
Debt Term – for debt/equity sensitivity analysis	20 years
Inflation	1.9%
Feed Escalation	0%
Product Escalation	0%
Construction Period	3 years
Construction Investment Schedule	8% / 60% / 32%
Stream Factor in Start-Up Year	75% of later year stream factor
Stream Factor	95% (50% for sugar mills)
Operating Life	20 years
Annual Replacement Capital Allowance	0%
Depreciation	Country Specific
USA	7, 20 year double declining balance
Other Countries	Straight line, variable number of years
Project basis	Corporate, after tax
Year basis	2005
Effective Tax Rate – country specific	e.g., USA = 39%

Table 6. Plant gate prices, 2005$, 100 MM GPY Plant

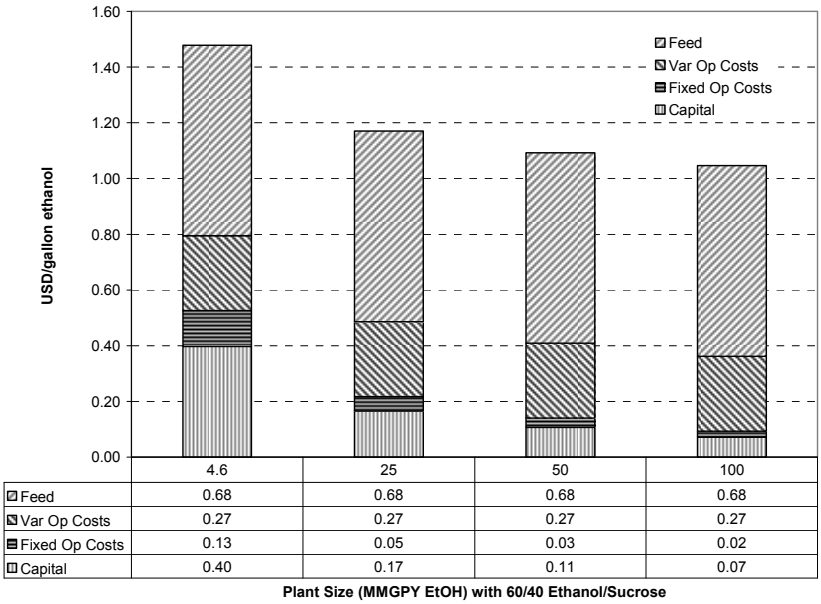
Product - Feed	USA	Argentina	Brazil	Canada	Caribbean Basin	China	Colombia	India	Mexico
	← 2005 USD/gal product →								
Ethanol - Corn	1.29	1.49	1.54	1.06		1.48			1.31
Ethanol - Sugar Cane	1.66		1.05		1.06	1.42	0.82	1.05	1.67
Ethanol (TC) - Bagasse	0.93	0.62	0.54		0.62	0.65	0.63	0.57	0.54
Ethanol (TC) - Ag Residues	0.93	1.10	0.83	0.79	0.71	0.88	0.63	0.57	0.93
Ethanol (TC) - Wood/Perennials	0.93	1.10	1.04	1.06	1.12	1.13	1.04	1.05	0.93
Ethanol (BC) - Bagasse	1.17	0.90	0.83		0.90	0.92	0.90	0.81	0.81
Ethanol (BC) - Ag Residues	1.17	1.32	1.09	1.06	0.98	1.14	0.90	0.81	1.17
Ethanol (BC) - Wood/Perennials	1.17	1.32	1.27	1.30	1.34	1.35	1.27	1.28	1.17
Ethanol - Wheat	1.39	1.20		1.31		1.89			
Biodiesel - Soybeans	2.11	0.92	2.00			3.42	0.98		
Renewable Diesel - Soybeans	2.27	0.98	2.14			3.61	0.97		
Biodiesel - Palm Oil					1.44		1.91		
Pyrolytic Fuel Oil - Bagasse	0.50	0.30	0.26		0.30	0.32	0.32	0.26	0.29
Pyrolytic Fuel Oil - Ag Residues	0.50	0.58	0.43	0.38	0.35	0.46	0.32	0.26	0.52
Pyrolytic Fuel Oil - Wood/Perennials	0.50	0.58	0.55	0.54	0.59	0.60	0.56	0.55	0.52

Two study results are shown in Figure 2 and Figure 3 to illustrate the relative impact of capital and feedstock on plant gate prices. In Figure 2, for sugar cane ethanol production in Brazil, the capital intensity is low and feedstock plays a large role in price, especially as the

plant size increases. Prices are assumed to be independent of plant size, while capital cost decreases according to the 0.7 rule. In this example feedstock represents about 50 % of price at 5 MM GPY (capital 22%), while at 50 MM GPY feedstock represents about 67% of price (capital 7.5%). Figure 3 is representative of the opposite extreme, a capital intensive process with low feedstock cost–thermochemical ethanol from bagasse in Brazil. In this case feedstock represents only 10% of price at a 25 MM GPY scale, increasing to 17% of price at 100 MM GPY; at the same time capital represents 55% of price at 25 MM GPY, decreasing to 48% at 100 MM GPY.

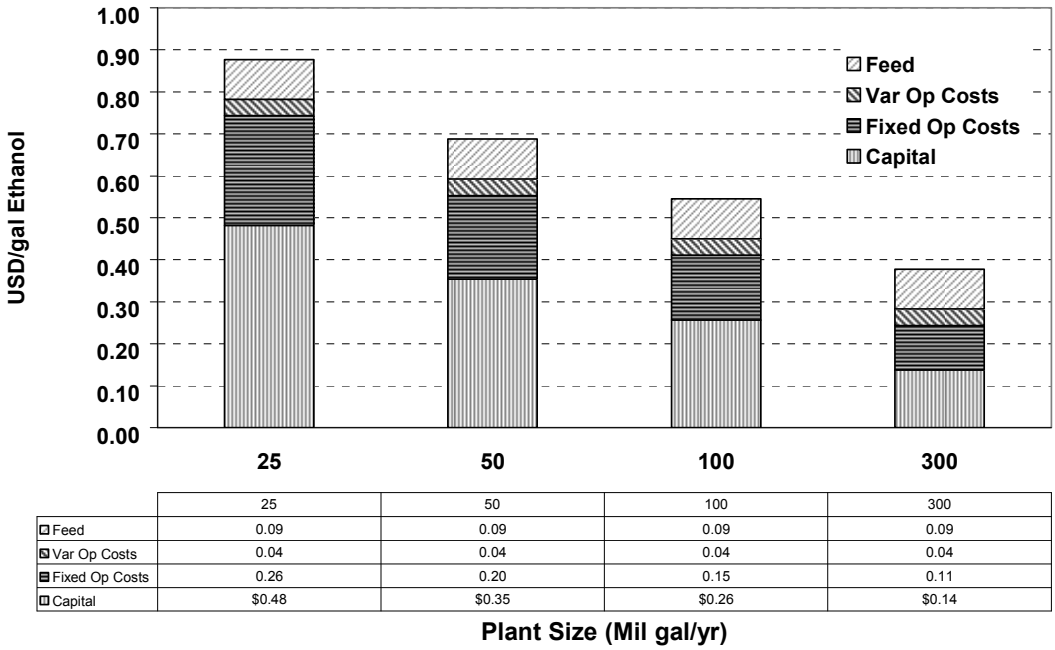
Figures 4 - 6 present comparisons of the plant gate price of ethanol from three biomass sources–sugar cane, corn, and bagasse. For sugar cane, Figure 4, plant gate prices are primarily impacted by feedstock costs; the fraction of PGP representing feedstock ranges from 61% in the Caribbean to 78% in Mexico. There are small variations in capital and non-feedstock operating costs between countries. Comparable trends are seen for ethanol from corn dry mills, Figure 5. Again, capital and non-feedstock PGP contribution variations are small between countries. Feedstock has the largest contribution to PGP, and shows the most variation between countries. Feedstock cost percentages range from 46% in Canada to 66% in Brazil. Figure 6, shows a comparison for cellulosic ethanol from bagasse. The USA PGP assumes a high cost for bagasse, $35/ton, which is a value equal to that assumed in modeling for woody feedstocks. At this time there is no USA supply curve for bagasse. For the USA case feedstock represents 35% and capital 40%. For other countries, the bagasse cost estimates were estimated from the ORNL report, and represent between 11% (Caribbean Basin), and 23% (Colombia).

Figure 7 shows a comparison of biodiesel PGPs for both biodiesel from soybeans and from palm oil. PGPs are primarily a function of feedstock cost.



	4.6	25	50	100
Feed	0.68	0.68	0.68	0.68
Var Op Costs	0.27	0.27	0.27	0.27
Fixed Op Costs	0.13	0.05	0.03	0.02
Capital	0.40	0.17	0.11	0.07

Figure 2. Plant gate price of sugar cane ethanol in Brazil



	25	50	100	300
Feed	0.09	0.09	0.09	0.09
Var Op Costs	0.04	0.04	0.04	0.04
Fixed Op Costs	0.26	0.20	0.15	0.11
Capital	$0.48	$0.35	$0.26	$0.14

Figure 3. Plant gate price for thermochemical cellulosic ethanol from bagasse in Brazil

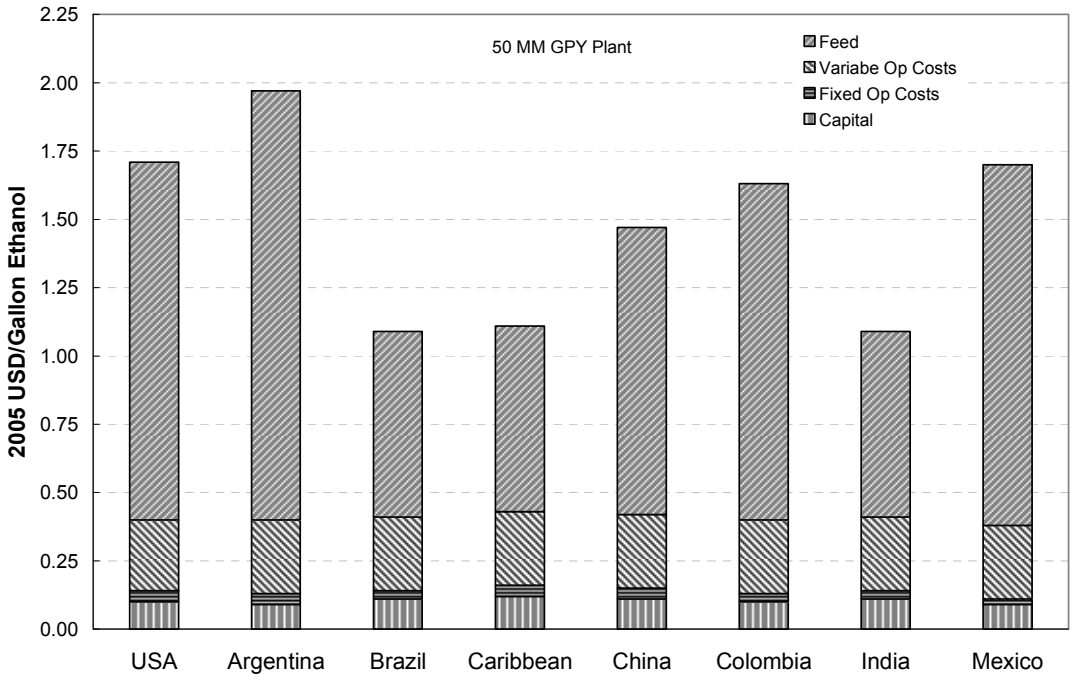


Figure 4. Comparison of sugar cane ethanol plant gate prices

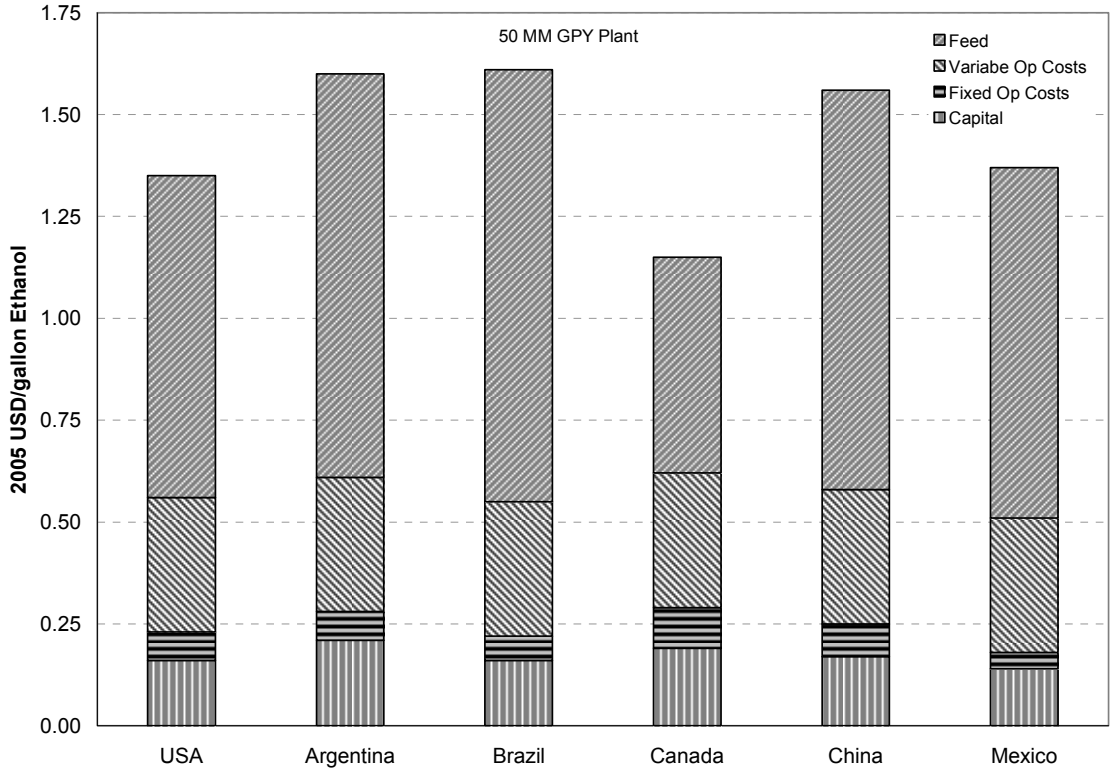


Figure 5. Comparison of corn dry mill ethanol plant gate prices

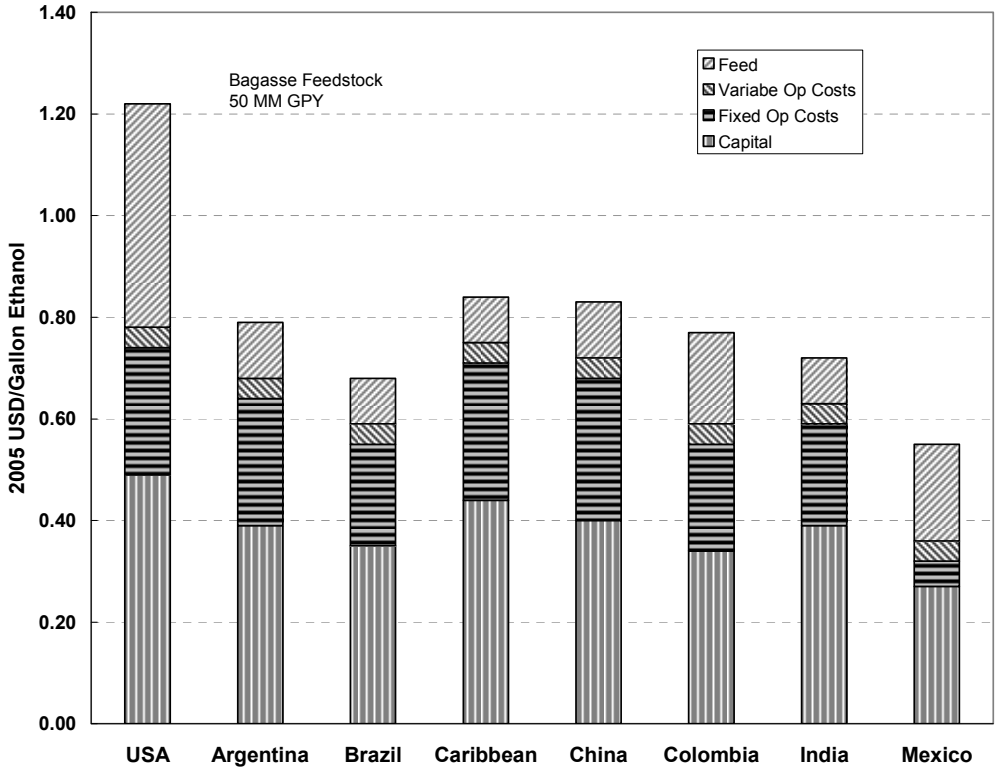


Figure 6. Comparison of cellulosic ethanol (TC) plant gate prices

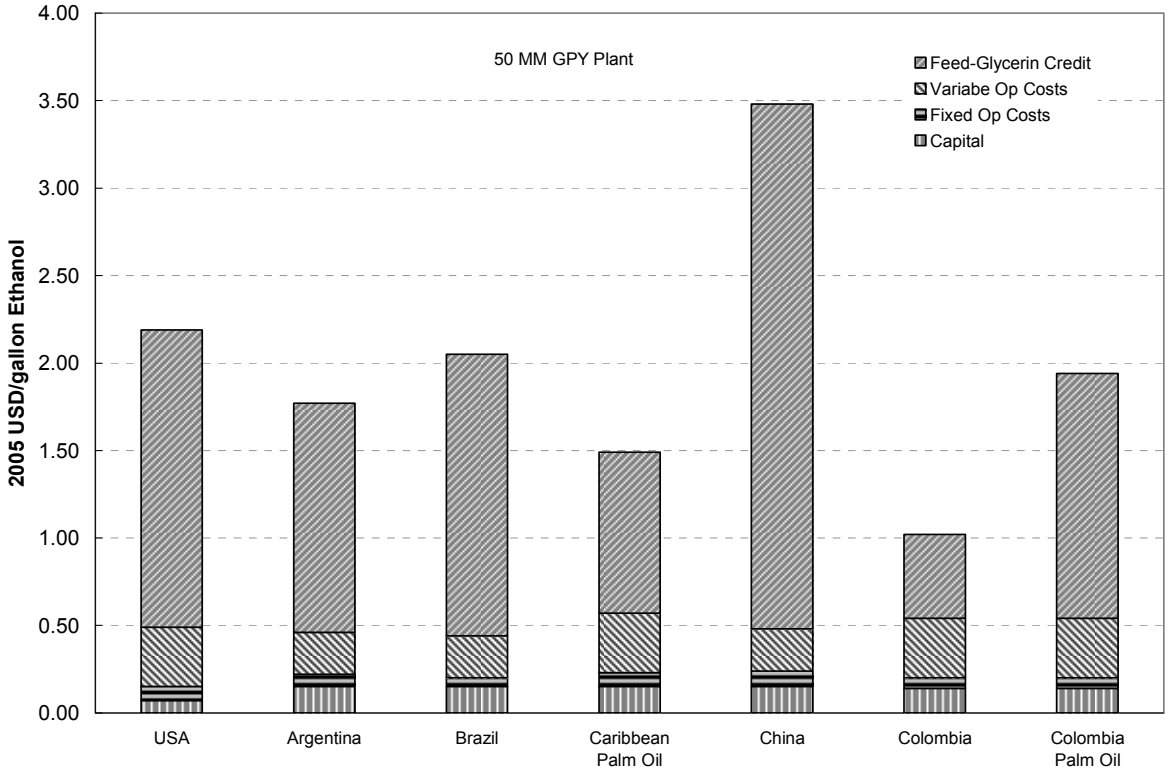


Figure 7. Comparison of biodiesel plant gate prices

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1 Introduction

The overall objective of the joint EERE-PI project is to estimate the worldwide potential to produce and transport ethanol and other biofuels, with an emphasis on the 5 year and 10 year potential for biofuels supply to the United States. The project identifies four specific tasks:

- Task 1: Identify the range of countries to be included in the study
- Task 2: Assess the resource potential for production of ethanol from sugar and starch-based feedstocks, and biodiesel.
- Task 3: Assess the resource potential for production of other biofuels, including lignocellulosic ethanol and other biofuels, such as biomass gasification with gas-to-liquids technology.
- Task 4: Integrate results into the MARKAL energy policy model

The first task was completed by all participants in consultation with DOE. The next two tasks, which are largely data collection, analysis, and synthesis, have been integrated into the MARKAL model to improve its global representation of biofuels. ORNL was responsible for the completion of Task 2; NREL was responsible for Task 3; and BNL was responsible for the MARKAL model integration, Task 4.

The time frame for the study is designed to coincide with the President's "20 in 10" initiative and thus will be focused on two periods – what can be produced in 5 years and 10 years. The study also considers a longer-term period of 20 years in which barriers, constraints, and study assumptions (e.g., crop yields) can be somewhat more relaxed. The longer time period allows consideration of scenarios more comparable to the joint DOE-USDA billion-ton assessment. The NREL effort focused on the conversion technologies for ethanol from starch and sugar, lignocellulosic ethanol, biodiesel, and residual fuel oil via pyrolysis; conversion scale-up and infrastructure requirements, and estimated costs of biofuels in the context of conventional fuels and financial operating conditions.

The range of countries and/or regions identified in the joint EERE-PI project includes Brazil, the Caribbean Basin, Central America, Mexico, Europe, China, India, and Sub-Saharan Africa. These countries and regions are not entirely consistent with those used in the DOE MARKAL 15-region world energy model. The outcome of this task is an agreed upon list of countries and regions for subsequent assessment and analysis. The countries selected for this study are Argentina, Brazil, Canada, the Caribbean Basin, China, Colombia, India, and Mexico.

This task estimated the range of biofuels production plant gate prices (PGP), for example, ethanol and biodiesel, for each of the identified feedstock/conversion pathways. Estimated minimum biofuel selling prices for each period was compared to predicted prices of conventional fuels. The task took into account variation in feedstock costs and likely progress made in conversion technology either through reductions in capital and operating or changes in biorefinery conversion efficiencies. All appropriate costing assumptions, methods, and models have been documented. Costs are presented using U.S. costs as the base model, and converted to costs for the selected countries/regions using cost multipliers. Plant gates prices are presented on a post-tax basis to permit comparison with domestic production of biofuels.

2 Methodology

2.1 Approach

The technology evaluations are based on a 'factor' analysis (Valle-Riestra 1983). This is an approximate method that involves the use of factors for estimating the capital cost of process systems or process equipment based on purchased equipment costs (PC). Factor estimates are based on published values from a number of sources (Valle-Riestra 1983, Peters and Timmerhaus 1991), and primarily use studies of individual plant construction records. When applied to a new process the factors give approximate results, typically in the plus forty/minus ten percent range. They are used to give preliminary results before moving to the more costly estimates based on detailed engineering design and vendor quotes. The factors used are based on values developed at NREL for a number of detailed process design studies (Spath et al. 2005), and provide estimates of installation, instruments and controls, piping and insulation, electrical facilities, buildings, yard improvements, and auxiliary facilities. Table 7. Capital equipment costing factors gives the values of the factors used in this study.

Table 7. Capital equipment costing factors

Total Installed Cost (TIC)	
	% of PC
Purchased Equipment Cost (PC)	100
Installation	39
Instrumentation and controls	26
Piping & Insulation	31
Electrical facilities	10
Buildings	29
Yard improvements	12
Auxiliary facilities (OSBL)	0
Total	247

In this study factored cost estimates developed in one country, typically the United States, need to be converted to costs in other countries. Since location multipliers are different for capital and labor, estimates of equipment/labor splits for each of the costing factors are used, based on discussions given in Valle-Riestra (1983), as shown in Table 8.

Purchased equipment plus installation costs are added together to give total installed capital (TIC) cost. A number of indirect project costs must be added to determine total plant investment (TPI); including engineering costs, construction costs, contractor and legal costs, and project contingency costs. Not included as an indirect cost in this study are owner's costs, although many of the individual costs such as prepaid royalties and land are included. Costing factors for these indirect costs are given in Table 9. The project contingency used is 10% of PC (4% of TIC). This is typical of detailed cost estimates and is low for order of magnitude cost factor estimates. However, the project contingency is consistent with 'nth' plant analyses. The added uncertainty and risk associated with cost factor analysis is evaluated through sensitivity analysis.

Table 8. Capital/labor ratios for costing factors

		% Capital	% Labor	Capital Cost Multiplier (CCM)	Labor Cost Multiplier (LCM)
	% of PC			% of PC	% of PC
Purchased Equipment Cost (PC)	100	100	0	100.0	0.0
Installation	39	25	75	9.8	29.3
Instrumentation & Controls	26	50	50	13.0	13.0
Piping & Insulation	31	50	50	15.5	15.5
Electrical Facilities	10	25	75	2.5	7.5
Buildings	29	50	50	14.5	14.5
Yard improvements	12	25	75	3.0	9.0
Auxiliary facilities (OSBL)	0	25	75	0.0	0.0

Table 9. Capital cost indirect cost factors

Indirect Costs	
	% of TIC
Engineering	13
Construction	10
Legal & Contractors Fees	7
Project Contingency	4
Total	34

Total plant cost (TPC) is determined by adding TPI and 'allowance for funds used during construction' (AFUDC), also referred to as interest during construction. Since this analysis assumes equity financing, no AFUDC is estimated. Total capital cost (TCC) is estimated by adding land and start-up costs to TPC.

Operating costs use a combination of cost factor analysis and estimated costs, e.g., feedstock cost and methanol cost for biodiesel. Labor costs are estimated based on costs developed for the thermochemical ethanol process (Phillips et al. 2007). Standard fixed costs and multipliers (Valle-Riestra 1983) are given in Table 10.

2.2 Financial Analysis

The technologies are financially compared using a discounted cash flow rate of return (DCFROR) analysis with a zero net present value (NPV) at a fixed return on equity of 10 percent. Project financial assumptions are given in Table 11.

Table 10. Fixed costs

Fixed Cost Category	Value
Labor	Based on Phillips, et al. 2007
Maintenance	3% of TIC
General Overhead	65% of Labor and Maintenance
Direct Overhead	45% of Labor
Insurance	0.5% of TIC

Table 11. Financial analysis assumptions

Factor	
Discount Rate	10%
Equity / Debt	100 / 0 %
Cost of Capital – for Debt/Equity	7%
Debt Term – for Debt/Equity	20 years
Inflation	1.9%
Feedstock Escalation	0%
Product Escalation	0%
Construction Period	3 years
Construction Investment Schedule	8% / 60% / 32%
Stream Factor in Start-Up Year	75% of later year stream factor
Stream Factor	95% (50% for sugar mills)
Operating Life	20 years
Annual Replacement Capital Allowance	0%
Depreciation	Country specific
USA	7, 20 year double declining balance
Other Countries	Straight line, variable number of years
Project Basis	Corporate, after tax
Year Basis	2005
Effective Tax Rate – Country Specific	e.g., USA = 39%

All of the financial factors are standard. Since information on 'loss carry-forward' or 'depreciation carry-forward' is not available for all of the countries being studied, a corporate analysis is used. A project basis analysis assumes that depreciation deductions in any year are

limited to taxable income. Excess depreciation can be carried forward to future years. The number of years of allowable carry-forward is specified by tax law. If a corporate basis is used the assumption is made that the business entity has other income to offset excess project depreciation, and all of the yearly depreciation can be used in estimating yearly cash flow.

All costs are presented in 2005 U.S. dollars (USD). For cost estimates developed in other years the *Chemical Engineering* chemical plant cost index (CEPCI) is used to convert to 2005 dollars (Chemical Engineering 2007).

The CEPCI is a standard cost index that NREL uses to update cost estimates to a given year. It is made up of 41 Bureau of Labor Statistics (BLS) producer price indexes, 12 BLS labor cost indexes, and a calculated labor productivity multiplier. A plot of the CEPCI is given by Figure 8. The least squares curve fit is used to extrapolate a preliminary value for 2007 dollars.

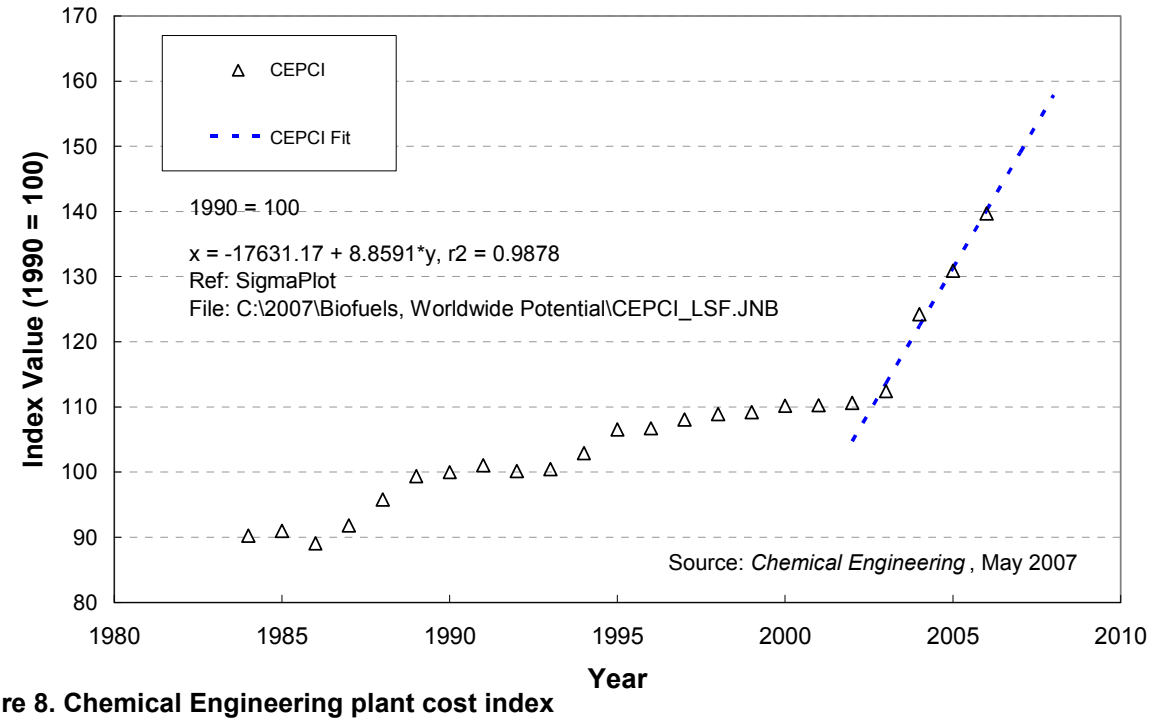


Figure 8. Chemical Engineering plant cost index

2.3 Base Case Analysis

For each technology evaluated in this study a base case technology is used, and the costs converted to costs in the other countries using capital and operating cost factors, individual

country feedstock costs, and individual country tax laws. To the extent possible, USA costs are used to develop the base case estimates. The only exception to this is in the case of sugar cane sugar/ethanol, where USA capital costs are not available. For sugar cane sugar/ethanol Brazil is used for the base case. The results for individual technologies are presented in later sections of this report.

Capital and operating costs are scaled using a 0.7 default scaling factor or individual scaling factor where known (0.50 – 0.85). Peters and Timmerhaus (2003) state "It is often necessary to estimate the cost of a piece of equipment when no cost data are available for the particular size of operational capacity involved. Good results can be obtained by using the logarithmic relationship known as the 'six-tenths-factor rule,' if the new piece of equipment is similar to one of another capacity for which cost data are available. According to this rule, if the cost of a given unit at one capacity is known, the cost of a similar unit with X times the capacity of the first is approximately $(X)^{0.6}$ times the cost of the initial unit." Valle-Riesta (1983) states " A logical consequence of the 'sixth-tenths-factor' rule for characterizing the relationship between equipment capacity and cost is that a similar relationship should hold for the direct fixed capital of specific plants...In point of fact, the capacity exponent for plants, on the average, turns out to be closer to 0.7." The exception to this rule happens when plant capacity is increased by change in efficiency, not change in equipment size. In this case, capital cost in dollars remains constant, and capital cost in $/size decreases in proportion to efficiency increase.

In this section the cost sheets and cash flow results for cellulosic ethanol (thermochemical) are presented as an example. Plant size and yield information are given in Table 12. The capital costs (Phillips et al. 2007) are given in Table 13 as a function of plant size based on ethanol (primary product). Operating costs are given in Table 14. The information in Tables 12-14 is used in a cash flow calculation. The input cash flow information is given in Table 15.

Table 12. Plant size and yield information for cellulosic ethanol (TC), USA basis

Country **USA** **Code =** 1

Cost component	Units	Cost Factor	Scale Factor	USA Cellulosic Ethanol (TC)	USA Cellulosic Ethanol (TC)	USA Cellulosic Ethanol (TC)	USA Cellulosic Ethanol (TC)
Year $	$			2005	2005	2005	2005
Cost Index (2 = M&S, 3 = CE)			3	130.93	130.93	130.93	130.93
Plant Size	dry short ton/day			1,800	900	3,601	10,801
	dry tonne/day			1,632	816	3,264	9,793
Stream Factor	%			95%	95%	95%	95%
Feed	Dry short ton/yr			6.242E+05	3.121E+05	1.248E+06	3.745E+06
	GJ/short ton			1.794E+01	1.794E+01	1.794E+01	1.794E+01
	GJ/yr			1.119E+07	5.598E+06	2.239E+07	6.717E+07
Feed Cost	USD/dt			**$ 35.00**	**$ 35.00**	**$ 35.00**	**$ 35.00**
Yield (gal/Dry US Ton)							
Ethanol	gal/short ton			80.1	80.1	80.1	80.1
Mixed alcohols	gal/short ton			94.1	94.1	94.1	94.1
Process Efficiency - to ethanol	% HHV			39.6%	39.6%	39.6%	39.6%
Process efficiency - overall	% HHV			47.4%	47.4%	47.4%	47.4%
Ethanol	gal/yr			5.000E+07	2.500E+07	1.000E+08	3.000E+08
	Mil Gal/YR			**50.00**	**25.00**	**100.00**	**300.00**
	tpy			1.657E+05	8.288E+04	3.315E+05	9.945E+05
	GJ/yr			4.436E+06	2.218E+06	8.873E+06	2.662E+07
	gal/Stream day			1.442E+05	7.210E+04	2.884E+05	8.652E+05
	bbl/s stream day			3.433E+03	1.717E+03	6.867E+03	2.060E+04
Higher Alcohols							
	gal/ton			14.0	14.0	14.0	14.0
	gal/yr			8.74E+06	4.37E+06	1.75E+07	5.24E+07

Table 13. Capital costs, cellulosic ethanol (TC), USA basis

Country **USA** **Code =** 1

Cost component	Units	Cost Factor	Scale Factor	USA Cellulosic Ethanol (TC)	USA Cellulosic Ethanol (TC)	USA Cellulosic Ethanol (TC)	USA Cellulosic Ethanol (TC)
Capital Cost (million USD)							
Feed Handling & Drying			0.70	23.20	14.28	37.69	81.32
Gasification			0.80	12.90	7.41	22.46	54.09
Tar Reforming & Quench			0.70	38.40	23.64	62.38	134.60
Acid Gas & Sulfur Removal			0.85	14.50	8.05	26.14	66.50
Alcohol synthesis - Compression			0.65	16.00	10.20	25.11	51.28
Alcohol Synthesis - Other			0.65	4.60	2.93	7.22	14.74
Alcohol Separation			0.65	7.20	4.59	11.30	23.08
Steam System & Power Generation			0.70	16.80	10.34	27.29	58.89
Cooling Water & Other Utilities			0.70	3.60	2.22	5.85	12.62
Direct Fixed Capital (DFC), also called TIC				137.20	83.65	225.44	497.12
Engineering	DFC x MF	0.12		16.46	10.04	27.05	59.65
Construction	DFC x MF	0.13		17.84	10.88	29.31	64.63
Contractor & Legal	DFC x MF	0.08		10.98	6.69	18.04	39.77
Process/Project Contingency	DFC x MF	0.0412		5.65	3.45	9.29	20.48
Total Plant Cost (TPC)				188.13	114.71	309.13	681.65
AFUDC							
Total Plant Investment (TPI)				188.13	114.71	309.13	681.65
Land			0.60	2.21	2.21	5.08	15.23
Startup				0.00	0.00	0.00	0.00
Total Capital Cost (TCC)				190.34	116.92	314.21	696.88
Contingency/TPI							
Working Capital	DFC x MF	0.05		9.41	5.74	15.46	34.08

Table 14. Operating costs, cellulosic ethanol (TC), USA basis

Country **USA** **Code =** 1

Cost component	Units	Cost Factor	Scale Factor	USA Cellulosic Ethanol (TC)	USA Cellulosic Ethanol (TC)	USA Cellulosic Ethanol (TC)	USA Cellulosic Ethanol (TC)
Variable Operating Costs (million USD/yr)							
Feed				21.85	10.92	43.70	131.09
Utilities				0.30	0.12	0.49	1.47
Other				1.00	0.50	2.00	6.00
Catalysts and Chemicals				0.70	0.35	1.40	4.20
Total				23.85	11.90	47.59	142.75
Fixed Operating Costs (million USD/yr)							
Labor (SF from V-R)	DFC x MF	0.0165	0.25	2.26	1.90	2.69	3.54
Maintenance (3% of A)			0.03	4.12	2.51	6.76	14.91
General Overhead (65% of labor + maint)			0.65	4.15	2.87	6.15	12.00
Direct Overhead (45% of Labor)			0.45	1.02	0.86	1.21	1.59
Insurance (0.5% of TIC)			0.005	0.95	0.58	1.57	3.48
Total				12.50	8.72	18.38	35.53

Table 15. DCFROR input, DCFROR analysis, cellulosic ethanol (TC), 50 MM GPY, USA basis

Case No:	**Cellulosic Ethanol (TC):2000-2005:Jul2007**			
Project Description:	TC Ethanol - 1800 TPD - 2005			
Construction Period	3	yrs	Solve	
Operating Life	20	yrs		
EtOH Production	4,436,016	* GJ/yr		
EtOH COP	$ 12.36	/GJ	$ 1.10	/gal
Capital Cost	190,338,640	*		
Depreciable Capital	188,128,640	*		
3 year				
5 year				
7 year	160,156,160			
10 year				
15 year				
20 year	27,972,480	*		
5 year SL				
9 year SL				
10 year SL				
15 year SL				
20 year SL				
% capital year 1	8%			
% capital year 2	60%			
% capital year 3	32%			
Inflated Capital	194,845,006			
Inflated depreciable capi	192,582,683			
Replacement Capital				
Variable Cost (I = 0)				
year 1				
year 2				
year 3	0	*		
year 4	17,884,811	*		
year 5 to n	23,846,415	*		
Fixed Cost	12,497,073	*		
Working Cap	9,406,432	*		
Revenues				
Ethanol	54,834,054			
Capacity Paymt				
Coproduct	10,049,351	Co-Prod Val	1.15	* USD/gal
Total Revenue	64,883,405			
Yr 4 Prod, %	75.0%			
Inflation rate, %	1.90%			
Percent Debt	0.00%			
Cost of Debt	7.0%			
Term	20			
Taxes				
Federal				35.0%
State				3.9%

Table 16 gives the depreciation schedules used in the study.

Table 16. Depreciation schedules

MACRS with half-year rule						Straight Line				
3-yr	5-yr	7-yr	10-yr	15-yr	20-yr	5-yr	7-yr	10-yr	11-yr	20-yr
33.33	20.00	14.29	10.00	5.00	3.750	20.000	14.286	10.000	9.091	5.000
44.45	32.00	24.49	18.00	9.50	7.219	20.000	14.286	10.000	9.091	5.000
14.81	19.20	17.49	14.40	8.55	6.677	20.000	14.286	10.000	9.091	5.000
7.41	11.52	12.49	11.52	7.70	6.177	20.000	14.286	10.000	9.091	5.000
	11.52	8.93	9.22	6.93	5.713	20.000	14.286	10.000	9.091	5.000
	5.76	8.92	7.37	6.23	5.285		14.286	10.000	9.091	5.000
		8.93	6.55	5.90	4.888		14.286	10.000	9.091	5.000
		4.46	6.55	5.90	4.522			10.000	9.091	5.000
			6.56	5.91	4.462			10.000	9.091	5.000
			6.55	5.90	4.461			10.000	9.091	5.000
			3.28	5.91	4.462				9.091	5.000
				5.90	4.461					5.000
				5.91	4.462					5.000
				5.90	4.461					5.000
				5.91	4.462					5.000
				2.95	4.461					
					4.462					
					4.461					
					4.462					
					4.461					
					2.231					

Table 17 presents the cash flow for the process. Other summary information can also be estimated from the DCFROR analysis. Figure 9 shows the 50 MM GPY project cumulative cash flow. The payback is about 7.5 years after start of operation, which is typical for 10% return. The breakdown of costs as a function of plant size is given in Figure 10.

2.4 Country Costs

Plant gate prices in other countries are converted to selected country costs using conceptual equipment and labor cost estimating factors based on a number of references (ASPEN Tech 2007, Humphries 2005a, Humphries 2005b, KMPG 2006, Richardson Engineering 1997). Capital costs are divided into domestic equipment (DE) and imported equipment (IE). For imported equipment duty, freight, and Value Added Tax (VAT) are considered in determining a multiplication factor (PCMI). A local material index (PCML) is used for domestic equipment.

If PCC_x = purchased equipment cost in country X, then

$$PCC_x = \text{USA PC} * (\%IE * PCMI + \%DE * PCML) \quad (1)$$

Labor costs (LC_x) are based on USA costs, with labor rate multipliers (LRM) and labor productivity multipliers (LPM).

$$LRM_x = \text{Country x labor rate/USA labor rate} \quad (2)$$

$$LC_x = LRM_x * LPM_x \quad (3)$$

These factors, in combination with the estimated equipment/labor percentages shown in Table 8 are used to convert base case capital and operating costs to the specified country. Country factors are given in Table 18. Where factors are not available default values for imported materials (1), and depreciation schedule (10% SL) are used.

Table 17. Cash flow, cellulosic ethanol, 50 MM GPY, USA basis

Year	Income	Production Credit	Equity	Debt	Debt Service	Remaining Capital	Principal Paymt	Working Capital	Fixed Op cost	Replacement Capital
1			15,227,091	0	0					
2			116,373,044	0	0					
3			63,244,871	0	0	0				
4	51,489,355	0			0	0	0	9,952,850	13,223,026	
5	69,956,870	0			0	0	0		13,474,264	
6	71,286,051	0			0	0	0		13,730,275	
7	72,640,486	0			0	0	0		13,991,150	
8	74,020,655	0			0	0	0		14,256,982	
9	75,427,047	0			0	0	0		14,527,865	
10	76,860,161	0			0	0	0		14,803,894	
11	78,320,504	0			0	0	0		15,085,168	
12	79,808,594	0			0	0	0		15,371,786	
13	81,324,957	0			0	0	0		15,663,850	
14	82,870,131	0			0	0	0		15,961,463	
15	84,444,664	0			0	0	0		16,264,731	
16	86,049,112	0			0	0	0		16,573,761	
17	87,684,046	0			0	0	0		16,888,663	
18	89,350,042	0			0	0	0		17,209,547	
19	91,047,693	0			0	0	0		17,536,529	
20	92,777,599	0			0	0	0		17,869,723	
21	94,540,374	0			0	0	0		18,209,247	
22	96,336,641	0			0	0	0		18,555,223	
23	98,167,037	0			0	0	0	(9,952,850)	18,907,772	

					Project Internal Rate of Return	
					Rate of Return Estimate	
COP	12.36	$/GJ	$ 1.10	/gal		15.00%
PROD CRE	0.00				Internal Rate of Return	
TAX CREDI	0.00					10.00%
					Desired Return	10.00%
					NPV	0
			$ 1.10	$/gal EtOH eq		

Table 17: (cont.)

Year	Variable Op cost	Pre-Dep Income	Deprec Schedule	Depreciation	Pre-tax Calculation	Tax	After-Tax Income	Cash Flow	Cum Cash Flow
1		(15,227,091)			(15,227,091)	0	(15,227,091)	(15,227,091)	(15,227,091)
2		(116,373,044)			(116,373,044)	0	(116,373,044)	(116,373,044)	(131,600,136)
3		(63,244,871)			(63,244,871)	0	(63,244,871)	(63,244,871)	(194,845,006)
4	18,923,737	9,389,741	0.1272	24,501,964	(15,112,223)	0	(15,112,223)	9,389,741	(185,455,266)
5	25,711,051	30,771,555	0.2192	42,217,993	(11,446,438)	0	(11,446,438)	30,771,555	(154,683,711)
6	26,199,561	31,356,214	0.1588	30,586,437	769,778	299,444	470,334	31,056,771	(123,626,940)
7	26,697,353	31,951,983	0.1155	22,245,866	9,706,117	3,775,679	5,930,437	28,176,303	(95,450,637)
8	27,204,603	32,559,070	0.0845	16,276,454	16,282,616	6,333,938	9,948,679	26,225,132	(69,225,504)
9	27,721,490	33,177,693	0.0838	16,137,502	17,040,190	6,628,634	10,411,556	26,549,059	(42,676,446)
10	28,248,198	33,808,069	0.0833	16,040,217	17,767,851	6,911,694	10,856,157	26,896,374	(15,780,071)
11	28,784,914	34,450,422	0.0447	8,606,941	25,843,481	10,053,114	15,790,367	24,397,308	8,617,237
12	29,331,828	35,104,980	0.0066	1,277,682	33,827,298	13,158,819	20,668,479	21,946,161	30,563,398
13	29,889,132	35,771,975	0.0066	1,277,396	34,494,579	13,418,391	21,076,188	22,353,583	52,916,981
14	30,457,026	36,451,642	0.0066	1,277,682	35,173,960	13,682,670	21,491,290	22,768,972	75,685,953
15	31,035,709	37,144,223	0.0066	1,277,396	35,866,827	13,952,196	21,914,632	23,192,027	98,877,981
16	31,625,388	37,849,964	0.0066	1,277,682	36,572,281	14,226,617	22,345,664	23,623,346	122,501,327
17	32,226,270	38,569,113	0.0066	1,277,396	37,291,717	14,506,478	22,785,239	24,062,635	146,563,962
18	32,838,569	39,301,926	0.0066	1,277,682	38,024,244	14,791,431	23,232,813	24,510,495	171,074,457
19	33,462,502	40,048,663	0.0066	1,277,396	38,771,267	15,082,023	23,689,244	24,966,640	196,041,097
20	34,098,290	40,809,587	0.0066	1,277,682	39,531,905	15,377,911	24,153,994	25,431,676	221,472,773
21	34,746,157	41,584,969	0.0066	1,277,396	40,307,573	15,679,646	24,627,927	25,905,323	247,378,096
22	35,406,334	42,375,084	0.0066	1,277,682	41,097,402	15,986,889	25,110,512	26,388,195	273,766,291
23	36,079,054	53,133,061	0.0066	1,277,396	51,855,665	20,171,854	31,683,811	32,961,207	306,727,498

				Project Internal Rate of Return	
				Rate of Return Estimate	
COP	COP	12.36	$/GJ		15%
PROD CRE	PROD CREDIT	0		Internal Rate of Return	
TAX CREDI	TAX CREDIT	0			10%
				Desired Return	10%
				NPV	0
			1.10	$/gal EtOH eq	

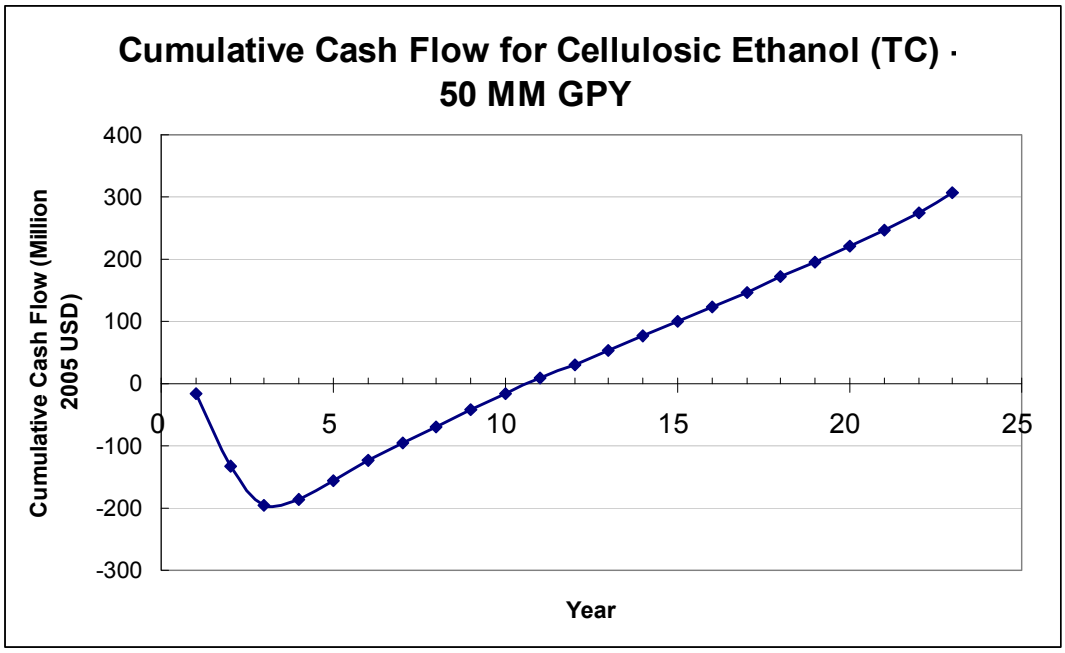
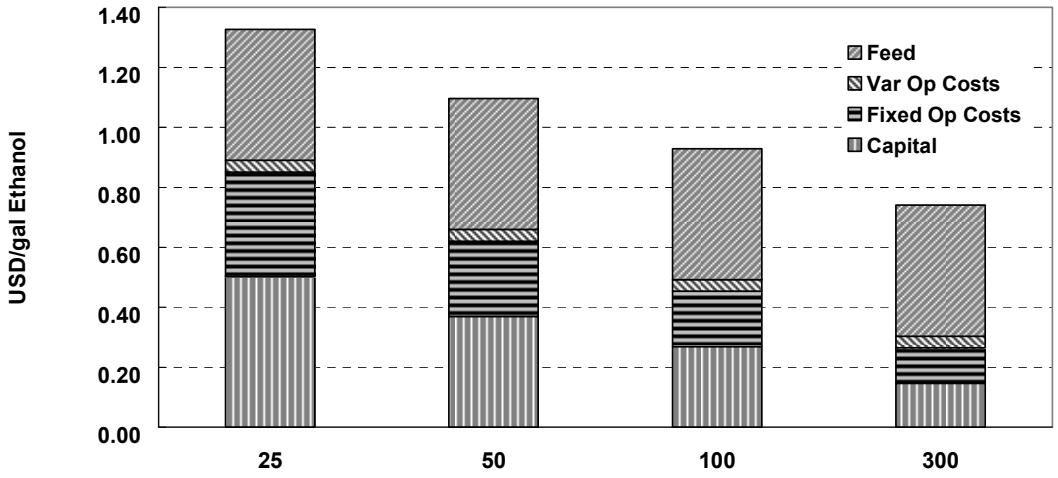


Figure 9. Cash flow, cellulosic ethanol (TC), 50 MM GPY



	25	50	100	300
Feed	0.44	0.44	0.44	0.44
Var Op Costs	0.04	0.04	0.04	0.04
Fixed Op Costs	0.35	0.25	0.18	0.12
Capital	$0.50	$0.37	$0.27	$0.15

Figure 10. Cellulosic ethanol (TC) cost contributions

Table 18. International cost location factors

Cost Variable \ Country/Region		USA	Brazil	China	India	Argentina	Colombia	Canada	Mexico	Caribbean Basin
Country Code		1	2	3	4	5	6	7	8	9
% domestic equipment		100%	80%	80%	50%	50%	50%	75%	50%	25%
% imported equipment		0%	20%	20%	50%	50%	50%	25%	50%	75%
Exchange Rate in 2005	Country = 'x" USD	1	0.425	0.124	0.022	0.328	0.438	0.859	0.094	0.131
Imported Material	Duty, %	0	14	8	65	1	1	0	7	1
	Freight, %	0	10	10	20	1	1	5	5	1
	VAT, %	0	18	17	0	1	1	13.5	10	1
Imported Material Index		1	1.42	1.35	1.85	1.25	1.25	1.07	1.22	1.25
Local Material Index		1	1.34	1.03	1.06	1.15	1.14	1.1	1.02	1.14
Labor	$/hr	20.00	4.00	6.07	2.27	7.63	5.65	24.00	2.47	8.39
USA	Productivity	1.00	2.13	3.66	3.30	2.23	2.25	1.40	1.95	2.29
	Location Cost Factor	1	1	1	1	1	1	1	1	1
Tax Rate		0.39	0.34	0.33	0.3366	0.35	0.35	0.3	0.35	0.3
Depreciation		7,20 y DDB	10% SL 4 % SL bldgs	9% SL 4.5% SL bldgs	15% SL 10% SL bldgs	10% SL 2% SL bldgs	10% SL 5% SL bldgs	10 % SL	5% SL 74% LS	10 % SL

The feedstock supply curves developed by Oak Ridge National Laboratory give costs versus supply for a base case, low growth, and high growth. The initial technology costing effort is intended to provide non-feedstock capital and operating cost information to the market modeling effort by Brookhaven National Laboratory. To gain insights on comparative technology costs one representative feedstock cost for each feedstock in each country was chosen–a pseudo-average baseline supply curve feedstock cost. These values are given in Table 19. The cellulosic feedstock supply costs from the ORNL study (ORNL 2007) were separated into bagasse, agricultural residues (primarily corn stover and wheat straw), and woody/perennial feeds. Costs of these materials by country are given in Table 20.

Table 19. Representative feedstock costs for base modeling

	Sugar Cane	Corn		Soy Beans		Wheat		Palm Oil
	$/ton	$/ton	$/bu	$/ton	$/bu	$/ton	$/bu	$/ton
USA	29.00	107.0	3.00	187.6	5.60	113.3	3.40	
Argentina	34.30	127.5	3.57	143.6	4.29	92.5	2.78	
Brazil	10.45	135.0	3.78	175.0	5.22			
Canada		86.0	2.41			102.0	3.06	
Caribbean Basin	15.00							275
Colombia	26.85							406
China	23.00	126.0	3.53	319.8	9.55	159.0	4.77	
India	15.00							
Mexico	29.00	130.0	3.64					

Table 20. Feedstock prices for bagasse, agriculture residues, and wood/perennials

Country	**Bagasse**	**Ag Residues**	**Woody /Perennial**
		(2005 USD/ST)	
USA	35.0	35.0	35.0
Argentina	9.1	47.2	47.2
Brazil	7.6	30.8	47.2
Canada	--	10.0	16.3-47.2 (31.8)
Caribbean Basin	7.6	14.5	47.2
China	9.1	28.1	47.2
Colombia	14.5	14.5	47.2
India	7.3	7.3	47.2
Mexico	15.4	47.2	47.2

3 Ethanol – Corn Dry Mill

The discussion of the corn dry mill is taken verbatim from McAloon et al. (2000). Figure 11 depicts the dry mill process. The majority of the flowsheet information was provided by Delta-T Corporation, which designs, constructs, and operates corn ethanol plants (Delta-T Corporation 1997).

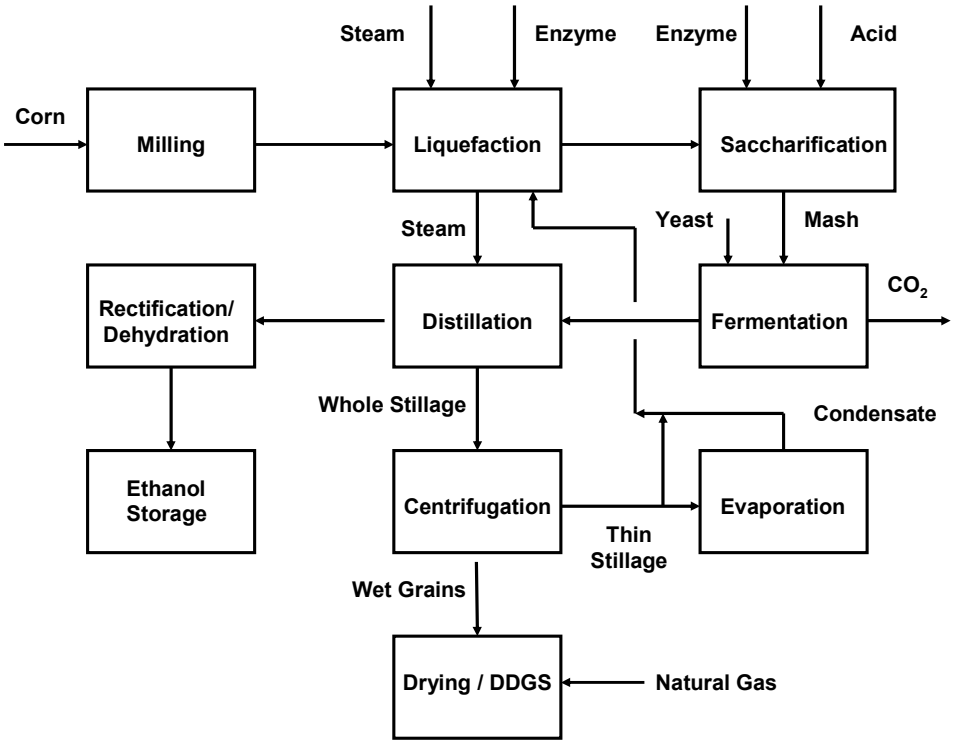


Figure 11. Corn dry mill process flow diagram

Corn is received and conveyed to two storage silos, having a combined capacity of 10 days. Stored corn is conveyed to grain-cleaning equipment where trash such as tramp metal and rocks (0.4%) is removed, and then to two hammer mills (two operating mills, plus one standby). The corn meal is metered to a continuous liquefaction tank, where it is mixed with hot evaporator condensate, and purchased alpha-amylase enzyme. The condensate is heated with steam to maintain 88°C (190°F) in the tank. Used caustic from the clean-in-place system and lime are also added to provide optimum pH (6) and calcium for the alpha-amylase. Urea is added to provide nitrogen to the yeast fermentation. After liquefaction, backset (recycled thin stillage fro the centrifuge) is added, amounting to 15 % by volume of the final mash. Then the mash is heated to 110°C (230°F), held for 20 minutes, and cooled to 60°C (140°F). Continuous saccharification takes place in a stirred tank where purchased glucoamylase is added with sulfuric acid for pH control (4.4). Residence time in the saccharification tank is 6 hours. The saccharified mash is cooled to 32°C (89°F) and fed to four continuous cascade fermentors where yeast is added. Total residence time in the fermenter is 46 hours.

Temperature is maintained below 34°C (93°F) by recirculation through two external heat exchangers, and pH is maintained above 3.5. Recirculating the off-gas through a compressor mixes the airlift fermentors. The concentration of ethanol in the whole beer leaving the fermentors is 9% by weight (12% by volume).

In liquefaction, the alpha-amylase attacks the starch polymer randomly, producing maltose (di-glucose) and higher oligomers. In saccharification, the gluco-amylase attacks the non-reducing end of maltose and higher oligomers, splitting off glucose. In addition to the alpha 1-4 linkages, there are alpha 1-6 branch points. These are attacked by pullulanase. This enzyme is probably found as a minor constituent of commercial enzymes, which are not pure enzyme preparations, but complex mixtures. The latest development in dry-mill ethanol enzymes is alpha amylase containing some protease that makes some of the corn protein available for yeast nutrition.

The whole beer is heated, degassed, and fed to the beer column. Steam and cooling water for heating and cooling of the mash, whole beer, and whole stillage are conserved by the use of heat recovery exchangers. Fermenter off-gas and vapors from degassing the whole beer are sent to a water scrubber where ethanol vapor is removed and recycled. The scrubbed CO_2 is released to the atmosphere. The whole stillage leaves the bottom of the beer column at less than 0.1% by weight ethanol. The overhead vapors pass to the bottom of the rectifier, where the concentration of the ethanol is increased from 45% to 91% by weight. The bottoms of the rectifier are pumped to the top of the stripper. The bottoms from the stripper (less than 0.1 % by weight ethanol) are recycled to the liquefaction tank along with the evaporator condensate. The concentrated vapor from the rectifier is superheated and passes through one of two dehydrating molecular sieve beds; one is used while the other is regenerated. Vapors from the regenerated bed are condensed and recycled to the rectifier. The superheated vapor passing through the molecular sieve bed contains more than 99% by weight ethanol. The product is condensed, cooled, stored, denatured with gasoline (5% by volume), and shipped. Ethanol storage is 12 days.

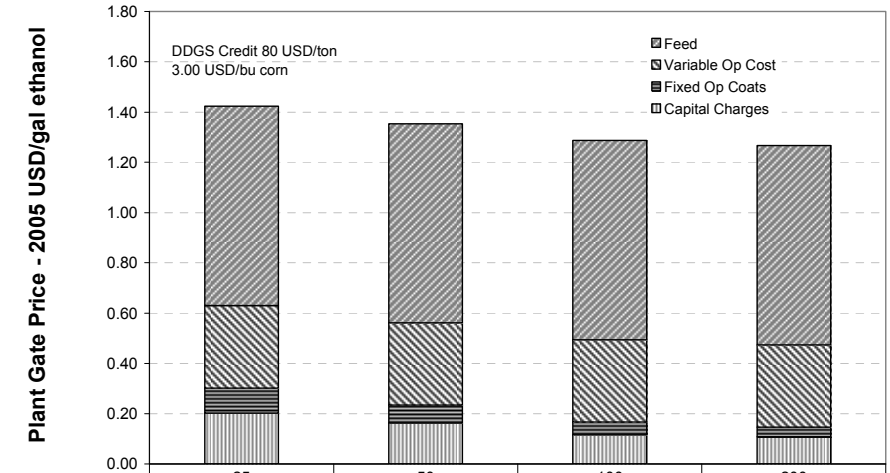
The whole stillage is partially evaporated in the first three stages of a six-effect vacuum evaporator. The partially evaporated whole stillage is separated in a decanter centrifuge (one operating plus one standby). The wet grains leave the centrifuge at 35% by weight total solids. The thin stillage from the centrifuge is partially recycled as backset, and the remainder concentrated in the three final stages of the evaporator syrup containing 55% by weight solids. To conserve steam and cooling water, the condensation of overhead vapors from the rectifier to provide reflux for distillation is accomplished in the evaporator. The syrup and wet grains are mixed and dried in a gas-fired rotary dryer. The distillers dry grains (DDG) leaving the dryer contain 9% moisture by weight. The process is designed to be essentially zero discharge. Makeup water is added only for the cooling tower and the CO_2 scrubber, and no wastewater is produced.

The base case for the corn dry-mill is the United States. Capital and operating costs (McAloon et al. 2000; Ibsen et al. 2005; Jechura 2005) are given in Table 21. A summary, based on 3 USD/bu corn is shown in Figure 12. Plant gate price decreases from 1.41 USD/gal for a 4.6 MM GPY plant to 1.25 USD/gallon for a 200 MM GPY. Corn cost is the largest component at 1.05 USD/gallon, and DDGS credit is 0.27 USD/gallon. Figure 13 shows the

impact of corn price on plant gate price for 3 plant sizes - 25, 50, and 100 MM GPY. The slope of the curves is 0.35 (USD/gallon) / (USD/bu).

Table 21. Corn dry mill capital and operating costs, USA base case

Country	USA	Code =	1				
Cost component	Units	Cost Factor	Scale Factor	USA Dry Mill Ethanol	USA Dry Mill Ethanol	USA Dry Mill Ethanol	USA Dry Mill Ethanol
Year $	$			2005	2005	2005	2005
Cost Index (2 = M&S, 3 = CE)			3	130.93	130.93	130.93	130.93
Plant Size	dry short ton/day			708	1,415	2,833	5,666
	dry tonne/day			642	1,284	2,570	5,140
Stream Factor	%			95%	95%	95%	95%
Feed	Dry short ton/yr			2.454E+05	4.908E+05	9.823E+05	1.965E+06
	GJ/short ton			1.688E+01	1.688E+01	1.688E+01	1.688E+01
	GJ/yr			4.142E+06	8.284E+06	1.658E+07	3.316E+07
Feed Cost	USD/dt			$ 107.14	$ 107.14	$ 107.14	$ 107.14
Yield (gal/Dry US Ton)							
Ethanol	gal/short ton			101.8	101.8	101.8	101.8
DDGs	dry ton/ton			0.33	0.33	0.33	0.33
Process Efficiency - to ethanol	% HHV			53.5%	53.5%	53.5%	53.5%
Process efficiency - overall	% HHV						
Ethanol	gal/yr			2.498E+07	4.996E+07	1.000E+08	2.000E+08
	Mil Gal/YR			**25.0**	**50.0**	**100.0**	**200.0**
	tpy			8.281E+04	1.656E+05	3.315E+05	6.630E+05
	GJ/yr			2.216E+06	4.433E+06	8.872E+06	1.774E+07
	gal/Stream day			7.204E+04	1.441E+05	2.884E+05	5.768E+05
	bbl/s stream day			1.715E+03	3.431E+03	6.866E+03	1.373E+04
DDGs	dry ton/yr			8.098E+04	1.620E+05	3.242E+05	6.483E+05
Corn density	lb/bu			56.0	56.0	56.0	56.0
Corn	$/bu			**3.00**	**3.00**	**3.00**	**3.00**
Corn HHV	Btu/lb			8.00E+03	8.00E+03	8.00E+03	8.00E+03
	MMBtu/ton			1.60E+01	1.60E+01	1.60E+01	1.60E+01
Capital Cost (million USD)							
Feed Handling			0.70	1.95	3.16	5.14	8.36
Saccharification			0.70	1.61	2.62	4.26	6.93
Fermentation			0.70	3.53	5.74	9.33	15.16
Distillation			0.70	3.91	6.36	10.34	16.79
Solid/Syrup Separation			0.70	8.63	14.02	22.79	37.03
Storage/Load out			0.70	1.09	1.77	2.87	4.67
Wastewater Treatment			0.70	0.52	0.85	1.37	2.23
Air compressor			0.70	0.10	0.16	0.26	0.43
Steam Gen & Cooling Water			0.70	1.37	2.22	3.61	5.87
Direct Fixed Capital (DFC), also called TIC				22.72	36.91	59.99	97.46
Engineering	DFC x MF	0.12		2.73	4.43	7.20	11.69
Construction	DFC x MF	0.13		2.95	4.80	7.80	12.67
Contractor & Legal	DFC x MF	0.08		1.82	2.95	4.80	7.80
Process/Project Contingency	DFC x MF	0.0412		0.94	1.52	2.47	4.02
Total Plant Cost (TPC)				31.15	50.61	82.26	133.63
AFUDC							
Total Plant Investment (TPI)				31.15	50.61	82.26	133.63
Land			0.60	2.21	3.35	5.08	10.16
Startup				**0**	**0.00**	**0.00**	**0.00**
Total Capital Cost (TCC)				33.36	53.96	87.34	143.79
Contingency/TPI							
Working Capital	DFC x MF	0.05		1.56	2.53	4.11	6.68
Variable Operating Costs (million USD/yr)							
Feed				26.29	52.58	105.25	210.50
Nat Gas, GJ/y	8.51E+05	6.33	USD/GJ	5.39	10.78	21.57	43.14
Electricity, kWh/y	2.01E+07	0.05	$/kWh	1.01	2.01	4.02	8.05
Catalysts and Chemicals, Misc				1.79	3.58	7.17	14.33
Total				34.48	68.95	138.01	276.02
Fixed Operating Costs (million USD/yr)							
Labor (SF from V-R)	DFC x MF	0.0255	0.25	0.58	0.69	0.82	0.97
Maintenance (3% of A)			0.03	0.68	1.11	1.80	2.92
General Overhead (65% of labor + maint)			0.65	0.82	1.17	1.70	2.53
Direct Overhead (45% of Labor)			0.45	0.26	0.31	0.37	0.44
Insurance (0.5% of TIC)			0.005	0.17	0.27	0.44	0.72
Total				2.51	3.54	5.13	7.59



	25	50	100	200
Feed	0.79	0.79	0.79	0.79
Variable Op Cost	0.33	0.33	0.33	0.33
Fixed Op Coats	0.10	0.07	0.05	0.04
Capital Charges	0.20	0.16	0.11	0.11

Plant Size - MMGPY Ethanol

Figure 12. USA base cost of ethanol, corn dry mill

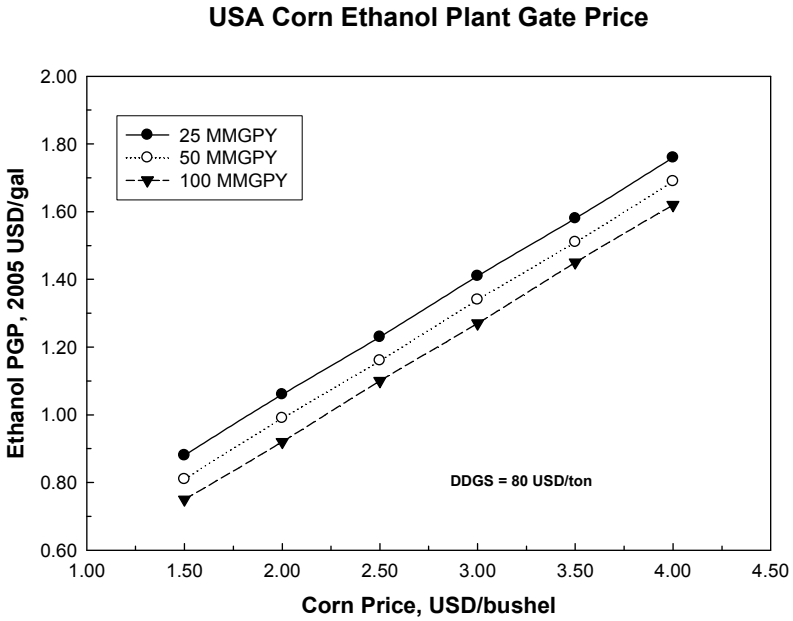


Figure 13. USA ethanol plant gate prices, impact of corn price and plant size

Capital and operating for the other countries with projected corn supplies–Argentina, Brazil, Canada, China, and Mexico–are given by Tables 22 through 26.

Table 22. Corn dry mill ethanol: Argentina capital and operating costs

Country	Argentina	Code =	5					
Cost component	Units	Cost Factor	Scale Factor	USA Dry Mill Ethanol	Argentina Dry Mill Ethanol	Argentina Dry Mill Ethanol	Argentina Dry Mill Ethanol	Argentina Dry Mill Ethanol
Year $	$			2005	2005	2005	2005	2005
Cost Index (2 = M&S, 3 = CE)			3	130.93	130.93	130.93	130.93	130.93
Plant Size	dry short ton/day			708	708	1,415	2,833	5,666
	dry tonne/day			642	642	1,284	2,570	5,140
Stream Factor	%			95%	95%	95%	95%	95%
Feed	Dry short ton/yr			2.454E+05	2.454E+05	4.908E+05	9.823E+05	1.965E+06
	GJ/short ton			1.688E+01	1.688E+01	1.688E+01	1.688E+01	1.688E+01
	GJ/yr			4.142E+06	4.142E+06	8.284E+06	1.658E+07	3.316E+07
Feed Cost	USD/dt			$ 125.00	$ 127.50	$ 127.50	$ 127.50	$ 127.50
Yield (gal/Dry US Ton)								
Ethanol	gal/short ton			101.8	101.8	101.8	101.8	101.8
DDGs	dry ton/ton			0.33	0.33	0.33	0.33	0.33
Process Efficiency - to ethanol	% HHV			53.5%	53.5%	53.5%	53.5%	53.5%
Process efficiency - overall	% HHV							
Ethanol	gal/yr			2.498E+07	2.498E+07	4.996E+07	1.000E+08	2.000E+08
	Mil Gal/YR			**25.0**	**25.0**	**50.0**	**100.0**	**200.0**
	tpy			8.281E+04	8.281E+04	1.656E+05	3.315E+05	6.630E+05
	GJ/yr			2.216E+06	2.216E+06	4.433E+06	8.872E+06	1.774E+07
	gal/Stream day			7.204E+04	7.204E+04	1.441E+05	2.884E+05	5.768E+05
	bbl/s stream day			1.715E+03	1.715E+03	3.431E+03	6.866E+03	1.373E+04
DDGs	dry ton/yr			8.098E+04	8.098E+04	1.620E+05	3.242E+05	6.483E+05
Corn density	lb/bu			56.0	56.0	56.0	56.0	56.0
Corn	$/bu			**3.50**	**3.57**	**3.57**	**3.57**	**3.57**
Corn HHV	Btu/lb			8.00E+03	8.00E+03	8.00E+03	8.00E+03	8.00E+03
	MMBtu/ton			1.60E+01	1.60E+01	1.60E+01	1.60E+01	1.60E+01
Capital Cost (million USD)								
Feed Handling			0.70	1.95	2.09	3.40	5.52	8.97
Saccharification			0.70	1.61	1.73	2.82	4.58	7.44
Fermentation			0.70	3.53	3.80	6.17	10.02	16.28
Distillation			0.70	3.91	4.20	6.83	11.10	18.03
Solid/Syrup Separation			0.70	8.63	9.27	15.06	24.47	39.76
Storage/Load out			0.70	1.09	1.17	1.90	3.09	5.01
Wastewater Treatment			0.70	0.52	0.56	0.91	1.48	2.40
Air compressor			0.70	0.10	0.11	0.17	0.28	0.46
Steam Gen & Cooling Water			0.70	1.37	1.47	2.39	3.88	6.30
Direct Fixed Capital (DFC), also called TIC				22.72	24.40	39.63	64.42	104.65
Engineering	DFC x MF	0.12		2.73	2.93	4.76	7.73	12.56
Construction	DFC x MF	0.13		2.95	3.17	5.15	8.37	13.60
Contractor & Legal	DFC x MF	0.08		1.82	1.95	3.17	5.15	8.37
Process/Project Contingency	DFC x MF	0.0412		0.94	1.01	1.63	2.65	4.31
Total Plant Cost (TPC)				31.15	33.45	54.34	88.33	143.49
AFUDC								
Total Plant Investment (TPI)				31.15	33.45	54.34	88.33	143.49
Land			0.60	2.21	2.21	3.35	5.08	10.16
Startup				**0**	**0**	**0.00**	**0.00**	**0.00**
Total Capital Cost (TCC)				33.36	35.66	57.69	93.41	153.65
Contingency/TPI								
Working Capital	DFC x MF	0.05		1.56	1.67	2.72	4.42	7.17
Variable Operating Costs (million USD/yr)								
Feed				30.67	31.29	62.57	125.24	250.49
Nat Gas, GJ/y	8.51E+05	6.33	USD/GJ	5.39	5.39	10.78	21.57	43.14
Electricity, kWh/y	2.01E+07	0.05	$/kWh	1.01	1.01	2.01	4.02	8.05
Catalysts and Chemicals, Misc				1.79	1.79	3.58	7.17	14.33
Total				38.86	39.47	78.94	158.01	316.01
Fixed Operating Costs (million USD/yr)								
Labor (SF from V-R)	DFC x MF	0.0255	0.25	0.58	0.49	0.58	0.70	0.83
Maintenance (3% of A)			0.03	0.68	0.73	1.19	1.93	3.14
General Overhead (65% of labor + maint)			0.65	0.82	0.80	1.15	1.71	2.58
Direct Overhead (45% of Labor)			0.45	0.26	0.22	0.26	0.31	0.37
Insurance (0.5% of TIC)			0.005	0.17	0.18	0.29	0.47	0.77
Total				2.51	2.42	3.48	5.12	7.68

Table 23. Corn dry mill ethanol: Brazil capital and operating costs

Country	Brazil	Code =	2					
Cost component	Units	Cost Factor	Scale Factor	USA Dry Mill Ethanol	Brazil Dry Mill Ethanol	Brazil Dry Mill Ethanol	Brazil Dry Mill Ethanol	Brazil Dry Mill Ethanol
Year $	$			2005	2005	2005	2005	2005
Cost Index (2 = M&S, 3 = CE)			3	130.93	130.93	130.93	130.93	130.93
Plant Size	dry short ton/day			708	708	1,415	2,833	5,666
	dry tonne/day			642	642	1,284	2,570	5,140
Stream Factor	%			95%	95%	95%	95%	95%
Feed	Dry short ton/yr			2.454E+05	2.454E+05	4.908E+05	9.823E+05	1.965E+06
	GJ/short ton			1.688E+01	1.688E+01	1.688E+01	1.688E+01	1.688E+01
	GJ/yr			4.142E+06	4.142E+06	8.284E+06	1.658E+07	3.316E+07
Feed Cost	USD/dt			$ 125.00	$ 134.29	$ 134.29	$ 134.29	$ 134.29
Yield (gal/Dry US Ton)								
Ethanol	gal/short ton			101.8	101.8	101.8	101.8	101.8
DDGs	dry ton/ton			0.33	0.33	0.33	0.33	0.33
Process Efficiency - to ethanol	% HHV			53.5%	53.5%	53.5%	53.5%	53.5%
Process efficiency - overall	% HHV							
Ethanol	gal/yr			2.498E+07	2.498E+07	4.996E+07	1.000E+08	2.000E+08
	Mil Gal/YR			**25.0**	**25.0**	**50.0**	**100.0**	**200.0**
	tpy			8.281E+04	8.281E+04	1.656E+05	3.315E+05	6.630E+05
	GJ/yr			2.216E+06	2.216E+06	4.433E+06	8.872E+06	1.774E+07
	gal/Stream day			7.204E+04	7.204E+04	1.441E+05	2.884E+05	5.768E+05
	bbl/s stream day			1.715E+03	1.715E+03	3.431E+03	6.866E+03	1.373E+04
DDGs	dry ton/yr			8.098E+04	8.098E+04	1.620E+05	3.242E+05	6.483E+05
Corn density	lb/bu			56.0	56.0	56.0	56.0	56.0
Corn	$/bu			**3.50**	**3.76**	**3.76**	**3.76**	**3.76**
Corn HHV	Btu/lb			8.00E+03	8.00E+03	8.00E+03	8.00E+03	8.00E+03
	MMBtu/ton			1.60E+01	1.60E+01	1.60E+01	1.60E+01	1.60E+01
Capital Cost (million USD)								
Feed Handling			0.70	1.95	1.99	3.23	5.26	8.54
Saccharification			0.70	1.61	1.65	2.68	4.36	7.08
Fermentation			0.70	3.53	3.61	5.87	9.54	15.49
Distillation			0.70	3.91	4.00	6.50	10.56	17.16
Solid/Syrup Separation			0.70	8.63	8.82	14.33	23.29	37.84
Storage/Load out			0.70	1.09	1.11	1.81	2.94	4.77
Wastewater Treatment			0.70	0.52	0.53	0.86	1.40	2.28
Air compressor			0.70	0.10	0.10	0.16	0.27	0.43
Steam Gen & Cooling Water			0.70	1.37	1.40	2.27	3.69	6.00
Direct Fixed Capital (DFC), also called TIC				22.72	23.22	37.72	61.31	99.59
Engineering	DFC x MF	0.12		2.73	2.79	4.53	7.36	11.95
Construction	DFC x MF	0.13		2.95	3.02	4.90	7.97	12.95
Contractor & Legal	DFC x MF	0.08		1.82	1.86	3.02	4.90	7.97
Process/Project Contingency	DFC x MF	0.0412		0.94	0.96	1.55	2.53	4.10
Total Plant Cost (TPC)				31.15	31.84	51.72	84.06	136.56
AFUDC								
Total Plant Investment (TPI)				31.15	31.84	51.72	84.06	136.56
Land			0.60	2.21	2.21	3.35	5.08	10.16
Startup				**0**	**0**	**0.00**	**0.00**	**0.00**
Total Capital Cost (TCC)				33.36	34.05	55.07	89.14	146.72
Contingency/TPI								
Working Capital	DFC x MF	0.05		1.56	1.59	2.59	4.20	6.83
Variable Operating Costs (million USD/yr)								
Feed				30.67	32.95	65.90	131.91	263.82
Nat Gas, GJ/y	8.51E+05	6.33	USD/GJ	5.39	5.39	10.78	21.57	43.14
Electricity, kWh/y	2.01E+07	0.05	$/kWh	1.01	1.01	2.01	4.02	8.05
Catalysts and Chemicals, Misc				1.79	1.79	3.58	7.17	14.33
Total				38.86	41.14	82.27	164.67	329.34
Fixed Operating Costs (million USD/yr)								
Labor (SF from V-R)	DFC x MF	0.0255	0.25	0.58	0.25	0.29	0.35	0.42
Maintenance (3% of A)			0.03	0.68	0.70	1.13	1.84	2.99
General Overhead (65% of labor + maint)			0.65	0.82	0.61	0.93	1.42	2.21
Direct Overhead (45% of Labor)			0.45	0.26	0.11	0.13	0.16	0.19
Insurance (0.5% of TIC)			0.005	0.17	0.17	0.28	0.45	0.73
Total				2.51	1.84	2.76	4.21	6.54

Table 24. Corn dry mill ethanol: Canada capital and operating costs

Country	Canada	Code =	7					
Cost component	Units	Cost Factor	Scale Factor	USA Dry Mill Ethanol	Canada Dry Mill Ethanol	Canada Dry Mill Ethanol	Canada Dry Mill Ethanol	Canada Dry Mill Ethanol
Year $	$			2005	2005	2005	2005	2005
Cost Index (2 = M&S, 3 = CE)			3	130.93	130.93	130.93	130.93	130.93
Plant Size	dry short ton/day			708	708	1,415	2,833	5,666
	dry tonne/day			642	642	1,284	2,570	5,140
Stream Factor	%			95%	95%	95%	95%	95%
Feed	Dry short ton/yr			2.454E+05	2.454E+05	4.908E+05	9.823E+05	1.965E+06
	GJ/short ton			1.688E+01	1.688E+01	1.688E+01	1.688E+01	1.688E+01
	GJ/yr			4.142E+06	4.142E+06	8.284E+06	1.658E+07	3.316E+07
Feed Cost	USD/dt			$ 125.00	$ 80.00	$ 80.00	$ 80.00	$ 80.00
Yield (gal/Dry US Ton)								
Ethanol	gal/short ton			101.8	101.8	101.8	101.8	101.8
DDGs	dry ton/ton			0.33	0.33	0.33	0.33	0.33
Process Efficiency - to ethanol	% HHV			53.5%	53.5%	53.5%	53.5%	53.5%
Process efficiency - overall	% HHV							
Ethanol	gal/yr			2.498E+07	2.498E+07	4.996E+07	1.000E+08	2.000E+08
	Mil Gal/YR			**25.0**	**25.0**	**50.0**	**100.0**	**200.0**
	tpy			8.281E+04	8.281E+04	1.656E+05	3.315E+05	6.630E+05
	GJ/yr			2.216E+06	2.216E+06	4.433E+06	8.872E+06	1.774E+07
	gal/Stream day			7.204E+04	7.204E+04	1.441E+05	2.884E+05	5.768E+05
	bbl/s stream day			1.715E+03	1.715E+03	3.431E+03	6.866E+03	1.373E+04
DDGs	dry ton/yr			8.098E+04	8.098E+04	1.620E+05	3.242E+05	6.483E+05
Corn density	lb/bu			56.0	56.0	56.0	56.0	56.0
Corn	$/bu			**3.50**	**2.24**	**2.24**	**2.24**	**2.24**
Corn HHV	Btu/lb			8.00E+03	8.00E+03	8.00E+03	8.00E+03	8.00E+03
	MMBtu/ton			1.60E+01	1.60E+01	1.60E+01	1.60E+01	1.60E+01
Capital Cost (million USD)								
Feed Handling			0.70	1.95	2.54	4.12	6.70	10.89
Saccharification			0.70	1.61	2.10	3.42	5.56	9.02
Fermentation			0.70	3.53	4.61	7.48	12.16	19.75
Distillation			0.70	3.91	5.10	8.29	13.47	21.88
Solid/Syrup Separation			0.70	8.63	11.25	18.27	29.70	48.24
Storage/Load out			0.70	1.09	1.42	2.30	3.75	6.09
Wastewater Treatment			0.70	0.52	0.68	1.10	1.79	2.91
Air compressor			0.70	0.10	0.13	0.21	0.34	0.55
Steam Gen & Cooling Water			0.70	1.37	1.78	2.90	4.71	7.65
Direct Fixed Capital (DFC), also called TIC				22.72	29.60	48.09	78.17	126.98
Engineering	DFC x MF	0.12		2.73	3.55	5.77	9.38	15.24
Construction	DFC x MF	0.13		2.95	3.85	6.25	10.16	16.51
Contractor & Legal	DFC x MF	0.08		1.82	2.37	3.85	6.25	10.16
Process/Project Contingency	DFC x MF	0.0412		0.94	1.22	1.98	3.22	5.23
Total Plant Cost (TPC)				31.15	40.59	65.94	107.18	174.12
AFUDC								
Total Plant Investment (TPI)				31.15	40.59	65.94	107.18	174.12
Land			0.60	2.21	2.21	3.35	5.08	10.16
Startup				**0**	**0**	**0.00**	**0.00**	**0.00**
Total Capital Cost (TCC)				33.36	42.80	69.29	112.26	184.28
Contingency/TPI								
Working Capital	DFC x MF	0.05		1.56	2.03	3.30	5.36	8.71
Variable Operating Costs (million USD/yr)								
Feed				30.67	19.63	39.26	78.58	157.17
Nat Gas, GJ/y	8.51E+05	6.33	USD/GJ	5.39	5.39	10.78	21.57	43.14
Electricity, kWh/y	2.01E+07	0.05	$/kWh	1.01	1.01	2.01	4.02	8.05
Catalysts and Chemicals, Misc				1.79	1.79	3.58	7.17	14.33
Total				38.86	27.81	55.63	111.35	222.69
Fixed Operating Costs (million USD/yr)								
Labor (SF from V-R)	DFC x MF	0.0255	0.25	0.58	0.97	1.16	1.38	1.64
Maintenance (3% of A)			0.03	0.68	0.89	1.44	2.35	3.81
General Overhead (65% of labor + maint)			0.65	0.82	1.21	1.69	2.42	3.54
Direct Overhead (45% of Labor)			0.45	0.26	0.44	0.52	0.62	0.74
Insurance (0.5% of TIC)			0.005	0.17	0.21	0.35	0.56	0.92
Total				2.51	3.72	5.16	7.32	10.64

Table 25. Corn dry mill ethanol: China capital and operating costs

Country **China** **Code =** 3

Cost component	Units	Cost Factor	Scale Factor	USA Dry Mill Ethanol	China Dry Mill Ethanol	China Dry Mill Ethanol	China Dry Mill Ethanol	China Dry Mill Ethanol
Year $	$			2005	2005	2005	2005	2005
Cost Index (2 = M&S, 3 = CE)			3	130.93	130.93	130.93	130.93	130.93
Plant Size	dry short ton/day			708	708	1,415	2,833	5,666
	dry tonne/day			642	642	1,284	2,570	5,140
Stream Factor	%			95%	95%	95%	95%	95%
Feed	Dry short ton/yr			2.454E+05	2.454E+05	4.908E+05	9.823E+05	1.965E+06
	GJ/short ton			1.688E+01	1.688E+01	1.688E+01	1.688E+01	1.688E+01
	GJ/yr			4.142E+06	4.142E+06	8.284E+06	1.658E+07	3.316E+07
Feed Cost	USD/dt			$ 125.00	$ 126.43	$ 126.43	$ 126.43	$ 126.43
Yield (gal/Dry US Ton)								
Ethanol	gal/short ton			101.8	101.8	101.8	101.8	101.8
DDGs	dry ton/ton			0.33	0.33	0.33	0.33	0.33
Process Efficiency - to ethanol	% HHV			53.5%	53.5%	53.5%	53.5%	53.5%
Process efficiency - overall	% HHV							
Ethanol	gal/yr			2.498E+07	2.498E+07	4.996E+07	1.000E+08	2.000E+08
	Mil Gal/YR			**25.0**	**25.0**	**50.0**	**100.0**	**200.0**
	tpy			8.281E+04	8.281E+04	1.656E+05	3.315E+05	6.630E+05
	GJ/yr			2.216E+06	2.216E+06	4.433E+06	8.872E+06	1.774E+07
	gal/Stream day			7.204E+04	7.204E+04	1.441E+05	2.884E+05	5.768E+05
	bbl/s stream day			1.715E+03	1.715E+03	3.431E+03	6.866E+03	1.373E+04
DDGs	dry ton/yr			8.098E+04	8.098E+04	1.620E+05	3.242E+05	6.483E+05
Corn density	lb/bu			56.0	56.0	56.0	56.0	56.0
Corn	$/bu			**3.50**	**3.54**	**3.54**	**3.54**	**3.54**
Corn HHV	Btu/lb			8.00E+03	8.00E+03	8.00E+03	8.00E+03	8.00E+03
	MMBtu/ton			1.60E+01	1.60E+01	1.60E+01	1.60E+01	1.60E+01
Capital Cost (million USD)								
Feed Handling			0.70	1.95	2.14	3.48	5.66	9.19
Saccharification			0.70	1.61	1.78	2.89	4.69	7.62
Fermentation			0.70	3.53	3.89	6.32	10.27	16.68
Distillation			0.70	3.91	4.31	7.00	11.37	18.48
Solid/Syrup Separation			0.70	8.63	9.50	15.43	25.08	40.75
Storage/Load out			0.70	1.09	1.20	1.95	3.16	5.14
Wastewater Treatment			0.70	0.52	0.57	0.93	1.51	2.46
Air compressor			0.70	0.10	0.11	0.18	0.29	0.47
Steam Gen & Cooling Water			0.70	1.37	1.51	2.45	3.98	6.46
Direct Fixed Capital (DFC), also called TIC				22.72	25.00	40.62	66.02	107.25
Engineering	DFC x MF	0.12		2.73	3.00	4.87	7.92	12.87
Construction	DFC x MF	0.13		2.95	3.25	5.28	8.58	13.94
Contractor & Legal	DFC x MF	0.08		1.82	2.00	3.25	5.28	8.58
Process/Project Contingency	DFC x MF	0.0412		0.94	1.03	1.67	2.72	4.42
Total Plant Cost (TPC)				31.15	34.28	55.69	90.52	147.06
AFUDC								
Total Plant Investment (TPI)				31.15	34.28	55.69	90.52	147.06
Land			0.60	2.21	2.21	3.35	5.08	10.16
Startup				**0**	**0**	**0.00**	**0.00**	**0.00**
Total Capital Cost (TCC)				33.36	36.49	59.04	95.60	157.22
Contingency/TPI								
Working Capital	DFC x MF	0.05		1.56	1.71	2.78	4.53	7.35
Variable Operating Costs (million USD/yr)								
Feed				30.67	31.02	62.05	124.19	248.38
Nat Gas, GJ/y	8.51E+05	6.33	USD/GJ	5.39	5.39	10.78	21.57	43.14
Electricity, kWh/y	2.01E+07	0.05	$/kWh	1.01	1.01	2.01	4.02	8.05
Catalysts and Chemicals, Misc				1.79	1.79	3.58	7.17	14.33
Total				38.86	39.21	78.42	156.95	313.91
Fixed Operating Costs (million USD/yr)								
Labor (SF from V-R)	DFC x MF	0.0255	0.25	0.58	0.64	0.77	0.91	1.08
Maintenance (3% of A)			0.03	0.68	0.75	1.22	1.98	3.22
General Overhead (65% of labor + maint)			0.65	0.82	0.91	1.29	1.88	2.80
Direct Overhead (45% of Labor)			0.45	0.26	0.29	0.34	0.41	0.49
Insurance (0.5% of TIC)			0.005	0.17	0.18	0.30	0.48	0.79
Total				2.51	2.77	3.91	5.66	8.37

Table 26. Corn dry-mill ethanol: Mexico capital and operating costs

Country	Mexico	Code =	8					
Cost component	Units	Cost Factor	Scale Factor	USA Dry Mill Ethanol	Mexico Dry Mill Ethanol	Mexico Dry Mill Ethanol	Mexico Dry Mill Ethanol	Mexico Dry Mill Ethanol
Year $	$			2005	2005	2005	2005	2005
Cost Index (2 = M&S, 3 = CE)			3	130.93	130.93	130.93	130.93	130.93
Plant Size	dry short ton/day			708	708	1,415	2,833	5,666
	dry tonne/day			642	642	1,284	2,570	5,140
Stream Factor	%			95%	95%	95%	95%	95%
Feed	Dry short ton/yr			2.454E+05	2.454E+05	4.908E+05	9.823E+05	1.965E+06
	GJ/short ton			1.688E+01	1.688E+01	1.688E+01	1.688E+01	1.688E+01
	GJ/yr			4.142E+06	4.142E+06	8.284E+06	1.658E+07	3.316E+07
Feed Cost	USD/dt			$ 125.00	$ 113.57	$ 113.57	$ 113.57	$ 113.57
Yield (gal/Dry US Ton)								
Ethanol	gal/short ton			101.8	101.8	101.8	101.8	101.8
DDGs	dry ton/ton			0.45	0.45	0.45	0.45	0.45
Process Efficiency - to ethanol	% HHV			53.5%	53.5%	53.5%	53.5%	53.5%
Process efficiency - overall	% HHV							
Ethanol	gal/yr			2.498E+07	2.498E+07	4.996E+07	1.000E+08	2.000E+08
	Mil Gal/YR			**25.0**	**25.0**	**50.0**	**100.0**	**200.0**
	tpy			8.281E+04	8.281E+04	1.656E+05	3.315E+05	6.630E+05
	GJ/yr			2.216E+06	2.216E+06	4.433E+06	8.872E+06	1.774E+07
	gal/Stream day			7.204E+04	7.204E+04	1.441E+05	2.884E+05	5.768E+05
	bbl/s stream day			1.715E+03	1.715E+03	3.431E+03	6.866E+03	1.373E+04
DDGs	dry ton/yr			8.559E+04	8.559E+04	1.712E+05	3.426E+05	6.852E+05
Corn density	lb/bu			56.0	56.0	56.0	56.0	56.0
Corn	$/bu			**3.50**	**3.18**	**3.18**	**3.18**	**3.18**
Corn HHV	Btu/lb			8.00E+03	8.00E+03	8.00E+03	8.00E+03	8.00E+03
	MMBtu/ton			1.60E+01	1.60E+01	1.60E+01	1.60E+01	1.60E+01
Capital Cost (million USD)								
Feed Handling			0.70	1.95	1.57	2.55	4.14	6.72
Saccharification			0.70	1.61	1.30	2.11	3.43	5.57
Fermentation			0.70	3.53	2.84	4.62	7.51	12.19
Distillation			0.70	3.91	3.15	5.12	8.31	13.51
Solid/Syrup Separation			0.70	8.63	6.94	11.28	18.33	29.78
Storage/Load out			0.70	1.09	0.88	1.42	2.31	3.76
Wastewater Treatment			0.70	0.52	0.42	0.68	1.11	1.80
Air compressor			0.70	0.10	0.08	0.13	0.21	0.34
Steam Gen & Cooling Water			0.70	1.37	1.10	1.79	2.91	4.72
Direct Fixed Capital (DFC), also called TIC				22.72	18.28	29.69	48.25	78.39
Engineering	DFC x MF	0.12		2.73	2.19	3.56	5.79	9.41
Construction	DFC x MF	0.13		2.95	2.38	3.86	6.27	10.19
Contractor & Legal	DFC x MF	0.08		1.82	1.46	2.38	3.86	6.27
Process/Project Contingency	DFC x MF	0.0412		0.94	0.75	1.22	1.99	3.23
Total Plant Cost (TPC)				31.15	25.06	40.71	66.17	107.49
AFUDC								
Total Plant Investment (TPI)				31.15	25.06	40.71	66.17	107.49
Land			0.60	2.21	2.21	3.35	5.08	10.16
Startup								
Total Capital Cost (TCC)				33.36	27.27	44.06	71.25	117.65
Contingency/TPI								
Working Capital	DFC x MF	0.05		1.56	1.25	2.04	3.31	5.37
Variable Operating Costs (million USD/yr)								
Feed				30.67	27.87	55.74	111.56	223.13
Nat Gas, GJ/y	8.51E+05	6.33	USD/GJ	5.39	5.39	10.78	21.57	43.14
Electricity, kWh/y	2.01E+07	0.05	$/kWh	1.01	1.01	2.01	4.02	8.05
Catalysts and Chemicals, Misc				1.79	1.79	3.58	7.17	14.33
Total				38.86	36.05	72.11	144.32	288.65
Fixed Operating Costs (million USD/yr)								
Labor (SF from V-R)	DFC x MF	0.0255	0.25	0.58	0.14	0.17	0.20	0.24
Maintenance (3% of A)			0.03	0.68	0.55	0.89	1.45	2.35
General Overhead (65% of labor + maint)			0.65	0.82	0.45	0.69	1.07	1.68
Direct Overhead (45% of Labor)			0.45	0.26	0.06	0.07	0.09	0.11
Insurance (0.5% of TIC)			0.005	0.17	0.14	0.22	0.36	0.59
Total				2.51	1.33	2.04	3.16	4.96
Capital Cost (TI)	USD/annual gal			0.91	0.73	0.59	0.48	0.39
	USD/daily bbl			13246	10654	8654	7028	5708
	USD/annual gal EtOH			0.91	0.73	0.59	0.48	0.39
	USD/daily bbl EtOH eq			13,246	10,654	8,654	7,028	5,708
	USD/daily bbl COE			21,751	17,495	14,211	11,540	9,373
Variable Operating Cost	USD/gal			1.56	1.44	1.44	1.44	1.44
Fixed Operating Cost	USD/gal			0.10	0.05	0.04	0.03	0.02
Feed	USD/gal			1.23	1.12	1.12	1.12	1.12
DDG Credit			80	0.27	0.27	0.27	0.27	0.27

The capital and operating costs given in Tables 22 through 26 were used to generate plant gate costs for each country using representative corn prices. The corn price selected was taken from (ORNL 2007), assuming the corn price at 50% of 2017 maximum supply potential for low, base, and high growth scenarios. Corn production in billions of bushels (50% of maximum) is given by Table 27. For comparison, USA corn production in 2006 was 10.5 billion bushels (NCGA 2007).

Table 27. Country corn production in 2017 (50% of maximum supply)

	Low	Base	High
		Billion bushels	
Argentina	0.303	0.484	0.917
Brazil	0.850	1.063	1.413
Canada	0.185	0.315	0.425
China	3.283	3.937	4.764
Mexico	0.425	0.528	0.655
Conversion Factor: 0.0394 bil bu/MMT			

Table 28 and Table 29 give the corresponding corn prices at 50% production in USD/short ton, and USD/ bu, respectively.

Table 28. 2017 Corn prices (50% of maximum supply) in USD/short ton

	Low	Base	High
		USD/short ton	
Argentina	127.50	127.50	127.50
Brazil	99.06	134.40	128.64
Canada	80.02	80.02	80.02
China	126.50	126.50	126.50
Mexico	117.70	113.60	113.60
Conversion Factor:		35.71	bu/short ton

Table 29. 2017 Corn prices (50% of maximum supply) in USD/bushel

	Low	Base	High
		USD/bushel	
Argentina	3.57	3.57	3.57
Brazil	2.77	3.76	3.60
Canada	2.24	2.24	2.24
China	3.54	3.54	3.54
Mexico	3.30	3.18	3.18
Conversion Factor:		35.71	bu/short ton

These values were used to calculate plant gate prices. The summary results are given in Table 30 (25 MM GPY) and Table 31. Figure 14 presents the PGP results graphically.

Table 30. Country summary costs, 25 MM GPY plant

Ethanol-Corn Dry Mill	Units	USA	Argentina	Brazil	Canada	Caribbean Basin	China	Colombia	India	Mexico
Plant Size	MM gal/yr	25	25	25	25		25			25
Yields										
Primary Product Yield	gal/ton	101.8	101.8	101.8	101.8		101.8			101.8
By Product A		DDG	DDG	DDG	DDG		DDG			DDG
Unit		ton	ton	ton	ton		ton			ton
Annual Yield		8.10E+04	8.10E+04	8.10E+04	8.10E+04		8.10E+04			8.10E+04
Price unit		80	80	80	80		80			80
MM USD/yr		6.48	6.48	6.48	6.48		6.48			6.48
By Product B										
Unit										
Annual Yield										
Price unit										
Annual Cost	MM USD/yr									
Energy Inputs										
Electricity										
Cost	$/kWh	0.05	0.05	0.05	0.05		0.05			0.05
Amount	kWh/yr	2.01E+07	2.01E+07	2.01E+07	2.01E+07		2.01E+07			2.01E+07
Annual Cost	MM USD/yr	1.01E+00	1.01E+00	1.01E+00	1.01E+00		1.01E+00			1.01E+00
Fuel										
Type		Nat Gas	Nat Gas	Nat Gas	Nat Gas		Nat Gas			Nat Gas
Unit		GJ	GJ	GJ	GJ		GJ			GJ
Amount		8.51E+05	8.51E+05	8.51E+05	8.51E+05		8.51E+05			8.51E+05
Cost	USD/unit	6.33	6.33	6.33	6.33		6.33			6.33
Annual Cost	MM USD/yr	5.39	5.39	5.39	5.39		5.39			5.39
Capital & Operating Costs										
Capital	MMUSD	33.36	35.66	34.05	42.80		36.94			27.27
Operating w/o feed	MM USD/yr	10.69	10.6	10.02	11.9		10.95			9.51
Feed										
Unit		ton								
Cost/unit	USD/unit	107.14	127.5	134.29	80		124.63			113.57
	USD/bu	3.00	3.57	3.76	2.24		3.54			3.18
Rate	unit/day	642	642	642	642		642			642
Yearly Cost	MM USD/yr	26.29	31.29	32.95	19.63		31.02			31.02
Product Plant Gate Cost										
Basis		USTL	10 SL	10 SL	10 SL		10 SL			5 SL
Value	USD/gal	1.42	1.63	1.66	1.24		1.63			1.41

Table 31. Country summary costs, 100 MM GPY plant

Ethanol-Corn Dry Mill	Units	USA	Argentina	Brazil	Canada	Caribbean Basin	China	Colombia	India	Mexico
Plant Size	MM gal/yr	100	100	100	100		100			100
Yields										
Primary Product Yield	gal/ton	101.8	101.8	101.8	101.8		101.8			101.8
By Product A										
Unit		DDG	DDG	DDG	DDG		DDG			DDG
Yield unit		ton	ton	ton	ton		ton			ton
Annual Yield		3.242E+05	3.242E+05	3.242E+05	3.242E+05		3.242E+05			3.242E+05
Price unit		80.00	80.00	80.00	80.00		80.00			80.00
MM USD/yr		25.93	25.93	25.93	25.93		25.93			25.93
By Product B										
Yield unit										
Annual Yield										
Price unit										
Annual Cost	MM USD/yr									
Energy Inputs										
Electricity										
Cost	$/kWh	0.05	0.05	0.05	0.05		0.05			0.05
Amount	kWh/yr	8.04E+07	8.04E+07	8.04E+07	8.04E+07		8.04E+07			8.04E+07
Annual Cost	MM USD/yr	4.02	4.02	4.02	4.02		4.02			4.02
Fuel										
Type		Nat Gas	Nat Gas	Nat Gas	Nat Gas		Nat Gas			Nat Gas
Unit		GJ/yr	GJ/yr	GJ/yr	GJ/yr		GJ/yr			GJ/yr
Amount		3.40E+06	3.40E+06	3.40E+06	3.40E+06		3.40E+06			3.40E+06
Cost	USD/unit	6.33	6.33	6.33	6.33		6.33			6.33
Annual Cost	MM USD/yr	21.67	21.67	21.67	21.67		21.67			21.67
Capital & Operating Costs										
Capital	MMUSD	87.34	93.41	89.14	112.26		95.60			71.25
Operating w/o feed	MM USD/yr	37.89	37.88	36.97	40.08		38.42			32.76
Feed										
Unit		d ton	d ton	d ton	d ton		d ton			d ton
Cost/unit	USD/unit	107.14	127.5	134.29	80		124.63			113.57
	USD/bu	3.00	3.57	5.76	2.24		3.54			3.18
Rate	unit/day	2570	2570	2570	2570		2570			2570
Yearly Cost	MM USD/yr	107.14	125.24	131.91	78.58		124.19			124.19
Product Plant Gate Cost										
Basis		USTL	10 SL	10 SL	10 SL		10 SL			5 SL
Value	USD/gal	1.29	1.49	1.54	1.06		1.48			1.31

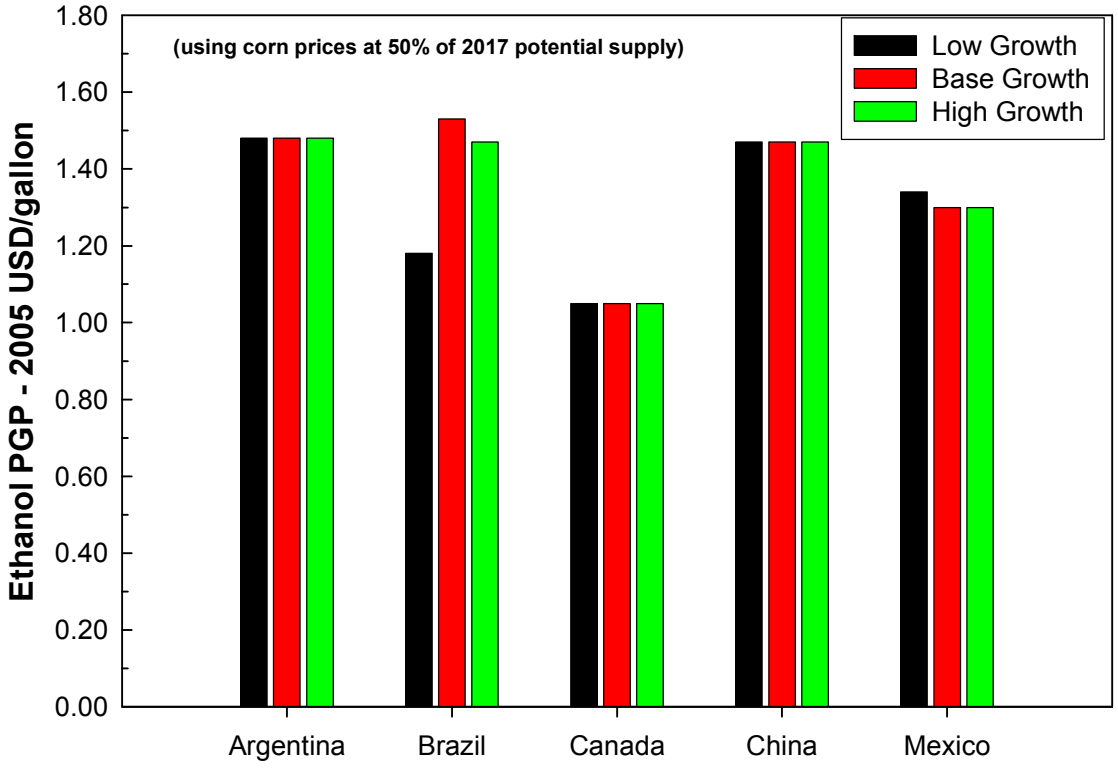


Figure 14. Country 2017 corn dry mill ethanol plant gate prices at 50% of corn supply

4 Ethanol – Sugar Cane Mill

A review of the literature and personal communications (Turn 2007) showed no published information for estimates of capital and operating costs of an integrated sugar-ethanol mill in the United States. Therefore, Brazil was chosen as the base case model. A process flow diagram for a prototypical Brazilian mill is shown in Figure 15. The mill operator has the ability to change the amount of sucrose going to sugar and the amount going to ethanol depending upon market demands and the relative prices of sugar and ethanol. A review of the literature on the Brazilian sugar industry and personal communication (Walter 2007) showed no published detailed capital cost estimates for integrated sugar-ethanol mills. Two references (Bohlmann 2006, van den Wall Bake 2006) gave overall capital cost values, but a review of their literature sources showed the data were taken from a non-published report. Therefore, the total installed cost (TIC) data given by Bohlmann were used to generate a capital cost curve, Figure 16, for a Brazilian base case.

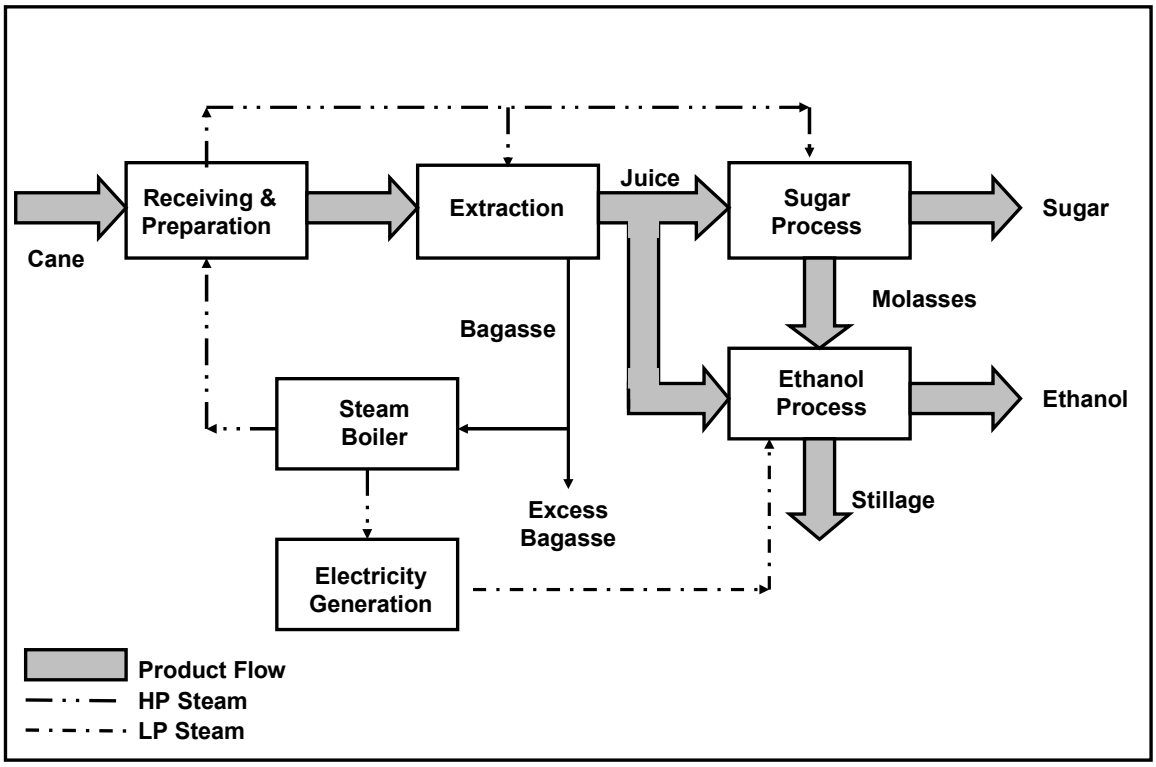


Figure 15. Brazilian sugar mill model (Oliverio and Ribeiro 2006)

The curve fit of the data was used to estimate TIC costs for a base mill and the procedure outlined in the methodology section was then followed to estimate capital and operating costs for the suite of countries. The prototypical mill produces both sugar and ethanol. The financial analysis can be performed two ways. Either a known plant gate price for one of the products can be used and the second calculated, or both can be calculated. In the second case a protocol is needed for the estimate. In this study the energy contents of sugar and ethanol are used to estimate yearly total product energy content; the product price in USD/GJ is

estimated using a NPV=0 calculation; and then separate product prices are estimated based on energy content.

A number of operating variables need to be assumed to estimate plant gate prices for sugar and ethanol. Included are cane sugar content, sugar recovery efficiency, ethanol recovery efficiency, ratio of ethanol to sugar production, and plant stream factor. The values selected are those given by Oliverio (2006) for a state-of-the-art Brazilian mill; 97% sugar recovery and 90% sugar to ethanol conversion efficiency. A cane sugar content of 14% (Rosillo-Calle et al. 2000, Bohlmann 2006) and a stream factor of 50% are used for the initial set of comparisons. The ethanol/sugar ratio is set at 60/40, which is about the maximum historical ratio (van den Wall Bake 2006). Additional work is needed to determine capacity factors for individual countries. For example, mill operation in the United States can range from 2 months in some Louisiana mills to 11 months in some Hawaii mills.

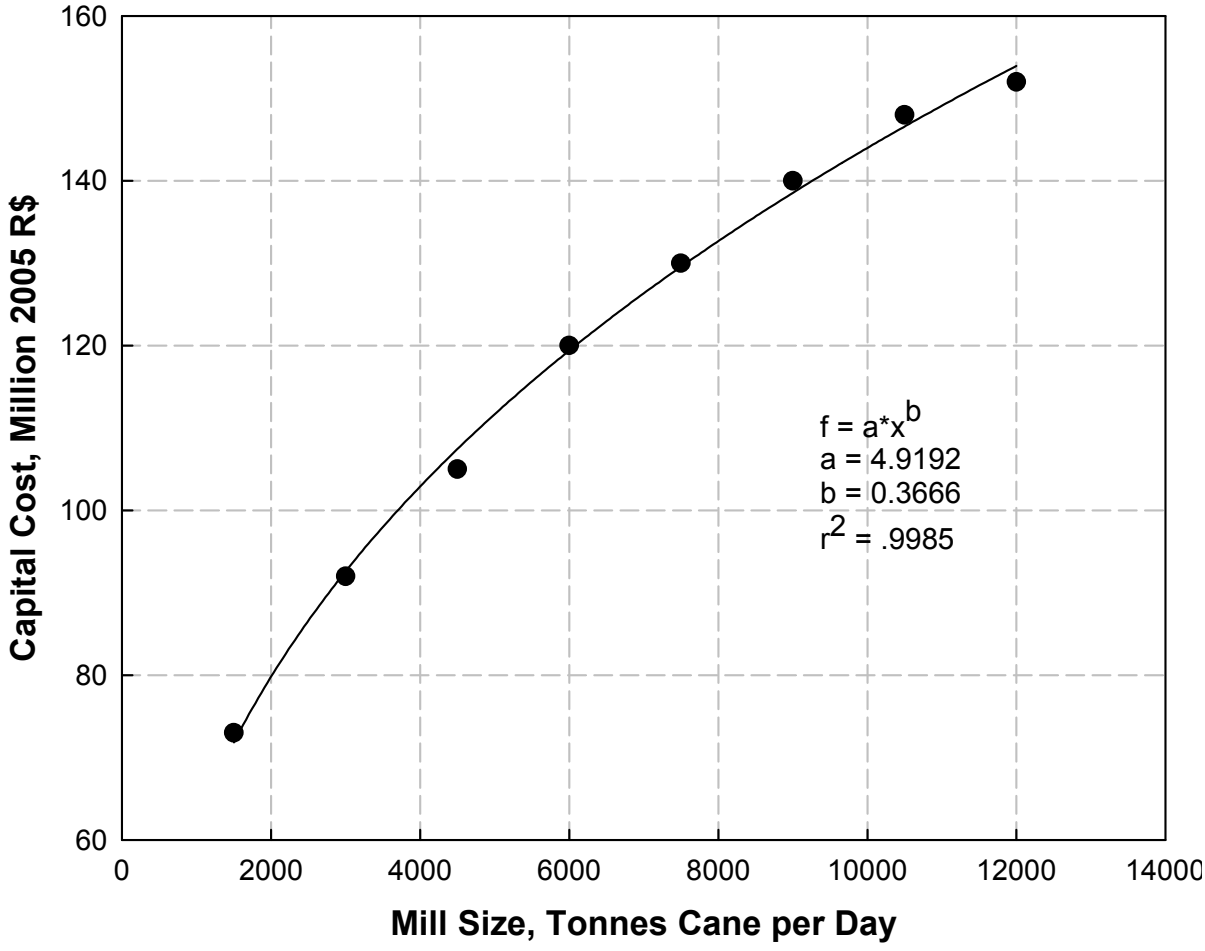


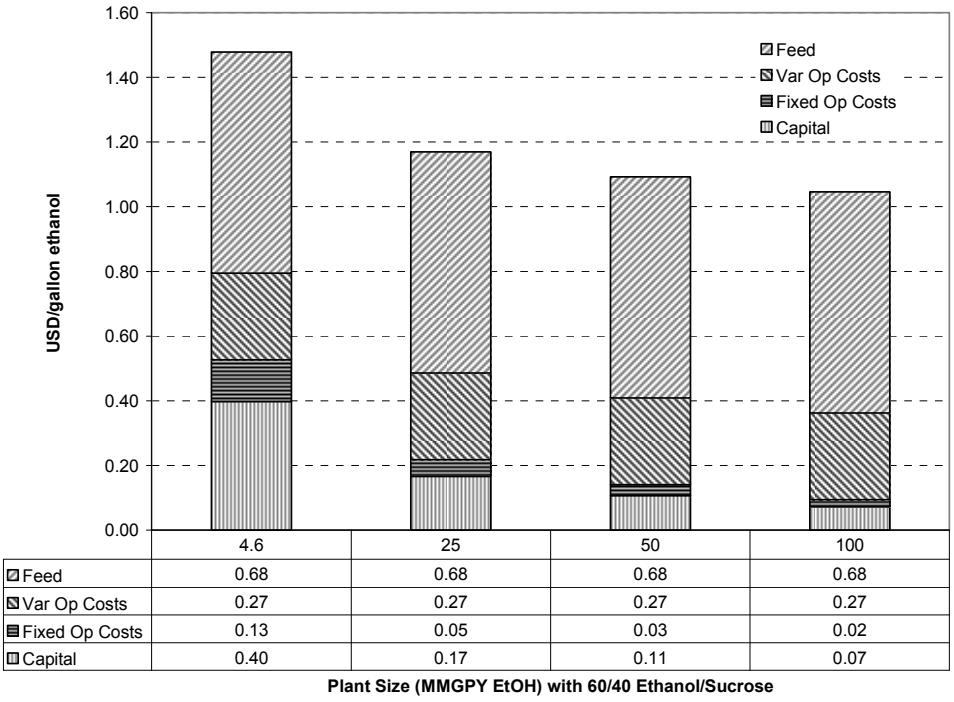
Figure 16. Brazilian sugar mill capital costs, Bohlmann (2006)

The Brazilian base case model was used to evaluate the cost of production versus plant size for the representative feedstock case from the methodology section, and the results are shown in Figure 17. Plant gate costs (10.45 USD/short ton) decrease from 1.27 USD/gallon for a

small 4.6 MM GPY plant to 0.84 USD/gallon for a 100 MM GPY plant. As plant size increases, the feedstock cost becomes a larger percentage of plant gate cost, increasing from about 38% for the 4.6 MM GPY plant to 57% for the 100 MM GPY plant.

The ORNL Brazil supply curves were used to estimate plant gate costs as a function of supply for the 2017 low, base, and high growth scenarios. The results are shown in Figure 18. Capital and operating costs estimates for the eight countries are given by Table 32 through Table 39.

Summary cost information for three plant sizes, 25, 50, and 100 MM GPY is given in Table 40- Table 42.



	4.6	25	50	100
Feed	0.68	0.68	0.68	0.68
Var Op Costs	0.27	0.27	0.27	0.27
Fixed Op Costs	0.13	0.05	0.03	0.02
Capital	0.40	0.17	0.11	0.07

Figure 17. Brazil sugar cane ethanol cost contributions

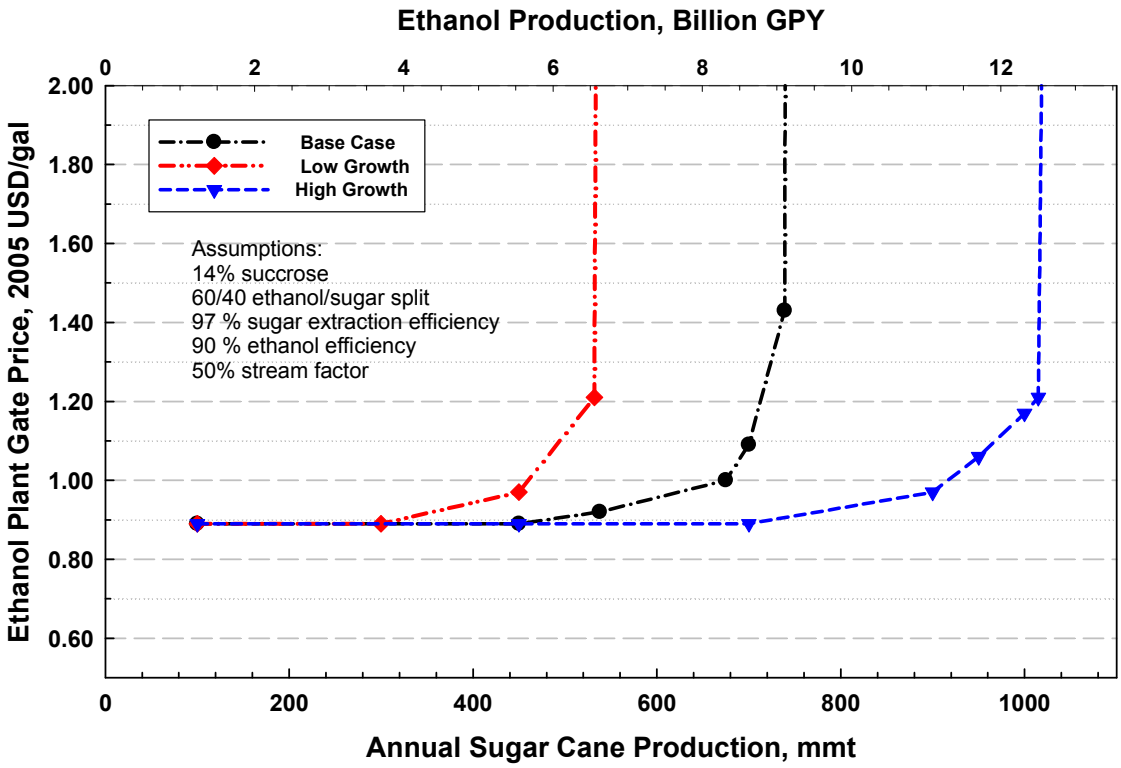


Figure 18. Brazil ethanol potential (based on 07-25-2007 ORNL Supply Curves Table 1-3)

Table 32. Capital and operating costs, Brazil sugar-ethanol mill

Country	Brazil	Code =	2				
Cost component	**Units**	**Cost Factor**	**Scale Factor**	**Brazil Sugar Mill**	**Brazil Sugar Mill**	**Brazil Sugar Mill**	**Brazil Sugar Mill**
Year $	$			2005	2005	2005	2005
Cost Index (2 = M&S, 3 = CE)			3	130.93	130.93	130.93	130.93
Plant Size	dry short ton/day			2,206	11,118	22,236	44,473
	dry tonne/day			2,000	10,080	20,160	40,320
Stream Factor	%			**50%**	**50%**	**50%**	**50%**
Feed	Dry short ton/yr			4.026E+05	2.029E+06	4.058E+06	8.116E+06
	GJ/short ton						
	GJ/yr			0.000E+00	0.000E+00	0.000E+00	0.000E+00
Feed Cost	USD/dt			**$ 10.45**	**$ 10.45**	**$ 10.45**	**$ 10.45**
Yield (gal/Dry US Ton)							
Ethanol	gal/short ton			12.32	12.32	12.32	12.32
Sugar	ton/short ton			0.057	0.057	0.057	0.057
Process Efficiency - to ethanol	% HHV						
Process efficiency - overall	% HHV						
Ethanol	gal/yr			4.960E+06	2.500E+07	5.000E+07	1.000E+08
	Mil Gal/YR			**4.96**	**25.00**	**50.00**	**100.00**
	tpy			1.639E+04	8.263E+04	1.653E+05	3.305E+05
	GJ/yr			4.401E+05	2.218E+06	4.436E+06	8.873E+06
	gal/Stream day			2.718E+04	1.370E+05	2.740E+05	5.480E+05
	bbl/s stream day			6.472E+02	3.262E+03	6.523E+03	1.305E+04
Sugar, GJ/yr	14.877	GJ/yr		3.427E+05	1.727E+06	3.454E+06	6.908E+06
Sugar (glucose +fructose)	ton/yr			2.30E+04	1.16E+05	2.32E+05	4.64E+05
Sugar Cane - Sucrose Content		wt %		14.00%	14.00%	14.00%	14.00%
Ethanol/sugar Split		%		**60%**	**60%**	**60%**	**60%**
Sugar extraction efficiency		%		97.0%	97.0%	97.0%	97.0%
Ethanol Production efficiency		%		90.0%	90.0%	90.0%	90.0%
lb ethanol/lb sucrose to ethanol train	0.5386	lb/lb		0.4848	0.4848	0.4848	0.4848
Capital Cost (million USD)							
Total Capital			0.38	15.33	33.54	43.65	56.80
Direct Fixed Capital (DFC), also called TIC				15.33	33.54	43.65	56.80
Engineering	DFC x MF	0.12		1.84	4.03	5.24	6.82
Construction	DFC x MF	0.13		1.99	4.36	5.67	7.38
Contractor & Legal	DFC x MF	0.08		1.23	2.68	3.49	4.54
Process/Project Contingency	DFC x MF	0.0412		0.63	1.38	1.80	2.34
Total Plant Cost (TPC)				21.02	45.99	59.85	77.89
AFUDC							
Total Plant Investment (TPI)				21.02	45.99	59.85	77.89
Land			0.20	2.21	3.05	3.51	7.02
Startup				0.00	0.00	0.00	0.00
Total Capital Cost (TCC)				23.23	49.05	63.36	84.91
Contingency/TPI							
Working Capital	DFC x MF	0.05		1.05	2.30	2.99	3.89
Variable Operating Costs (million USD/yr)							
Feed				4.21	21.20	42.41	84.82
Utilities				0.36	1.79	3.58	7.16
Other				1.18	5.96	11.93	23.86
Catalysts and Chemicals				0.83	4.18	8.35	16.70
Total				6.57	33.13	66.27	132.53
Fixed Operating Costs (million USD/yr)							
Labor (SF from V-R)	DFC x MF	0.0165	0.25	0.12	0.19	0.22	0.26
Maintenance (3% of A)			0.03	0.46	1.01	1.31	1.70
General Overhead (65% of labor + maint)			0.65	0.38	0.78	1.00	1.28
Direct Overhead (45% of Labor)			0.45	0.06	0.08	0.10	0.12
Insurance (0.5% of TIC)			0.005	0.12	0.25	0.32	0.42
Total				1.14	2.30	2.94	3.79

Table 33. Capital and operating costs, Argentina sugar-ethanol mill

Country	Argentina	Code =	5				
Cost component	**Units**	**Cost Factor**	**Scale Factor**	**Argentina Sugar Mill**	**Argentina Sugar Mill**	**Argentina Sugar Mill**	**Argentina Sugar Mill**
Year $	$			2005	2005	2005	2005
Cost Index (2 = M&S, 3 = CE)			3	130.93	130.93	130.93	130.93
Plant Size	dry short ton/day			2,206	11,118	22,236	44,473
	dry tonne/day			2,000	10,080	20,160	40,320
Stream Factor	%			**50%**	**50%**	**50%**	**50%**
Feed	Dry short ton/yr			4.026E+05	2.029E+06	4.058E+06	8.116E+06
	GJ/short ton						
	GJ/yr			0.000E+00	0.000E+00	0.000E+00	0.000E+00
Feed Cost	USD/dt			**$ 34.30**	**$ 34.30**	**$ 34.30**	**$ 34.30**
Yield (gal/Dry US Ton)							
Ethanol	gal/short ton			12.32	12.32	12.32	12.32
Sugar	ton/short ton			0.057	0.057	0.057	0.057
Process Efficiency - to ethanol	% HHV						
Process efficiency - overall	% HHV						
Ethanol	gal/yr			4.960E+06	2.500E+07	5.000E+07	1.000E+08
	Mil Gal/YR			**4.96**	**25.00**	**50.00**	**100.00**
	tpy			1.639E+04	8.263E+04	1.653E+05	3.305E+05
	GJ/yr			4.401E+05	2.218E+06	4.436E+06	8.873E+06
	gal/Stream day			2.718E+04	1.370E+05	2.740E+05	5.480E+05
	bbl/s stream day			6.472E+02	3.262E+03	6.523E+03	1.305E+04
Sugar, GJ/yr	14.877	GJ/yr		3.427E+05	1.727E+06	3.454E+06	6.908E+06
Sugar (glucose +fructose)	ton/yr			2.30E+04	1.16E+05	2.32E+05	4.64E+05
Sugar Cane - Sucrose Content		wt %		14.00%	14.00%	14.00%	14.00%
Ethanol/sugar Split		%		**60%**	**60%**	**60%**	**60%**
Sugar extraction efficiency		%		97.0%	97.0%	97.0%	97.0%
Ethanol Production efficiency		%		90.0%	90.0%	90.0%	90.0%
lb ethanol/lb sucrose to ethanol train	0.5386	lb/lb		0.4848	0.4848	0.4848	0.4848
Capital Cost (million USD)							
Total Capital			0.38	16.11	35.24	45.87	59.69
Direct Fixed Capital (DFC), also called TIC				16.11	35.24	45.87	59.69
Engineering	DFC x MF	0.12		1.93	4.23	5.50	7.16
Construction	DFC x MF	0.13		2.09	4.58	5.96	7.76
Contractor & Legal	DFC x MF	0.08		1.29	2.82	3.67	4.77
Process/Project Contingency	DFC x MF	0.0412		0.66	1.45	1.89	2.46
Total Plant Cost (TPC)				22.08	48.33	62.89	81.84
AFUDC							
Total Plant Investment (TPI)				22.08	48.33	62.89	81.84
Land			0.20	2.21	3.05	3.51	7.02
Startup				0.00	0.00	0.00	0.00
Total Capital Cost (TCC)				24.29	51.38	66.40	88.86
Contingency/TPI							
Working Capital	DFC x MF	0.05		1.10	2.42	3.14	4.09
Variable Operating Costs (million USD/yr)							
Feed				13.81	69.60	139.19	278.39
Utilities				0.36	1.79	3.58	7.16
Other				1.18	5.96	11.93	23.86
Catalysts and Chemicals				0.83	4.18	8.35	16.70
Total				16.18	81.53	163.05	326.11
Fixed Operating Costs (million USD/yr)							
Labor (SF from V-R)	DFC x MF	0.0165	0.25	0.25	0.37	0.44	0.53
Maintenance (3% of A)			0.03	0.48	1.06	1.38	1.79
General Overhead (65% of labor + maint)			0.65	0.48	0.93	1.18	1.51
Direct Overhead (45% of Labor)			0.45	0.11	0.17	0.20	0.24
Insurance (0.5% of TIC)			0.005	0.12	0.26	0.33	0.44
Total				1.44	2.78	3.53	4.50

Table 34. Capital and operating costs, Caribbean basin sugar-ethanol mill

Country	Caribbean	Code =	9				
Cost component	**Units**	**Cost Factor**	**Scale Factor**	**Caribbean Sugar Mill**	**Caribbean Sugar Mill**	**Caribbean Sugar Mill**	**Caribbean Sugar Mill**
Year $	$			2005	2005	2005	2005
Cost Index (2 = M&S, 3 = CE)			3	130.93	130.93	130.93	130.93
Plant Size	dry short ton/day			2,206	11,118	22,236	44,473
	dry tonne/day			2,000	10,080	20,160	40,320
Stream Factor	%			**50%**	**50%**	**50%**	**50%**
Feed	Dry short ton/yr			4.026E+05	2.029E+06	4.058E+06	8.116E+06
	GJ/short ton						
	GJ/yr			0.000E+00	0.000E+00	0.000E+00	0.000E+00
Feed Cost	USD/dt			**$ 15.00**	**$ 15.00**	**$ 15.00**	**$ 15.00**
Yield (gal/Dry US Ton)							
Ethanol	gal/short ton			12.32	12.32	12.32	12.32
Sugar	ton/short ton			0.057	0.057	0.057	0.057
Process Efficiency - to ethanol	% HHV						
Process efficiency - overall	% HHV						
Ethanol	gal/yr			4.960E+06	2.500E+07	5.000E+07	1.000E+08
	Mil Gal/YR			**4.96**	**25.00**	**50.00**	**100.00**
	tpy			1.639E+04	8.263E+04	1.653E+05	3.305E+05
	GJ/yr			4.401E+05	2.218E+06	4.436E+06	8.873E+06
	gal/Stream day			2.718E+04	1.370E+05	2.740E+05	5.480E+05
	bbl/s stream day			6.472E+02	3.262E+03	6.523E+03	1.305E+04
Sugar, GJ/yr	14.877	GJ/yr		3.427E+05	1.727E+06	3.454E+06	6.908E+06
Sugar (glucose +fructose)	ton/yr			2.30E+04	1.16E+05	2.32E+05	4.64E+05
Sugar Cane - Sucrose Content		wt %		14.00%	14.00%	14.00%	14.00%
Ethanol/sugar Split		%		**60%**	**60%**	**60%**	**60%**
Sugar extraction efficiency		%		97.0%	97.0%	97.0%	97.0%
Ethanol Production efficiency		%		90.0%	90.0%	90.0%	90.0%
lb ethanol/lb sucrose to ethanol train	0.5386	lb/lb		0.4848	0.4848	0.4848	0.4848
Capital Cost (million USD)							
Total Capital			0.38	16.92	37.03	48.19	62.72
Direct Fixed Capital (DFC), also called TIC				16.92	37.03	48.19	62.72
Engineering	DFC x MF	0.12		2.03	4.44	5.78	7.53
Construction	DFC x MF	0.13		2.20	4.81	6.27	8.15
Contractor & Legal	DFC x MF	0.08		1.35	2.96	3.86	5.02
Process/Project Contingency	DFC x MF	0.0412		0.70	1.53	1.99	2.58
Total Plant Cost (TPC)				23.21	50.78	66.08	86.00
AFUDC							
Total Plant Investment (TPI)				23.21	50.78	66.08	86.00
Land			0.20	2.21	3.05	3.51	7.02
Startup				0.00	0.00	0.00	0.00
Total Capital Cost (TCC)				25.42	53.84	69.59	93.02
Contingency/TPI							
Working Capital	DFC x MF	0.05		1.16	2.54	3.30	4.30
Variable Operating Costs (million USD/yr)							
Feed				6.04	30.44	60.87	121.74
Utilities				0.36	1.79	3.58	7.16
Other				1.18	5.96	11.93	23.86
Catalysts and Chemicals				0.83	4.18	8.35	16.70
Total				8.41	42.37	84.73	169.46
Fixed Operating Costs (million USD/yr)							
Labor (SF from V-R)	DFC x MF	0.0165	0.25	0.28	0.42	0.50	0.60
Maintenance (3% of A)			0.03	0.51	1.11	1.45	1.88
General Overhead (65% of labor + maint)			0.65	0.51	1.00	1.27	1.61
Direct Overhead (45% of Labor)			0.45	0.13	0.19	0.23	0.27
Insurance (0.5% of TIC)			0.005	0.13	0.27	0.35	0.47
Total				1.56	2.99	3.79	4.82

Table 35. Capital and operating costs, China sugar-ethanol mill

Country	China	Code =	3				
Cost component	**Units**	**Cost Factor**	**Scale Factor**	**China Sugar Mill**	**China Sugar Mill**	**China Sugar Mill**	**China Sugar Mill**
Year $	$			2005	2005	2005	2005
Cost Index (2 = M&S, 3 = CE)			3	130.93	130.93	130.93	130.93
Plant Size	dry short ton/day			2,206	11,118	22,236	44,473
	dry tonne/day			2,000	10,080	20,160	40,320
Stream Factor	%			**50%**	**50%**	**50%**	**50%**
Feed	Dry short ton/yr			4.026E+05	2.029E+06	4.058E+06	8.116E+06
	GJ/short ton						
	GJ/yr			0.000E+00	0.000E+00	0.000E+00	0.000E+00
Feed Cost	USD/dt			**$ 23.00**	**$ 23.00**	**$ 23.00**	**$ 23.00**
Yield (gal/Dry US Ton)							
Ethanol	gal/short ton			12.32	12.32	12.32	12.32
Sugar	ton/short ton			0.057	0.057	0.057	0.057
Process Efficiency - to ethanol	% HHV						
Process efficiency - overall	% HHV						
Ethanol	gal/yr			4.960E+06	2.500E+07	5.000E+07	1.000E+08
	Mil Gal/YR			**4.96**	**25.00**	**50.00**	**100.00**
	tpy			1.639E+04	8.263E+04	1.653E+05	3.305E+05
	GJ/yr			4.401E+05	2.218E+06	4.436E+06	8.873E+06
	gal/Stream day			2.718E+04	1.370E+05	2.740E+05	5.480E+05
	bbl/s stream day			6.472E+02	3.262E+03	6.523E+03	1.305E+04
Sugar, GJ/yr	14.877	GJ/yr		3.427E+05	1.727E+06	3.454E+06	6.908E+06
Sugar (glucose +fructose)	ton/yr			2.30E+04	1.16E+05	2.32E+05	4.64E+05
Sugar Cane - Sucrose Content		wt %		14.00%	14.00%	14.00%	14.00%
Ethanol/sugar Split		%		**60%**	**60%**	**60%**	**60%**
Sugar extraction efficiency		%		97.0%	97.0%	97.0%	97.0%
Ethanol Production efficiency		%		90.0%	90.0%	90.0%	90.0%
lb ethanol/lb sucrose to ethanol train	0.5386	lb/lb		0.4848	0.4848	0.4848	0.4848
Capital Cost (million USD)							
Total Capital			0.38	16.51	36.12	47.01	61.17
Direct Fixed Capital (DFC), also called TIC				16.51	36.12	47.01	61.17
Engineering	DFC x MF	0.12		1.98	4.33	5.64	7.34
Construction	DFC x MF	0.13		2.15	4.70	6.11	7.95
Contractor & Legal	DFC x MF	0.08		1.32	2.89	3.76	4.89
Process/Project Contingency	DFC x MF	0.0412		0.68	1.49	1.94	2.52
Total Plant Cost (TPC)				22.63	49.53	64.45	83.88
AFUDC							
Total Plant Investment (TPI)				22.63	49.53	64.45	83.88
Land			0.20	2.21	3.05	3.51	7.02
Startup				0.00	0.00	0.00	0.00
Total Capital Cost (TCC)				24.84	52.58	67.96	90.89
Contingency/TPI							
Working Capital	DFC x MF	0.05		1.13	2.48	3.22	4.19
Variable Operating Costs (million USD/yr)							
Feed				9.26	46.67	93.34	186.68
Utilities				0.36	1.79	3.58	7.16
Other				1.18	5.96	11.93	23.86
Catalysts and Chemicals				0.83	4.18	8.35	16.70
Total				11.63	58.60	117.20	234.39
Fixed Operating Costs (million USD/yr)							
Labor (SF from V-R)	DFC x MF	0.0165	0.25	0.33	0.49	0.58	0.69
Maintenance (3% of A)			0.03	0.50	1.08	1.41	1.84
General Overhead (65% of labor + maint)			0.65	0.53	1.02	1.29	1.64
Direct Overhead (45% of Labor)			0.45	0.15	0.22	0.26	0.31
Insurance (0.5% of TIC)			0.005	0.12	0.26	0.34	0.45
Total				1.63	3.08	3.89	4.93

Table 36. Capital and operating costs, Colombia sugar-ethanol mill

Country	Colombia	Code =	6				
Cost component	**Units**	**Cost Factor**	**Scale Factor**	**Colombia Sugar Mill**	**Colombia Sugar Mill**	**Colombia Sugar Mill**	**Colombia Sugar Mill**
Year $	$			2005	2005	2005	2005
Cost Index (2 = M&S, 3 = CE)			3	130.93	130.93	130.93	130.93
Plant Size	dry short ton/day			2,206	11,118	22,236	44,473
	dry tonne/day			2,000	10,080	20,160	40,320
Stream Factor	%			**50%**	**50%**	**50%**	**50%**
Feed	Dry short ton/yr			4.026E+05	2.029E+06	4.058E+06	8.116E+06
	GJ/short ton						
	GJ/yr			0.000E+00	0.000E+00	0.000E+00	0.000E+00
Feed Cost	USD/dt			**$ 26.85**	**$ 26.85**	**$ 26.85**	**$ 26.85**
Yield (gal/Dry US Ton)							
Ethanol	gal/short ton			12.32	12.32	12.32	12.32
Sugar	ton/short ton			0.057	0.057	0.057	0.057
Process Efficiency - to ethanol	% HHV						
Process efficiency - overall	% HHV						
Ethanol	gal/yr			4.960E+06	2.500E+07	5.000E+07	1.000E+08
	Mil Gal/YR			**4.96**	**25.00**	**50.00**	**100.00**
	tpy			1.639E+04	8.263E+04	1.653E+05	3.305E+05
	GJ/yr			4.401E+05	2.218E+06	4.436E+06	8.873E+06
	gal/Stream day			2.718E+04	1.370E+05	2.740E+05	5.480E+05
	bbl/s stream day			6.472E+02	3.262E+03	6.523E+03	1.305E+04
Sugar, GJ/yr	14.877	GJ/yr		3.427E+05	1.727E+06	3.454E+06	6.908E+06
Sugar (glucose +fructose)	ton/yr			2.30E+04	1.16E+05	2.32E+05	4.64E+05
Sugar Cane - Sucrose Content		wt %		14.00%	14.00%	14.00%	14.00%
Ethanol/sugar Split		%		**60%**	**60%**	**60%**	**60%**
Sugar extraction efficiency		%		97.0%	97.0%	97.0%	97.0%
Ethanol Production efficiency		%		90.0%	90.0%	90.0%	90.0%
lb ethanol/lb sucrose to ethanol train	0.5386	lb/lb		0.4848	0.4848	0.4848	0.4848
Capital Cost (million USD)							
Total Capital			0.38	14.92	32.64	42.48	55.28
Direct Fixed Capital (DFC), also called TIC				14.92	32.64	42.48	55.28
Engineering	DFC x MF	0.12		1.79	3.92	5.10	6.63
Construction	DFC x MF	0.13		1.94	4.24	5.52	7.19
Contractor & Legal	DFC x MF	0.08		1.19	2.61	3.40	4.42
Process/Project Contingency	DFC x MF	0.0412		0.61	1.34	1.75	2.28
Total Plant Cost (TPC)				20.45	44.76	58.25	75.80
AFUDC							
Total Plant Investment (TPI)				20.45	44.76	58.25	75.80
Land			0.20	2.21	3.05	3.51	7.02
Startup				0.00	0.00	0.00	0.00
Total Capital Cost (TCC)				22.66	47.81	61.75	82.81
Contingency/TPI							
Working Capital	DFC x MF	0.05		1.02	2.24	2.91	3.79
Variable Operating Costs (million USD/yr)							
Feed				10.81	54.48	108.96	217.92
Utilities				0.36	1.79	3.58	7.16
Other				1.18	5.96	11.93	23.86
Catalysts and Chemicals				0.83	4.18	8.35	16.70
Total				13.18	66.41	132.82	265.64
Fixed Operating Costs (million USD/yr)							
Labor (SF from V-R)	DFC x MF	0.0165	0.25	0.19	0.28	0.33	0.40
Maintenance (3% of A)			0.03	0.45	0.98	1.27	1.66
General Overhead (65% of labor + maint)			0.65	0.41	0.82	1.04	1.33
Direct Overhead (45% of Labor)			0.45	0.08	0.13	0.15	0.18
Insurance (0.5% of TIC)			0.005	0.11	0.24	0.31	0.41
Total				1.24	2.44	3.11	3.98

Table 37. Capital and operating costs, India sugar-ethanol mill

Country	India	Code =	4					
Cost component	Units	Cost Factor	Scale Factor	Brazil Sugar Mill	India Sugar Mill	India Sugar Mill	India Sugar Mill	India Sugar Mill
Year $	$			2002	2005	2005	2005	2005
Cost Index (2 = M&S, 3 = CE)			3	110.63	130.93	130.93	130.93	130.93
Plant Size	dry short ton/day			2,206	2,206	11,118	22,236	44,473
	dry tonne/day			2,000	2,000	10,080	20,160	40,320
Stream Factor	%			**50%**	**50%**	**50%**	**50%**	**50%**
Feed	Dry short ton/yr			4.026E+05	4.026E+05	2.029E+06	4.058E+06	8.116E+06
	GJ/short ton							
	GJ/yr			0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Feed Cost	USD/dt			**$ 15.00**	**$ 15.00**	**$ 15.00**	**$ 15.00**	**$ 15.00**
Yield (gal/Dry US Ton)								
Ethanol	gal/short ton			12.32	12.32	12.32	12.32	12.32
Sugar	ton/short ton			0.057	0.057	0.057	0.057	0.057
Process Efficiency - to ethanol	% HHV							
Process efficiency - overall	% HHV							
Ethanol	gal/yr			4.960E+06	4.960E+06	2.500E+07	5.000E+07	1.000E+08
	Mil Gal/YR			4.96	**4.96**	**25.00**	**50.00**	**100.00**
	tpy			1.639E+04	1.639E+04	8.263E+04	1.653E+05	3.305E+05
	GJ/yr			4.401E+04	4.401E+05	2.218E+06	4.436E+06	8.873E+06
	gal/Stream day			2.718E+04	2.718E+04	1.370E+05	2.740E+05	5.480E+05
	bbl/s stream day			6.472E+02	6.472E+02	3.262E+03	6.523E+03	1.305E+04
Sugar, GJ/yr	14.877	GJ/yr		3.427E+05	3.427E+05	1.727E+06	3.454E+06	6.908E+06
Sugar (glucose +fructose)	ton/yr			2.30E+04	2.30E+04	1.16E+05	2.32E+05	4.64E+05
Sugar Cane - Sucrose Content		wt %		14.00%	14.00%	14.00%	14.00%	14.00%
Ethanol/sugar Split		%		60.0%	**60%**	**60%**	**60%**	**60%**
Sugar extraction efficiency		%		97.0%	97.0%	97.0%	97.0%	97.0%
Ethanol Production efficiency		%		90.0%	90.0%	90.0%	90.0%	90.0%
lb ethanol/lb sucrose to ethanol train	0.5386	lb/lb		0.4848	0.4848	0.4848	0.4848	0.4848
Capital Cost (million USD)								
Total Capital			0.38	15.00	16.00	35.01	45.56	59.29
Direct Fixed Capital (DFC), also called TIC				15.00	16.00	35.01	45.56	59.29
Engineering	DFC x MF	0.12		1.80	1.92	4.20	5.47	7.11
Construction	DFC x MF	0.13		1.95	2.08	4.55	5.92	7.71
Contractor & Legal	DFC x MF	0.08		1.20	1.28	2.80	3.64	4.74
Process/Project Contingency	DFC x MF	0.0412		0.62	0.66	1.44	1.88	2.44
Total Plant Cost (TPC)				20.57	21.94	48.01	62.47	81.30
AFUDC								
Total Plant Investment (TPI)				20.57	21.94	48.01	62.47	81.30
Land			0.20	2.21	2.21	3.05	3.51	7.02
Startup				0.00	0.00	0.00	0.00	0.00
Total Capital Cost (TCC)				22.78	24.15	51.06	65.98	88.31
Contingency/TPI								
Working Capital	DFC x MF	0.05		1.03	1.10	2.40	3.12	4.06
Variable Operating Costs (million USD/yr)								
Feed				6.04	6.04	30.44	60.87	121.74
Utilities				0.30	0.36	1.79	3.58	7.16
Other				1.00	1.18	5.96	11.93	23.86
Catalysts and Chemicals				0.70	0.83	4.18	8.35	16.70
Total				8.04	8.41	42.37	84.73	169.46
Fixed Operating Costs (million USD/yr)								
Labor (SF from V-R)	DFC x MF	0.0165	0.25	0.25	0.11	0.16	0.20	0.23
Maintenance (3% of A)			0.03	0.45	0.48	1.05	1.37	1.78
General Overhead (65% of labor + maint)			0.65	0.45	0.38	0.79	1.02	1.31
Direct Overhead (45% of Labor)			0.45	0.11	0.05	0.07	0.09	0.10
Insurance (0.5% of TIC)			0.005	0.11	0.12	0.26	0.33	0.44
Total				1.38	1.14	2.33	3.00	3.86

Table 38. Capital and operating costs, Mexico sugar-ethanol mill

Country	Mexico	Code =	8				
Cost component	**Units**	**Cost Factor**	**Scale Factor**	**Mexico Sugar Mill**	**Mexico Sugar Mill**	**Mexico Sugar Mill**	**Mexico Sugar Mill**
Year $	$			2005	2005	2005	2005
Cost Index (2 = M&S, 3 = CE)			3	130.93	130.93	130.93	130.93
Plant Size	dry short ton/day			2,206	11,118	22,236	44,473
	dry tonne/day			2,000	10,080	20,160	40,320
Stream Factor	%			**50%**	**50%**	**50%**	**50%**
Feed	Dry short ton/yr			4.026E+05	2.029E+06	4.058E+06	8.116E+06
	GJ/short ton						
	GJ/yr			0.000E+00	0.000E+00	0.000E+00	0.000E+00
Feed Cost	USD/dt			**$ 29.00**	**$ 29.00**	**$ 29.00**	**$ 29.00**
Yield (gal/Dry US Ton)							
Ethanol	gal/short ton			12.32	12.32	12.32	12.32
Sugar	ton/short ton			0.057	0.057	0.057	0.057
Process Efficiency - to ethanol	% HHV						
Process efficiency - overall	% HHV						
Ethanol	gal/yr			4.960E+06	2.500E+07	5.000E+07	1.000E+08
	Mil Gal/YR			**4.96**	**25.00**	**50.00**	**100.00**
	tpy			1.639E+04	8.263E+04	1.653E+05	3.305E+05
	GJ/yr			4.401E+05	2.218E+06	4.436E+06	8.873E+06
	gal/Stream day			2.718E+04	1.370E+05	2.740E+05	5.480E+05
	bbl/s stream day			6.472E+02	3.262E+03	6.523E+03	1.305E+04
Sugar, GJ/yr	14.877	GJ/yr		3.427E+05	1.727E+06	3.454E+06	6.908E+06
Sugar (glucose +fructose)	ton/yr			2.30E+04	1.16E+05	2.32E+05	4.64E+05
Sugar Cane - Sucrose Content		wt %		14.00%	14.00%	14.00%	14.00%
Ethanol/sugar Split		%		**60%**	**60%**	**60%**	**60%**
Sugar extraction efficiency		%		97.0%	97.0%	97.0%	97.0%
Ethanol Production efficiency		%		90.0%	90.0%	90.0%	90.0%
lb ethanol/lb sucrose to ethanol train	0.5386	lb/lb		0.4848	0.4848	0.4848	0.4848
Capital Cost (million USD)							
Total Capital			0.38	12.07	26.40	34.36	44.71
Direct Fixed Capital (DFC), also called TIC				12.07	26.40	34.36	44.71
Engineering	DFC x MF	0.12		1.45	3.17	4.12	5.37
Construction	DFC x MF	0.13		1.57	3.43	4.47	5.81
Contractor & Legal	DFC x MF	0.08		0.97	2.11	2.75	3.58
Process/Project Contingency	DFC x MF	0.0412		0.50	1.09	1.42	1.84
Total Plant Cost (TPC)				16.54	36.20	47.11	61.31
AFUDC							
Total Plant Investment (TPI)				16.54	36.20	47.11	61.31
Land			0.20	2.21	3.05	3.51	7.02
Startup				0.00	0.00	0.00	0.00
Total Capital Cost (TCC)				18.75	39.26	50.62	68.32
Contingency/TPI							
Working Capital	DFC x MF	0.05		0.83	1.81	2.36	3.07
Variable Operating Costs (million USD/yr)							
Feed				11.68	58.84	117.69	235.37
Utilities				0.36	1.79	3.58	7.16
Other				1.18	5.96	11.93	23.86
Catalysts and Chemicals				0.83	4.18	8.35	16.70
Total				14.04	70.77	141.55	283.09
Fixed Operating Costs (million USD/yr)							
Labor (SF from V-R)	DFC x MF	0.0165	0.25	0.07	0.11	0.13	0.15
Maintenance (3% of A)			0.03	0.36	0.79	1.03	1.34
General Overhead (65% of labor + maint)			0.65	0.28	0.58	0.75	0.97
Direct Overhead (45% of Labor)			0.45	0.03	0.05	0.06	0.07
Insurance (0.5% of TIC)			0.005	0.09	0.20	0.25	0.34
Total				0.84	1.73	2.22	2.87

Table 39. Capital and operating costs, USA sugar-ethanol mill

Country	USA	Code =	1				
Cost component	**Units**	**Cost Factor**	**Scale Factor**	**USA Sugar Mill**	**USA Sugar Mill**	**USA Sugar Mill**	**USA Sugar Mill**
Year $	$			2005	2005	2005	2005
Cost Index (2 = M&S, 3 = CE)			3	130.93	130.93	130.93	130.93
Plant Size	dry short ton/day			2,206	11,118	22,236	44,473
	dry tonne/day			2,000	10,080	20,160	40,320
Stream Factor	%			**50%**	**50%**	**50%**	**50%**
Feed	Dry short ton/yr			4.026E+05	2.029E+06	4.058E+06	8.116E+06
	GJ/short ton						
	GJ/yr			0.000E+00	0.000E+00	0.000E+00	0.000E+00
Feed Cost	USD/dt			**$ 29.00**	**$ 29.00**	**$ 29.00**	**$ 29.00**
Yield (gal/Dry US Ton)							
Ethanol	gal/short ton			12.32	12.32	12.32	12.32
Sugar	ton/short ton			0.059	0.059	0.059	0.059
Process Efficiency - to ethanol	% HHV						
Process efficiency - overall	% HHV						
Ethanol	gal/yr			4.960E+06	2.500E+07	5.000E+07	1.000E+08
	Mil Gal/YR			**4.96**	**25.00**	**50.00**	**100.00**
	tpy			1.639E+04	8.263E+04	1.653E+05	3.305E+05
	GJ/yr			4.401E+05	2.218E+06	4.436E+06	8.873E+06
	gal/Stream day			2.718E+04	1.370E+05	2.740E+05	5.480E+05
	bbl/s stream day			6.472E+02	3.262E+03	6.523E+03	1.305E+04
Sugar, GJ/yr	14.877	GJ/yr		3.532E+05	1.780E+06	3.561E+06	7.121E+06
Sugar (glucose +fructose)	ton/yr			2.37E+04	1.20E+05	2.39E+05	4.79E+05
Sugar Cane - Sucrose Content		wt %		14.00%	14.00%	14.00%	14.00%
Ethanol/sugar Split		%		**60%**	**60%**	**60%**	**60%**
Sugar extraction efficiency		%		97.0%	97.0%	97.0%	97.0%
Ethanol Production efficiency		%		90.0%	90.0%	90.0%	90.0%
lb ethanol/lb sucrose to ethanol train	0.5386	lb/lb		0.4848	0.4848	0.4848	0.4848
Capital Cost (million USD)							
Total Capital			0.38	15.00	32.82	42.72	55.59
Direct Fixed Capital (DFC), also called TIC				15.00	32.82	42.72	55.59
Engineering	DFC x MF	0.12		1.80	3.94	5.13	6.67
Construction	DFC x MF	0.13		1.95	4.27	5.55	7.23
Contractor & Legal	DFC x MF	0.08		1.20	2.63	3.42	4.45
Process/Project Contingency	DFC x MF	0.0412		0.62	1.35	1.76	2.29
Total Plant Cost (TPC)				20.57	45.01	58.57	76.22
AFUDC							
Total Plant Investment (TPI)				20.57	45.01	58.57	76.22
Land			0.20	2.21	3.05	3.51	7.02
Startup				0.00	0.00	0.00	0.00
Total Capital Cost (TCC)				22.78	48.06	62.08	83.24
Contingency/TPI							
Working Capital	DFC x MF	0.05		1.03	2.25	2.93	3.81
Variable Operating Costs (million USD/yr)							
Feed				11.68	58.84	117.69	235.37
Utilities				0.36	1.79	3.58	7.16
Other				1.18	5.96	11.93	23.86
Catalysts and Chemicals				0.83	4.18	8.35	16.70
Total				14.04	70.77	141.55	283.09
Fixed Operating Costs (million USD/yr)							
Labor (SF from V-R)	DFC x MF	0.0165	0.25	0.29	0.44	0.52	0.62
Maintenance (3% of A)			0.03	0.45	0.98	1.28	1.67
General Overhead (65% of labor + maint)			0.65	0.48	0.93	1.17	1.49
Direct Overhead (45% of Labor)			0.45	0.13	0.20	0.23	0.28
Insurance (0.5% of TIC)			0.005	0.11	0.24	0.31	0.42
Total				1.47	2.79	3.52	4.47

Table 40. Sugar cane ethanol: summary yields, costs, and plant gate prices, 25 MM GPY ethanol

Sugar Cane	Units	USA	Argentina	Brazil	Canada	Caribbean Basin	China	Colombia	India	Mexico
Plant Size	MM gal/yr	25		25		25	25	25	25	25
Yields										
Primary Product Yield	gal/ton	12.32		12.32		12.32	12.32	12.32	12.32	12.32
By Product A		Sugar		Sugar		Sugar	Sugar	Sugar	Sugar	Sugar
Yield unit	ton									
Annual Yield	ton/yr	1.16E+05		1.16E+05		1.16E+05	1.16E+05	1.16E+05	1.16E+05	1.16E+05
Price unit		300.60		161.36		201.52	262.21	157.79	194.48	295.76
MM USD/yr		34.87		18.72		23.38	30.42	18.30	22.56	34.31
By Product B										
Yield unit										
Annual Yield										
Price unit										
Annual Cost	MM USD/yr									
Energy Inputs										
Electricity										
Cost	$/kWh									
Amount	kWh/yr	N/A		N/A		N/A	N/A	N/A	N/A	N/A
Annual Cost	MM USD/yr									
Fuel										
Type										
Unit										
Amount		N/A		N/A		N/A	N/A	N/A	N/A	N/A
Cost	USD/unit									
Annual Cost	MM USD/yr									
Capital & Operating Costs										
Capital	MMUSD	48.06		49.05		53.84	52.58	47.81	51.06	39.26
Operating w/o feed	MM USD/yr	14.72		14.23		14.92	15.01	14.37	14.26	13.66
Feed										
Unit		d ton		d ton		d ton	d ton	d ton	d ton	d ton
Cost/unit	USD/unit	29		10.45		15	23	26.85	15	29
Rate	unit/day	10080		10080		10080	10080	10080	10080	10080
Yearly Cost	MM USD/yr	58.84		21.2		30.44	46.67	54.48	30.44	58.84
Product Plant Gate Cost										
Basis				10 SL		10 SL	10 SL	10 SL	10 SL	5 SL
Value	USD/gal	1.79		1.17		1.2	1.56	1.71	1.18	1.76

Table 41. Sugar cane ethanol: summary yields, costs, and plant gate prices, 50 MM GPY ethanol

Sugar Cane	Units	USA	Argentina	Brazil	Canada	Caribbean Basin	China	Colombia	India	Mexico
Plant Size	MM gal/yr	50		50		50	50	50	50	50
Yields										
Primary Product Yield	gal/ton	12.32		12.32		12.32	12.32	12.32	12.32	12.32
By Product A		Sugar		Sugar		Sugar	Sugar	Sugar	Sugar	Sugar
Yield unit		ton		ton		ton	ton	ton	ton	ton
Annual Yield		2.32E+05		2.32E+05		2.32E+05	2.32E+05	2.32E+05	2.32E+05	2.32E+05
Price unit		287.22		148.4		186.58	247.42	144.83	184.6	285.49
MM USD/yr		66.64		34.43		43.29	57.40	33.60	42.83	66.23
By Product B										
Yield unit										
Annual Yield										
Price unit										
Annual Cost	MM USD/yr									
Energy Inputs										
Electricity										
Cost	$/kWh	N/A		N/A		N/A	N/A	N/A	N/A	N/A
Amount	kWh/yr									
Annual Cost	MM USD/yr									
Fuel										
Type		N/A		N/A		N/A	N/A	N/A	N/A	N/A
Unit										
Amount										
Cost	USD/unit									
Annual Cost	MM USD/yr									
Capital & Operating Costs										
Capital	MMUSD	62.08		63.36		69.59	67.96	61.75	65.98	50.62
Operating w/o feed	MM USD/yr	27.38		26.8		27.65	27.75	26.97	26.85	26.08
Feed										
Unit		d ton		d ton		d ton	d ton	d ton	d ton	d ton
Cost/unit	USD/unit			10.45		15	23	26.85	15	29
Rate	unit/day	20160		20160		20160	20160	20160	20160	20160
Yearly Cost	MM USD/yr	117.69		42.41		60.87	93.34	108.96	60.87	117.69
Product Plant Gate Cost										
Basis				10-SL		10-SL	10-SL	10-SL	10-SL	5-SL
Value	USD/gal	1.71		1.09		1.11	1.48	1.63	1.10	1.7

Table 42. Sugar cane ethanol: summary yields, costs, and plant gate prices, 100 MM GPY ethanol

Sugar Cane	Units	USA	Argentina	Brazil	Canada	Caribbean Basin	China	Colombia	India	Mexico
Plant Size	MM gal/yr	100		100		100	100	100	100	100
Yields										
Primary Product Yield	gal/ton	12.32		12.32		12.32	12.32	12.32	12.32	12.32
By Product A		Sugar		Sugar		Sugar	Sugar	Sugar	Sugar	Sugar
Yield unit		ton		ton		ton	ton	ton	ton	ton
Annual Yield		4.64E+05		4.64E+05		4.64E+05	4.64E+05	4.64E+05	4.64E+05	4.64E+05
Price unit		279.16		140.57		177.51	238.46	137.02	176.29	179.31
MM USD/yr		1.30E+02		6.52E+01		8.24E+01	1.11E+02	6.36E+01	8.18E+01	8.32E+01
By Product B										
Yield unit										
Annual Yield										
Price unit										
Annual Cost	MM USD/yr									
Energy Inputs										
Electricity		N/A		N/A		N/A	N/A	N/A	N/A	N/A
Cost	$/kWh									
Amount	kWh/yr									
Annual Cost	MM USD/yr									
Fuel		N/A		N/A		N/A	N/A	N/A	N/A	N/A
Type										
Unit										
Amount										
Cost	USD/unit									
Annual Cost	MM USD/yr									
Capital & Operating Costs										
Capital	MMUSD	83.24		84.91		93.02	90.89	82.81	88.31	68.32
Operating w/o feed	MM USD/yr	52.19		51.51		52.54	52.65	51.70	51.58	50.59
Feed										
Unit		d ton		d ton		d ton	d ton	d ton	d ton	d ton
Cost/unit	USD/unit	29		10.45		15	23	26.85	15	29
Rate	unit/day	40320		40320		40320	40320	40320	40320	40320
Yearly Cost	MM USD/yr	235.37		84.82		121.74	186.68	217.92	121.74	235.37
Product Plant Gate Cost										
Basis				10-SL		10-SL	10-SL	10-SL	10-SL	5-SL
Value	USD/gal	1.66		1.05		1.06	1.42	1.59	1.05	1.67

5 Cellulosic Ethanol (Biochemical)

The process overview discussion is excerpted from Aden et al. (2002). The process can be described as using co-current dilute acid prehydrolysis of the lignocellulosic biomass with enzymatic saccharification of the remaining cellulose and co-fermentation of the resulting glucose and xylose to ethanol. The process design also includes feedstock handling and storage, product purification, wastewater treatment, lignin combustion, product storage, and all other required utilities. In all, the process is divided into eight areas, see Figure 19.

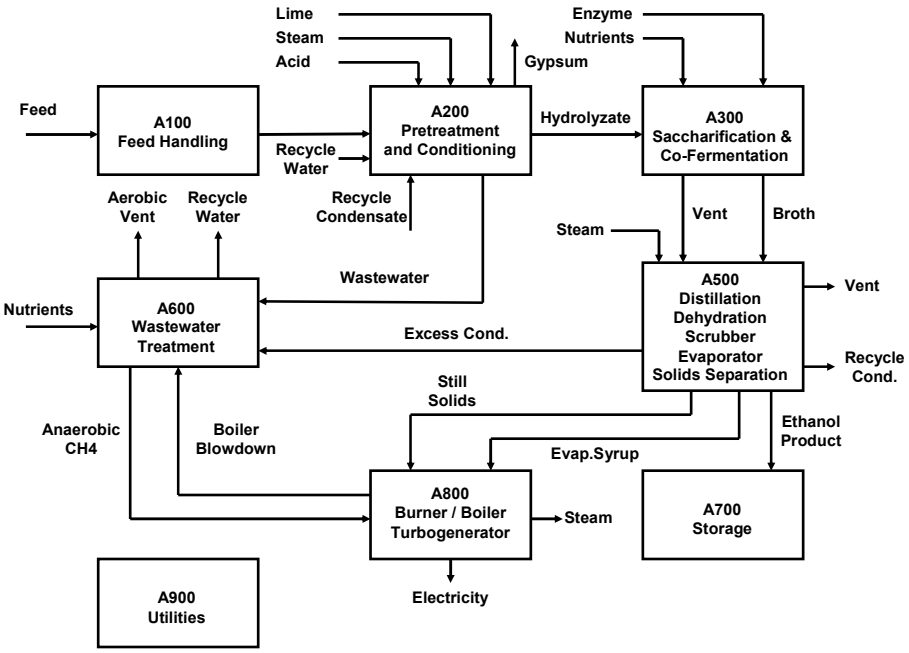


Figure 19. Overall biochemical process flow diagram

The feedstock, in this case corn stover (comprised of leaves, cobs, and husks), is delivered to the feedstock handling area (A100) for storage and size reduction. From there the biomass is conveyed to pretreatment and detoxification (A200). In this area, the biomass is treated with dilute sulfuric acid catalyst for a short time, liberating the hemicellulose sugars and other compounds. Separation with washing removes the acid from the solids for neutralization. Overliming is required to remove compounds liberated in the pretreatment that are toxic to the fermenting organism. Detoxification is applied only to the liquid portion of the hydrolysis stream.

Enzymatic hydrolysis (or saccharification) coupled with co-fermentation (A300) of the detoxified hydrolyzate slurry is carried out in continuous hydrolysis tanks and anaerobic fermentation tanks in series. A purchased cellulase enzyme preparation is added to the hydrolyzate in the hydrolysis tanks that are maintained at a temperature to optimize the enzyme's activity. The fermenting organism *Zymomonas mobilis* is first grown in a series of progressively larger batch anaerobic fermentations to make enough cells to inoculate the

main fermentors. The inoculum, along with other nutrients, is added to the first ethanol fermentor along with the partially saccharified slurry at a reduced temperature. The cellulose will continue to be hydrolyzed, although at a slower rate, at the lower temperature. After several days of separate and combined saccharification and co-fermentation, most of the cellulose and xylose will have been converted to ethanol. The resulting beer is sent to product recovery.

Product recovery (A500) involves distilling the beer to separate ethanol from the water and residual solids. A mixture of nearly azeotropic water and ethanol is purified to pure ethanol using a vapor-phase molecular sieve. Solids from the distillation bottoms are separated and sent to the boiler. Concentration of the distillation bottoms liquid is performed by evaporation, using waste heat. The evaporated condensate is returned to the process and the concentrated syrup is sent to the combustor.

Part of the evaporator condensate, along with other wastewater, is treated by anaerobic and aerobic digestion (A600). The biogas (high in methane) from the anaerobic digestion is sent to the combustor for energy recovery. The treated water is suitable for recycling and is returned to the process.

The solids from distillation, the concentrated syrup from the evaporator, and biogas form anaerobic digestion are combusted in a fluidized bed combustor (A800) to produce high-pressure steam for electricity production and process heat. The majority of the process steam demand is in the pretreatment reactor and distillation areas. Generally, the process produces excess steam that is converted to electricity for use in the plant and for sale to the grid.

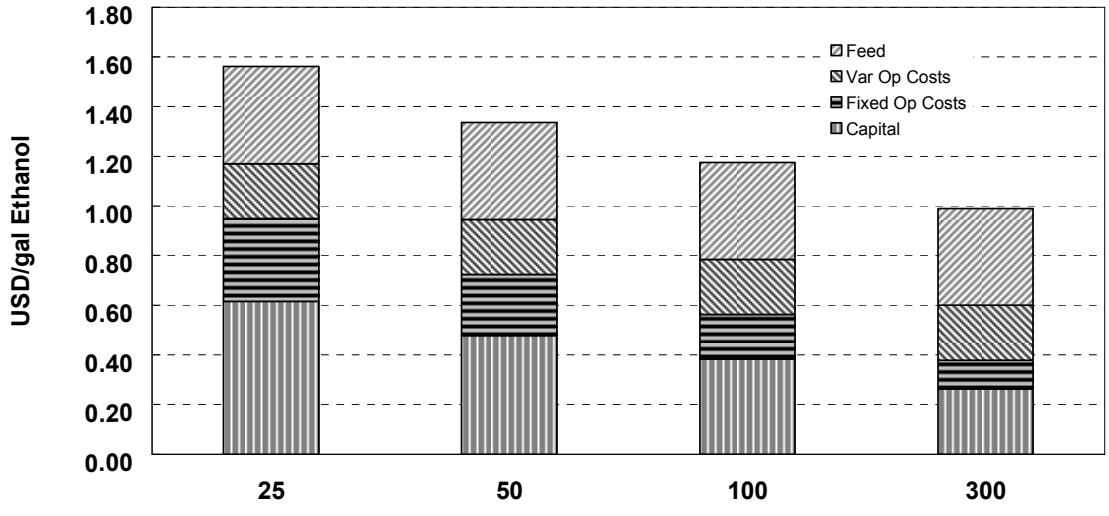
Capital and operating costs for the USA base case are given in Table 43. Figure 20 gives the cost breakdown for the USA base case as a function of plant size using 35 USD/ton feed. Cellulosic feedstock costs for all countries are given in Table 19 (in the methodology section). Capital and operating costs for other countries are given in Table 44 through Table 51.

Table 52 and Table 53 summarize the bagasse capital/operating costs and plant gate costs for 25 MM GPY and 100 MM GPY plants, respectively. Table 54 -

Table 57 summarize the same information for agricultural residues and wood/perennial feeds, respectively. Table 58 summarizes the cellulosic ethanol (BC) plant gate price estimates.

Table 43. USA cellulosic ethanol (bc) capital and operating costs

Country	USA	Code =	1					
Cost component	**Units**	**Cost Factor**	**Scale Factor**	**USA Cellulosic Ethanol (TC)**	**USA Cellulosic Ethanol (TC)**	**USA Cellulosic Ethanol (TC)**	**USA Cellulosic Ethanol (TC)**	**USA Cellulosic Ethanol (TC)**
Year $	$			2002	2005	2005	2005	2005
Cost Index (2 = M&S, 3 = CE)			3	110.63	130.93	130.93	130.93	130.93
Plant Size	dry short ton/day			2,206	**1,608**	**804**	**3,215**	**9,645**
	dry tonne/day			2,000	1,457	729	2,915	8,744
Stream Factor	%			95%	95%	95%	95%	95%
Feed	Dry short ton/yr			7.649E+05	5.574E+05	2.787E+05	1.115E+06	3.344E+06
	GJ/short ton			1.794E+01	1.794E+01	1.794E+01	1.794E+01	1.794E+01
	GJ/yr			1.372E+07	9.997E+06	4.999E+06	1.999E+07	5.998E+07
Feed Cost	USD/dt			**$ 35.00**	**$ 35.00**	**$ 35.00**	**$ 35.00**	**$ 35.00**
Yield (gal/Dry US Ton)								
Ethanol	gal/short ton			89.7	89.7	89.7	89.70	89.7
Electricity	kWh/gal EtOH			2.18	2.18	2.18	2.18	2.18
Process Efficiency - to ethanol	% HHV			44.4%	44.4%	44.4%	44.4%	44.4%
Process efficiency - overall	% HHV							
Ethanol	gal/yr			6.861E+07	5.000E+07	2.500E+07	1.000E+08	3.000E+08
	Mil Gal/YR			68.61	**50.00**	**25.00**	**100.00**	**300.00**
	tpy			2.275E+05	1.657E+05	8.287E+04	3.315E+05	9.945E+05
	GJ/yr			6.088E+06	4.436E+06	2.218E+06	8.872E+06	2.662E+07
	gal/Stream day			1.979E+05	1.442E+05	7.210E+04	2.884E+05	8.652E+05
	bbl/s stream day			4.711E+03	3.433E+03	1.717E+03	6.866E+03	2.060E+04
Electricity	kWh/yr			1.50E+08	1.09E+08	5.45E+07	2.18E+08	6.54E+08
Capital Cost (million USD)								
Feed Handling			0.70	7.50	8.88	6.47	17.07	36.82
Pretreatment			0.80	19.00	22.49	12.92	39.15	94.29
Neutralization/Conditioning			0.70	7.90	9.35	5.76	15.19	32.77
Saccharification & Fermentation			0.85	9.40	11.13	6.17	20.05	51.02
Distillation & Solids Recovery			0.65	21.90	25.92	16.52	40.67	83.06
Wastewater Treatment			0.65	3.10	3.67	2.34	5.76	11.76
Storage			0.65	2.10	2.49	1.58	3.90	7.97
Boiler/Turbogenerator			0.70	38.60	45.68	28.12	74.21	160.13
Utilities			0.70	4.60	5.44	3.35	8.84	19.08
Direct Fixed Capital (DFC), also called TIC				114.10	135.04	83.22	224.84	496.90
Engineering	DFC x MF	0.12		13.69	16.20	9.99	26.98	59.63
Construction	DFC x MF	0.13		14.83	17.56	10.82	29.23	64.60
Contractor & Legal	DFC x MF	0.08		9.13	10.80	6.66	17.99	39.75
Process/Project Contingency	DFC x MF	0.0412		4.70	5.56	3.43	9.26	20.47
Total Plant Cost (TPC)				156.45	185.17	114.11	308.30	681.35
AFUDC								
Total Plant Investment (TPI)				156.45	185.17	114.11	308.30	681.35
Land			0.60	2.21	2.21	2.21	5.08	15.23
Startup				0	0	0.00	0.00	0.00
Total Capital Cost (TCC)				158.66	187.38	116.32	313.38	696.58
Contingency/TPI								
Working Capital	DFC x MF	0.05		7.82	9.26	5.71	15.42	34.07
Variable Operating Costs (million USD/yr)								
Feed				26.77	19.51	9.75	39.02	117.06
Utilities				0.00	0.00	0.00	0.00	0.00
Waste Disposal				2.50	1.82	0.91	3.64	10.93
Catalysts and Chemicals	Major comp is cellulase			12.70	9.25	4.63	18.51	55.53
Total				41.97	30.59	15.29	61.17	183.51
Fixed Operating Costs (million USD/yr)								
Labor (SF from V-R)	DFC x MF	0.0165	0.25	1.88	2.23	1.73	2.45	3.22
Maintenance (3% of A)			0.03	3.42	4.05	2.50	6.75	14.91
General Overhead (65% of labor + maint)			0.65	3.45	4.08	2.75	5.98	11.78
Direct Overhead (45% of Labor)			0.45	0.85	1.00	0.78	1.10	1.45
Insurance (0.5% of TIC)			0.005	0.79	0.94	0.58	1.57	3.48
Total				10.39	12.30	8.34	17.84	34.85



	25	50	100	300
Feed	0.39	0.39	0.39	0.39
Var Op Costs	0.22	0.22	0.22	0.22
Fixed Op Costs	0.33	0.25	0.18	0.12
Capital	$0.62	$0.48	$0.38	$0.26

Plant Size (mil gal/yr)

Figure 20. USA base case cellulosic ethanol (biochemical) plant gate prices

Table 44. Argentina cellulosic ethanol (bc) capital and operating costs, bagasse

Country	Argentina	Code =	5				
Cost component	**Units**	**Cost Factor**	**Scale Factor**	**Argentina Cellulosic Ethanol (TC)**	**Argentina Cellulosic Ethanol (TC)**	**Argentina Cellulosic Ethanol (TC)**	**Argentina Cellulosic Ethanol (TC)**
Year $	$			2005	2005	2005	2005
Cost Index (2 = M&S, 3 = CE)			3	130.93	130.93	130.93	130.93
Plant Size	dry short ton/day			**1,608**	**804**	**3,215**	**9,645**
	dry tonne/day			1,457	729	2,915	8,744
Stream Factor	%			95%	95%	95%	95%
Feed	Dry short ton/yr			5.574E+05	2.787E+05	1.115E+06	3.344E+06
	GJ/short ton			1.794E+01	1.794E+01	1.794E+01	1.794E+01
	GJ/yr			9.997E+06	4.999E+06	1.999E+07	5.998E+07
Feed Cost	USD/dt			**$ 9.10**	**$ 9.10**	**$ 9.10**	**$ 9.10**
Yield (gal/Dry US Ton)							
Ethanol	gal/short ton			89.7	89.7	89.70	89.7
Electricity	kWh/gal EtOH			2.18	2.18	2.18	2.18
Process Efficiency - to ethanol	% HHV			44.4%	44.4%	44.4%	44.4%
Process efficiency - overall	% HHV						
Ethanol	gal/yr			5.000E+07	2.500E+07	1.000E+08	3.000E+08
	Mil Gal/YR			**50.00**	**25.00**	**100.00**	**300.00**
	tpy			1.657E+05	8.287E+04	3.315E+05	9.945E+05
	GJ/yr			4.436E+06	2.218E+06	8.872E+06	2.662E+07
	gal/Stream day			1.442E+05	7.210E+04	2.884E+05	8.652E+05
	bbl/s stream day			3.433E+03	1.717E+03	6.866E+03	2.060E+04
Electricity	kWh/yr			1.09E+08	5.45E+07	2.18E+08	6.54E+08
Capital Cost (million USD)							
Feed Handling			0.70	9.53	6.94	18.32	39.54
Pretreatment			0.80	24.15	13.87	42.04	101.24
Neutralization/Conditioning			0.70	10.04	6.18	16.31	35.19
Saccharification & Fermentation			0.85	11.95	6.63	21.53	54.78
Distillation & Solids Recovery			0.65	27.83	17.74	43.67	89.19
Wastewater Treatment			0.65	3.94	2.51	6.18	12.63
Storage			0.65	2.67	1.70	4.19	8.55
Boiler/Turbogenerator			0.70	49.05	30.20	79.68	171.94
Utilities			0.70	5.85	3.60	9.50	20.49
Direct Fixed Capital (DFC), also called TIC				145.00	89.36	241.42	533.55
Engineering	DFC x MF	0.12		17.40	10.72	28.97	64.03
Construction	DFC x MF	0.13		18.85	11.62	31.38	69.36
Contractor & Legal	DFC x MF	0.08		11.60	7.15	19.31	42.68
Process/Project Contingency	DFC x MF	0.0412		5.97	3.68	9.95	21.98
Total Plant Cost (TPC)				198.82	122.53	331.04	731.60
AFUDC							
Total Plant Investment (TPI)				198.82	122.53	331.04	731.60
Land			0.60	2.21	2.21	5.08	15.23
Startup				0	0.00	0.00	0.00
Total Capital Cost (TCC)				201.03	**124.74**	**336.11**	746.83
Contingency/TPI							
Working Capital	DFC x MF	0.05		9.94	6.13	16.55	36.58
Variable Operating Costs (million USD/yr)							
Feed				5.07	2.54	10.14	30.43
Utilities				0.00	0.00	0.00	0.00
Waste Disposal				1.82	0.91	3.64	10.93
Catalysts and Chemicals	Major comp is cellulase			9.25	4.63	18.51	55.53
Total				16.15	8.07	32.30	96.89
Fixed Operating Costs (million USD/yr)							
Labor (SF from V-R)	DFC x MF	0.0165	0.25	1.89	1.47	2.08	2.73
Maintenance (3% of A)			0.03	4.35	2.68	7.24	16.01
General Overhead (65% of labor + maint)			0.65	4.06	2.70	6.06	12.18
Direct Overhead (45% of Labor)			0.45	0.85	0.66	0.93	1.23
Insurance (0.5% of TIC)			0.005	1.01	0.62	1.68	3.73
Total				12.15	8.13	17.99	35.89

Table 45. Brazil cellulosic ethanol (bc) capital and operating costs, bagasse

Country	Brazil	Code =	2				
Cost component	**Units**	**Cost Factor**	**Scale Factor**	**Brazil Cellulosic Ethanol (TC)**	**Brazil Cellulosic Ethanol (TC)**	**Brazil Cellulosic Ethanol (TC)**	**Brazil Cellulosic Ethanol (TC)**
Year $	$			2005	2005	2005	2005
Cost Index (2 = M&S, 3 = CE)			3	130.93	130.93	130.93	130.93
Plant Size	dry short ton/day			**1,608**	**804**	**3,215**	**9,645**
	dry tonne/day			1,457	729	2,915	8,744
Stream Factor	%			95%	95%	95%	95%
Feed	Dry short ton/yr			5.574E+05	2.787E+05	1.115E+06	3.344E+06
	GJ/short ton			1.794E+01	1.794E+01	1.794E+01	1.794E+01
	GJ/yr			9.997E+06	4.999E+06	1.999E+07	5.998E+07
Feed Cost	USD/dt			**$ 7.60**	**$ 7.60**	**$ 7.60**	**$ 7.60**
Yield (gal/Dry US Ton)							
Ethanol	gal/short ton			89.7	89.7	89.70	89.7
Electricity	kWh/gal EtOH			2.18	2.18	2.18	2.18
Process Efficiency - to ethanol	% HHV			44.4%	44.4%	44.4%	44.4%
Process efficiency - overall	% HHV						
Ethanol	gal/yr			5.000E+07	2.500E+07	1.000E+08	3.000E+08
	Mil Gal/YR			**50.00**	**25.00**	**100.00**	**300.00**
	tpy			1.657E+05	8.287E+04	3.315E+05	9.945E+05
	GJ/yr			4.436E+06	2.218E+06	8.872E+06	2.662E+07
	gal/Stream day			1.442E+05	7.210E+04	2.884E+05	8.652E+05
	bbl/s stream day			3.433E+03	1.717E+03	6.866E+03	2.060E+04
Electricity	kWh/yr			1.09E+08	5.45E+07	2.18E+08	6.54E+08
Capital Cost (million USD)							
Feed Handling			0.70	9.07	6.61	17.44	37.63
Pretreatment			0.80	22.98	13.20	40.01	96.35
Neutralization/Conditioning			0.70	9.55	5.88	15.52	33.49
Saccharification & Fermentation			0.85	11.37	6.31	20.49	52.14
Distillation & Solids Recovery			0.65	26.49	16.88	41.56	84.89
Wastewater Treatment			0.65	3.75	2.39	5.88	12.02
Storage			0.65	2.54	1.62	3.99	8.14
Boiler/Turbogenerator			0.70	46.68	28.74	75.84	163.64
Utilities			0.70	5.56	3.42	9.04	19.50
Direct Fixed Capital (DFC), also called TIC				138.00	85.05	229.77	507.79
Engineering	DFC x MF	0.12		16.56	10.21	27.57	60.93
Construction	DFC x MF	0.13		17.94	11.06	29.87	66.01
Contractor & Legal	DFC x MF	0.08		11.04	6.80	18.38	40.62
Process/Project Contingency	DFC x MF	0.0412		5.69	3.50	9.47	20.92
Total Plant Cost (TPC)				189.22	116.61	315.06	696.28
AFUDC							
Total Plant Investment (TPI)				189.22	116.61	315.06	696.28
Land			0.60	2.21	2.21	5.08	15.23
Startup				0	0.00	0.00	0.00
Total Capital Cost (TCC)				191.43	**118.82**	**320.13**	711.51
Contingency/TPI							
Working Capital	DFC x MF	0.05		9.46	5.83	15.75	34.81
Variable Operating Costs (million USD/yr)							
Feed				4.24	2.12	8.47	25.42
Utilities				0.00	0.00	0.00	0.00
Waste Disposal				1.82	0.91	3.64	10.93
Catalysts and Chemicals	Major comp is cellulase			9.25	4.63	18.51	55.53
Total				15.31	7.66	30.62	91.88
Fixed Operating Costs (million USD/yr)							
Labor (SF from V-R)	DFC x MF	0.0165	0.25	0.95	0.74	1.04	1.37
Maintenance (3% of A)			0.03	4.14	2.55	6.89	15.23
General Overhead (65% of labor + maint)			0.65	3.31	2.14	5.16	10.79
Direct Overhead (45% of Labor)			0.45	0.43	0.33	0.47	0.62
Insurance (0.5% of TIC)			0.005	0.96	0.59	1.60	3.56
Total				9.78	6.35	15.17	31.58

Table 46. Canada cellulosic ethanol (bc) capital and operating costs, ag residues

Country **Canada** **Code =** 7

Cost component	Units	Cost Factor	Scale Factor	Canada Cellulosic Ethanol (BC)	Canada Cellulosic Ethanol (BC)	Canada Cellulosic Ethanol (BC)	Canada Cellulosic Ethanol (BC)
Year $	$			2005	2005	2005	2005
Cost Index (2 = M&S, 3 = CE)			3	130.93	130.93	130.93	130.93
Plant Size	dry short ton/day			**1,608**	**804**	**3,215**	**9,645**
	dry tonne/day			1,457	729	2,915	8,744
Stream Factor	%			95%	95%	95%	95%
Feed	Dry short ton/yr			5.574E+05	2.787E+05	1.115E+06	3.344E+06
	GJ/short ton			1.794E+01	1.794E+01	1.794E+01	1.794E+01
	GJ/yr			9.997E+06	4.999E+06	1.999E+07	5.998E+07
Feed Cost	USD/dt			**$ 10.00**	**$ 10.00**	**$ 10.00**	**$ 10.00**
Yield (gal/Dry US Ton)							
Ethanol	gal/short ton			89.7	89.7	89.70	89.7
Electricity	kWh/gal EtOH			2.18	2.18	2.18	2.18
Process Efficiency - to ethanol	% HHV			44.4%	44.4%	44.4%	44.4%
Process efficiency - overall	% HHV						
Ethanol	gal/yr			5.000E+07	2.500E+07	1.000E+08	3.000E+08
	Mil Gal/YR			**50.00**	**25.00**	**100.00**	**300.00**
	tpy			1.657E+05	8.287E+04	3.315E+05	9.945E+05
	GJ/yr			4.436E+06	2.218E+06	8.872E+06	2.662E+07
	gal/Stream day			1.442E+05	7.210E+04	2.884E+05	8.652E+05
	bbl/s stream day			3.433E+03	1.717E+03	6.866E+03	2.060E+04
Electricity	kWh/yr			1.09E+08	5.45E+07	2.18E+08	6.54E+08
Capital Cost (million USD)							
Feed Handling			0.70	11.57	8.43	22.24	47.98
Pretreatment			0.80	29.30	16.83	51.01	122.85
Neutralization/Conditioning			0.70	12.18	7.50	19.79	42.70
Saccharification & Fermentation			0.85	14.50	8.04	26.13	66.48
Distillation & Solids Recovery			0.65	33.77	21.52	52.99	108.23
Wastewater Treatment			0.65	4.78	3.05	7.50	15.32
Storage			0.65	3.24	2.06	5.08	10.38
Boiler/Turbogenerator			0.70	59.52	36.64	96.69	208.64
Utilities			0.70	7.09	4.37	11.52	24.86
Direct Fixed Capital (DFC), also called TIC				175.95	108.43	292.96	647.44
Engineering	DFC x MF	0.12		21.11	13.01	35.15	77.69
Construction	DFC x MF	0.13		22.87	14.10	38.08	84.17
Contractor & Legal	DFC x MF	0.08		14.08	8.67	23.44	51.79
Process/Project Contingency	DFC x MF	0.0412		7.25	4.47	12.07	26.67
Total Plant Cost (TPC)				241.26	148.69	401.70	887.76
AFUDC							
Total Plant Investment (TPI)				241.26	148.69	401.70	887.76
Land			0.60	2.21	2.21	5.08	15.23
Startup				0	0.00	0.00	0.00
Total Capital Cost (TCC)				243.47	**150.90**	**406.78**	902.99
Contingency/TPI							
Working Capital	DFC x MF	0.05		12.06	7.43	20.09	44.39
Variable Operating Costs (million USD/yr)							
Feed				5.57	2.79	11.15	33.44
Utilities				0.00	0.00	0.00	0.00
Waste Disposal				1.82	0.91	3.64	10.93
Catalysts and Chemicals	Major comp is cellulase			9.25	4.63	18.51	55.53
Total				16.65	8.33	33.30	99.90
Fixed Operating Costs (million USD/yr)							
Labor (SF from V-R)	DFC x MF	0.0165	0.25	3.74	2.91	4.11	5.41
Maintenance (3% of A)			0.03	5.28	3.25	8.79	19.42
General Overhead (65% of labor + maint)			0.65	5.86	4.00	8.38	16.14
Direct Overhead (45% of Labor)			0.45	1.68	1.31	1.85	2.43
Insurance (0.5% of TIC)			0.005	1.22	0.75	2.03	4.51
Total				17.78	12.22	25.16	47.92

Table 47. Caribbean basin cellulosic ethanol (bc) capital and operating costs, bagasse

Country	Caribbean	Code =	9				
Cost component	**Units**	**Cost Factor**	**Scale Factor**	**Caribbean Cellulosic Ethanol (TC)**	**Caribbean Cellulosic Ethanol (TC)**	**Caribbean Cellulosic Ethanol (TC)**	**Caribbean Cellulosic Ethanol (TC)**
Year $	$			2005	2005	2005	2005
Cost Index (2 = M&S, 3 = CE)			3	130.93	130.93	130.93	130.93
Plant Size	dry short ton/day			**1,608**	**804**	**3,215**	**9,645**
	dry tonne/day			1,457	729	2,915	8,744
Stream Factor	%			95%	95%	95%	95%
Feed	Dry short ton/yr			5.574E+05	2.787E+05	1.115E+06	3.344E+06
	GJ/short ton			1.794E+01	1.794E+01	1.794E+01	1.794E+01
	GJ/yr			9.997E+06	4.999E+06	1.999E+07	5.998E+07
Feed Cost	USD/dt			**$ 7.60**	**$ 7.60**	**$ 7.60**	**$ 7.60**
Yield (gal/Dry US Ton)							
Ethanol	gal/short ton			89.7	89.7	89.70	89.7
Electricity	kWh/gal EtOH			2.18	2.18	2.18	2.18
Process Efficiency - to ethanol	% HHV			44.4%	44.4%	44.4%	44.4%
Process efficiency - overall	% HHV						
Ethanol	gal/yr			5.000E+07	2.500E+07	1.000E+08	3.000E+08
	Mil Gal/YR			**50.00**	**25.00**	**100.00**	**300.00**
	tpy			1.657E+05	8.287E+04	3.315E+05	9.945E+05
	GJ/yr			4.436E+06	2.218E+06	8.872E+06	2.662E+07
	gal/Stream day			1.442E+05	7.210E+04	2.884E+05	8.652E+05
	bbl/s stream day			3.433E+03	1.717E+03	6.866E+03	2.060E+04
Electricity	kWh/yr			1.09E+08	5.45E+07	2.18E+08	6.54E+08
Capital Cost (million USD)							
Feed Handling			0.70	10.02	7.30	19.25	41.55
Pretreatment			0.80	25.37	14.57	44.17	106.38
Neutralization/Conditioning			0.70	10.55	6.49	17.14	36.98
Saccharification & Fermentation			0.85	12.55	6.96	22.62	57.56
Distillation & Solids Recovery			0.65	29.24	18.64	45.89	93.72
Wastewater Treatment			0.65	4.14	2.64	6.50	13.27
Storage			0.65	2.80	1.79	4.40	8.99
Boiler/Turbogenerator			0.70	51.54	31.73	83.73	180.67
Utilities			0.70	6.14	3.78	9.98	21.53
Direct Fixed Capital (DFC), also called TIC				152.36	93.90	253.68	560.65
Engineering	DFC x MF	0.12		18.28	11.27	30.44	67.28
Construction	DFC x MF	0.13		19.81	12.21	32.98	72.88
Contractor & Legal	DFC x MF	0.08		12.19	7.51	20.29	44.85
Process/Project Contingency	DFC x MF	0.0412		6.28	3.87	10.45	23.10
Total Plant Cost (TPC)				208.92	128.75	347.85	768.76
AFUDC							
Total Plant Investment (TPI)				208.92	128.75	347.85	768.76
Land			0.60	2.21	2.21	5.08	15.23
Startup				0	0.00	0.00	0.00
Total Capital Cost (TCC)				211.13	**130.96**	**352.93**	783.99
Contingency/TPI							
Working Capital	DFC x MF	0.05		10.45	6.44	17.39	38.44
Variable Operating Costs (million USD/yr)							
Feed				4.24	2.12	8.47	25.42
Utilities				0.00	0.00	0.00	0.00
Waste Disposal				1.82	0.91	3.64	10.93
Catalysts and Chemicals	Major comp is cellulase			9.25	4.63	18.51	55.53
Total				15.31	7.66	30.62	91.88
Fixed Operating Costs (million USD/yr)							
Labor (SF from V-R)	DFC x MF	0.0165	0.25	2.14	1.66	2.35	3.09
Maintenance (3% of A)			0.03	4.57	2.82	7.61	16.82
General Overhead (65% of labor + maint)			0.65	4.36	2.91	6.47	12.94
Direct Overhead (45% of Labor)			0.45	0.96	0.75	1.06	1.39
Insurance (0.5% of TIC)			0.005	1.06	0.65	1.76	3.92
Total				13.09	8.79	19.26	38.17

Table 48. China cellulosic ethanol capital (bc) and operating costs, bagasse

Country	China	Code =	3				
Cost component	**Units**	**Cost Factor**	**Scale Factor**	**China Cellulosic Ethanol (TC)**	**China Cellulosic Ethanol (TC)**	**China Cellulosic Ethanol (TC)**	**China Cellulosic Ethanol (TC)**
Year $	$			2005	2005	2005	2005
Cost Index (2 = M&S, 3 = CE)			3	130.93	130.93	130.93	130.93
Plant Size	dry short ton/day			**1,608**	**804**	**3,215**	**9,645**
	dry tonne/day			1,457	729	2,915	8,744
Stream Factor	%			95%	95%	95%	95%
Feed	Dry short ton/yr			5.574E+05	2.787E+05	1.115E+06	3.344E+06
	GJ/short ton			1.794E+01	1.794E+01	1.794E+01	1.794E+01
	GJ/yr			9.997E+06	4.999E+06	1.999E+07	5.998E+07
Feed Cost	USD/dt			**$ 9.10**	**$ 9.10**	**$ 9.10**	**$ 9.10**
Yield (gal/Dry US Ton)							
Ethanol	gal/short ton			89.7	89.7	89.70	89.7
Electricity	kWh/gal EtOH			2.18	2.18	2.18	2.18
Process Efficiency - to ethanol	% HHV			44.4%	44.4%	44.4%	44.4%
Process efficiency - overall	% HHV						
Ethanol	gal/yr			5.000E+07	2.500E+07	1.000E+08	3.000E+08
	Mil Gal/YR			**50.00**	**25.00**	**100.00**	**300.00**
	tpy			1.657E+05	8.287E+04	3.315E+05	9.945E+05
	GJ/yr			4.436E+06	2.218E+06	8.872E+06	2.662E+07
	gal/Stream day			1.442E+05	7.210E+04	2.884E+05	8.652E+05
	bbl/s stream day			3.433E+03	1.717E+03	6.866E+03	2.060E+04
Electricity	kWh/yr			1.09E+08	5.45E+07	2.18E+08	6.54E+08
Capital Cost (million USD)							
Feed Handling			0.70	9.77	7.12	18.78	40.52
Pretreatment			0.80	24.75	14.21	43.08	103.76
Neutralization/Conditioning			0.70	10.29	6.33	16.71	36.06
Saccharification & Fermentation			0.85	12.24	6.79	22.07	56.14
Distillation & Solids Recovery			0.65	28.52	18.18	44.76	91.41
Wastewater Treatment			0.65	4.04	2.57	6.34	12.94
Storage			0.65	2.74	1.74	4.29	8.77
Boiler/Turbogenerator			0.70	50.27	30.95	81.67	176.21
Utilities			0.70	5.99	3.69	9.73	21.00
Direct Fixed Capital (DFC), also called TIC				148.60	91.58	247.43	546.81
Engineering	DFC x MF	0.12		17.83	10.99	29.69	65.62
Construction	DFC x MF	0.13		19.32	11.91	32.17	71.09
Contractor & Legal	DFC x MF	0.08		11.89	7.33	19.79	43.75
Process/Project Contingency	DFC x MF	0.0412		6.12	3.77	10.19	22.53
Total Plant Cost (TPC)				203.77	125.58	339.27	749.79
AFUDC							
Total Plant Investment (TPI)				203.77	125.58	339.27	749.79
Land			0.60	2.21	2.21	5.08	15.23
Startup				0	0.00	0.00	0.00
Total Capital Cost (TCC)				205.98	**127.79**	**344.35**	765.02
Contingency/TPI							
Working Capital	DFC x MF	0.05		10.19	6.28	16.96	37.49
Variable Operating Costs (million USD/yr)							
Feed				5.07	2.54	10.14	30.43
Utilities				0.00	0.00	0.00	0.00
Waste Disposal				1.82	0.91	3.64	10.93
Catalysts and Chemicals	Major comp is cellulase			9.25	4.63	18.51	55.53
Total				16.15	8.07	32.30	96.89
Fixed Operating Costs (million USD/yr)							
Labor (SF from V-R)	DFC x MF	0.0165	0.25	2.48	1.92	2.72	3.58
Maintenance (3% of A)			0.03	4.46	2.75	7.42	16.40
General Overhead (65% of labor + maint)			0.65	4.51	3.04	6.59	12.99
Direct Overhead (45% of Labor)			0.45	1.11	0.87	1.22	1.61
Insurance (0.5% of TIC)			0.005	1.03	0.64	1.72	3.83
Total				13.59	9.21	19.69	38.42

Table 49. Colombia cellulosic ethanol (bc) capital and operating costs, bagasse

Country	Colombia	Code =	6					
Cost component	**Units**	**Cost Factor**	**Scale Factor**	**USA Cellulosic Ethanol (TC)**	**Colombia Cellulosic Ethanol (TC)**	**Colombia Cellulosic Ethanol (TC)**	**Colombia Cellulosic Ethanol (TC)**	**Colombia Cellulosic Ethanol (TC)**
Year $	$			2002	2005	2005	2005	2005
Cost Index (2 = M&S, 3 = CE)			3	110.63	130.93	130.93	130.93	130.93
Plant Size	dry short ton/day			2,206	**1,608**	**804**	**3,215**	**9,645**
	dry tonne/day			2,000	1,457	729	2,915	8,744
Stream Factor	%			95%	95%	95%	95%	95%
Feed	Dry short ton/yr			7.649E+05	5.574E+05	2.787E+05	1.115E+06	3.344E+06
	GJ/short ton			1.794E+01	1.794E+01	1.794E+01	1.794E+01	1.794E+01
	GJ/yr			1.372E+07	9.997E+06	4.999E+06	1.999E+07	5.998E+07
Feed Cost	USD/dt			**$ 35.00**	**$ 14.50**	**$ 14.50**	**$ 14.50**	**$ 14.50**
Yield (gal/Dry US Ton)								
Ethanol	gal/short ton			89.7	89.7	89.7	89.70	89.7
Electricity	kWh/gal EtOH			2.18	2.18	2.18	2.18	2.18
Process Efficiency - to ethanol	% HHV			44.4%	44.4%	44.4%	44.4%	44.4%
Process efficiency - overall	% HHV							
Ethanol	gal/yr			6.861E+07	5.000E+07	2.500E+07	1.000E+08	3.000E+08
	Mil Gal/YR			68.61	**50.00**	**25.00**	**100.00**	**300.00**
	tpy			2.275E+05	1.657E+05	8.287E+04	3.315E+05	9.945E+05
	GJ/yr			6.088E+06	4.436E+06	2.218E+06	8.872E+06	2.662E+07
	gal/Stream day			1.979E+05	1.442E+05	7.210E+04	2.884E+05	8.652E+05
	bbl/s stream day			4.711E+03	3.433E+03	1.717E+03	6.866E+03	2.060E+04
Electricity	kWh/yr			1.50E+08	1.09E+08	5.45E+07	2.18E+08	6.54E+08
Capital Cost (million USD)								
Feed Handling			0.70	7.50	8.83	6.43	16.97	36.62
Pretreatment			0.80	19.00	22.36	12.84	38.93	93.76
Neutralization/Conditioning			0.70	7.90	9.30	5.72	15.10	32.59
Saccharification & Fermentation			0.85	9.40	11.06	6.14	19.94	50.74
Distillation & Solids Recovery			0.65	21.90	25.77	16.43	40.44	82.60
Wastewater Treatment			0.65	3.10	3.65	2.33	5.72	11.69
Storage			0.65	2.10	2.47	1.58	3.88	7.92
Boiler/Turbogenerator			0.70	38.60	45.43	27.97	73.80	159.24
Utilities			0.70	4.60	5.41	3.33	8.79	18.98
Direct Fixed Capital (DFC), also called TIC				114.10	134.29	82.76	223.59	494.14
Engineering	DFC x MF	0.12		13.69	16.11	9.93	26.83	59.30
Construction	DFC x MF	0.13		14.83	17.46	10.76	29.07	64.24
Contractor & Legal	DFC x MF	0.08		9.13	10.74	6.62	17.89	39.53
Process/Project Contingency	DFC x MF	0.0412		4.70	5.53	3.41	9.21	20.36
Total Plant Cost (TPC)				156.45	184.14	113.48	306.59	677.56
AFUDC								
Total Plant Investment (TPI)				156.45	184.14	113.48	306.59	677.56
Land			0.60	2.21	2.21	2.21	5.08	15.23
Startup				0	0	0.00	0.00	0.00
Total Capital Cost (TCC)				158.66	186.35	**115.69**	**311.66**	692.79
Contingency/TPI								
Working Capital	DFC x MF	0.05		7.82	9.21	5.67	15.33	33.88
Variable Operating Costs (million USD/yr)								
Feed				26.77	8.08	4.04	16.16	48.49
Utilities				0.00	0.00	0.00	0.00	0.00
Waste Disposal				2.50	1.82	0.91	3.64	10.93
Catalysts and Chemicals	Major comp is cellulase			12.70	9.25	4.63	18.51	55.53
Total				41.97	19.16	9.58	38.32	114.95
Fixed Operating Costs (million USD/yr)								
Labor (SF from V-R)	DFC x MF	0.0165	0.25	1.88	1.42	1.10	1.56	2.05
Maintenance (3% of A)			0.03	3.42	4.03	2.48	6.71	14.82
General Overhead (65% of labor + maint)			0.65	3.45	3.54	2.33	5.37	10.97
Direct Overhead (45% of Labor)			0.45	0.85	0.64	0.50	0.70	0.92
Insurance (0.5% of TIC)			0.005	0.79	0.93	0.58	1.56	3.46
Total				10.39	10.56	6.99	15.90	32.23

Table 50. India cellulosic ethanol (bc) capital and operating costs, bagasse

Country	India	Code =	4				
Cost component	**Units**	**Cost Factor**	**Scale Factor**	**India Cellulosic Ethanol (TC)**	**India Cellulosic Ethanol (TC)**	**India Cellulosic Ethanol (TC)**	**India Cellulosic Ethanol (TC)**
Year $	$			2005	2005	2005	2005
Cost Index (2 = M&S, 3 = CE)			3	130.93	130.93	130.93	130.93
Plant Size	dry short ton/day			**1,608**	**804**	**3,215**	**9,645**
	dry tonne/day			1,457	729	2,915	8,744
Stream Factor	%			95%	95%	95%	95%
Feed	Dry short ton/yr			5.574E+05	2.787E+05	1.115E+06	3.344E+06
	GJ/short ton			1.794E+01	1.794E+01	1.794E+01	1.794E+01
	GJ/yr			9.997E+06	4.999E+06	1.999E+07	5.998E+07
Feed Cost	USD/dt			**$ 7.30**	**$ 7.30**	**$ 7.30**	**$ 7.30**
Yield (gal/Dry US Ton)							
Ethanol	gal/short ton			89.7	89.7	89.70	89.7
Electricity	kWh/gal EtOH			2.18	2.18	2.18	2.18
Process Efficiency - to ethanol	% HHV			44.4%	44.4%	44.4%	44.4%
Process efficiency - overall	% HHV						
Ethanol	gal/yr			5.000E+07	2.500E+07	1.000E+08	3.000E+08
	Mil Gal/YR			**50.00**	**25.00**	**100.00**	**300.00**
	tpy			1.657E+05	8.287E+04	3.315E+05	9.945E+05
	GJ/yr			4.436E+06	2.218E+06	8.872E+06	2.662E+07
	gal/Stream day			1.442E+05	7.210E+04	2.884E+05	8.652E+05
	bbl/s stream day			3.433E+03	1.717E+03	6.866E+03	2.060E+04
Electricity	kWh/yr			1.09E+08	5.45E+07	2.18E+08	6.54E+08
Capital Cost (million USD)							
Feed Handling			0.70	9.47	6.90	18.20	39.28
Pretreatment			0.80	23.98	13.78	41.76	100.57
Neutralization/Conditioning			0.70	9.97	6.14	16.20	34.96
Saccharification & Fermentation			0.85	11.87	6.58	21.39	54.42
Distillation & Solids Recovery			0.65	27.65	17.62	43.38	88.60
Wastewater Treatment			0.65	3.91	2.49	6.14	12.54
Storage			0.65	2.65	1.69	4.16	8.50
Boiler/Turbogenerator			0.70	48.73	29.99	79.16	170.79
Utilities			0.70	5.81	3.57	9.43	20.35
Direct Fixed Capital (DFC), also called TIC				144.03	88.77	239.82	530.00
Engineering	DFC x MF	0.12		17.28	10.65	28.78	63.60
Construction	DFC x MF	0.13		18.72	11.54	31.18	68.90
Contractor & Legal	DFC x MF	0.08		11.52	7.10	19.19	42.40
Process/Project Contingency	DFC x MF	0.0412		5.93	3.66	9.88	21.84
Total Plant Cost (TPC)				197.50	121.72	328.84	726.74
AFUDC							
Total Plant Investment (TPI)				197.50	121.72	328.84	726.74
Land			0.60	2.21	2.21	5.08	15.23
Startup				0	0.00	0.00	0.00
Total Capital Cost (TCC)				199.71	**123.93**	**333.91**	741.97
Contingency/TPI							
Working Capital	DFC x MF	0.05		9.88	6.09	16.44	36.34
Variable Operating Costs (million USD/yr)							
Feed				4.07	2.03	8.14	24.41
Utilities				0.00	0.00	0.00	0.00
Waste Disposal				1.82	0.91	3.64	10.93
Catalysts and Chemicals	Major comp is cellulase			9.25	4.63	18.51	55.53
Total				15.15	7.57	30.29	90.87
Fixed Operating Costs (million USD/yr)							
Labor (SF from V-R)	DFC x MF	0.0165	0.25	0.83	0.65	0.92	1.21
Maintenance (3% of A)			0.03	4.32	2.66	7.19	15.90
General Overhead (65% of labor + maint)			0.65	3.35	2.15	5.27	11.12
Direct Overhead (45% of Labor)			0.45	0.38	0.29	0.41	0.54
Insurance (0.5% of TIC)			0.005	1.00	0.62	1.67	3.71
Total				9.88	6.37	15.46	32.48

Table 51. Mexico cellulosic ethanol (bc) capital and operating costs, bagasse

Country	Mexico	Code =	8				
Cost component	**Units**	**Cost Factor**	**Scale Factor**	**Mexico Cellulosic Ethanol (TC)**	**Mexico Cellulosic Ethanol (TC)**	**Mexico Cellulosic Ethanol (TC)**	**Mexico Cellulosic Ethanol (TC)**
Year $	$			2005	2005	2005	2005
Cost Index (2 = M&S, 3 = CE)			3	130.93	130.93	130.93	130.93
Plant Size	dry short ton/day			**1,608**	**804**	**3,215**	**9,645**
	dry tonne/day			1,457	729	2,915	8,744
Stream Factor	%			95%	95%	95%	95%
Feed	Dry short ton/yr			5.574E+05	2.787E+05	1.115E+06	3.344E+06
	GJ/short ton			1.794E+01	1.794E+01	1.794E+01	1.794E+01
	GJ/yr			9.997E+06	4.999E+06	1.999E+07	5.998E+07
Feed Cost	USD/dt			**$ 15.40**	**$ 15.40**	**$ 15.40**	**$ 15.40**
Yield (gal/Dry US Ton)							
Ethanol	gal/short ton			89.7	89.7	89.70	89.7
Electricity	kWh/gal EtOH			2.18	2.18	2.18	2.18
Process Efficiency - to ethanol	% HHV			44.4%	44.4%	44.4%	44.4%
Process efficiency - overall	% HHV						
Ethanol	gal/yr			5.000E+07	2.500E+07	1.000E+08	3.000E+08
	Mil Gal/YR			**50.00**	**25.00**	**100.00**	**300.00**
	tpy			1.657E+05	8.287E+04	3.315E+05	9.945E+05
	GJ/yr			4.436E+06	2.218E+06	8.872E+06	2.662E+07
	gal/Stream day			1.442E+05	7.210E+04	2.884E+05	8.652E+05
	bbl/s stream day			3.433E+03	1.717E+03	6.866E+03	2.060E+04
Electricity	kWh/yr			1.09E+08	5.45E+07	2.18E+08	6.54E+08
Capital Cost (million USD)							
Feed Handling			0.70	7.14	5.20	13.73	29.62
Pretreatment			0.80	18.09	10.39	31.49	75.84
Neutralization/Conditioning			0.70	7.52	4.63	12.22	26.36
Saccharification & Fermentation			0.85	8.95	4.96	16.13	41.04
Distillation & Solids Recovery			0.65	20.85	13.29	32.71	66.81
Wastewater Treatment			0.65	2.95	1.88	4.63	9.46
Storage			0.65	2.00	1.27	3.14	6.41
Boiler/Turbogenerator			0.70	36.75	22.62	59.69	128.80
Utilities			0.70	4.38	2.70	7.11	15.35
Direct Fixed Capital (DFC), also called TIC				108.62	66.94	180.85	399.68
Engineering	DFC x MF	0.12		13.03	8.03	21.70	47.96
Construction	DFC x MF	0.13		14.12	8.70	23.51	51.96
Contractor & Legal	DFC x MF	0.08		8.69	5.36	14.47	31.97
Process/Project Contingency	DFC x MF	0.0412		4.48	2.76	7.45	16.47
Total Plant Cost (TPC)				148.94	91.79	247.98	548.04
AFUDC							
Total Plant Investment (TPI)				148.94	91.79	247.98	548.04
Land			0.60	2.21	2.21	5.08	15.23
Startup				0	0.00	0.00	0.00
Total Capital Cost (TCC)				151.15	**94.00**	**253.06**	563.27
Contingency/TPI							
Working Capital	DFC x MF	0.05		7.45	4.59	12.40	27.40
Variable Operating Costs (million USD/yr)							
Feed				8.58	4.29	17.17	51.50
Utilities				0.00	0.00	0.00	0.00
Waste Disposal				1.82	0.91	3.64	10.93
Catalysts and Chemicals	Major comp is cellulase			9.25	4.63	18.51	55.53
Total				19.66	9.83	39.32	117.96
Fixed Operating Costs (million USD/yr)							
Labor (SF from V-R)	DFC x MF	0.0165	0.25	0.54	0.42	0.59	0.78
Maintenance (3% of A)			0.03	3.26	2.01	5.43	11.99
General Overhead (65% of labor + maint)			0.65	2.47	1.58	3.91	8.30
Direct Overhead (45% of Labor)			0.45	0.24	0.19	0.27	0.35
Insurance (0.5% of TIC)			0.005	0.76	0.47	1.27	2.82
Total				7.26	4.66	11.46	24.23

Table 52. Cellulosic ethanol (biochemical) summary yields, costs, and plant gate prices, 25 MM GPY, bagasse

Technology	Units	USA	Argentina	Brazil	Canada	Caribbean Basin	China	Colombia	India	Mexico
Plant Size	MM gal/yr	25	25	25	25	25	25	25	25	25
Yields										
Primary Product Yield	gal/ton	89.7	89.7	89.7		89.7	89.7	89.7	89.7	89.7
By Product A										
Unit		electricity	electricity	electricity		electricity	electricity	electricity	electricity	electricity
Yield unit		kWh	kWh	kWh		kWh	kWh	kWh	kWh	kWh
Annual Yield		5.45E+07	5.45E+07	5.45E+07		5.45E+07	5.45E+07	5.45E+07	5.45E+07	5.45E+07
Price unit		0.04	0.04	0.04		0.04	0.04	0.04	0.04	0.04
MM USD/yr		2.18	2.18	2.18		2.18	2.18	2.18	2.18	2.18
By Product B										
Unit										
Yield unit										
Annual Yield										
Price unit										
Annual Cost	MM USD/yr									
Energy Inputs										
Electricity										
Cost	$/kWh	N/A	N/A	N/A		N/A	N/A	N/A	N/A	N/A
Amount	kWh/yr									
Annual Cost	MM USD/yr									
Fuel										
Type		N/A	N/A	N/A		N/A	N/A	N/A	N/A	N/A
Unit										
Amount										
Cost	USD/unit									
Annual Cost	MM USD/yr									
Capital & Operating Costs										
Capital	MMUSD	116.32	124.74	118.82		130.96	127.79	115.69	123.93	94.00
Operating w/o feed	MM USD/yr	13.87	13.67	11.89		14.33	14.75	12.53	11.91	10.2
Feed										
Unit		ton								
Cost/unit	USD/unit	35	9.1	7.6		7.6	9.1	14.5	7.3	15.4
Rate	unit/day	804	804	804		804	804	804	804	804
Yearly Cost	MM USD/yr	9.75	2.54	2.12		2.12	2.54	4.04	2.03	4.29
Product Plant Gate Cost										
Basis										
Value	USD/gal	1.56	1.29	1.15		1.30	1.35	1.24	1.18	1.05

Table 53. Cellulosic ethanol (biochemical) summary yields, costs, and plant gate prices, 100 MM GPY, bagasse

Technology	Units	USA	Argentina	Brazil	Canada	Caribbean Basin	China	Colombia	India	Mexico
Plant Size	MM gal/yr	100	100	100	100	100	100	100	100	100
Yields										
Primary Product Yield	gal/ton	89.7	89.7	89.7		89.7	89.7	89.7	89.7	89.7
By Product A										
Unit		electricity	electricity	electricity		electricity	electricity	electricity	electricity	electricity
Yield unit		kWh	kWh	kWh		kWh	kWh	kWh	kWh	kWh
Annual Yield		2.18E+08	2.18E+08	2.18E+08		2.18E+08	2.18E+08	2.18E+08	2.18E+08	2.18E+08
Price unit		0.04	0.04	0.04		0.04	0.04	0.04	0.04	0.04
MM USD/yr		8.72	8.72	8.72		8.72	8.72	8.72	8.72	8.72
By Product B										
Unit										
Yield unit										
Annual Yield										
Price unit										
Annual Cost	MM USD/yr									
Energy Inputs										
Electricity		N/A	N/A	N/A		N/A	N/A	N/A	N/A	N/A
Cost	$/kWh									
Amount	kWh/yr									
Annual Cost	MM USD/yr									
Fuel										
Type		N/A	N/A	N/A		N/A	N/A	N/A	N/A	N/A
Unit										
Amount										
Cost	USD/unit									
Annual Cost	MM USD/yr									
Capital & Operating Costs										
Capital	MMUSD	313.38	336.11	320.13		352.93	344.35	311.66	333.91	253.06
Operating w/o feed	MM USD/yr	39.99	40.15	37.32		41.41	41.84	38.05	37.62	33.61
Feed										
Unit		ton								
Cost/unit	USD/unit	35	9.1	7.6		7.6	9.1	14.5	7.3	15.4
Rate	unit/day	3125	3125	3125		3125	3125	3125	3125	3125
Yearly Cost	MM USD/yr	39.03	10.14	8.47		8.47	10.14	16.16	8.14	17.17
Product Plant Gate Cost										
Basis										
Value	USD/gal	1.17	0.90	0.83		0.90	0.92	0.90	0.81	0.81

Table 54. Cellulosic ethanol (biochemical) summary yields, costs, and plant gate prices, 25 MM GPY, ag residue

Technology	Units	USA	Argentina	Brazil	Canada	Caribbean Basin	China	Colombia	India	Mexico
Plant Size	MM gal/yr	25	25	25	25	25	25	25	25	25
Yields										
Primary Product Yield	gal/ton	89.7	89.7	89.7	89.7	89.7	89.7	89.7	89.7	89.7
By Product A										
Unit		electricity	electricity	electricity	electricity	electricity	electricity	electricity	electricity	electricity
Yield unit		kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh
Annual Yield		5.45E+07	5.45E+07	5.45E+07	5.45E+07	5.45E+07	5.45E+07	5.45E+07	5.45E+07	5.45E+07
Price unit		0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
MM USD/yr		2.18	2.18	2.18	2.18	2.18	2.18	2.18	2.18	2.18
By Product B										
Unit										
Yield unit										
Annual Yield										
Price unit										
Annual Cost	MM USD/yr									
Energy Inputs										
Electricity										
Cost	$/kWh	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Amount	kWh/yr									
Annual Cost	MM USD/yr									
Fuel										
Type		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Unit										
Amount										
Cost	USD/unit									
Annual Cost	MM USD/yr									
Capital & Operating Costs										
Capital	MMUSD	116.32	124.74	118.82	150.9	130.96	127.79	115.69	123.93	94.00
Operating w/o feed	MM USD/yr	13.87	13.67	11.89	17.76	14.33	14.75	12.53	11.91	10.2
Feed										
Unit										
Cost/unit	USD/unit	35	47.2	30.8	10	14.5	28.1	14.5	7.3	47.2
Rate	unit/day	804	804	804	804	804	804	804	804	804
Yearly Cost	MM USD/yr	9.75	26.31	8.58	2.79	4.04	7.83	4.04	2.03	13.15
Product Plant Gate Cost										
Basis										
Value	USD/gal	1.56	1.70	1.41	1.57	1.37	1.56	1.24	1.18	1.4

Table 55. Cellulosic ethanol (biochemical) summary yields, costs, and plant gate prices, 100 MM GPY, ag residues

Technology	Units	USA	Argentina	Brazil	Canada	Caribbean Basin	China	Colombia	India	Mexico
Plant Size	MM gal/yr	100	100	100	100	100	100	100	100	100
Yields										
Primary Product Yield	gal/ton	89.7	89.7	89.7	89.7	89.7	89.7	89.7	89.7	89.7
By Product A										
Unit		electricity	electricity	electricity	electricity	electricity	electricity	electricity	electricity	electricity
Yield unit		kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh
Annual Yield		2.18E+08	2.18E+08	2.18E+08	2.18E+08	2.18E+08	2.18E+08	2.18E+08	2.18E+08	2.18E+08
Price unit		0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
MM USD/yr		8.72	8.72	8.72	8.72	8.72	8.72	8.72	8.72	8.72
By Product B										
Unit										
Yield unit										
Annual Yield										
Price unit										
Annual Cost	MM USD/yr									
Energy Inputs										
Electricity		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cost	$/kWh									
Amount	kWh/yr									
Annual Cost	MM USD/yr									
Fuel										
Type		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Unit										
Amount										
Cost	USD/unit									
Annual Cost	MM USD/yr									
Capital & Operating Costs										
Capital	MMUSD	313.38	336.11	320.13	406.78	352.93	344.35	311.66	333.91	253.06
Operating w/o feed	MM USD/yr	39.99	40.15	37.32	47.31	41.41	41.84	38.05	37.62	33.61
Feed										
Unit		ton								
Cost/unit	USD/unit	35	47.2	30.8	10	14.5	28.1	14.5	7.3	47.2
Rate	unit/day	3125	3125	3125	3125	3125	3125	3125	3125	3125
Yearly Cost	MM USD/yr	39.03	52.62	34.33	4.11	16.16	31.33	16.16	8.14	52.62
Product Plant Gate Cost										
Basis										
Value	USD/gal	1.17	1.32	1.09	1.06	0.98	1.14	0.90	0.81	1.17

Table 56. Cellulosic ethanol (biochemical) summary yields, costs, and plant gate prices, 25 MM GPY, wood/perennial

Technology	Units	USA	Argentina	Brazil	Canada	Caribbean Basin	China	Colombia	India	Mexico
Plant Size	MM gal/yr	25	25	25	25	25	25	25	25	25
Yields										
Primary Product Yield	gal/ton	89.7	89.7	89.7	89.7	89.7	89.7	89.7	89.7	89.7
By Product A										
Unit		electricity	electricity	electricity	electricity	electricity	electricity	electricity	electricity	electricity
Yield unit		kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh
Annual Yield		5.45E+07	5.45E+07	5.45E+07	5.45E+07	5.45E+07	5.45E+07	5.45E+07	5.45E+07	5.45E+07
Price unit		0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
MM USD/yr		2.18	2.18	2.18	2.18	2.18	2.18	2.18	2.18	2.18
By Product B										
Unit										
Yield unit										
Annual Yield										
Price unit										
Annual Cost	MM USD/yr									
Energy Inputs										
Electricity										
Cost	$/kWh	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Amount	kWh/yr									
Annual Cost	MM USD/yr									
Fuel										
Type		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Unit										
Amount										
Cost	USD/unit									
Annual Cost	MM USD/yr									
Capital & Operating Costs										
Capital	MMUSD	116.32	124.74	118.82	150.9	130.96	127.79	115.69	123.93	94.00
Operating w/o feed	MM USD/yr	13.87	13.67	11.89	17.76	14.33	14.75	12.53	11.91	10.2
Feed										
Unit										
Cost/unit	USD/unit	35	47.2	47.2	31.8	47.2	47.2	47.2	47.2	47.2
Rate	unit/day	804	804	804	804	804	804	804	804	804
Yearly Cost	MM USD/yr	9.75	13.15	13.15	8.86	13.15	13.15	13.15	13.15	13.15
Product Plant Gate Cost										
Basis										
Value	USD/gal	1.56	1.70	1.59	1.81	1.74	1.77	1.40	1.64	1.4

Table 57. Cellulosic ethanol (biochemical) summary yields, costs, and plant gate prices, 100 MM GPY, wood/perennial

Technology	Units	USA	Argentina	Brazil	Canada	Caribbean Basin	China	Colombia	India	Mexico
Plant Size	MM gal/yr	100	100	100	100	100	100	100	100	100
Yields										
Primary Product Yield	gal/ton	89.7	89.7	89.7	89.7	89.7	89.7	89.7	89.7	89.7
By Product A										
Unit		electricity	electricity	electricity	electricity	electricity	electricity	electricity	electricity	electricity
Yield unit		kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh
Annual Yield		2.18E+08	2.18E+08	2.18E+08	2.18E+08	2.18E+08	2.18E+08	2.18E+08	2.18E+08	2.18E+08
Price unit		0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
MM USD/yr		8.72	8.72	8.72	8.72	8.72	8.72	8.72	8.72	8.72
By Product B										
Unit										
Yield unit										
Annual Yield										
Price unit										
Annual Cost	MM USD/yr									
Energy Inputs										
Electricity		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cost	$/kWh									
Amount	kWh/yr									
Annual Cost	MM USD/yr									
Fuel										
Type		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Unit										
Amount										
Cost	USD/unit									
Annual Cost	MM USD/yr									
Capital & Operating Costs										
Capital	MMUSD	313.38	336.11	320.13	406.78	352.93	344.35	311.66	333.91	253.06
Operating w/o feed	MM USD/yr	39.99	40.15	37.32	47.31	41.41	41.84	38.05	37.62	33.61
Feed										
Unit		ton								
Cost/unit	USD/unit	35	47.2	47.2	31.8	47.2	47.2	47.2	47.2	47.2
Rate	unit/day	3125	3125	3125	3125	3125	3125	3125	3125	3125
Yearly Cost	MM USD/yr	39.03	52.62	52.62	35.45	52.62	52.62	52.62	52.62	52.62
Product Plant Gate Cost										
Basis										
Value	USD/gal	1.17	1.32	1.27	1.30	1.34	1.35	1.27	1.28	1.17

Table 58. Cellulosic ethanol (biochemical) plant gate prices

Plant Size, MM GPY	25	100	25	100	25	100
Feed	Bagasse		Ag Residues		Wood /Perennials	
Country	Ethanol Plant Gate Cost (USD/gal ethanol)					
USA	1.56	1.17	1.56	1.17	1.56	1.17
Argentina	1.29	0.90	1.70	1.32	1.70	1.32
Brazil	1.15	0.83	1.41	1.09	1.59	1.27
Canada	--	--	1.57	1.06	1.81	1.30
Caribbean Basin	1.30	0.90	1.37	0.98	1.74	1.34
China	1.35	0.92	1.56	1.14	1.77	1.35
Colombia	1.24	0.90	1.24	0.90	1.60	1.27
India	1.18	0.81	1.18	0.81	1.64	1.28
Mexico	1.05	0.81	1.40	1.17	1.40	1.17

6 Cellulosic Ethanol (Thermochemical)

The cellulosic ethanol process for the country comparisons is a conceptual nth plant process that is used by the Office of the Biomass Program as a benchmark for defining research and development goals and performance metrics. Portions of the Phillips et al. (2007) design report are excerpted below to provide background information and a brief discussion of the technology.

This assessment directly builds upon an initial analysis for the TC production of ethanol and other alcohol co-products (Aden et al. 2006), which, in turn, was based upon a detailed design and economic analysis for the production of hydrogen from biomass (Spath et al). This design report is complementary to other studies being funded by the DOE OBP, including the RBAEF (Role of Biomass in America's Energy Future) study. However, the RBAEF study differs in many ways from this study. For example, RBAEF is designed for a further time horizon than 2012. It is based on a different feedstock, switchgrass, and it considers a variety of thermochemical product options, including ethanol, power and Fischer-Tropsch liquids (Larson et al, 2006).

Indirect steam gasification was chosen as the technology around which this process was developed based upon previous technoeconomic studies for the production of methanol and hydrogen from biomass (Bain et al. 2000). The sub-process operations for ethanol production are very similar to those for methanol production (although the specific process configuration will be different). The general process areas include: feedstock preparation, gasification, gas cleanup and conditioning, and alcohol synthesis and purification.

Gasification involves the devolatilization and conversion of biomass in an atmosphere of steam and/or oxygen to produce a medium-calorific value gas. There are two general classes of gasifiers. *Partial oxidation (POX)* gasifiers (directly-heated gasifiers) use the exothermic reaction between oxygen and organics to provide the heat necessary to devolatilize biomass and to convert residual carbon-rich chars. In POX gasifiers, the heat to drive the process is generated internally within the gasifier. A disadvantage of POX gasifiers is that oxygen production is expensive and typically requires large plant sizes to improve economics.

The second general class, *steam gasifiers* (indirectly-heated gasifiers), accomplish biomass heating and gasification through heat transfer from a hot solid or through a heat transfer surface. Either byproduct char and/or a portion of the product gas can be combusted with air (external to the gasifier itself) to provide the energy required for gasification. Steam gasifiers have the advantage of not requiring oxygen; but since most operate at low pressure they require product gas compression for downstream purification and synthesis unit operations.

A number of POX and steam gasifiers are under development and have the potential to produce a synthesis gas suitable for liquid fuel synthesis. These gasifiers have been operated in the 4 to 350 ton per day scale. The decision as to which type of gasifier (POX or steam) will be the most economic depends upon the entire process, not just the cost for the gasifier itself. One indicator for comparing processes is "capital intensity," the capital cost required on a per unit product basis. Figure 21 shows the capital intensity of methanol processes

(Wyman et al. 1993; Chem Systems 1989; Feldmann et al. 1988; Wan and Fraser 1989; Hamelinck and Faaij 2001; Williams et al. 1995) based on indirect steam gasification and direct POX gasification. This figure shows that steam gasification capital intensity is comparable or lower than POX gasification. The estimates indicate that both steam gasification and POX gasification processes should be evaluated, but if the processes need to be evaluated sequentially, choosing steam gasification for the first evaluation is reasonable.

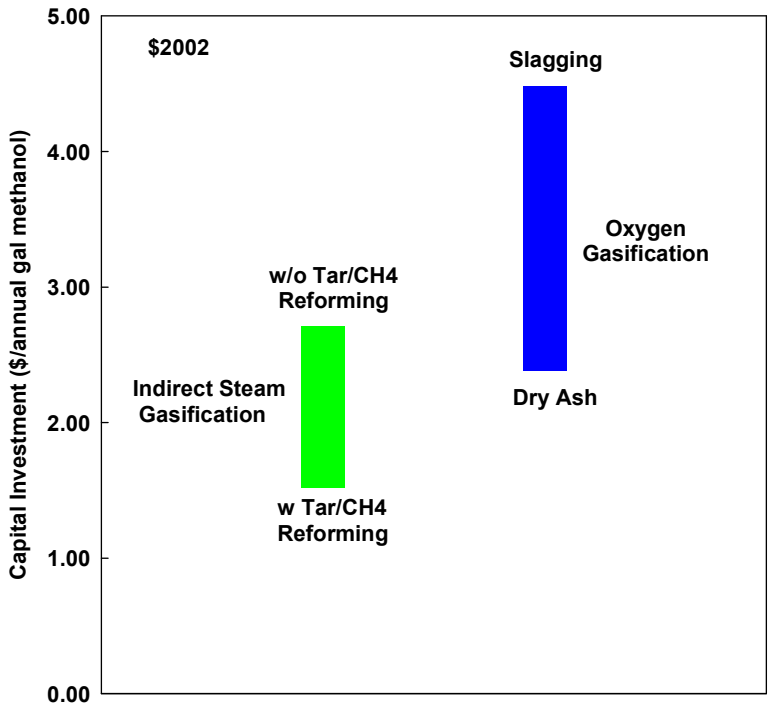


Figure 21. Estimated capital intensities for 2000 tpd biomass-to-methanol processes (Wyman et al. 1993, Williams et al. 1995, Hamelinck and Faaij 2001)

Another philosophy applied to the process development was the idea of making the process "electrical energy neutral." It was recognized that the heat and power requirements of the process could not be met just with char combustion and would require additional fuel. Several options were considered. Additional biomass could be added as fuel directly to the heat and power system; however, this would increase the process beyond 2,000 tonnes/day. Fossil fuels (coal or natural gas) could also be added directly to provide the additional fuel. Alternately syngas could be diverted from liquid fuel production to heat and power production. This option makes the design more energy self-sufficient, but also lowers the overall process yield of alcohols.

It was decided that (1) no additional fuel would be used for heat and power and (2) only enough syngas would be diverted so that the internal heat and power requirements would be

exactly met. Thus, there would neither be electricity sales to the grid nor electricity purchases. The only exception to this would be if other operating specifications were such that syngas could no longer be backed out of the heat and power system but there is still excess electricity (that could then be sold to the grid for a co-product credit).

The capital costs were developed from a variety of sources. For some sub-processes that are well known technology and can be purchased as modular packages (i.e. amine treatment, acid gas removal), an overall cost for the package unit was used. Many of the common equipment items (tanks, pumps, simple heat exchangers) were costed using the Aspen Icarus™ Questimate® costing software. Other more specific unit operations (gasifier, molecular sieve, etc) used cost estimates from other studies and/or from vendor quotes. As documented in the hydrogen design report (Spath et al. 2005) capital costs were developed using general plant-wide factors. The installation costs incorporated cost contributions for not only the actual installation of the purchased equipment but also instrumentation and controls, piping, electrical systems, buildings, yard improvements, etc. A simple block flow diagram of the design is depicted in Figure 22.

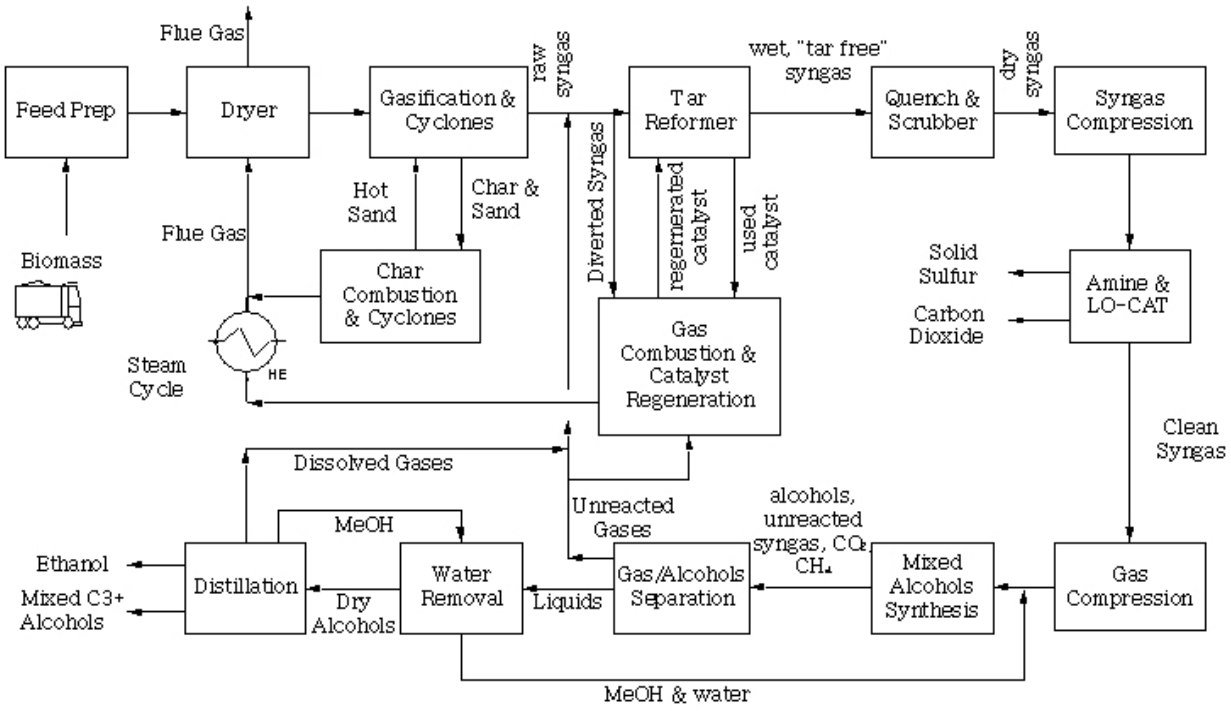


Figure 22. Process flow diagram, cellulosic ethanol (thermochemical)

The process has the following steps:

- *Feedstock Handling and Preparation.* The biomass feedstock is dried from the as-received moisture to that required for proper feeding into the gasifier using flue gases from the char combustor and tar reformer catalyst regenerator.

- *Gasification.* Indirect gasification is considered in this assessment. Heat for the endothermic gasification reactions is supplied by circulating hot synthetic olivine between the gasifier and the char combustor. Conveyors and hoppers are used to feedstock the biomass to the low-pressure indirectly-heated entrained flow gasifier. Steam is injected into the gasifier to aid in stabilizing the entrained flow of biomass and sand through the gasifier. The biomass chemically converts to a mixture of syngas components (CO, H_2, CO_2, CH_4, etc.), tars, and a solid "char" that is mainly the fixed carbon residual from the biomass plus carbon (coke) deposited on the sand. Cyclones at the exit of the gasifier separate the char and sand from the syngas. These solids flow by gravity from the cyclones into the char combustor. Air is introduced to the bottom of the reactor and serves as a carrier gas for the fluidized bed plus the oxidant for burning the char and coke. The heat of combustion heats the sand to over 1800°F. The hot sand and residual ash from the char is carried out of the combustor by the combustion gases and separated from the hot gases using another pair of cyclones. The first cyclone is designed to capture mostly sand while the smaller ash particles remain entrained in the gas exiting the cyclone. The second cyclone is designed to capture the ash and any sand passing through the first cyclone. The hot sand captured by the first cyclone flows by gravity back into the gasifier to provide the heat for the gasification reaction. Ash and sand particles captured in the second cyclone are cooled, moistened to minimize dust and sent to a land fill for disposal.

- *Gas Cleanup and Conditioning.* This consists of multiple operations: reforming of tars and other hydrocarbons to CO and H_2; syngas cooling/quench; and acid gas (CO_2 and H_2S) removal with subsequent reduction of H_2S to sulfur. Tar reforming is envisioned to occur in an isothermal fluidized bed reactor; de-activated reforming catalyst is separated from the effluent syngas and regenerated on-line. The hot syngas is cooled through heat exchange with the steam cycle and additional cooling via water scrubbing. The scrubber also removes impurities such as particulates and ammonia along with any residual tars. The excess scrubber water is sent off-site to a waste-water treatment facility. The cooled syngas enters an amine unit to remove the CO_2 and H_2S. The H_2S is reduced to elemental sulfur and stockpiled for disposal. The CO_2 is vented to the atmosphere in this design.

- *Alcohol Synthesis.* The cleaned and conditioned syngas is converted to alcohols in a fixed bed reactor. The mixture of alcohol and unconverted syngas is cooled through heat exchange with the steam cycle and other process streams. The liquid alcohols are separated by condensing them away from the unconverted syngas. Though the unconverted syngas has the potential to be recycled back to the entrance of the alcohol synthesis reactor, this recycle is not done in this process design. Instead it is recycled to the Gas Cleanup and Conditioning section, mostly as feed to the tar reformer.

- *Alcohol Separation.* The alcohol stream from the Alcohol Synthesis section is depressurized in preparation of dehydration and separation. Another rough separation is performed in a flash separator; the evolved syngas is recycled to the Gas Cleanup and Conditioning section, mostly as feed to the tar reformer. The depressurized alcohol stream is dehydrated using vapor-phase molecular sieves. The dehydrated alcohol stream is introduced to the main alcohol separation column that splits methanol and ethanol from the higher molecular weight alcohols. The overheads are topped in a second column to remove the methanol to ASTM sales specifications. The methanol leaving in the overheads is used to flush the adsorbed water from the molecular sieves. This methanol/water mixture is recycled back to the entrance of the alcohol synthesis reactor.

- *Heat and Power.* A conventional steam cycle produces heat (as steam) for the gasifier and reformer operations and electricity for internal power requirements (with the possibility of exporting excess electricity as a co-product). The steam cycle is integrated with the biomass conversion process. Pre-heaters, steam generators, and super-heaters are integrated within the process design to create the steam. The steam will run through turbines to drive compressors, generate electricity or be withdrawn at various pressure levels for injection into the process. The condensate will be sent back to the steam cycle, de-gassed, and combined with make-up water.

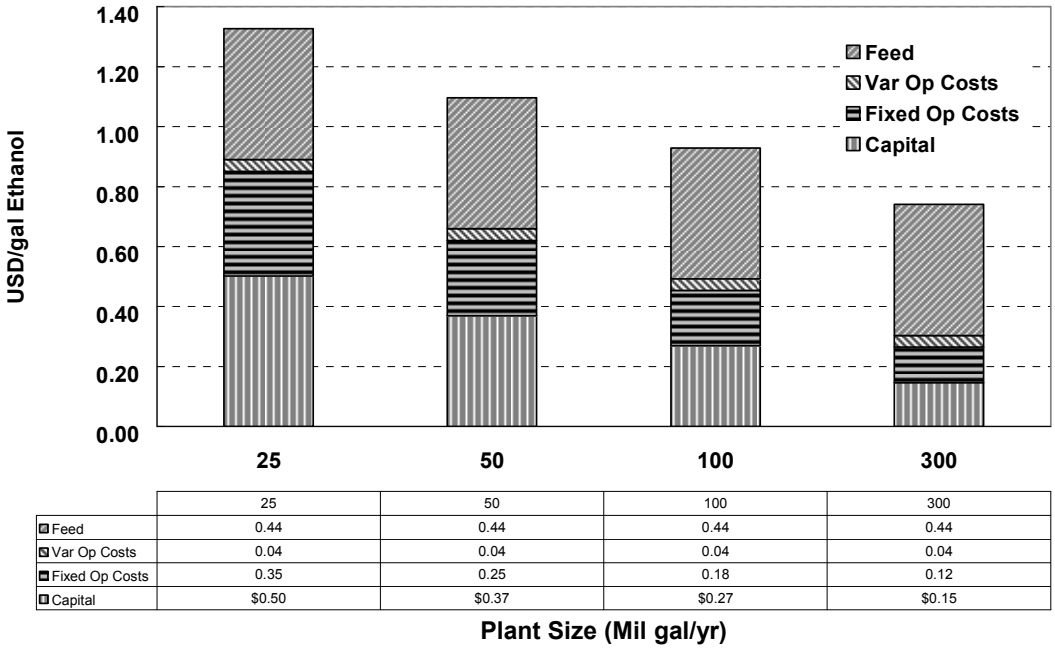
A cooling water system is also included in the model to determine the requirements of each cooling water heat exchanger within the biomass conversion process as well as the requirements of the cooling tower.

Capital and operating costs for the USA base case are given in Table 59. Figure 23 shows the impact of plant size for the USA base case. Table 19 (in the methodology section) gives cellulosic feedstock costs from the ORNL feedstock report (Draft, August 2007); Table 60 gives the corresponding plant gate costs. Representative capital and operating costs for the other countries are given by Table 61 through Table 68.

Table 69 and Table 70 summarize the capital and operating costs, and plant gate prices for 25 MM GPY and 100 MM GPY plants, respectively, using bagasse feedstock. Similarly Table 71 and Table 72 are for agricultural residues, and Table 73 and Table 74 are for wood/perennial feeds.

Table 59. USA cellulosic ethanol (TC) capital and operating costs

Country	USA	Code =	1				
Cost component	**Units**	**Cost Factor**	**Scale Factor**	**USA Cellulosic Ethanol (TC)**	**USA Cellulosic Ethanol (TC)**	**USA Cellulosic Ethanol (TC)**	**USA Cellulosic Ethanol (TC)**
Year $	$			2005	2005	2005	2005
Cost Index (2 = M&S, 3 = CE)			3	130.93	130.93	130.93	130.93
Plant Size	dry short ton/day			1,800	900	3,601	10,801
	dry tonne/day			1,632	816	3,264	9,793
Stream Factor	%			95%	95%	95%	95%
Feed	Dry short ton/yr			6.242E+05	3.121E+05	1.248E+06	3.745E+06
	GJ/short ton			1.794E+01	1.794E+01	1.794E+01	1.794E+01
	GJ/yr			1.119E+07	5.598E+06	2.239E+07	6.717E+07
Feed Cost	USD/dt			**$ 35.00**	**$ 35.00**	**$ 35.00**	**$ 35.00**
Yield (gal/Dry US Ton)							
Ethanol	gal/short ton			80.1	80.1	80.1	80.1
Mixed alcohols	gal/short ton			94.1	94.1	94.1	94.1
Process Efficiency - to ethanol	% HHV			39.6%	39.6%	39.6%	39.6%
Process efficiency - overall	% HHV			47.4%	47.4%	47.4%	47.4%
Ethanol	gal/yr			5.000E+07	2.500E+07	1.000E+08	3.000E+08
	Mil Gal/YR			**50.00**	**25.00**	**100.00**	**300.00**
	tpy			1.657E+05	8.288E+04	3.315E+05	9.945E+05
	GJ/yr			4.436E+06	2.218E+06	8.873E+06	2.662E+07
	gal/Stream day			1.442E+05	7.210E+04	2.884E+05	8.652E+05
	bbl/s stream day			3.433E+03	1.717E+03	6.867E+03	2.060E+04
Higher Alcohols							
	gal/ton			14.0	14.0	14.0	14.0
	gal/yr			8.74E+06	4.37E+06	1.75E+07	5.24E+07
	GJ/gal						
Capital Cost (million USD)							
Feed Handling & Drying			0.70	23.20	14.28	37.69	81.32
Gasification			0.80	12.90	7.41	22.46	54.09
Tar Reforming & Quench			0.70	38.40	23.64	62.38	134.60
Acid Gas & Sulfur Removal			0.85	14.50	8.05	26.14	66.50
Alcohol synthesis - Compression			0.65	16.00	10.20	25.11	51.28
Alcohol Synthesis - Other			0.65	4.60	2.93	7.22	14.74
Alcohol Separation			0.65	7.20	4.59	11.30	23.08
Steam System & Power Generation			0.70	16.80	10.34	27.29	58.89
Cooling Water & Other Utilities			0.70	3.60	2.22	5.85	12.62
Direct Fixed Capital (DFC), also called TIC				137.20	83.65	225.44	497.12
Engineering	DFC x MF	0.12		16.46	10.04	27.05	59.65
Construction	DFC x MF	0.13		17.84	10.88	29.31	64.63
Contractor & Legal	DFC x MF	0.08		10.98	6.69	18.04	39.77
Process/Project Contingency	DFC x MF	0.0412		5.65	3.45	9.29	20.48
Total Plant Cost (TPC)				188.13	114.71	309.13	681.65
AFUDC							
Total Plant Investment (TPI)				188.13	114.71	309.13	681.65
Land			0.60	2.21	2.21	5.08	15.23
Startup				0.00	0.00	0.00	0.00
Total Capital Cost (TCC)				190.34	116.92	314.21	696.88
Contingency/TPI							
Working Capital	DFC x MF	0.05		9.41	5.74	15.46	34.08
Variable Operating Costs (million USD/yr)							
Feed				21.85	10.92	43.70	131.09
Utilities				0.30	0.12	0.49	1.47
Other				1.00	0.50	2.00	6.00
Catalysts and Chemicals				0.70	0.35	1.40	4.20
Total				23.85	11.90	47.59	142.75
Fixed Operating Costs (million USD/yr)							
Labor (SF from V-R)	DFC x MF	0.0165	0.25	2.26	1.90	2.69	3.54
Maintenance (3% of A)			0.03	4.12	2.51	6.76	14.91
General Overhead (65% of labor + maint)			0.65	4.15	2.87	6.15	12.00
Direct Overhead (45% of Labor)			0.45	1.02	0.86	1.21	1.59
Insurance (0.5% of TIC)			0.005	0.95	0.58	1.57	3.48
Total				12.50	8.72	18.38	35.53



	25	50	100	300
Feed	0.44	0.44	0.44	0.44
Var Op Costs	0.04	0.04	0.04	0.04
Fixed Op Costs	0.35	0.25	0.18	0.12
Capital	$0.50	$0.37	$0.27	$0.15

Figure 23. Cellulosic Ethanol (TC) Plant Gate Price

Table 60. Cellulosic ethanol (TC) plant gate costs

Plant Size, MM GPY	25	100	25	100	25	100
Feed	Bagasse		Ag Residues		Wood /Perennials	
Country	Ethanol Plant Gate Cost (USD/gal ethanol)					
USA	1.33	0.93	1.33	0.93	1.33	0.93
Argentina	1.02	0.62	1.49	1.10	1.49	1.10
Brazil	0.88	0.54	1.17	0.83	1.37	1.04
Canada	--	--	1.32	0.79	1.60	1.06
Caribbean Basin	1.03	0.62	1.12	0.71	1.53	1.12
China	1.07	0.65	1.31	0.88	1.59	1.13
Colombia	1.01	0.63	1.01	0.63	1.39	1.04
India	0.89	0.57	0.89	0.57	1.39	1.05
Mexico	0.80	0.54	1.20	0.93	1.20	0.93

Table 61. Brazil cellulosic ethanol (TC) capital and operating costs, bagasse

Country	Brazil	Code =	2				
Cost component	**Units**	**Cost Factor**	**Scale Factor**	**Brazil Cellulosic Ethanol (TC)**	**Brazil Cellulosic Ethanol (TC)**	**Brazil Cellulosic Ethanol (TC)**	**Brazil Cellulosic Ethanol (TC)**
Year $	$			2005	2005	2005	2005
Cost Index (2 = M&S, 3 = CE)			3	130.93	130.93	130.93	130.93
Plant Size	dry short ton/day			1,800	900	3,601	10,801
	dry tonne/day			1,632	816	3,264	9,793
Stream Factor	%			95%	95%	95%	95%
Feed	Dry short ton/yr			6.242E+05	3.121E+05	1.248E+06	3.745E+06
	GJ/short ton			1.794E+01	1.794E+01	1.794E+01	1.794E+01
	GJ/yr			1.119E+07	5.598E+06	2.239E+07	6.717E+07
Feed Cost	USD/dt			**$ 7.60**	**$ 7.60**	**$ 7.60**	**$ 7.60**
Yield (gal/Dry US Ton)							
Ethanol	gal/short ton			80.1	80.1	80.1	80.1
Mixed alcohols	gal/short ton			94.1	94.1	94.1	94.1
Process Efficiency - to ethanol	% HHV			39.6%	39.6%	39.6%	39.6%
Process efficiency - overall	% HHV			47.4%	47.4%	47.4%	47.4%
Ethanol	gal/yr			5.000E+07	2.500E+07	1.000E+08	3.000E+08
	Mil Gal/YR			**50.00**	**25.00**	**100.00**	**300.00**
	tpy			1.657E+05	8.288E+04	3.315E+05	9.945E+05
	GJ/yr			4.436E+06	2.218E+06	8.873E+06	2.662E+07
	gal/Stream day			1.442E+05	7.210E+04	2.884E+05	8.652E+05
	bbl/s stream day			3.433E+03	1.717E+03	6.867E+03	2.060E+04
Higher Alcohols							
	gal/ton			14.0	14.0	14.0	14.0
	gal/yr			8.74E+06	4.37E+06	1.75E+07	5.24E+07
	GJ/gal						
Capital Cost (million USD)							
Feed Handling & Drying			0.70	23.71	14.60	38.52	83.10
Gasification			0.80	13.18	7.57	22.95	55.28
Tar Reforming & Quench			0.70	39.24	24.16	63.75	137.55
Acid Gas & Sulfur Removal			0.85	14.82	8.22	26.71	67.96
Alcohol synthesis - Compression			0.65	16.35	10.42	25.66	52.40
Alcohol Synthesis - Other			0.65	4.70	3.00	7.38	15.07
Alcohol Separation			0.65	7.36	4.69	11.55	23.58
Steam System & Power Generation			0.70	17.17	10.57	27.89	60.18
Cooling Water & Other Utilities			0.70	3.68	2.26	5.98	12.90
Direct Fixed Capital (DFC), also called TIC				140.21	85.49	230.38	508.01
Engineering	DFC x MF	0.12		16.82	10.26	27.65	60.96
Construction	DFC x MF	0.13		18.23	11.11	29.95	66.04
Contractor & Legal	DFC x MF	0.08		11.22	6.84	18.43	40.64
Process/Project Contingency	DFC x MF	0.0412		5.78	3.52	9.49	20.93
Total Plant Cost (TPC)				192.25	117.22	315.90	696.59
AFUDC							
Total Plant Investment (TPI)				192.25	117.22	315.90	696.59
Land			0.60	2.21	2.21	5.08	15.23
Startup				0.00	0.00	0.00	0.00
Total Capital Cost (TCC)				194.46	119.43	320.98	711.82
Contingency/TPI							
Working Capital	DFC x MF	0.05		9.61	5.86	15.80	34.83
Variable Operating Costs (million USD/yr)							
Feed				4.74	2.37	9.49	28.46
Utilities				0.30	0.12	0.49	1.47
Other				1.00	0.50	2.00	6.00
Catalysts and Chemicals				0.70	0.35	1.40	4.20
Total				6.74	3.34	13.38	40.13
Fixed Operating Costs (million USD/yr)							
Labor (SF from V-R)	DFC x MF	0.0165	0.25	0.96	0.81	1.15	1.51
Maintenance (3% of A)			0.03	4.21	2.56	6.91	15.24
General Overhead (65% of labor + maint)			0.65	3.36	2.19	5.24	10.89
Direct Overhead (45% of Labor)			0.45	0.43	0.37	0.52	0.68
Insurance (0.5% of TIC)			0.005	0.97	0.60	1.60	3.56
Total				9.94	6.53	15.42	31.88

Table 62. Argentina cellulosic ethanol (TC) capital and operating costs, bagasse

Country **Argentina** **Code =** 5

Cost component	Units	Cost Factor	Scale Factor	Argentina Cellulosic Ethanol (TC)	Argentina Cellulosic Ethanol (TC)	Argentina Cellulosic Ethanol (TC)	Argentina Cellulosic Ethanol (TC)
Year $	$			2005	2005	2005	2005
Cost Index (2 = M&S, 3 = CE)			3	130.93	130.93	130.93	130.93
Plant Size	dry short ton/day			1,800	900	3,601	10,801
	dry tonne/day			1,632	816	3,264	9,793
Stream Factor	%			95%	95%	95%	95%
Feed	Dry short ton/yr			6.242E+05	3.121E+05	1.248E+06	3.745E+06
	GJ/short ton			1.794E+01	1.794E+01	1.794E+01	1.794E+01
	GJ/yr			1.119E+07	5.598E+06	2.239E+07	6.717E+07
Feed Cost	USD/dt			**$ 9.10**	**$ 9.10**	**$ 9.10**	**$ 9.10**
Yield (gal/Dry US Ton)							
Ethanol	gal/short ton			80.1	80.1	80.1	80.1
Mixed alcohols	gal/short ton			94.1	94.1	94.1	94.1
Process Efficiency - to ethanol	% HHV			39.6%	39.6%	39.6%	39.6%
Process efficiency - overall	% HHV			47.4%	47.4%	47.4%	47.4%
Ethanol	gal/yr			5.000E+07	2.500E+07	1.000E+08	3.000E+08
	Mil Gal/YR			**50.00**	**25.00**	**100.00**	**300.00**
	tpy			1.657E+05	8.288E+04	3.315E+05	9.945E+05
	GJ/yr			4.436E+06	2.218E+06	8.873E+06	2.662E+07
	gal/Stream day			1.442E+05	7.210E+04	2.884E+05	8.652E+05
	bbl/s stream day			3.433E+03	1.717E+03	6.867E+03	2.060E+04
Higher Alcohols							
	gal/ton			14.0	14.0	14.0	14.0
	gal/yr			8.74E+06	4.37E+06	1.75E+07	5.24E+07
Capital Cost (million USD)							
Feed Handling & Drying			0.70	24.91	15.34	40.47	87.32
Gasification			0.80	13.85	7.96	24.12	58.08
Tar Reforming & Quench			0.70	41.23	25.38	66.99	144.53
Acid Gas & Sulfur Removal			0.85	15.57	8.64	28.07	71.40
Alcohol synthesis - Compression			0.65	17.18	10.95	26.96	55.06
Alcohol Synthesis - Other			0.65	4.94	3.15	7.75	15.83
Alcohol Separation			0.65	7.73	4.93	12.13	24.78
Steam System & Power Generation			0.70	18.04	11.11	29.31	63.23
Cooling Water & Other Utilities			0.70	3.87	2.38	6.28	13.55
Direct Fixed Capital (DFC), also called TIC				147.32	89.82	242.07	533.78
Engineering	DFC x MF	0.12		17.68	10.78	29.05	64.05
Construction	DFC x MF	0.13		19.15	11.68	31.47	69.39
Contractor & Legal	DFC x MF	0.08		11.79	7.19	19.37	42.70
Process/Project Contingency	DFC x MF	0.0412		6.07	3.70	9.97	21.99
Total Plant Cost (TPC)				202.00	123.17	331.93	731.92
AFUDC							
Total Plant Investment (TPI)				202.00	123.17	331.93	731.92
Land			0.60	2.21	2.21	5.08	15.23
Startup				0.00	0.00	0.00	0.00
Total Capital Cost (TCC)				204.21	125.38	337.00	747.15
Contingency/TPI							
Working Capital	DFC x MF	0.05		10.10	6.16	16.60	36.60
Variable Operating Costs (million USD/yr)							
Feed				5.68	2.84	11.36	34.08
Utilities				0.30	0.12	0.49	1.47
Other				1.00	0.50	2.00	6.00
Catalysts and Chemicals				0.70	0.35	1.40	4.20
Total				7.68	3.81	15.25	45.75
Fixed Operating Costs (million USD/yr)							
Labor (SF from V-R)	DFC x MF	0.0165	0.25	1.92	1.62	2.28	3.01
Maintenance (3% of A)			0.03	4.42	2.69	7.26	16.01
General Overhead (65% of labor + maint)			0.65	4.12	2.80	6.21	12.36
Direct Overhead (45% of Labor)			0.45	0.86	0.73	1.03	1.35
Insurance (0.5% of TIC)			0.005	1.02	0.63	1.69	3.74
Total				12.35	8.47	18.47	36.47

Table 63. Canada cellulosic ethanol (TC) capital and operating costs, ag residue

Country **Canada** **Code =** 7

Cost component	Units	Cost Factor	Scale Factor	Canada Cellulosic Ethanol (TC)	Canada Cellulosic Ethanol (TC)	Canada Cellulosic Ethanol (TC)	Canada Cellulosic Ethanol (TC)
Year $	$			2005	2005	2005	2005
Cost Index (2 = M&S, 3 = CE)			3	130.93	130.93	130.93	130.93
Plant Size	dry short ton/day			1,800	900	3,601	10,801
	dry tonne/day			1,632	816	3,264	9,793
Stream Factor	%			95%	95%	95%	95%
Feed	Dry short ton/yr			6.242E+05	3.121E+05	1.248E+06	3.745E+06
	GJ/short ton			1.794E+01	1.794E+01	1.794E+01	1.794E+01
	GJ/yr			1.119E+07	5.598E+06	2.239E+07	6.717E+07
Feed Cost	USD/dt			**$ 10.00**	**$ 10.00**	**$ 10.00**	**$ 10.00**
Yield (gal/Dry US Ton)							
Ethanol	gal/short ton			80.1	80.1	80.1	80.1
Mixed alcohols	gal/short ton			94.1	94.1	94.1	94.1
Process Efficiency - to ethanol	% HHV			39.6%	39.6%	39.6%	39.6%
Process efficiency - overall	% HHV			47.4%	47.4%	47.4%	47.4%
Ethanol	gal/yr			5.000E+07	2.500E+07	1.000E+08	3.000E+08
	Mil Gal/YR			**50.00**	**25.00**	**100.00**	**300.00**
	tpy			1.657E+05	8.288E+04	3.315E+05	9.945E+05
	GJ/yr			4.436E+06	2.218E+06	8.873E+06	2.662E+07
	gal/Stream day			1.442E+05	7.210E+04	2.884E+05	8.652E+05
	bbl/s stream day			3.433E+03	1.717E+03	6.867E+03	2.060E+04
Higher Alcohols							
	gal/ton			14.0	14.0	14.0	14.0
	gal/yr			8.74E+06	4.37E+06	1.75E+07	5.24E+07
Capital Cost (million USD)							
Feed Handling & Drying			0.70	30.23	18.61	49.11	105.96
Gasification			0.80	16.81	9.65	29.27	70.48
Tar Reforming & Quench			0.70	50.03	30.80	81.28	175.38
Acid Gas & Sulfur Removal			0.85	18.89	10.48	34.06	86.64
Alcohol synthesis - Compression			0.65	20.85	13.29	32.71	66.81
Alcohol Synthesis - Other			0.65	5.99	3.82	9.41	19.21
Alcohol Separation			0.65	9.38	5.98	14.72	30.07
Steam System & Power Generation			0.70	21.89	13.48	35.56	76.73
Cooling Water & Other Utilities			0.70	4.69	2.89	7.62	16.44
Direct Fixed Capital (DFC), also called TIC				178.76	109.00	293.74	647.72
Engineering	DFC x MF	0.12		21.45	13.08	35.25	77.73
Construction	DFC x MF	0.13		23.24	14.17	38.19	84.20
Contractor & Legal	DFC x MF	0.08		14.30	8.72	23.50	51.82
Process/Project Contingency	DFC x MF	0.0412		7.37	4.49	12.10	26.69
Total Plant Cost (TPC)				245.12	149.46	402.78	888.15
AFUDC							
Total Plant Investment (TPI)				245.12	149.46	402.78	888.15
Land			0.60	2.21	2.21	5.08	15.23
Startup				0.00	0.00	0.00	0.00
Total Capital Cost (TCC)				247.33	151.67	407.86	903.38
Contingency/TPI							
Working Capital	DFC x MF	0.05		12.26	7.47	20.14	44.41
Variable Operating Costs (million USD/yr)							
Feed				6.24	3.12	12.48	37.45
Utilities				0.30	0.12	0.49	1.47
Other				1.00	0.50	2.00	6.00
Catalysts and Chemicals				0.70	0.35	1.40	4.20
Total				8.24	4.09	16.37	49.12
Fixed Operating Costs (million USD/yr)							
Labor (SF from V-R)	DFC x MF	0.0165	0.25	3.80	3.19	4.52	5.95
Maintenance (3% of A)			0.03	5.36	3.27	8.81	19.43
General Overhead (65% of labor + maint)			0.65	5.96	4.20	8.66	16.50
Direct Overhead (45% of Labor)			0.45	1.71	1.44	2.03	2.68
Insurance (0.5% of TIC)			0.005	1.24	0.76	2.04	4.52
Total				18.06	12.86	26.07	49.07

Table 64. Caribbean cellulosic ethanol (TC) capital and operating costs, bagasse

Country	Caribbean	Code =	9				
Cost component	**Units**	**Cost Factor**	**Scale Factor**	**Caribbean Cellulosic Ethanol (TC)**	**Caribbean Cellulosic Ethanol (TC)**	**Caribbean Cellulosic Ethanol (TC)**	**Caribbean Cellulosic Ethanol (TC)**
Year $	$			2005	2005	2005	2005
Cost Index (2 = M&S, 3 = CE)			3	130.93	130.93	130.93	130.93
Plant Size	dry short ton/day			1,800	900	3,601	10,801
	dry tonne/day			1,632	816	3,264	9,793
Stream Factor	%			95%	95%	95%	95%
Feed	Dry short ton/yr			6.242E+05	3.121E+05	1.248E+06	3.745E+06
	GJ/short ton			1.794E+01	1.794E+01	1.794E+01	1.794E+01
	GJ/yr			1.119E+07	5.598E+06	2.239E+07	6.717E+07
Feed Cost	USD/dt			**$ 7.60**	**$ 7.60**	**$ 7.60**	**$ 7.60**
Yield (gal/Dry US Ton)							
Ethanol	gal/short ton			80.1	80.1	80.1	80.1
Mixed alcohols	gal/short ton			94.1	94.1	94.1	94.1
Process Efficiency - to ethanol	% HHV			39.6%	39.6%	39.6%	39.6%
Process efficiency - overall	% HHV			47.4%	47.4%	47.4%	47.4%
Ethanol	gal/yr			5.000E+07	2.500E+07	1.000E+08	3.000E+08
	Mil Gal/YR			**50.00**	**25.00**	**100.00**	**300.00**
	tpy			1.657E+05	8.288E+04	3.315E+05	9.945E+05
	GJ/yr			4.436E+06	2.218E+06	8.873E+06	2.662E+07
	gal/Stream day			1.442E+05	7.210E+04	2.884E+05	8.652E+05
	bbl/s stream day			3.433E+03	1.717E+03	6.867E+03	2.060E+04
Higher Alcohols							
	gal/ton			14.0	14.0	14.0	14.0
	gal/yr			8.74E+06	4.37E+06	1.75E+07	5.24E+07
Capital Cost (million USD)							
Feed Handling & Drying			0.70	26.18	16.11	42.53	91.75
Gasification			0.80	14.55	8.36	25.34	61.03
Tar Reforming & Quench			0.70	43.33	26.67	70.39	151.87
Acid Gas & Sulfur Removal			0.85	16.36	9.08	29.49	75.03
Alcohol synthesis - Compression			0.65	18.05	11.51	28.33	57.86
Alcohol Synthesis - Other			0.65	5.19	3.31	8.14	16.63
Alcohol Separation			0.65	8.12	5.18	12.75	26.04
Steam System & Power Generation			0.70	18.96	11.67	30.79	66.44
Cooling Water & Other Utilities			0.70	4.06	2.50	6.60	14.24
Direct Fixed Capital (DFC), also called TIC				154.80	94.39	254.37	560.89
Engineering	DFC x MF	0.12		18.58	11.33	30.52	67.31
Construction	DFC x MF	0.13		20.12	12.27	33.07	72.92
Contractor & Legal	DFC x MF	0.08		12.38	7.55	20.35	44.87
Process/Project Contingency	DFC x MF	0.0412		6.38	3.89	10.48	23.11
Total Plant Cost (TPC)				212.26	129.42	348.79	769.10
AFUDC							
Total Plant Investment (TPI)				212.26	129.42	348.79	769.10
Land			0.60	2.21	2.21	5.08	15.23
Startup				0.00	0.00	0.00	0.00
Total Capital Cost (TCC)				214.47	131.63	353.86	784.33
Contingency/TPI							
Working Capital	DFC x MF	0.05		10.61	6.47	17.44	38.45
Variable Operating Costs (million USD/yr)							
Feed				4.74	2.37	9.49	28.46
Utilities				0.30	0.12	0.49	1.47
Other				1.00	0.50	2.00	6.00
Catalysts and Chemicals				0.70	0.35	1.40	4.20
Total				6.74	3.34	13.38	40.13
Fixed Operating Costs (million USD/yr)							
Labor (SF from V-R)	DFC x MF	0.0165	0.25	2.17	1.83	2.59	3.40
Maintenance (3% of A)			0.03	4.64	2.83	7.63	16.83
General Overhead (65% of labor + maint)			0.65	4.43	3.03	6.64	13.15
Direct Overhead (45% of Labor)			0.45	0.98	0.82	1.16	1.53
Insurance (0.5% of TIC)			0.005	1.07	0.66	1.77	3.92
Total				13.30	9.17	19.79	38.83

Table 65. China cellulosic ethanol (TC) capital and operating costs, bagasse

Country	China	Code =	3				
Cost component	**Units**	**Cost Factor**	**Scale Factor**	**China Cellulosic Ethanol (TC)**	**China Cellulosic Ethanol (TC)**	**China Cellulosic Ethanol (TC)**	**China Cellulosic Ethanol (TC)**
Year $	$			2005	2005	2005	2005
Cost Index (2 = M&S, 3 = CE)			3	130.93	130.93	130.93	130.93
Plant Size	dry short ton/day			1,800	900	3,601	10,801
	dry tonne/day			1,632	816	3,264	9,793
Stream Factor	%			95%	95%	95%	95%
Feed	Dry short ton/yr			6.242E+05	3.121E+05	1.248E+06	3.745E+06
	GJ/short ton			1.794E+01	1.794E+01	1.794E+01	1.794E+01
	GJ/yr			1.119E+07	5.598E+06	2.239E+07	6.717E+07
Feed Cost	USD/dt			**$ 9.10**	**$ 9.10**	**$ 9.10**	**$ 9.10**
Yield (gal/Dry US Ton)							
Ethanol	gal/short ton			80.1	80.1	80.1	80.1
Mixed alcohols	gal/short ton			94.1	94.1	94.1	94.1
Process Efficiency - to ethanol	% HHV			39.6%	39.6%	39.6%	39.6%
Process efficiency - overall	% HHV			47.4%	47.4%	47.4%	47.4%
Ethanol	gal/yr			5.000E+07	2.500E+07	1.000E+08	3.000E+08
	Mil Gal/YR			**50.00**	**25.00**	**100.00**	**300.00**
	tpy			1.657E+05	8.288E+04	3.315E+05	9.945E+05
	GJ/yr			4.436E+06	2.218E+06	8.873E+06	2.662E+07
	gal/Stream day			1.442E+05	7.210E+04	2.884E+05	8.652E+05
	bbl/s stream day			3.433E+03	1.717E+03	6.867E+03	2.060E+04
Higher Alcohols							
	gal/ton			14.0	14.0	14.0	14.0
	gal/yr			8.74E+06	4.37E+06	1.75E+07	5.24E+07
Capital Cost (million USD)							
Feed Handling & Drying			0.70	25.53	15.72	41.48	89.49
Gasification			0.80	14.20	8.15	24.72	59.52
Tar Reforming & Quench			0.70	42.26	26.01	68.65	148.12
Acid Gas & Sulfur Removal			0.85	15.96	8.85	28.76	73.18
Alcohol synthesis - Compression			0.65	17.61	11.22	27.63	56.43
Alcohol Synthesis - Other			0.65	5.06	3.23	7.94	16.22
Alcohol Separation			0.65	7.92	5.05	12.43	25.39
Steam System & Power Generation			0.70	18.49	11.38	30.04	64.80
Cooling Water & Other Utilities			0.70	3.96	2.44	6.44	13.89
Direct Fixed Capital (DFC), also called TIC				150.98	92.06	248.09	547.05
Engineering	DFC x MF	0.12		18.12	11.05	29.77	65.65
Construction	DFC x MF	0.13		19.63	11.97	32.25	71.12
Contractor & Legal	DFC x MF	0.08		12.08	7.36	19.85	43.76
Process/Project Contingency	DFC x MF	0.0412		6.22	3.79	10.22	22.54
Total Plant Cost (TPC)				207.03	126.23	340.18	750.12
AFUDC							
Total Plant Investment (TPI)				207.03	126.23	340.18	750.12
Land			0.60	2.21	2.21	5.08	15.23
Startup				0.00	0.00	0.00	0.00
Total Capital Cost (TCC)				209.24	128.44	345.26	765.35
Contingency/TPI							
Working Capital	DFC x MF	0.05		10.35	6.31	17.01	37.51
Variable Operating Costs (million USD/yr)							
Feed				5.68	2.84	11.36	34.08
Utilities				0.30	0.12	0.49	1.47
Other				1.00	0.50	2.00	6.00
Catalysts and Chemicals				0.70	0.35	1.40	4.20
Total				7.68	3.81	15.25	45.75
Fixed Operating Costs (million USD/yr)							
Labor (SF from V-R)	DFC x MF	0.0165	0.25	2.52	2.12	2.99	3.94
Maintenance (3% of A)			0.03	4.53	2.76	7.44	16.41
General Overhead (65% of labor + maint)			0.65	4.58	3.17	6.78	13.23
Direct Overhead (45% of Labor)			0.45	1.13	0.95	1.35	1.77
Insurance (0.5% of TIC)			0.005	1.05	0.64	1.73	3.83
Total				13.81	9.64	20.29	39.18

Table 66. Colombia cellulosic ethanol (TC) capital and operating costs, bagasse

Country	Colombia	Code =	6				
Cost component	**Units**	**Cost Factor**	**Scale Factor**	**Colombia Cellulosic Ethanol (TC)**	**Colombia Cellulosic Ethanol (TC)**	**Colombia Cellulosic Ethanol (TC)**	**Colombia Cellulosic Ethanol (TC)**
Year $	$			2005	2005	2005	2005
Cost Index (2 = M&S, 3 = CE)			3	130.93	130.93	130.93	130.93
Plant Size	dry short ton/day			1,800	900	3,601	10,801
	dry tonne/day			1,632	816	3,264	9,793
Stream Factor	%			95%	95%	95%	95%
Feed	Dry short ton/yr			6.242E+05	3.121E+05	1.248E+06	3.745E+06
	GJ/short ton			1.794E+01	1.794E+01	1.794E+01	1.794E+01
	GJ/yr			1.119E+07	5.598E+06	2.239E+07	6.717E+07
Feed Cost	USD/dt			**$ 14.50**	**$ 14.50**	**$ 14.50**	**$ 14.50**
Yield (gal/Dry US Ton)							
Ethanol	gal/short ton			80.1	80.1	80.1	80.1
Mixed alcohols	gal/short ton			94.1	94.1	94.1	94.1
Process Efficiency - to ethanol	% HHV			39.6%	39.6%	39.6%	39.6%
Process efficiency - overall	% HHV			47.4%	47.4%	47.4%	47.4%
Ethanol	gal/yr			5.000E+07	2.500E+07	1.000E+08	3.000E+08
	Mil Gal/YR			**50.00**	**25.00**	**100.00**	**300.00**
	tpy			1.657E+05	8.288E+04	3.315E+05	9.945E+05
	GJ/yr			4.436E+06	2.218E+06	8.873E+06	2.662E+07
	gal/Stream day			1.442E+05	7.210E+04	2.884E+05	8.652E+05
	bbl/s stream day			3.433E+03	1.717E+03	6.867E+03	2.060E+04
Higher Alcohols							
	gal/ton			14.0	14.0	14.0	14.0
	gal/yr			8.74E+06	4.37E+06	1.75E+07	5.24E+07
	GJ/gal						
	gal/ethanol eq/yr						
	gal/ton EtOH eq						
	BBl EtOH eq/day						
Capital Cost (million USD)							
Feed Handling & Drying			0.70	23.07	14.20	37.48	80.87
Gasification			0.80	12.83	7.37	22.34	53.79
Tar Reforming & Quench			0.70	38.19	23.51	62.04	133.85
Acid Gas & Sulfur Removal			0.85	14.42	8.00	25.99	66.13
Alcohol synthesis - Compression			0.65	15.91	10.14	24.97	50.99
Alcohol Synthesis - Other			0.65	4.57	2.92	7.18	14.66
Alcohol Separation			0.65	7.16	4.56	11.24	22.95
Steam System & Power Generation			0.70	16.71	10.28	27.14	58.56
Cooling Water & Other Utilities			0.70	3.58	2.20	5.82	12.55
Direct Fixed Capital (DFC), also called TIC				136.44	83.19	224.19	494.35
Engineering	DFC x MF	0.12		16.37	9.98	26.90	59.32
Construction	DFC x MF	0.13		17.74	10.81	29.14	64.27
Contractor & Legal	DFC x MF	0.08		10.91	6.66	17.94	39.55
Process/Project Contingency	DFC x MF	0.0412		5.62	3.43	9.24	20.37
Total Plant Cost (TPC)				187.08	114.07	307.41	677.86
AFUDC							
Total Plant Investment (TPI)				187.08	114.07	307.41	677.86
Land			0.60	2.21	2.21	5.08	15.23
Startup				0.00	0.00	0.00	0.00
Total Capital Cost (TCC)				189.29	**116.28**	**312.49**	693.09
Contingency/TPI							
Working Capital	DFC x MF	0.05		9.35	5.70	15.37	33.89
Variable Operating Costs (million USD/yr)							
Feed				9.05	4.53	18.10	54.31
Utilities				0.30	0.12	0.49	1.47
Other				1.00	0.50	2.00	6.00
Catalysts and Chemicals				0.70	0.35	1.40	4.20
Total				11.05	5.50	21.99	65.98
Fixed Operating Costs (million USD/yr)							
Labor (SF from V-R)	DFC x MF	0.0165	0.25	1.44	1.21	1.71	2.26
Maintenance (3% of A)			0.03	4.09	2.50	6.73	14.83
General Overhead (65% of labor + maint)			0.65	3.60	2.41	5.49	11.11
Direct Overhead (45% of Labor)			0.45	0.65	0.55	0.77	1.02
Insurance (0.5% of TIC)			0.005	0.95	0.58	1.56	3.47
Total				10.73	7.25	16.26	32.67

Table 67. India cellulosic ethanol (TC) capital and operating costs, bagasse

Country **India** **Code =** 4

Cost component	Units	Cost Factor	Scale Factor	India Cellulosic Ethanol (TC)	India Cellulosic Ethanol (TC)	India Cellulosic Ethanol (TC)	India Cellulosic Ethanol (TC)
Year $	$			2005	2005	2005	2005
Cost Index (2 = M&S, 3 = CE)			3	130.93	130.93	130.93	130.93
Plant Size	dry short ton/day			1,800	900	3,601	10,801
	dry tonne/day			1,632	816	3,264	9,793
Stream Factor	%			95%	95%	95%	95%
Feed	Dry short ton/yr			6.242E+05	3.121E+05	1.248E+06	3.745E+06
	GJ/short ton			1.794E+01	1.794E+01	1.794E+01	1.794E+01
	GJ/yr			1.119E+07	5.598E+06	2.239E+07	6.717E+07
Feed Cost	USD/dt			**$ 7.30**	**$ 7.30**	**$ 7.30**	**$ 7.30**
Yield (gal/Dry US Ton)							
Ethanol	gal/short ton			80.1	80.1	80.1	80.1
Mixed alcohols	gal/short ton			94.1	94.1	94.1	94.1
Process Efficiency - to ethanol	% HHV			39.6%	39.6%	39.6%	39.6%
Process efficiency - overall	% HHV			47.4%	47.4%	47.4%	47.4%
Ethanol	gal/yr			5.000E+07	2.500E+07	1.000E+08	3.000E+08
	Mil Gal/YR			**50.00**	**25.00**	**100.00**	**300.00**
	tpy			1.657E+05	8.288E+04	3.315E+05	9.945E+05
	GJ/yr			4.436E+06	2.218E+06	8.873E+06	2.662E+07
	gal/Stream day			1.442E+05	7.210E+04	2.884E+05	8.652E+05
	bbl/s stream day			3.433E+03	1.717E+03	6.867E+03	2.060E+04
Higher Alcohols							
	gal/ton			14.0	14.0	14.0	14.0
	gal/yr			8.74E+06	4.37E+06	1.75E+07	5.24E+07
Capital Cost (million USD)							
Feed Handling & Drying			0.70	24.75	15.23	40.20	86.74
Gasification			0.80	13.76	7.90	23.96	57.69
Tar Reforming & Quench			0.70	40.96	25.21	66.54	143.57
Acid Gas & Sulfur Removal			0.85	15.47	8.58	27.88	70.93
Alcohol synthesis - Compression			0.65	17.07	10.88	26.78	54.69
Alcohol Synthesis - Other			0.65	4.91	3.13	7.70	15.72
Alcohol Separation			0.65	7.68	4.89	12.05	24.61
Steam System & Power Generation			0.70	17.92	11.03	29.11	62.81
Cooling Water & Other Utilities			0.70	3.84	2.36	6.24	13.46
Direct Fixed Capital (DFC), also called TIC				146.34	89.23	240.46	530.23
Engineering	DFC x MF	0.12		17.56	10.71	28.86	63.63
Construction	DFC x MF	0.13		19.02	11.60	31.26	68.93
Contractor & Legal	DFC x MF	0.08		11.71	7.14	19.24	42.42
Process/Project Contingency	DFC x MF	0.0412		6.03	3.68	9.91	21.85
Total Plant Cost (TPC)				200.66	122.35	329.72	727.05
AFUDC							
Total Plant Investment (TPI)				200.66	122.35	329.72	727.05
Land			0.60	2.21	2.21	5.08	15.23
Startup				0.00	0.00	0.00	0.00
Total Capital Cost (TCC)				202.87	124.56	334.80	742.29
Contingency/TPI							
Working Capital	DFC x MF	0.05		10.03	6.12	16.49	36.35
Variable Operating Costs (million USD/yr)							
Feed				4.56	2.28	9.11	27.34
Utilities				0.30	0.12	0.49	1.47
Other				1.00	0.50	2.00	6.00
Catalysts and Chemicals				0.70	0.35	1.40	4.20
Total				6.56	3.25	13.00	39.01
Fixed Operating Costs (million USD/yr)							
Labor (SF from V-R)	DFC x MF	0.0165	0.25	0.85	0.71	1.01	1.33
Maintenance (3% of A)			0.03	4.39	2.68	7.21	15.91
General Overhead (65% of labor + maint)			0.65	3.40	2.20	5.34	11.20
Direct Overhead (45% of Labor)			0.45	0.38	0.32	0.45	0.60
Insurance (0.5% of TIC)			0.005	1.01	0.62	1.67	3.71
Total				10.04	6.53	15.69	32.74

Table 68. Mexico cellulosic ethanol (TC) capital and operating costs, bagasse

Country	Mexico	Code =	8				
Cost component	**Units**	**Cost Factor**	**Scale Factor**	**Mexico Cellulosic Ethanol (TC)**	**Mexico Cellulosic Ethanol (TC)**	**Mexico Cellulosic Ethanol (TC)**	**Mexico Cellulosic Ethanol (TC)**
Year $	$			2005	2005	2005	2005
Cost Index (2 = M&S, 3 = CE)			3	130.93	130.93	130.93	130.93
Plant Size	dry short ton/day			1,800	900	3,601	10,801
	dry tonne/day			1,632	816	3,264	9,793
Stream Factor	%			95%	95%	95%	95%
Feed	Dry short ton/yr			6.242E+05	3.121E+05	1.248E+06	3.745E+06
	GJ/short ton			1.794E+01	1.794E+01	1.794E+01	1.794E+01
	GJ/yr			1.119E+07	5.598E+06	2.239E+07	6.717E+07
Feed Cost	USD/dt			**$ 15.40**	**$ 15.40**	**$ 15.40**	**$ 15.40**
Yield (gal/Dry US Ton)							
Ethanol	gal/short ton			80.1	80.1	80.1	80.1
Mixed alcohols	gal/short ton			94.1	94.1	94.1	94.1
Process Efficiency - to ethanol	% HHV			39.6%	39.6%	39.6%	39.6%
Process efficiency - overall	% HHV			47.4%	47.4%	47.4%	47.4%
Ethanol	gal/yr			5.000E+07	2.500E+07	1.000E+08	3.000E+08
	Mil Gal/YR			**50.00**	**25.00**	**100.00**	**300.00**
	tpy			1.657E+05	8.288E+04	3.315E+05	9.945E+05
	GJ/yr			4.436E+06	2.218E+06	8.873E+06	2.662E+07
	gal/Stream day			1.442E+05	7.210E+04	2.884E+05	8.652E+05
	bbl/s stream day			3.433E+03	1.717E+03	6.867E+03	2.060E+04
Higher Alcohols							
	gal/ton			14.0	14.0	14.0	14.0
	gal/yr			8.74E+06	4.37E+06	1.75E+07	5.24E+07
Capital Cost (million USD)							
Feed Handling & Drying			0.70	18.66	11.49	30.32	65.41
Gasification			0.80	10.38	5.96	18.07	43.51
Tar Reforming & Quench			0.70	30.89	19.01	50.18	108.27
Acid Gas & Sulfur Removal			0.85	11.66	6.47	21.02	53.49
Alcohol synthesis - Compression			0.65	12.87	8.20	20.20	41.25
Alcohol Synthesis - Other			0.65	3.70	2.36	5.81	11.86
Alcohol Separation			0.65	5.79	3.69	9.09	18.56
Steam System & Power Generation			0.70	13.51	8.32	21.95	47.37
Cooling Water & Other Utilities			0.70	2.90	1.78	4.70	10.15
Direct Fixed Capital (DFC), also called TIC				110.36	67.29	181.34	399.86
Engineering	DFC x MF	0.12		13.24	8.07	21.76	47.98
Construction	DFC x MF	0.13		14.35	8.75	23.57	51.98
Contractor & Legal	DFC x MF	0.08		8.83	5.38	14.51	31.99
Process/Project Contingency	DFC x MF	0.0412		4.55	2.77	7.47	16.47
Total Plant Cost (TPC)				151.32	92.26	248.65	548.28
AFUDC							
Total Plant Investment (TPI)				151.32	92.26	248.65	548.28
Land			0.60	2.21	2.21	5.08	15.23
Startup				0.00	0.00	0.00	0.00
Total Capital Cost (TCC)				153.53	94.47	253.72	563.51
Contingency/TPI							
Working Capital	DFC x MF	0.05		7.57	4.61	12.43	27.41
Variable Operating Costs (million USD/yr)							
Feed				9.61	4.81	19.23	57.68
Utilities				0.30	0.12	0.49	1.47
Other				1.00	0.50	2.00	6.00
Catalysts and Chemicals				0.70	0.35	1.40	4.20
Total				11.61	5.78	23.12	69.35
Fixed Operating Costs (million USD/yr)							
Labor (SF from V-R)	DFC x MF	0.0165	0.25	0.55	0.46	0.65	0.86
Maintenance (3% of A)			0.03	3.31	2.02	5.44	12.00
General Overhead (65% of labor + maint)			0.65	2.51	1.61	3.96	8.35
Direct Overhead (45% of Labor)			0.45	0.25	0.21	0.29	0.39
Insurance (0.5% of TIC)			0.005	0.77	0.47	1.27	2.82
Total				7.38	4.77	11.61	24.41

Table 69. Cellulosic ethanol (TC) summary yields, costs, and plant gate prices, 25 MM GPY, bagasse

Technology	Units	USA	Argentina	Brazil	Canada	Caribbean Basin	China	Colombia	India	Mexico
Plant Size	MM gal/yr	100	100	100	100	100	100	100	100	100
Yields										
Primary Product Yield	gal/ton	80.1	80.1	80.1		80.1	80.1	80.1	80.1	80.1
By Product A		Mix Alcohol	Mix Alcohol	Mix Alcohol		Mix Alcohol	Mix Alcohol	Mix Alcohol	Mix Alcohol	Mix Alcohol
Unit		gal/ton	gal/ton	gal/ton		gal/ton	gal/ton	gal/ton	gal/ton	gal/ton
Yield unit		14	14	14		14	14	14	14	14
Annual Yield	MM gal/yr	17.5	17.5	17.5		17.5	17.5	17.5	17.5	17.5
Price unit		1.15	1.15	1.15		1.15	1.15	1.15	1.15	1.15
MM USD/yr		20.1	20.1	20.1		20.1	20.1	20.1	20.1	20.1
By Product B										
Unit										
Yield unit										
Annual Yield										
Price unit										
Annual Cost	MM USD/yr									
Energy Inputs										
Electricity		N/A	N/A	N/A		N/A	N/A	N/A	N/A	N/A
Cost	$/kWh									
Amount	kWh/yr									
Annual Cost	MM USD/yr									
Fuel		N/A	N/A	N/A		N/A	N/A	N/A	N/A	N/A
Type										
Unit										
Amount										
Cost	USD/unit									
Annual Cost	MM USD/yr									
Capital & Operating Costs										
Capital	MMUSD	314.21	337.00	320.98		353.86	345.26	312.49	334.8	253.72
Operating w/o feed	MM USD/yr	22.27	22.38	19.31		23.68	24.18	20.15	19.58	15.50
Feed										
Unit		ton	ton	ton		ton	ton	ton	ton	ton
Cost/unit	USD/unit	35	9.1	7.6		7.6	9.1	14.5	7.3	15.4
Rate	unit/day	3601	3601	3601		3601	3601	3601	3601	3601
Yearly Cost	MM USD/yr	43.7	11.36	9.49		9.49	11.36	18.1	9.11	19.23
Product Plant Gate Cost										
Basis										
Value	USD/gal	0.93	0.62	0.54		0.62	0.65	0.63	0.57	0.54

Table 70.Cellulosic ethanol (TC) summary yields, costs, and plant gate prices, 100 MM GPY, bagasse

Technology	Units	USA	Argentina	Brazil	Canada	Caribbean Basin	China	Colombia	India	Mexico
Plant Size	MM gal/yr	100	100	100	100	100	100	100	100	100
Yields										
Primary Product Yield	gal/ton	80.1	80.1	80.1		80.1	80.1	80.1	80.1	80.1
By Product A		Mix Alcohol	Mix Alcohol	Mix Alcohol		Mix Alcohol	Mix Alcohol	Mix Alcohol	Mix Alcohol	Mix Alcohol
Unit		gal/ton	gal/ton	gal/ton		gal/ton	gal/ton	gal/ton	gal/ton	gal/ton
Yield unit		14	14	14		14	14	14	14	14
Annual Yield	MM gal/yr	17.5	17.5	17.5		17.5	17.5	17.5	17.5	17.5
Price unit		1.15	1.15	1.15		1.15	1.15	1.15	1.15	1.15
MM USD/yr		20.1	20.1	20.1		20.1	20.1	20.1	20.1	20.1
By Product B										
Unit										
Yield unit										
Annual Yield										
Price unit										
Annual Cost	MM USD/yr									
Energy Inputs										
Electricity		N/A	N/A	N/A		N/A	N/A	N/A	N/A	N/A
Cost	$/kWh									
Amount	kWh/yr									
Annual Cost	MM USD/yr									
Fuel		N/A	N/A	N/A		N/A	N/A	N/A	N/A	N/A
Type										
Unit										
Amount										
Cost	USD/unit									
Annual Cost	MM USD/yr									
Capital & Operating Costs										
Capital	MMUSD	314.21	337.00	320.98		353.86	345.26	312.49	334.8	253.72
Operating w/o feed	MM USD/yr	22.27	22.38	19.31		23.68	24.18	20.15	19.58	15.50
Feed										
Unit		ton	ton	ton		ton	ton	ton	ton	ton
Cost/unit	USD/unit	35	9.1	7.6		7.6	9.1	14.5	7.3	15.4
Rate	unit/day	3601	3601	3601		3601	3601	3601	3601	3601
Yearly Cost	MM USD/yr	43.7	11.36	9.49		9.49	11.36	18.1	9.11	19.23
Product Plant Gate Cost										
Basis										
Value	USD/gal	0.93	0.62	0.54		0.62	0.65	0.63	0.57	0.54

Table 71. Cellulosic ethanol (TC) summary yields, costs, and plant gate prices, 25 MM GPY, ag residues

Technology	Units	USA	Argentina	Brazil	Canada	Caribbean Basin	China	Colombia	India	Mexico
Plant Size	MM gal/yr	25	25	25	25	25	25	25	25	25
Yields										
Primary Product Yield	gal/ton	80	80	80	80	80	80	80	80	80
By Product A		Mix Alcohol	Mix Alcohol	Mix Alcohol	Mix Alcohol	Mix Alcohol	Mix Alcohol	Mix Alcohol	Mix Alcohol	Mix Alcohol
Unit		gal/ton	gal/ton	gal/ton	gal/ton	gal/ton	gal/ton	gal/ton	gal/ton	gal/ton
Yield unit		14	14	14	14	14	14	14	14	14
Annual Yield	MM gal/yr	4.37	4.37	4.37	4.37	4.37	4.37	4.37	4.37	4.37
Price unit		1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15
MM USD/yr		5.03	5.03	5.03	5.03	5.03	5.03	5.03	5.03	5.03
By Product B										
Unit										
Yield unit										
Annual Yield										
Price unit										
Annual Cost	MM USD/yr									
Energy Inputs										
Electricity		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cost	$/kWh									
Amount	kWh/yr									
Annual Cost	MM USD/yr									
Fuel		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Type										
Unit										
Amount										
Cost	USD/unit									
Annual Cost	MM USD/yr									
Capital & Operating Costs										
Capital	MMUSD	116.92	125.38	119.43	151.67	131.63	128.44	116.28	124.56	94.47
Operating w/o feed	MM USD/yr	9.7	9.44	7.51	13.84	10.14	10.62	8.22	7.51	5.74
Feed										
Unit		ton	ton	ton	ton	ton	ton	ton	ton	ton
Cost/unit	USD/unit	35	47.2	30.8	10	14.5	28.1	14.5	7.3	47.2
Rate	unit/day	900	900	900	900	900	900	900	900	900
Yearly Cost	MM USD/yr	10.92	14.73	9.61	3.12	4.53	8.77	4.53	2.28	14.73
Product Plant Gate Cost										
Basis										
Value	USD/gal	1.33	1.49	1.17	1.32	1.12	1.31	1.01	0.89	1.20

Table 72. Cellulosic ethanol (TC) summary yields, costs, and plant gate prices, 100 MM GPY, ag residues

Technology	Units	USA	Argentina	Brazil	Canada	Caribbean Basin	China	Colombia	India	Mexico
Plant Size	MM gal/yr	100	100	100	100	100	100	100	100	100
Yields										
Primary Product Yield	gal/ton	80.1	80.1	80.1	80.1	80.1	80.1	80.1	80.1	80.1
By Product A		Mix Alcohol	Mix Alcohol	Mix Alcohol	Mix Alcohol	Mix Alcohol	Mix Alcohol	Mix Alcohol	Mix Alcohol	Mix Alcohol
Unit		gal/ton	gal/ton	gal/ton	gal/ton	gal/ton	gal/ton	gal/ton	gal/ton	gal/ton
Yield unit		14	14	14	14	14	14	14	14	14
Annual Yield	MM gal/yr	17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5
Price unit		1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15
MM USD/yr		20.1	20.1	20.1	20.1	20.1	20.1	20.1	20.1	20.1
By Product B										
Unit										
Yield unit										
Annual Yield										
Price unit										
Annual Cost	MM USD/yr									
Energy Inputs										
Electricity		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cost	$/kWh									
Amount	kWh/yr									
Annual Cost	MM USD/yr									
Fuel		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Type										
Unit										
Amount										
Cost	USD/unit									
Annual Cost	MM USD/yr									
Capital & Operating Costs										
Capital	MMUSD	314.21	337.00	320.98	407.86	353.86	345.26	312.49	334.8	253.72
Operating w/o feed	MM USD/yr	22.27	22.36	19.31	29.96	23.68	24.18	20.15	19.58	15.50
Feed										
Unit		ton	ton	ton	ton	ton	ton	ton	ton	ton
Cost/unit	USD/unit	35	47.2	30.8	10	14.5	28.1	14.5	7.3	47.2
Rate	unit/day	3601	3601	3601	3601	3601	3601	3601	3601	3601
Yearly Cost	MM USD/yr	43.7	58.93	38.45	12.48	18.1	35.08	18.1	9.11	58.93
Product Plant Gate Cost										
Basis										
Value	USD/gal	0.93	1.10	0.83	0.79	0.71	0.88	0.63	0.57	0.93

Table 73. Cellulosic ethanol (TC) summary yields, costs, and plant gate prices, 25 MM GPY, wood/perennial

Technology	Units	USA	Argentina	Brazil	Canada	Caribbean Basin	China	Colombia	India	Mexico
Plant Size	MM gal/yr	25	25	25	25	25	25	25	25	25
Yields										
Primary Product Yield	gal/ton	80	80	80	80	80	80	80	80	80
By Product A		Mix Alcohol	Mix Alcohol	Mix Alcohol	Mix Alcohol	Mix Alcohol	Mix Alcohol	Mix Alcohol	Mix Alcohol	Mix Alcohol
Unit		gal/ton	gal/ton	gal/ton	gal/ton	gal/ton	gal/ton	gal/ton	gal/ton	gal/ton
Yield unit		14	14	14	14	14	14	14	14	14
Annual Yield	MM gal/yr	4.37	4.37	4.37	4.37	4.37	4.37	4.37	4.37	4.37
Price unit		1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15
MM USD/yr		5.03	5.03	5.03	5.03	5.03	5.03	5.03	5.03	5.03
By Product B										
Unit										
Yield unit										
Annual Yield										
Price unit										
Annual Cost	MM USD/yr									
Energy Inputs										
Electricity		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cost	$/kWh									
Amount	kWh/yr									
Annual Cost	MM USD/yr									
Fuel		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Type										
Unit										
Amount										
Cost	USD/unit									
Annual Cost	MM USD/yr									
Capital & Operating Costs										
Capital	MMUSD	116.92	125.38	119.43	151.67	131.63	128.44	116.28	124.56	94.47
Operating w/o feed	MM USD/yr	9.7	9.44	7.51	13.84	10.14	10.62	8.22	7.51	5.74
Feed										
Unit		ton	ton	ton	ton	ton	ton	ton	ton	ton
Cost/unit	USD/unit	35	47.2	47.2	31.8	47.2	47.2	47.2	47.2	47.2
Rate	unit/day	900	900	900	900	900	900	900	900	900
Yearly Cost	MM USD/yr	10.92	14.73	14.73	9.93	14.73	14.73	14.73	14.73	14.73
Product Plant Gate Cost										
Basis										
Value	USD/gal	1.33	1.49	1.37	1.60	1.53	1.59	1.39	1.39	1.20

Table 74. Cellulosic ethanol (TC) summary yields, costs, and plant gate prices, 100 MM GPY, wood/perennial

Technology	Units	USA	Argentina	Brazil	Canada	Caribbean Basin	China	Colombia	India	Mexico
Plant Size	MM gal/yr	100	100	100	100	100	100	100	100	100
Yields										
Primary Product Yield	gal/ton	80.1	80.1	80.1	80.1	80.1	80.1	80.1	80.1	80.1
By Product A		Mix Alcohol	Mix Alcohol	Mix Alcohol	Mix Alcohol	Mix Alcohol	Mix Alcohol	Mix Alcohol	Mix Alcohol	Mix Alcohol
Unit		gal/ton	gal/ton	gal/ton	gal/ton	gal/ton	gal/ton	gal/ton	gal/ton	gal/ton
Yield unit		14	14	14	14	14	14	14	14	14
Annual Yield	MM gal/yr	17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5
Price unit		1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15
MM USD/yr		20.1	20.1	20.1	20.1	20.1	20.1	20.1	20.1	20.1
By Product B										
Unit										
Yield unit										
Annual Yield										
Price unit										
Annual Cost	MM USD/yr									
Energy Inputs										
Electricity		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cost	$/kWh									
Amount	kWh/yr									
Annual Cost	MM USD/yr									
Fuel		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Type										
Unit										
Amount										
Cost	USD/unit									
Annual Cost	MM USD/yr									
Capital & Operating Costs										
Capital	MMUSD	314.21	337.00	320.98	407.86	353.86	345.26	312.49	334.8	253.72
Operating w/o feed	MM USD/yr	22.27	22.36	19.31	29.96	23.68	24.18	20.15	19.58	15.50
Feed										
Unit		ton	ton	ton	ton	ton	ton	ton	ton	ton
Cost/unit	USD/unit	35	47.2	47.2	31.8	47.2	47.2	47.2	47.2	47.2
Rate	unit/day	3601	3601	3601	3601	3601	3601	3601	3601	3601
Yearly Cost	MM USD/yr	43.7	58.936	58.93	39.7	58.93	58.93	58.93	58.93	58.93
Product Plant Gate Cost										
Basis										
Value	USD/gal	0.93	1.10	1.04	1.06	1.12	1.13	1.04	1.05	0.93

7 Residual Fuel Oil - Pyrolysis

Pyrolysis is one of the renewable processes for producing a liquid fuel from biomass. It offers advantages of a bio-oil that can be easily stored and transported. The primary oil can be used as a boiler fuel, or can be upgraded to chemicals or transportation fuels. Fast pyrolysis has achieved commercial status–the BIOSYN and Dynamotive processes–for production of specialty and chemicals and boiler fuels. Good reviews of pyrolysis are given by Czernik and Bridgwater (2004) and Mohan et al. (2006). This discussion of fast pyrolysis is excerpted from Putsche (2004) and Ringer et al. (2006).

The production of bio-oil from biomass is based on the fast pyrolysis process, which is composed of five major processing areas: feedstock handling and drying, pyrolysis, char combustion, product recovery and steam generation. Figure 24 is a block flow diagram of a fast pyrolysis process.

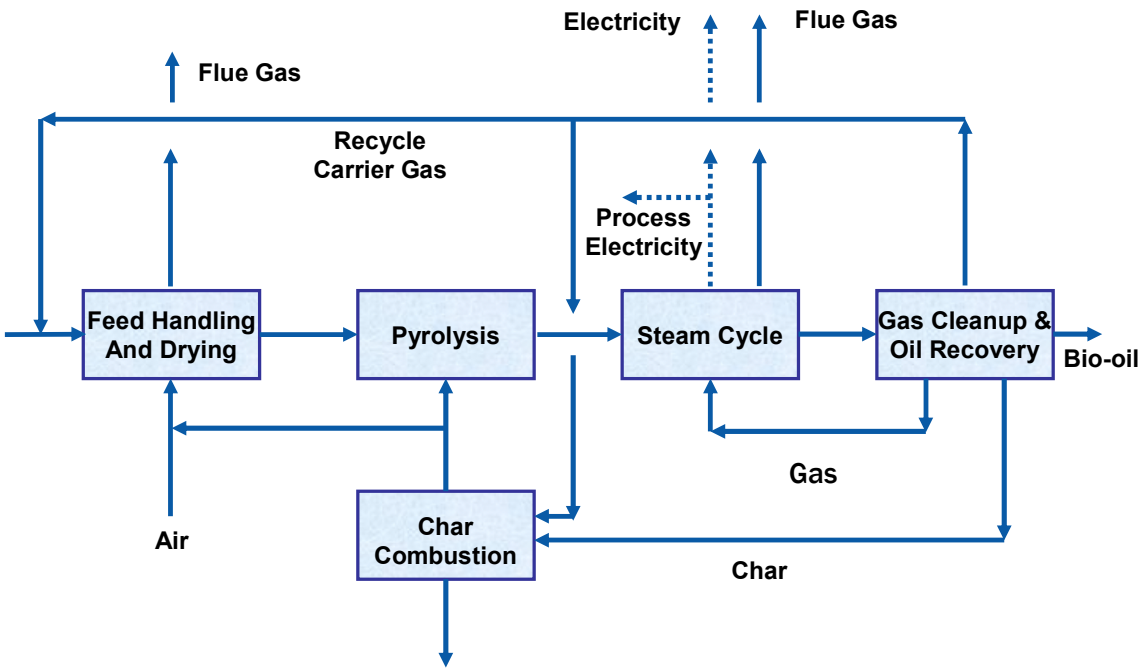


Figure 24. Fast pyrolysis process flow diagram

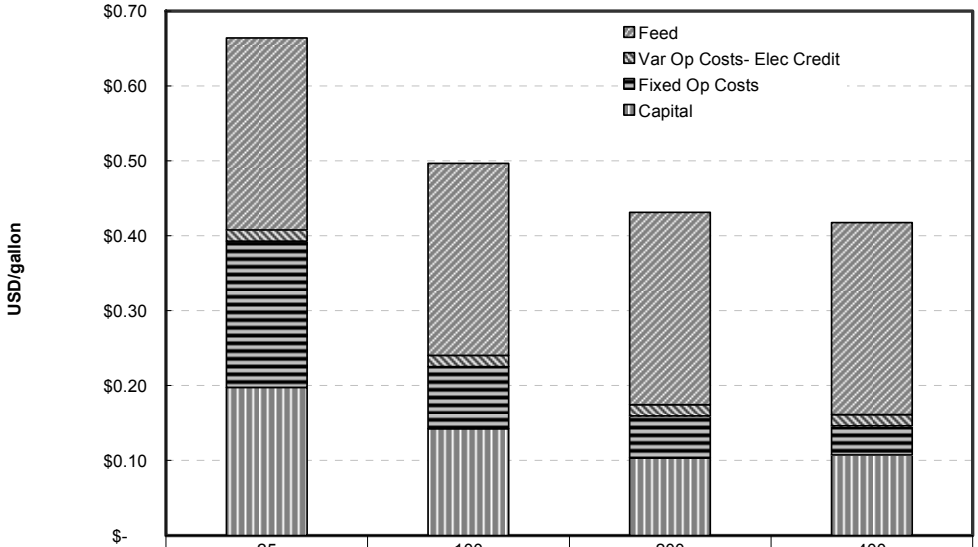
In the feedstock handling section, the biomass is reduced in size to <1-5mm and dried to 5-10% moisture. It is then sent to pyrolysis where it is heated to 400-500°C in an oxygen-deficient atmosphere to degrade the biomass into a mix of gases, bio-oils, and char. Char is removed using high efficiency cyclones and is combusted to fuel the pyrolysis reaction. To maximize the yield of bio-oils, the reaction is rapidly quenched through heat exchange or direct liquid (e.g., water or recycled bio-oils) injection. The bio-oils are present in the gas stream as aerosols and require scrubbers and/or wet electrostatic precipitators for efficient capture. After cleaning, some of the clean pyrolysis gases are recycled to fluidize the bed and the remaining gases are combusted for process heat. Where feasible, heat is recovered from the pyrolysis gases to generate steam for electricity production.

Capital and operating costs are given in Table 75.

Table 75. USA base case, fast pyrolysis capital and operating costs

Country	USA	Code =	1					
Cost component	Units	Cost Factor	Scale Factor	USA Pyrolytic Fuel Oil	USA Pyrolytic Fuel Oil	USA Pyrolytic Fuel Oil	USA Pyrolytic Fuel Oil	USA Pyrolytic Fuel Oil
Year $	$			2003	2005	2005	2005	2005
Cost Index (2 = M&S, 3 = CE)			3	112.42	130.93	130.93	130.93	130.93
Plant Size	dry short ton/day			2,205	529	2,113	5,512	11,023
	dry tonne/day			2,000	480	1,917	5,000	10,000
Stream Factor	%			95%	95%	95%	95%	95%
Feed	dtpy			7.64E+05	1.83E+05	7.33E+05	1.91E+06	3.82E+06
	GJ/ton			1.79E+01	1.79E+01	1.79E+01	1.79E+01	1.79E+01
	GJ/yr			1.37E+07	3.29E+06	1.31E+07	3.43E+07	6.86E+07
Feed Cost	$/dt			$ 35.00	$ 35.00	$ 35.00	$ 35.00	$ 35.00
Process Efficiency (overall)	%			67.5%	67.5%	67.5%	67.5%	67.5%
Process Efficiency (to RFO)	%			67.0%	67.0%	67.0%	67.0%	67.0%
RFO Production	Yield, wt%			70%	70%	70%	70%	70%
	Ton/yr			5.35E+05	1.28E+05	5.13E+05	1.34E+06	2.68E+06
	HHV, GJ/ton			17.16	17.16	17.16	17.16	17.16
	gal/yr			1.04E+08	2.50E+07	1.00E+08	2.61E+08	5.22E+08
	Mil Gal/YR			104.4	25.0	100.0	260.9	521.8
	tpy			5.35E+05	1.28E+05	5.13E+05	1.34E+06	2.68E+06
	GJ/yr			9.18E+06	2.20E+06	8.80E+06	2.30E+07	4.59E+07
	gal/ton			1.37E+02	1.37E+02	1.37E+02	1.37E+02	1.37E+02
	gal/Stream day			3.01E+05	7.22E+04	2.88E+05	7.52E+05	1.50E+06
	bbl/s day			7.17E+03	1.72E+03	6.87E+03	1.79E+04	3.58E+04
	gal EtOH eq/yr			1.03E+08	2.48E+07	9.92E+07	2.59E+08	5.17E+08
	gal EtOH eq/ton			1.35E+02	1.35E+02	1.35E+02	1.35E+02	1.35E+02
	bbl EtOH eq/day			6.75E+03	1.62E+03	6.47E+03	1.69E+04	3.38E+04
Electricity	kWh/y	2358.2	kWh/h	1.96E+07	4.71E+06	1.88E+07	4.91E+07	9.81E+07
	GJ eq/yr			6.89E+04	1.65E+04	6.61E+04	1.72E+05	3.45E+05
Capital Cost (million USD)								
Feed Preparation			0.70	12.81	5.49	14.49	28.34	46.03
Pyrolysis			0.80	9.01	3.35	10.14	21.83	38.02
Quench			0.70	3.30	1.42	3.73	7.30	11.86
Heat Recovery			0.85	2.62	0.91	2.95	6.65	11.99
Product Recovery and Storage			0.65	1.76	0.81	1.99	3.71	5.83
Recycle			0.65	2.24	1.03	2.54	4.74	7.43
Steam and Power Production			0.70	7.20	3.09	8.14	15.93	25.87
Utilities/auxiliaries			0.70	5.85	2.51	6.61	12.94	21.01
Direct Fixed Capital (DFC), also called TIC				44.79	18.61	50.59	101.44	168.05
Engineering	DFC x MF	0.12		5.37	2.23	6.07	12.17	20.17
Construction	DFC x MF	0.13		5.82	2.42	6.58	13.19	21.85
Contractor & Legal	DFC x MF	0.08		3.58	1.49	4.05	8.12	13.44
Process/Project Contingency	DFC x MF	0.0412		1.85	0.77	2.08	4.18	6.92
Total Plant Cost (TPC)				61.42	25.51	69.37	139.10	230.44
AFUDC								
Total Plant Investment (TPI)				61.42	25.51	69.37	139.10	230.44
Land			0.60	2.21	0.94	2.15	3.83	7.66
Startup								
Total Capital Cost (TCC)				63.63	26.45	71.52	142.93	238.10
Contingency/TPI								
Working Capital	DFC x MF	0.05		3.07	1.28	3.47	6.95	11.52
Variable Operating Costs (million USD/yr)								
Feed				26.76	6.42	25.65	66.89	133.78
Utilities				4.00	0.96	3.83	10.00	20.00
Other				1.00	0.24	0.96	2.50	5.00
Catalysts and Chemicals				0.70	0.17	0.67	1.75	3.50
Total				32.46	7.79	31.11	81.14	162.28
Fixed Operating Costs (million USD/yr)								
Labor (SF from V-R)	DFC x MF	0.05	0.25	2.24	1.83	2.58	3.28	3.90
Maintenance (3% of A)			0.03	1.34	0.56	1.52	3.04	5.04
General Overhead (65% of labor + maint)			0.65	2.33	1.55	2.66	4.11	5.81
Direct Overhead (45% of Labor)			0.45	1.01	0.82	1.16	1.48	1.76
Insurance (0.5% of TIC)			0.005	0.32	0.13	0.36	0.71	1.19
Total				7.24	4.89	8.28	12.62	17.70

Figure 25 presents a summary of the plant gate price breakdown for the USA base case. The feedstock costs by country for bagasse, agricultural residues, and wood/perennial feeds used are given in Table 19. Plant gate prices are given in Table 76.



	25	100	200	400
Feed	$0.26	$0.26	$0.26	$0.26
Var Op Costs- Elec Credit	$0.01	$0.01	$0.01	$0.01
Fixed Op Costs	$0.20	$0.08	$0.06	$0.04
Capital	$0.20	$0.14	$0.10	$0.11

Plant Size (mil gal/yr)

Figure 25. Residual fuel oil price as a function of plant size

Table 76. Pyrolytic fuel oil plant gate prices

Plant Size, MM GPY	25	100	25	100	25	100
Feed	Bagasse		Ag Residues		Wood /Perennials	
Country	Fuel Oil Plant Gate Cost (USD/gal fuel oil)					
USA	0.66	0.50	0.66	0.50	0.66	0.50
Argentina	0.46	0.30	0.74	0.58	0.74	0.58
Brazil	0.37	0.26	0.54	0.43	0.66	0.55
Canada	--	--	0.63	0.38	0.79	0.54
Caribbean Basin	0.47	0.30	0.52	0.35	0.76	0.59
China	0.50	0.32	0.64	0.46	0.78	0.60
Colombia	0.45	0.32	0.45	0.32	0.69	0.56
India	0.36	0.26	0.36	0.26	0.66	0.55
Mexico	0.36	0.29	0.60	0.52	0.60	0.52

Table 77 throughTable 84 give the capital and operating cost details for individual countries. Table 85 throughTable 90 give the summary operating cost details for the three types of cellulosic feeds for the individual countries.

Table 77. Argentina residual fuel oil capital and operating costs, bagasse

Country	Argentina	Code =	5				
Cost component	Units	Cost Factor	Scale Factor	Argentina Pyrolytic Fuel Oil	Argentina Pyrolytic Fuel Oil	Argentina Pyrolytic Fuel Oil	Argentina Pyrolytic Fuel Oil
Year $	$			2005	2005	2005	2005
Cost Index (2 = M&S, 3 = CE)			3	130.93	130.93	130.93	130.93
Plant Size	dry short ton/day			529	2,113	4,225	8,449
	dry tonne/day			480	1,917	3,833	7,665
Stream Factor	%			95%	95%	95%	95%
Feed	dtpy			1.83E+05	7.33E+05	1.47E+06	2.93E+06
	GJ/ton			1.79E+01	1.79E+01	1.79E+01	1.79E+01
	GJ/yr			3.29E+06	1.31E+07	2.63E+07	5.25E+07
Feed Cost	$/dt			$ 9.10	$ 9.10	$ 9.10	$ 9.10
Process Efficiency (overall)	%			67.5%	67.5%	67.5%	67.5%
Process Efficiency (to RFO)	%			67.0%	67.0%	67.0%	67.0%
RFO Production	Yield, wt%			70%	70%	70%	70%
	Ton/yr			1.28E+05	5.13E+05	1.03E+06	2.05E+06
	HHV, GJ/ton			17.16	17.16	17.16	17.16
	gal/yr			2.50E+07	1.00E+08	2.00E+08	4.00E+08
	Mil Gal/YR			25.0	100.0	200.0	400.0
	tpy			1.28E+05	5.13E+05	1.03E+06	2.05E+06
	GJ/yr			2.20E+06	8.80E+06	1.76E+07	3.52E+07
	gal/ton			1.37E+02	1.37E+02	1.37E+02	1.37E+02
	gal/Stream day			7.22E+04	2.88E+05	5.77E+05	1.15E+06
	bbl/s day			1.72E+03	6.87E+03	1.37E+04	2.75E+04
	gal EtOH eq/yr			2.48E+07	9.92E+07	1.98E+08	3.97E+08
	gal EtOH eq/ton			1.35E+02	1.35E+02	1.35E+02	1.35E+02
	bbl EtOH eq/day			1.62E+03	6.47E+03	1.29E+04	2.59E+04
Electricity	kWh/y	2358.2	kWh/h	4.71E+06	1.88E+07	3.76E+07	7.52E+07
	GJ eq/yr			1.65E+04	6.61E+04	1.32E+05	2.64E+05
Capital Cost (million USD)							
Feed Preparation			0.70	5.90	15.55	25.26	41.03
Pyrolysis			0.80	3.60	10.89	18.95	33.00
Quench			0.70	1.52	4.01	6.51	10.57
Heat Recovery			0.85	0.97	3.16	5.70	10.27
Product Recovery and Storage			0.65	0.87	2.14	3.36	5.26
Recycle			0.65	1.11	2.73	4.28	6.71
Steam and Power Production			0.70	3.32	8.74	14.20	23.06
Utilities/auxiliaries			0.70	2.69	7.10	11.53	18.73
Direct Fixed Capital (DFC), also called TIC				19.98	54.32	89.79	148.65
Engineering	DFC x MF	0.12		2.40	6.52	10.77	17.84
Construction	DFC x MF	0.13		2.60	7.06	11.67	19.32
Contractor & Legal	DFC x MF	0.08		1.60	4.35	7.18	11.89
Process/Project Contingency	DFC x MF	0.0412		0.82	2.24	3.70	6.12
Total Plant Cost (TPC)				27.40	74.48	123.12	203.83
AFUDC							
Total Plant Investment (TPI)				27.40	74.48	123.12	203.83
Land			0.60	0.94	2.15	3.27	6.53
Startup							
Total Capital Cost (TCC)				28.33	76.64	126.38	210.36
Contingency/TPI							
Working Capital	DFC x MF	0.05		1.37	3.72	6.16	10.19
Variable Operating Costs (million USD/yr)							
Feed				1.67	6.67	13.33	26.66
Utilities				0.96	3.83	7.67	15.33
Other				0.24	0.96	1.92	3.83
Catalysts and Chemicals				0.17	0.67	1.34	2.68
Total				3.04	12.13	24.26	48.51
Fixed Operating Costs (million USD/yr)							
Labor (SF from V-R)	DFC x MF	0.05	0.25	1.55	2.19	2.60	3.10
Maintenance (3% of A)			0.03	0.60	1.63	2.69	4.46
General Overhead (65% of labor + maint)			0.65	1.40	2.48	3.44	4.91
Direct Overhead (45% of Labor)			0.45	0.70	0.99	1.17	1.39
Insurance (0.5% of TIC)			0.005	0.14	0.38	0.63	1.05
Total				4.38	7.67	10.55	14.91

Table 78. Brazil residual fuel oil capital and operating costs, bagasse

Country	Brazil	Code =	2				
Cost component	Units	Cost Factor	Scale Factor	Brazil Pyrolytic Fuel Oil	Brazil Pyrolytic Fuel Oil	Brazil Pyrolytic Fuel Oil	Brazil Pyrolytic Fuel Oil
Year $	$			2005	2005	2005	2005
Cost Index (2 = M&S, 3 = CE)			3	130.93	130.93	130.93	130.93
Plant Size	dry short ton/day			529	2,113	4,225	8,449
	dry tonne/day			480	1,917	3,833	7,665
Stream Factor	%			95%	95%	95%	95%
Feed	dtpy			1.83E+05	7.33E+05	1.47E+06	2.93E+06
	GJ/ton			1.79E+01	1.79E+01	1.79E+01	1.79E+01
	GJ/yr			3.29E+06	1.31E+07	2.63E+07	5.25E+07
Feed Cost	$/dt			$ 7.60	$ 7.60	$ 7.60	$ 7.60
Process Efficiency (overall)	%			67.5%	67.5%	67.5%	67.5%
Process Efficiency (to RFO)	%			67.0%	67.0%	67.0%	67.0%
RFO Production	Yield, wt%			70%	70%	70%	70%
	Ton/yr			1.28E+05	5.13E+05	1.03E+06	2.05E+06
	HHV, GJ/ton			17.16	17.16	17.16	17.16
	gal/yr			2.50E+07	1.00E+08	2.00E+08	4.00E+08
	Mil Gal/YR			25.0	100.0	200.0	400.0
	tpy			1.28E+05	5.13E+05	1.03E+06	2.05E+06
	GJ/yr			2.20E+06	8.80E+06	1.76E+07	3.52E+07
	gal/ton			1.37E+02	1.37E+02	1.37E+02	1.37E+02
	gal/Stream day			7.22E+04	2.88E+05	5.77E+05	1.15E+06
	bbl/s day			1.72E+03	6.87E+03	1.37E+04	2.75E+04
	gal EtOH eq/yr			2.48E+07	9.92E+07	1.98E+08	3.97E+08
	gal EtOH eq/ton			1.35E+02	1.35E+02	1.35E+02	1.35E+02
	bbl EtOH eq/day			1.62E+03	6.47E+03	1.29E+04	2.59E+04
Electricity	kWh/y	2358.2	kWh/h	4.71E+06	1.88E+07	3.76E+07	7.52E+07
	GJ eq/yr			1.65E+04	6.61E+04	1.32E+05	2.64E+05
Capital Cost (million USD)							
Feed Preparation			0.70	5.62	14.80	24.04	39.05
Pyrolysis			0.80	3.42	10.36	18.04	31.40
Quench			0.70	1.45	3.81	6.19	10.06
Heat Recovery			0.85	0.93	3.01	5.42	9.78
Product Recovery and Storage			0.65	0.83	2.04	3.19	5.01
Recycle			0.65	1.06	2.60	4.07	6.39
Steam and Power Production			0.70	3.16	8.32	13.51	21.95
Utilities/auxiliaries			0.70	2.56	6.76	10.97	17.83
Direct Fixed Capital (DFC), also called TIC				19.01	51.70	85.45	141.47
Engineering	DFC x MF	0.12		2.28	6.20	10.25	16.98
Construction	DFC x MF	0.13		2.47	6.72	11.11	18.39
Contractor & Legal	DFC x MF	0.08		1.52	4.14	6.84	11.32
Process/Project Contingency	DFC x MF	0.0412		0.78	2.13	3.52	5.83
Total Plant Cost (TPC)				26.07	70.89	117.18	193.99
AFUDC							
Total Plant Investment (TPI)				26.07	70.89	117.18	193.99
Land			0.60	0.94	2.15	3.27	6.53
Startup							
Total Capital Cost (TCC)				27.01	73.04	120.44	200.52
Contingency/TPI							
Working Capital	DFC x MF	0.05		1.30	3.54	5.86	9.70
Variable Operating Costs (million USD/yr)							
Feed				1.39	5.57	11.13	22.27
Utilities				0.96	3.83	7.67	15.33
Other				0.24	0.96	1.92	3.83
Catalysts and Chemicals				0.17	0.67	1.34	2.68
Total				2.76	11.03	22.06	44.11
Fixed Operating Costs (million USD/yr)							
Labor (SF from V-R)	DFC x MF	0.05	0.25	0.78	1.10	1.31	1.56
Maintenance (3% of A)			0.03	0.57	1.55	2.56	4.24
General Overhead (65% of labor + maint)			0.65	0.88	1.72	2.52	3.77
Direct Overhead (45% of Labor)			0.45	0.35	0.49	0.59	0.70
Insurance (0.5% of TIC)			0.005	0.14	0.37	0.60	1.00
Total				2.71	5.23	7.58	11.27

Table 79. Canada residual fuel oil capital and operating costs, ag residues

Country	Canada	Code =	7				
Cost component	**Units**	**Cost Factor**	**Scale Factor**	**Canada Pyrolytic Fuel Oil**	**Canada Pyrolytic Fuel Oil**	**Canada Pyrolytic Fuel Oil**	**Canada Pyrolytic Fuel Oil**
Year $	$			2005	2005	2005	2005
Cost Index (2 = M&S, 3 = CE)			3	130.93	130.93	130.93	130.93
Plant Size	dry short ton/day			529	2,113	4,225	8,449
	dry tonne/day			480	1,917	3,833	7,665
Stream Factor	%			95%	95%	95%	95%
Feed	dtpy			1.83E+05	7.33E+05	1.47E+06	2.93E+06
	GJ/ton			1.79E+01	1.79E+01	1.79E+01	1.79E+01
	GJ/yr			3.29E+06	1.31E+07	2.63E+07	5.25E+07
Feed Cost	$/dt			$ 10.00	$ 10.00	$ 10.00	$ 10.00
Process Efficiency (overall)	%			67.5%	67.5%	67.5%	67.5%
Process Efficiency (to RFO)	%			67.0%	67.0%	67.0%	67.0%
RFO Production	Yield, wt%			70%	70%	70%	70%
	Ton/yr			1.28E+05	5.13E+05	1.03E+06	2.05E+06
	HHV, GJ/ton			17.16	17.16	17.16	17.16
	gal/yr			2.50E+07	1.00E+08	2.00E+08	4.00E+08
	Mil Gal/YR			25.0	100.0	200.0	400.0
	tpy			1.28E+05	5.13E+05	1.03E+06	2.05E+06
	GJ/yr			2.20E+06	8.80E+06	1.76E+07	3.52E+07
	gal/ton			1.37E+02	1.37E+02	1.37E+02	1.37E+02
	gal/Stream day			7.22E+04	2.88E+05	5.77E+05	1.15E+06
	bbl/s day			1.72E+03	6.87E+03	1.37E+04	2.75E+04
	gal EtOH eq/yr			2.48E+07	9.92E+07	1.98E+08	3.97E+08
	gal EtOH eq/ton			1.35E+02	1.35E+02	1.35E+02	1.35E+02
	bbl EtOH eq/day			1.62E+03	6.47E+03	1.29E+04	2.59E+04
Electricity	kWh/y	2358.2	kWh/h	4.71E+06	1.88E+07	3.76E+07	7.52E+07
	GJ eq/yr			1.65E+04	6.61E+04	1.32E+05	2.64E+05
Capital Cost (million USD)							
Feed Preparation			0.70	7.16	18.87	30.65	49.79
Pyrolysis			0.80	4.36	13.21	23.00	40.04
Quench			0.70	1.84	4.86	7.90	12.83
Heat Recovery			0.85	1.18	3.84	6.92	12.47
Product Recovery and Storage			0.65	1.06	2.60	4.07	6.39
Recycle			0.65	1.35	3.31	5.19	8.15
Steam and Power Production			0.70	4.02	10.61	17.23	27.99
Utilities/auxiliaries			0.70	3.27	8.61	13.99	22.73
Direct Fixed Capital (DFC), also called TIC				24.24	65.92	108.96	180.38
Engineering	DFC x MF	0.12		2.91	7.91	13.07	21.65
Construction	DFC x MF	0.13		3.15	8.57	14.16	23.45
Contractor & Legal	DFC x MF	0.08		1.94	5.27	8.72	14.43
Process/Project Contingency	DFC x MF	0.0412		1.00	2.72	4.49	7.43
Total Plant Cost (TPC)				33.24	90.38	149.40	247.34
AFUDC							
Total Plant Investment (TPI)				33.24	90.38	149.40	247.34
Land			0.60	0.94	2.15	3.27	6.53
Startup							
Total Capital Cost (TCC)				34.18	92.54	152.67	253.87
Contingency/TPI							
Working Capital	DFC x MF	0.05		1.66	4.52	7.47	12.37
Variable Operating Costs (million USD/yr)							
Feed				1.83	7.33	14.65	29.30
Utilities				0.96	3.83	7.67	15.33
Other				0.24	0.96	1.92	3.83
Catalysts and Chemicals				0.17	0.67	1.34	2.68
Total				3.20	12.79	25.57	51.14
Fixed Operating Costs (million USD/yr)							
Labor (SF from V-R)	DFC x MF	0.05	0.25	3.06	4.33	5.15	6.12
Maintenance (3% of A)			0.03	0.73	1.98	3.27	5.41
General Overhead (65% of labor + maint)			0.65	2.46	4.10	5.47	7.50
Direct Overhead (45% of Labor)			0.45	1.38	1.95	2.32	2.76
Insurance (0.5% of TIC)			0.005	0.17	0.46	0.76	1.27
Total				7.80	12.82	16.97	23.06

Table 80. Caribbean basin residual fuel oil capital and operating costs, bagasse

Country	Caribbean	Code =	9				
Cost component	Units	Cost Factor	Scale Factor	Caribbean Pyrolytic Fuel Oil	Caribbean Pyrolytic Fuel Oil	Caribbean Pyrolytic Fuel Oil	Caribbean Pyrolytic Fuel Oil
Year $	$			2005	2005	2005	2005
Cost Index (2 = M&S, 3 = CE)			3	130.93	130.93	130.93	130.93
Plant Size	dry short ton/day			529	2,113	4,225	8,449
	dry tonne/day			480	1,917	3,833	7,665
Stream Factor	%			95%	95%	95%	95%
Feed	dtpy			1.83E+05	7.33E+05	1.47E+06	2.93E+06
	GJ/ton			1.79E+01	1.79E+01	1.79E+01	1.79E+01
	GJ/yr			3.29E+06	1.31E+07	2.63E+07	5.25E+07
Feed Cost	$/dt			$ 7.60	$ 7.60	$ 7.60	$ 7.60
Process Efficiency (overall)	%			67.5%	67.5%	67.5%	67.5%
Process Efficiency (to RFO)	%			67.0%	67.0%	67.0%	67.0%
RFO Production	Yield, wt%			70%	70%	70%	70%
	Ton/yr			1.28E+05	5.13E+05	1.03E+06	2.05E+06
	HHV, GJ/ton			17.16	17.16	17.16	17.16
	gal/yr			2.50E+07	1.00E+08	2.00E+08	4.00E+08
	Mil Gal/YR			25.0	100.0	200.0	400.0
	tpy			1.28E+05	5.13E+05	1.03E+06	2.05E+06
	GJ/yr			2.20E+06	8.80E+06	1.76E+07	3.52E+07
	gal/ton			1.37E+02	1.37E+02	1.37E+02	1.37E+02
	gal/Stream day			7.22E+04	2.88E+05	5.77E+05	1.15E+06
	bbl/s day			1.72E+03	6.87E+03	1.37E+04	2.75E+04
	gal EtOH eq/yr			2.48E+07	9.92E+07	1.98E+08	3.97E+08
	gal EtOH eq/ton			1.35E+02	1.35E+02	1.35E+02	1.35E+02
	bbl EtOH eq/day			1.62E+03	6.47E+03	1.29E+04	2.59E+04
Electricity	kWh/y	2358.2	kWh/h	4.71E+06	1.88E+07	3.76E+07	7.52E+07
	GJ eq/yr			1.65E+04	6.61E+04	1.32E+05	2.64E+05
Capital Cost (million USD)							
Feed Preparation			0.70	6.20	16.34	26.54	43.12
Pyrolysis			0.80	3.78	11.44	19.92	34.67
Quench			0.70	1.60	4.21	6.84	11.11
Heat Recovery			0.85	1.02	3.32	5.99	10.79
Product Recovery and Storage			0.65	0.91	2.25	3.53	5.53
Recycle			0.65	1.17	2.87	4.50	7.06
Steam and Power Production			0.70	3.48	9.19	14.92	24.24
Utilities/auxiliaries			0.70	2.83	7.46	12.12	19.68
Direct Fixed Capital (DFC), also called TIC				20.99	57.08	94.35	156.20
Engineering	DFC x MF	0.12		2.52	6.85	11.32	18.74
Construction	DFC x MF	0.13		2.73	7.42	12.27	20.31
Contractor & Legal	DFC x MF	0.08		1.68	4.57	7.55	12.50
Process/Project Contingency	DFC x MF	0.0412		0.86	2.35	3.89	6.44
Total Plant Cost (TPC)				28.79	78.27	129.37	214.18
AFUDC							
Total Plant Investment (TPI)				28.79	78.27	129.37	214.18
Land			0.60	0.94	2.15	3.27	6.53
Startup							
Total Capital Cost (TCC)				29.73	80.42	132.64	220.71
Contingency/TPI							
Working Capital	DFC x MF	0.05		1.44	3.91	6.47	10.71
Variable Operating Costs (million USD/yr)							
Feed				1.39	5.57	11.13	22.27
Utilities				0.96	3.83	7.67	15.33
Other				0.24	0.96	1.92	3.83
Catalysts and Chemicals				0.17	0.67	1.34	2.68
Total				2.76	11.03	22.06	44.11
Fixed Operating Costs (million USD/yr)							
Labor (SF from V-R)	DFC x MF	0.05	0.25	1.75	2.48	2.95	3.50
Maintenance (3% of A)			0.03	0.63	1.71	2.83	4.69
General Overhead (65% of labor + maint)			0.65	1.55	2.72	3.76	5.32
Direct Overhead (45% of Labor)			0.45	0.79	1.12	1.33	1.58
Insurance (0.5% of TIC)			0.005	0.15	0.40	0.66	1.10
Total				4.87	8.43	11.52	16.20

Table 81. China residual fuel oil capital and operating costs, bagasse

Country	China	Code =	3				
Cost component	Units	Cost Factor	Scale Factor	China Pyrolytic Fuel Oil	China Pyrolytic Fuel Oil	China Pyrolytic Fuel Oil	China Pyrolytic Fuel Oil
Year $	$			2005	2005	2005	2005
Cost Index (2 = M&S, 3 = CE)			3	130.93	130.93	130.93	130.93
Plant Size	dry short ton/day			529	2,113	4,225	8,449
	dry tonne/day			480	1,917	3,833	7,665
Stream Factor	%			95%	95%	95%	95%
Feed	dtpy			1.83E+05	7.33E+05	1.47E+06	2.93E+06
	GJ/ton			1.79E+01	1.79E+01	1.79E+01	1.79E+01
	GJ/yr			3.29E+06	1.31E+07	2.63E+07	5.25E+07
Feed Cost	$/dt			$ 9.10	$ 9.10	$ 9.10	$ 9.10
Process Efficiency (overall)	%			67.5%	67.5%	67.5%	67.5%
Process Efficiency (to RFO)	%			67.0%	67.0%	67.0%	67.0%
RFO Production	Yield, wt%			70%	70%	70%	70%
	Ton/yr			1.28E+05	5.13E+05	1.03E+06	2.05E+06
	HHV, GJ/ton			17.16	17.16	17.16	17.16
	gal/yr			2.50E+07	1.00E+08	2.00E+08	4.00E+08
	Mil Gal/YR			25.0	100.0	200.0	400.0
	tpy			1.28E+05	5.13E+05	1.03E+06	2.05E+06
	GJ/yr			2.20E+06	8.80E+06	1.76E+07	3.52E+07
	gal/ton			1.37E+02	1.37E+02	1.37E+02	1.37E+02
	gal/Stream day			7.22E+04	2.88E+05	5.77E+05	1.15E+06
	bbl/s day			1.72E+03	6.87E+03	1.37E+04	2.75E+04
	gal EtOH eq/yr			2.48E+07	9.92E+07	1.98E+08	3.97E+08
	gal EtOH eq/ton			1.35E+02	1.35E+02	1.35E+02	1.35E+02
	bbl EtOH eq/day			1.62E+03	6.47E+03	1.29E+04	2.59E+04
Electricity	kWh/y	2358.2	kWh/h	4.71E+06	1.88E+07	3.76E+07	7.52E+07
	GJ eq/yr			1.65E+04	6.61E+04	1.32E+05	2.64E+05
Capital Cost (million USD)							
Feed Preparation			0.70	6.05	15.94	25.89	42.05
Pyrolysis			0.80	3.69	11.16	19.43	33.82
Quench			0.70	1.56	4.11	6.67	10.84
Heat Recovery			0.85	1.00	3.24	5.84	10.53
Product Recovery and Storage			0.65	0.89	2.19	3.44	5.40
Recycle			0.65	1.14	2.80	4.39	6.88
Steam and Power Production			0.70	3.40	8.96	14.55	23.64
Utilities/auxiliaries			0.70	2.76	7.28	11.82	19.20
Direct Fixed Capital (DFC), also called TIC				20.48	55.67	92.02	152.35
Engineering	DFC x MF	0.12		2.46	6.68	11.04	18.28
Construction	DFC x MF	0.13		2.66	7.24	11.96	19.81
Contractor & Legal	DFC x MF	0.08		1.64	4.45	7.36	12.19
Process/Project Contingency	DFC x MF	0.0412		0.84	2.29	3.79	6.28
Total Plant Cost (TPC)				28.08	76.34	126.18	208.90
AFUDC							
Total Plant Investment (TPI)				28.08	76.34	126.18	208.90
Land			0.60	0.94	2.15	3.27	6.53
Startup							
Total Capital Cost (TCC)				29.02	78.49	129.45	215.43
Contingency/TPI							
Working Capital	DFC x MF	0.05		1.40	3.82	6.31	10.44
Variable Operating Costs (million USD/yr)							
Feed				1.67	6.67	13.33	26.66
Utilities				0.96	3.83	7.67	15.33
Other				0.24	0.96	1.92	3.83
Catalysts and Chemicals				0.17	0.67	1.34	2.68
Total				3.04	12.13	24.26	48.51
Fixed Operating Costs (million USD/yr)							
Labor (SF from V-R)	DFC x MF	0.05	0.25	2.03	2.87	3.41	4.06
Maintenance (3% of A)			0.03	0.61	1.67	2.76	4.57
General Overhead (65% of labor + maint)			0.65	1.72	2.95	4.01	5.61
Direct Overhead (45% of Labor)			0.45	0.91	1.29	1.54	1.83
Insurance (0.5% of TIC)			0.005	0.15	0.39	0.65	1.08
Total				5.42	9.17	12.37	17.14

Table 82. Colombia residual fuel oil capital and operating costs, bagasse

Country	Colombia	Code =	6				
Cost component	**Units**	**Cost Factor**	**Scale Factor**	**Colombia Pyrolytic Fuel Oil**	**Colombia Pyrolytic Fuel Oil**	**Colombia Pyrolytic Fuel Oil**	**Colombia Pyrolytic Fuel Oil**
Year $	$			2005	2005	2005	2005
Cost Index (2 = M&S, 3 = CE)			3	130.93	130.93	130.93	130.93
Plant Size	dry short ton/day			529	2,113	4,225	8,449
	dry tonne/day			480	1,917	3,833	7,665
Stream Factor	%			95%	95%	95%	95%
Feed	dtpy			1.83E+05	7.33E+05	1.47E+06	2.93E+06
	GJ/ton			1.79E+01	1.79E+01	1.79E+01	1.79E+01
	GJ/yr			3.29E+06	1.31E+07	2.63E+07	5.25E+07
Feed Cost	$/dt			$ 14.50	$ 14.50	$ 14.50	$ 14.50
Process Efficiency (overall)	%			67.5%	67.5%	67.5%	67.5%
Process Efficiency (to RFO)	%			67.0%	67.0%	67.0%	67.0%
RFO Production	Yield, wt%			70%	70%	70%	70%
	Ton/yr			1.28E+05	5.13E+05	1.03E+06	2.05E+06
	HHV, GJ/ton			17.16	17.16	17.16	17.16
	gal/yr			2.50E+07	1.00E+08	2.00E+08	4.00E+08
	Mil Gal/YR			25.0	100.0	200.0	400.0
	tpy			1.28E+05	5.13E+05	1.03E+06	2.05E+06
	GJ/yr			2.20E+06	8.80E+06	1.76E+07	3.52E+07
	gal/ton			1.37E+02	1.37E+02	1.37E+02	1.37E+02
	gal/Stream day			7.22E+04	2.88E+05	5.77E+05	1.15E+06
	bbl/s day			1.72E+03	6.87E+03	1.37E+04	2.75E+04
	gal EtOH eq/yr			2.48E+07	9.92E+07	1.98E+08	3.97E+08
	gal EtOH eq/ton			1.35E+02	1.35E+02	1.35E+02	1.35E+02
	bbl EtOH eq/day			1.62E+03	6.47E+03	1.29E+04	2.59E+04
Electricity	kWh/y	2358.2	kWh/h	4.71E+06	1.88E+07	3.76E+07	7.52E+07
	GJ eq/yr			1.65E+04	6.61E+04	1.32E+05	2.64E+05
Capital Cost (million USD)							
Feed Preparation			0.70	5.46	14.40	23.40	38.00
Pyrolysis			0.80	3.33	10.08	17.55	30.56
Quench			0.70	1.41	3.71	6.03	9.79
Heat Recovery			0.85	0.90	2.93	5.28	9.51
Product Recovery and Storage			0.65	0.81	1.98	3.11	4.88
Recycle			0.65	1.03	2.53	3.96	6.22
Steam and Power Production			0.70	3.07	8.10	13.15	21.36
Utilities/auxiliaries			0.70	2.49	6.58	10.68	17.35
Direct Fixed Capital (DFC), also called TIC				18.50	50.31	83.16	137.67
Engineering	DFC x MF	0.12		2.22	6.04	9.98	16.52
Construction	DFC x MF	0.13		2.41	6.54	10.81	17.90
Contractor & Legal	DFC x MF	0.08		1.48	4.02	6.65	11.01
Process/Project Contingency	DFC x MF	0.0412		0.76	2.07	3.43	5.67
Total Plant Cost (TPC)				25.37	68.98	114.03	188.78
AFUDC							
Total Plant Investment (TPI)				25.37	68.98	114.03	188.78
Land			0.60	0.94	2.15	3.27	6.53
Startup							
Total Capital Cost (TCC)				26.31	71.14	117.29	195.30
Contingency/TPI							
Working Capital	DFC x MF	0.05		1.27	3.45	5.70	9.44
Variable Operating Costs (million USD/yr)							
Feed				2.66	10.62	21.24	42.48
Utilities				0.96	3.83	7.67	15.33
Other				0.24	0.96	1.92	3.83
Catalysts and Chemicals				0.17	0.67	1.34	2.68
Total				4.03	16.09	32.17	64.33
Fixed Operating Costs (million USD/yr)							
Labor (SF from V-R)	DFC x MF	0.05	0.25	1.16	1.64	1.95	2.32
Maintenance (3% of A)			0.03	0.56	1.51	2.49	4.13
General Overhead (65% of labor + maint)			0.65	1.12	2.05	2.89	4.20
Direct Overhead (45% of Labor)			0.45	0.52	0.74	0.88	1.05
Insurance (0.5% of TIC)			0.005	0.13	0.36	0.59	0.98
Total				3.49	6.30	8.81	12.67

Table 83. India residual fuel oil capital and operating costs, bagasse

Country **India** **Code =** 4

Cost component	Units	Cost Factor	Scale Factor	India Pyrolytic Fuel Oil	India Pyrolytic Fuel Oil	India Pyrolytic Fuel Oil	India Pyrolytic Fuel Oil
Year $	$			2005	2005	2005	2005
Cost Index (2 = M&S, 3 = CE)			3	130.93	130.93	130.93	130.93
Plant Size	dry short ton/day			529	2,113	4,225	8,449
	dry tonne/day			480	1,917	3,833	7,665
Stream Factor	%			95%	95%	95%	95%
Feed	dtpy			1.83E+05	7.33E+05	1.47E+06	2.93E+06
	GJ/ton			1.79E+01	1.79E+01	1.79E+01	1.79E+01
	GJ/yr			3.29E+06	1.31E+07	2.63E+07	5.25E+07
Feed Cost	$/dt			$ 7.30	$ 7.30	$ 7.30	$ 7.30
Process Efficiency (overall)	%			67.5%	67.5%	67.5%	67.5%
Process Efficiency (to RFO)	%			67.0%	67.0%	67.0%	67.0%
RFO Production	Yield, wt%			70%	70%	70%	70%
	Ton/yr			1.28E+05	5.13E+05	1.03E+06	2.05E+06
	HHV, GJ/ton			17.16	17.16	17.16	17.16
	gal/yr			2.50E+07	1.00E+08	2.00E+08	4.00E+08
	Mil Gal/YR			25.0	100.0	200.0	400.0
	tpy			1.28E+05	5.13E+05	1.03E+06	2.05E+06
	GJ/yr			2.20E+06	8.80E+06	1.76E+07	3.52E+07
	gal/ton			1.37E+02	1.37E+02	1.37E+02	1.37E+02
	gal/Stream day			7.22E+04	2.88E+05	5.77E+05	1.15E+06
	bbl/s day			1.72E+03	6.87E+03	1.37E+04	2.75E+04
	gal EtOH eq/yr			2.48E+07	9.92E+07	1.98E+08	3.97E+08
	gal EtOH eq/ton			1.35E+02	1.35E+02	1.35E+02	1.35E+02
	bbl EtOH eq/day			1.62E+03	6.47E+03	1.29E+04	2.59E+04
Electricity	kWh/y	2358.2	kWh/h	4.71E+06	1.88E+07	3.76E+07	7.52E+07
	GJ eq/yr			1.65E+04	6.61E+04	1.32E+05	2.64E+05
Capital Cost (million USD)							
Feed Preparation			0.70	5.86	15.45	25.09	40.76
Pyrolysis			0.80	3.57	10.82	18.83	32.78
Quench			0.70	1.51	3.98	6.47	10.50
Heat Recovery			0.85	0.97	3.14	5.66	10.20
Product Recovery and Storage			0.65	0.86	2.12	3.33	5.23
Recycle			0.65	1.10	2.71	4.25	6.67
Steam and Power Production			0.70	3.29	8.68	14.10	22.91
Utilities/auxiliaries			0.70	2.68	7.05	11.45	18.61
Direct Fixed Capital (DFC), also called TIC				19.85	53.96	89.19	147.66
Engineering	DFC x MF	0.12		2.38	6.48	10.70	17.72
Construction	DFC x MF	0.13		2.58	7.01	11.60	19.20
Contractor & Legal	DFC x MF	0.08		1.59	4.32	7.14	11.81
Process/Project Contingency	DFC x MF	0.0412		0.82	2.22	3.67	6.08
Total Plant Cost (TPC)				27.21	73.99	122.30	202.48
AFUDC							
Total Plant Investment (TPI)				27.21	73.99	122.30	202.48
Land			0.60	0.94	2.15	3.27	6.53
Startup							
Total Capital Cost (TCC)				28.15	76.14	125.57	209.01
Contingency/TPI							
Working Capital	DFC x MF	0.05		1.36	3.70	6.12	10.12
Variable Operating Costs (million USD/yr)							
Feed				1.34	5.35	10.69	21.39
Utilities				0.96	3.83	7.67	15.33
Other				0.24	0.96	1.92	3.83
Catalysts and Chemicals				0.17	0.67	1.34	2.68
Total				2.71	10.81	21.62	43.23
Fixed Operating Costs (million USD/yr)							
Labor (SF from V-R)	DFC x MF	0.05	0.25	0.68	0.97	1.15	1.37
Maintenance (3% of A)			0.03	0.60	1.62	2.68	4.43
General Overhead (65% of labor + maint)			0.65	0.83	1.68	2.49	3.77
Direct Overhead (45% of Labor)			0.45	0.31	0.43	0.52	0.61
Insurance (0.5% of TIC)			0.005	0.14	0.38	0.63	1.05
Total				2.56	5.08	7.45	11.22

Table 84. Mexico residual fuel oil capital and operating costs, bagasse

Country **Mexico** **Code =** 8

Cost component	Units	Cost Factor	Scale Factor	Mexico Pyrolytic Fuel Oil	Mexico Pyrolytic Fuel Oil	Mexico Pyrolytic Fuel Oil	Mexico Pyrolytic Fuel Oil
Year $	$			2005	2005	2005	2005
Cost Index (2 = M&S, 3 = CE)			3	130.93	130.93	130.93	130.93
Plant Size	dry short ton/day			529	2,113	4,225	8,449
	dry tonne/day			480	1,917	3,833	7,665
Stream Factor	%			95%	95%	95%	95%
Feed	dtpy			1.83E+05	7.33E+05	1.47E+06	2.93E+06
	GJ/ton			1.79E+01	1.79E+01	1.79E+01	1.79E+01
	GJ/yr			3.29E+06	1.31E+07	2.63E+07	5.25E+07
Feed Cost	$/dt			$ 15.40	$ 15.40	$ 15.40	$ 15.40
Process Efficiency (overall)	%			67.5%	67.5%	67.5%	67.5%
Process Efficiency (to RFO)	%			67.0%	67.0%	67.0%	67.0%
RFO Production	Yield, wt%			70%	70%	70%	70%
	Ton/yr			1.28E+05	5.13E+05	1.03E+06	2.05E+06
	HHV, GJ/ton			17.16	17.16	17.16	17.16
	gal/yr			2.50E+07	1.00E+08	2.00E+08	4.00E+08
	Mil Gal/YR			25.0	100.0	200.0	400.0
	tpy			1.28E+05	5.13E+05	1.03E+06	2.05E+06
	GJ/yr			2.20E+06	8.80E+06	1.76E+07	3.52E+07
	gal/ton			1.37E+02	1.37E+02	1.37E+02	1.37E+02
	gal/Stream day			7.22E+04	2.88E+05	5.77E+05	1.15E+06
	bbl/s day			1.72E+03	6.87E+03	1.37E+04	2.75E+04
	gal EtOH eq/yr			2.48E+07	9.92E+07	1.98E+08	3.97E+08
	gal EtOH eq/ton			1.35E+02	1.35E+02	1.35E+02	1.35E+02
	bbl EtOH eq/day			1.62E+03	6.47E+03	1.29E+04	2.59E+04
Electricity	kWh/y	2358.2	kWh/h	4.71E+06	1.88E+07	3.76E+07	7.52E+07
	GJ eq/yr			1.65E+04	6.61E+04	1.32E+05	2.64E+05
Capital Cost (million USD)							
Feed Preparation			0.70	4.42	11.65	18.92	30.74
Pyrolysis			0.80	2.69	8.16	14.20	24.72
Quench			0.70	1.14	3.00	4.88	7.92
Heat Recovery			0.85	0.73	2.37	4.27	7.70
Product Recovery and Storage			0.65	0.65	1.60	2.51	3.94
Recycle			0.65	0.83	2.04	3.21	5.03
Steam and Power Production			0.70	2.48	6.55	10.64	17.28
Utilities/auxiliaries			0.70	2.02	5.32	8.64	14.03
Direct Fixed Capital (DFC), also called TIC				14.97	40.69	67.26	111.35
Engineering	DFC x MF	0.12		1.80	4.88	8.07	13.36
Construction	DFC x MF	0.13		1.95	5.29	8.74	14.48
Contractor & Legal	DFC x MF	0.08		1.20	3.26	5.38	8.91
Process/Project Contingency	DFC x MF	0.0412		0.62	1.68	2.77	4.59
Total Plant Cost (TPC)				20.52	55.80	92.23	152.69
AFUDC							
Total Plant Investment (TPI)				20.52	55.80	92.23	152.69
Land			0.60	0.94	2.15	3.27	6.53
Startup							
Total Capital Cost (TCC)				21.46	57.95	95.49	159.22
Contingency/TPI							
Working Capital	DFC x MF	0.05		1.03	2.79	4.61	7.63
Variable Operating Costs (million USD/yr)							
Feed				2.83	11.28	22.56	45.12
Utilities				0.96	3.83	7.67	15.33
Other				0.24	0.96	1.92	3.83
Catalysts and Chemicals				0.17	0.67	1.34	2.68
Total				4.19	16.75	33.49	66.96
Fixed Operating Costs (million USD/yr)							
Labor (SF from V-R)	DFC x MF	0.05	0.25	0.44	0.62	0.74	0.88
Maintenance (3% of A)			0.03	0.45	1.22	2.02	3.34
General Overhead (65% of labor + maint)			0.65	0.58	1.20	1.79	2.74
Direct Overhead (45% of Labor)			0.45	0.20	0.28	0.33	0.40
Insurance (0.5% of TIC)			0.005	0.11	0.29	0.48	0.80
Total				1.77	3.61	5.36	8.16

Table 85. Pyrolysis residual fuel oil summary yields, costs, and plant gate prices, 25 MM GPY, bagasse

Technology	Units	USA	Argentina	Brazil	Canada	Caribbean Basin	China	Colombia	India	Mexico
Plant Size	MM gal/yr	25	25	25	25	25	25	25	25	25
Yields										
Primary Product Yield	gal/ton	136.6	136.6	136.6		136.6	136.6	136.6	136.6	136.6
By Product A										
Unit		Electricity	Electricity	Electricity		Electricity	Electricity	Electricity	Electricity	Electricity
Yield unit		kWh	kWh	kWh		kWh	kWh	kWh	kWh	kWh
Annual Yield		4.71E+06	4.71E+06	4.71E+06		4.71E+06	4.71E+06	4.71E+06	4.71E+06	4.71E+06
Price unit		0.04	0.04	0.04		0.04	0.04	0.04	0.04	0.04
MM USD/yr		0.187	0.187	0.187		0.187	0.187	0.187	0.187	0.187
By Product B										
Unit										
Yield unit										
Annual Yield										
Price unit										
Annual Cost	MM USD/yr									
Energy Inputs										
Electricity		N/A	N/A	N/A		N/A	N/A	N/A	N/A	N/A
Cost	$/kWh									
Amount	kWh/yr									
Annual Cost	MM USD/yr									
Fuel		N/A	N/A	N/A		N/A	N/A	N/A	N/A	N/A
Type										
Unit										
Amount										
Cost	USD/unit									
Annual Cost	MM USD/yr									
Capital & Operating Costs										
Capital	MMUSD	26.45	28.33	27.01		29.73	29.02	26.31	28.15	21.46
Operating w/o feed	MM USD/yr	6.26	5.75	4.08		6.24	6.79	4.86	3.93	3.14
Feed										
Unit		ton	ton	ton		ton	ton	ton	ton	ton
Cost/unit	USD/unit	35	9.1	7.6		7.6	9.1	14.5	7.3	15.4
Rate	unit/day	529	529	529		529	529	529	529	529
Yearly Cost	MM USD/yr	6.42	1.67	1.39		1.39	1.67	529	1.34	2.83
Product Plant Gate Cost										
Basis										
Value	USD/gal	0.66	0.46	0.46		0.47	0.5	0.45	0.36	0.36

Table 86. Pyrolysis residual fuel oil summary yields, costs, and plant gate prices, 100 MM GPY, bagasse

Technology	Units	USA	Argentina	Brazil	Canada	Caribbean Basin	China	Colombia	India	Mexico
Plant Size	MM gal/yr	100	100	100	100	100	100	100	100	100
Yields										
Primary Product Yield	gal/ton	136.6	136.6	136.6	136.6	136.6	136.6	136.6	136.6	136.6
By Product A		Electricity	Electricity	Electricity	Electricity	Electricity	Electricity	Electricity	Electricity	Electricity
Unit										
Yield unit		kwh	kwh	kwh	kwh	kwh	kwh	kwh	kwh	kwh
Annual Yield		1.88E+07	1.88E+07	1.88E+07	1.88E+07	1.88E+07	1.88E+07	1.88E+07	1.88E+07	1.88E+07
Price unit		0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
MM USD/yr		0.746	0.746	0.746	0.746	0.746	0.746	0.746	0.746	0.746
By Product B										
Unit										
Yield unit										
Annual Yield										
Price unit										
Annual Cost	MM USD/yr									
Energy Inputs										
Electricity		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cost	$/kWh									
Amount	kWh/yr									
Annual Cost	MM USD/yr									
Fuel		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Type										
Unit										
Amount										
Cost	USD/unit									
Annual Cost	MM USD/yr									
Capital & Operating Costs										
Capital	MMUSD	71.52	76.64	73.04		80.42	78.49	71.14	76.14	57.95
Operating w/o feed	MM USD/yr	26.8	13.13	10.7		13.9	14.64	11.76	10.54	9.08
Feed										
Unit		ton	ton	ton		ton	ton	ton	ton	ton
Cost/unit	USD/unit	35	9.1	7.6		7.6	9.1	14.5	7.3	15.4
Rate	unit/day	2113	2113	2113		2113	2113	2113	2113	2113
Yearly Cost	MM USD/yr	26.65	6.67	5.57		5.57	6.67	10.62	5.35	11.28
Product Plant Gate Cost										
Basis										
Value	USD/gal	0.50	0.3	0.26		0.3	0.32	0.32	0.26	0.29

Table 87. Pyrolysis residual fuel oil summary yields, costs, and plant gate prices, 25 MM GPY, ag residues

Technology	Units	USA	Argentina	Brazil	Canada	Caribbean Basin	China	Colombia	India	Mexico
Plant Size	MM gal/yr	25	25	25	25	25	25	25	25	25
Yields										
Primary Product Yield	gal/ton	136.6	136.6	136.6	136.6	136.6	136.6	136.6	136.6	136.6
By Product A										
Unit		Electricity	Electricity	Electricity	Electricity	Electricity	Electricity	Electricity	Electricity	Electricity
Yield unit		kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh
Annual Yield		4.71E+06	4.71E+06	4.71E+06	4.71E+06	4.71E+06	4.71E+06	4.71E+06	4.71E+06	4.71E+06
Price unit		0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
MM USD/yr		0.187	0.187	0.187	0.187	0.187	0.187	0.187	0.187	0.187
By Product B										
Unit										
Yield unit										
Annual Yield										
Price unit										
Annual Cost	MM USD/yr									
Energy Inputs										
Electricity		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cost	$/kWh									
Amount	kWh/yr									
Annual Cost	MM USD/yr									
Fuel		N/a	N/a	N/a	N/a	N/a	N/a	N/a	N/a	N/a
Type										
Unit										
Amount										
Cost	USD/unit									
Annual Cost	MM USD/yr									
Capital & Operating Costs										
Capital	MMUSD	26.45	28.33	27.01	34.18	29.73	29.02	26.31	28.15	221.46
Operating w/o feed	MM USD/yr	6.26	5.75	4.08	9.17	6.24	6.79	4.86	3.93	3.14
Feed										
Unit		ton	ton	ton		ton	ton	ton	ton	ton
Cost/unit	USD/unit	35	47.2	30.8	10	14.5	28.1	14.5	7.3	47.2
Rate	unit/day	529	529	529	529	529	529	529	529	529
Yearly Cost	MM USD/yr	6.42	8.66	5.65	1.83	2.66	5.16	2.66	1.34	8.66
Product Plant Gate Cost										
Basis										
Value	USD/gal	0.66	0.74	0.54	0.63	0.52	0.64	0.45	0.36	0.6

Table 88. Pyrolysis residual fuel oil summary yields, costs, and plant gate prices, 100 MM GPY, ag residues

Technology	Units	USA	Argentina	Brazil	Canada	Caribbean Basin	China	Colombia	India	Mexico
Plant Size	MM gal/yr	100	100	100	100	100	100	100	100	100
Yields										
Primary Product Yield	gal/ton	136.6	136.6	136.6	136.6	136.6	136.6	136.6	136.6	136.6
By Product A		Electricity	Electricity	Electricity	Electricity	Electricity	Electricity	Electricity	Electricity	Electricity
Unit										
Yield unit		kwh	kwh	kwh	kwh	kwh	kwh	kwh	kwh	kwh
Annual Yield		1.88E+07	1.88E+07	1.88E+07	1.88E+07	1.88E+07	1.88E+07	1.88E+07	1.88E+07	1.88E+07
Price unit		0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
MM USD/yr		0.746	0.746	0.746	0.746	0.746	0.746	0.746	0.746	0.746
By Product B										
Unit										
Yield unit										
Annual Yield										
Price unit										
Annual Cost	MM USD/yr									
Energy Inputs										
Electricity		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cost	$/kWh									
Amount	kWh/yr									
Annual Cost	MM USD/yr									
Fuel		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Type										
Unit										
Amount										
Cost	USD/unit									
Annual Cost	MM USD/yr									
Capital & Operating Costs										
Capital	MMUSD	71.52	76.64	73.04	92.54	81.42	78.49	71.14	76.14	57.95
Operating w/o feed	MM USD/yr	26.8	13.13	10.7	18.28	13.9	14.64	11.76	10.54	9.08
Feed										
Unit		ton	ton	ton	ton	ton	ton	ton	ton	ton
Cost/unit	USD/unit	35	47.2	30.8	10	14.5	28.1	14.5	7.3	47.2
Rate	unit/day	2113	2113	2113	2113	2113	2113	2113	2113	2113
Yearly Cost	MM USD/yr	26.65	34.58	22.57	7.33	10.62	20.59	10.62	5.35	34.58
Product Plant Gate Cost										
Basis										
Value	USD/gal	0.50	0.58	0.43	0.38	0.35	0.46	0.32	0.26	0.52

Table 89. Pyrolysis residual fuel oil summary yields, costs, and plant gate prices, 25 MM GPY, wood/perennials

Technology	Units	USA	Argentina	Brazil	Canada	Caribbean Basin	China	Colombia	India	Mexico
Plant Size	MM gal/yr	25	25	25	25	25	25	25	25	25
Yields										
Primary Product Yield	gal/ton	136.6								
By Product A										
Unit		Electricity	Electricity	Electricity	Electricity	Electricity	Electricity	Electricity	Electricity	Electricity
Yield unit		kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh
Annual Yield		4.71E+06	4.71E+06	4.71E+06	4.71E+06	4.71E+06	4.71E+06	4.71E+06	4.71E+06	4.71E+06
Price unit		0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
MM USD/yr		0.187	0.187	0.187	0.187	0.187	0.187	0.187	0.187	0.187
By Product B										
Unit										
Yield unit										
Annual Yield										
Price unit										
Annual Cost	MM USD/yr									
Energy Inputs										
Electricity		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cost	$/kWh									
Amount	kWh/yr									
Annual Cost	MM USD/yr									
Fuel		N/a	N/a	N/a	N/a	N/a	N/a	N/a	N/a	N/a
Type										
Unit										
Amount										
Cost	USD/unit									
Annual Cost	MM USD/yr									
Capital & Operating Costs										
Capital	MMUSD	26.45	28.33	27.01	34.18	29.73	29.02	26.31	28.15	21.46
Operating w/o feed	MM USD/yr	6.26	5.75	4.08	9.17	6.24	6.79	4.86	3.93	3.14
Feed										
Unit		ton	ton	ton	ton	ton	ton	ton	ton	ton
Cost/unit	USD/unit	35	47.2	47.2	31.8	47.2	47.2	47.2	47.2	47.2
Rate	unit/day	529	529	529	529	529	529	529	529	529
Yearly Cost	MM USD/yr	6.42	8.66	8.66	5.83	8.66	8.66	8.66	8.66	8.66
Product Plant Gate Cost										
Basis										
Value	USD/gal	0.66	0.74	0.66	0.79	0.76	0.78	0.69	0.66	0.60

Table 90. Pyrolysis residual fuel oil summary yields, costs, and plant gate prices, 100 MM GPY, wood/perennials

Technology	Units	USA	Argentina	Brazil	Canada	Caribbean Basin	China	Colombia	India	Mexico
Plant Size	MM gal/yr	100	100	100	100	100	100	100	100	100
Yields										
Primary Product Yield	gal/ton	136.6	136.6	136.6	136.6	136.6	136.6	136.6	136.6	136.6
By Product A		Electricity	Electricity	Electricity	Electricity	Electricity	Electricity	Electricity	Electricity	Electricity
Unit										
Yield unit		kwh	kwh	kwh	kwh	kwh	kwh	kwh	kwh	kwh
Annual Yield		1.88E+07	1.88E+07	1.88E+07	1.88E+07	1.88E+07	1.88E+07	1.88E+07	1.88E+07	1.88E+07
Price unit		0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
MM USD/yr		0.746	0.746	0.746	0.746	0.746	0.746	0.746	0.746	0.746
By Product B										
Unit										
Yield unit										
Annual Yield										
Price unit										
Annual Cost	MM USD/yr									
Energy Inputs										
Electricity		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cost	$/kWh									
Amount	kWh/yr									
Annual Cost	MM USD/yr									
Fuel		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Type										
Unit										
Amount										
Cost	USD/unit									
Annual Cost	MM USD/yr									
Capital & Operating Costs										
Capital	MMUSD	71.52	76.64	73.04	92.54	80.42	78.49	71.14	73.99	57.95
Operating w/o feed	MM USD/yr	26.8	13.13	10.7	18.28	13.9	14.64	11.76	10.54	9.08
Feed										
Unit		ton	ton	ton	ton	ton	ton	ton	ton	ton
Cost/unit	USD/unit	35	47.2	47.2	31.8	47.2	47.2	47.2	47.2	47.2
Rate	unit/day	2113	2113	2113	2113	2113	2113	2113	2113	2113
Yearly Cost	MM USD/yr	26.65	34.58	34.58	23.3	34.58	34.58	34.58	34.58	34.58
Product Plant Gate Cost										
Basis										
Value	USD/gal	0.50	0.58	0.55	0.54	0.59	0.60	0.56	0.55	0.52

8 Biodiesel

The biodiesel process used for the technoeconomic analysis is based on the model plant presented by Haas et al. (2006) for conversion of soy oil to biodiesel. The facility, Figure 26, contains three processing areas: (1) a transesterification unit to convert soy oil to fatty acid methyl esters (FAME) and crude glycerin, (2) a biodiesel purification unit, and (3) and a glycerin purification unit. For information purposes, the flow diagram also shows a dilute acid esterification unit for recycled greases.

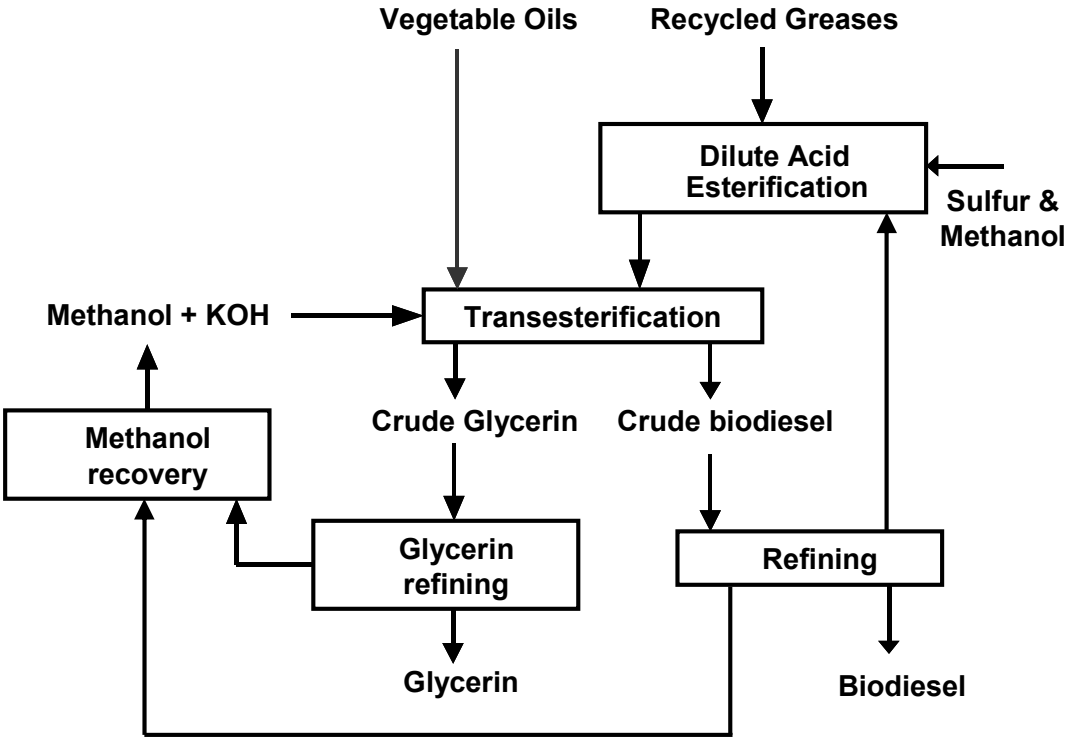


Figure 26. Biodiesel process flow diagram

The model is based on soy oil cost, but feedstock supply curves developed by ORNL are based on soybeans. To estimate the soy oil cost used as input in the cash flow model, an average soybean crush spread value was used. Soybean crush spread (Chicago Board of Trade 2006) is the dollar value quoted as the difference between the combined sales values of the products (soybean oil and soybean meal) and the cost of the raw soybeans. Crush spread is also known as "crush" and "GPM" (gross processing margin). When a bushel of soybeans weighing 60 pounds is crushed, the typical result is 11 pounds of soybean oil, 44 pounds of 48% protein soybean meal, 4 pounds of hulls, and 1 pound of waste. If the hulls are retained the result is 48 pounds of 44% soybean meal. The following equation is used to convert prices into cents per bushel.

GPM = [(price of soybean meal ($/ton) x 0.0222 +price of soybean oil (¢/lb) x 11/100] – price of soybeans ($/bu)

Historic crush values (USDA 2006) are used to estimate the ratio of oil to beans price, see Table 91 and Table 92. In the calculation of the average value to use in this study the year 2003 was considered an outlier.

Table 91. Historic crush values

Year	soybeans $/bu	Meal-48% $/ton A	Oil Cents/lb	Crush $	Beans $/ton B	Oil $/ton C	Meal/Beans A/B	Oil/Beans C/B
2000	4.5	173.60	14.15	0.87	152.09	283.00	1.141	1.861
2001	4.4	167.70	16.46	1.15	146.73	329.20	1.143	2.244
2002	5.5	181.60	22.04	0.93	185.26	440.80	0.980	2.379
2003	4.3	256.05	29.97	4.64	145.39	599.40	1.761	4.123
2004	5.7	182.90	23.01	0.85	192.29	460.20	0.951	2.393
2005	5.6	172.50	22.00	0.65	187.60	440.00	0.919	2.345

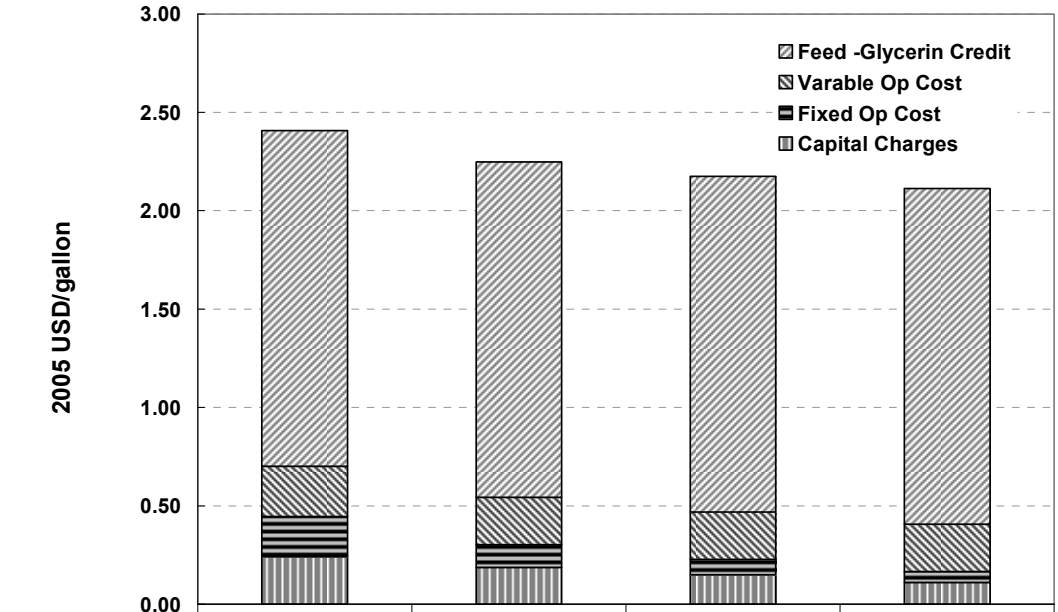
Table 92. Historic soybean oil to soybean price ratio based on crush

Year	C/B
2000	1.8607
2001	2.2435
2002	2.3790
2004	2.3932
2005	2.3454
AVE	**2.2444**

The capital and operating costs for the USA base case are given in Table 93. Figure 27. USA base case biodiesel plant gate prices, shows the breakdown of plant gate price as a function of plant size. Table 94 through Table 97 give capital and operating costs for selected countries. Table 98 andTable 99 give summary yields, capital costs, operating costs, and plant gate prices for the selected countries for 25 MM GPY and 100 MM GPY plants, respectively.

Table 93. USA biodiesel capital and operating costs

Country	USA	Code =	1				
Cost component	**Units**	**Cost Factor**	**Scale Factor**	**USA Biodiesel**	**USA Biodiesel**	**USA Biodiesel**	**USA Biodiesel**
Year $	$			2005	2005	2005	2005
Cost Index (2 = M&S, 3 = CE)			3	130.93	130.93	130.93	130.93
Plant Size	dry short ton/day			118	295	589	1,178
	dry tonne/day			107	267	534	1,068
Stream Factor	%			95%	95%	95%	95%
Feed	Dry short ton/yr			3.704E+04	9.259E+04	1.852E+05	3.704E+05
	GJ/short ton			3.592E+01	3.592E+01	3.592E+01	3.592E+01
	GJ/yr			1.331E+06	3.326E+06	6.653E+06	1.331E+07
Soy Oil Cost	USD/dt			**$ 480.00**	**$ 480.00**	**$ 480.00**	**$ 480.00**
	USD/gal			$ 1.84	$ 1.84	$ 1.84	$ 1.84
Biodiesel	gal/short ton			270.0	270.0	270.0	270.0
	GJ/yr			1.366E+06	3.416E+06	6.831E+06	1.366E+07
	gal/Stream day			3.181E+04	7.952E+04	1.590E+05	3.181E+05
	bbl/s stream day			7.574E+02	1.893E+03	3.787E+03	7.574E+03
	gal/yr			1.000E+07	2.500E+07	5.000E+07	1.000E+08
	Mil Gal/YR			**10**	**25**	**50**	**100**
Glycerin	ton/day			9.44	23.59	47.18	94.36
	ton/ton feed			0.080	0.080	0.080	0.080
	gal/yr			5.65E+05	1.41E+06	2.82E+06	5.65E+06
Process Efficiency - to biodiesel	% HHV			102.7%	102.7%	102.7%	102.7%
Process efficiency - overall	% HHV						
Capital Cost (million USD)							
Caustic Refining			0.70	3.00	6.75	10.97	17.82
Feed Handling			0.70	0.15	0.29	0.47	0.76
Esterification			0.70	0.42	0.81	1.31	2.13
Separation			0.70	2.12	4.02	6.53	10.62
Biodiesel Post-Treatment			0.70	1.61	3.06	4.96	8.06
Glycerin Purification & MeOH Recovery			0.70	1.00	1.90	3.08	5.01
Storage Facilities			0.70	1.44	2.73	4.43	7.20
Direct Fixed Capital (DFC), also called TIC				9.74	19.55	31.76	51.60
Engineering	DFC x MF	0.12		1.17	2.35	3.81	6.19
Construction	DFC x MF	0.13		1.27	2.54	4.13	6.71
Contractor & Legal	DFC x MF	0.08		0.78	1.56	2.54	4.13
Process/Project Contingency	DFC x MF	0.0412		0.40	0.81	1.31	2.13
Total Plant Cost (TPC)				13.36	26.81	43.55	70.75
AFUDC							
Total Plant Investment (TPI)				13.36	26.81	43.55	70.75
Land			0.60	2.21	3.83	5.80	11.61
Startup							
Total Capital Cost (TCC)				15.57	30.64	49.36	82.36
Contingency/TPI							
Working Capital	DFC x MF	0.05		0.67	1.34	2.18	3.54
Variable Operating Costs (million USD/yr)							
Feed				17.78	44.44	88.89	177.78
Utilities				0.62	1.16	2.32	4.64
Methanol				0.766	1.91	3.83	7.66
Catalysts and Chemicals				1.18	2.94	5.89	11.78
Total				20.34	50.46	100.93	201.85
Fixed Operating Costs (million USD/yr)							
Labor (SF from V-R)	DFC x MF	0.072	0.25	0.71	0.82	0.98	1.17
Maintenance (3% of A)			0.03	0.29	0.59	0.95	1.55
General Overhead (65% of labor + maint)			0.65	0.65	0.92	1.26	1.76
Direct Overhead (45% of Labor)			0.45	0.32	0.37	0.44	0.52
Insurance (0.5% of TIC)			0.005	0.08	0.15	0.25	0.41
Total				2.04	2.85	3.88	5.42



	10 MM GPY	25 MM GPY	50 MM GPY	100 MM GPY
Feed -Glycerin Credit	1.706	1.706	1.706	1.706
Varable Op Cost	0.256	0.241	0.241	0.241
Fixed Op Cost	0.204	0.114	0.078	0.054
Capital Charges	0.241	0.187	0.150	0.111

Figure 27. USA base case biodiesel plant gate prices

Table 94. Argentina biodiesel capital and operating costs

Country	Argentina	Code =	5				
Cost component	Units	Cost Factor	Scale Factor	Argentina Biodiesel	Argentina Biodiesel	Argentina Biodiesel	Argentina Biodiesel
Year $	$			2005	2005	2005	2005
Cost Index (2 = M&S, 3 = CE)			3	130.93	130.93	130.93	130.93
Plant Size	dry short ton/day			118	295	589	1,178
	dry tonne/day			107	267	534	1,068
Stream Factor	%			95%	95%	95%	95%
Feed	Dry short ton/yr			3.704E+04	9.259E+04	1.852E+05	3.704E+05
	GJ/short ton			3.592E+01	3.592E+01	3.592E+01	3.592E+01
	GJ/yr			1.331E+06	3.326E+06	6.653E+06	1.331E+07
Soy Oil Cost	USD/dt			**$ 157.24**	**$ 157.24**	**$ 157.24**	**$ 157.24**
	USD/gal			$ 0.60	$ 0.60	$ 0.60	$ 0.60
Biodiesel	gal/short ton			270.0	270.0	270.0	270.0
	GJ/yr			1.366E+06	3.416E+06	6.831E+06	1.366E+07
	gal/Stream day			3.181E+04	7.952E+04	1.590E+05	3.181E+05
	bbl/s stream day			7.574E+02	1.893E+03	3.787E+03	7.574E+03
	gal/yr			1.000E+07	2.500E+07	5.000E+07	1.000E+08
	Mil Gal/YR			**10**	**25**	**50**	**100**
Glycerin	ton/day			9.44	23.59	47.18	94.36
	ton/ton feed			0.080	0.080	0.080	0.080
	gal/yr			5.65E+05	1.41E+06	2.82E+06	5.65E+06
soy beans	ton/day			6.45E+02	1.60E+03	3.20E+03	6.40E+03
	bu/day			2.16E+04	5.37E+04	1.07E+05	2.14E+05
	bu/yr			6.734E+06	1.683E+07	3.367E+07	6.734E+07
	MM$/yr			12.19	30.47	60.94	121.88
Process Efficiency - to biodiesel	% HHV			102.7%	102.7%	102.7%	102.7%
Process efficiency - overall	% HHV						
Capital Cost (million USD)							
Caustic Refining			0.70	3.23	7.25	11.78	19.14
Feed Handling			0.70	0.16	0.31	0.50	0.81
Esterification			0.70	0.46	0.87	1.41	2.28
Separation			0.70	2.27	4.32	7.02	11.40
Biodiesel Post-Treatment			0.70	1.73	3.28	5.33	8.66
Glycerin Purification & MeOH Recovery			0.70	1.07	2.04	3.31	5.38
Storage Facilities			0.70	1.54	2.93	4.76	7.73
Direct Fixed Capital (DFC), also called TIC				10.46	20.99	34.10	55.40
Engineering	DFC x MF	0.12		1.26	2.52	4.09	6.65
Construction	DFC x MF	0.13		1.36	2.73	4.43	7.20
Contractor & Legal	DFC x MF	0.08		0.84	1.68	2.73	4.43
Process/Project Contingency	DFC x MF	0.0412		0.43	0.86	1.41	2.28
Total Plant Cost (TPC)				14.35	28.79	46.76	75.97
AFUDC							
Total Plant Investment (TPI)				14.35	28.79	46.76	75.97
Land			0.60	2.21	3.83	5.80	11.61
Startup							
Total Capital Cost (TCC)				16.56	32.62	52.57	87.58
Contingency/TPI							
Working Capital	DFC x MF	0.05		0.72	1.44	2.34	3.80
Variable Operating Costs (million USD/yr)							
Feed				5.82	14.56	29.12	58.24
Utilities				0.62	1.16	2.32	4.64
Methanol				0.766	1.91	3.83	7.66
Catalysts and Chemicals				1.18	2.94	5.89	11.78
Total				8.39	20.58	41.15	82.31
Fixed Operating Costs (million USD/yr)							
Labor (SF from V-R)	DFC x MF	0.072	0.25	0.60	0.70	0.83	0.99
Maintenance (3% of A)			0.03	0.31	0.63	1.02	1.66
General Overhead (65% of labor + maint)			0.65	0.59	0.86	1.21	1.72
Direct Overhead (45% of Labor)			0.45	0.27	0.32	0.37	0.45
Insurance (0.5% of TIC)			0.005	0.08	0.16	0.26	0.44
Total				1.86	2.67	3.70	5.26

Table 95. Brazil biodiesel capital and operating costs

Country	Brazil	Code =	2				
Cost component	Units	Cost Factor	Scale Factor	Brazil Biodiesel	Brazil Biodiesel	Brazil Biodiesel	Brazil Biodiesel
Year $	$			2005	2005	2005	2005
Cost Index (2 = M&S, 3 = CE)			3	130.93	130.93	130.93	130.93
Plant Size	dry short ton/day			118	295	589	1,178
	dry tonne/day			107	267	534	1,068
Stream Factor	%			95%	95%	95%	95%
Feed	Dry short ton/yr			3.704E+04	9.259E+04	1.852E+05	3.704E+05
	GJ/short ton			3.592E+01	3.592E+01	3.592E+01	3.592E+01
	GJ/yr			1.331E+06	3.326E+06	6.653E+06	1.331E+07
Soy Oil Cost	USD/dt			**$ 453.47**	**$ 453.47**	**$ 453.47**	**$ 453.47**
	USD/gal			$ 1.74	$ 1.74	$ 1.74	$ 1.74
Biodiesel	gal/short ton			270.0	270.0	270.0	270.0
	GJ/yr			1.366E+06	3.416E+06	6.831E+06	1.366E+07
	gal/Stream day			3.181E+04	7.952E+04	1.590E+05	3.181E+05
	bbl/s stream day			7.574E+02	1.893E+03	3.787E+03	7.574E+03
	gal/yr			1.000E+07	2.500E+07	5.000E+07	1.000E+08
	Mil Gal/YR			**10**	**25**	**50**	**100**
Glycerin	ton/day			9.44	23.59	47.18	94.36
	ton/ton feed			0.080	0.080	0.080	0.080
	gal/yr			5.65E+05	1.41E+06	2.82E+06	5.65E+06
soy beans	ton/day			6.45E+02	1.60E+03	3.20E+03	6.40E+03
	bu/day			2.16E+04	5.37E+04	1.07E+05	2.14E+05
	bu/yr			6.734E+06	1.683E+07	3.367E+07	6.734E+07
	MM$/yr			35.15	87.88	175.75	351.50
Process Efficiency - to biodiesel	% HHV			102.7%	102.7%	102.7%	102.7%
Process efficiency - overall	% HHV						
Capital Cost (million USD)							
Caustic Refining			0.70	3.07	6.90	11.21	18.21
Feed Handling			0.70	0.15	0.29	0.48	0.77
Esterification			0.70	0.43	0.82	1.34	2.17
Separation			0.70	2.16	4.11	6.68	10.85
Biodiesel Post-Treatment			0.70	1.64	3.12	5.07	8.24
Glycerin Purification & MeOH Recovery			0.70	1.02	1.94	3.15	5.12
Storage Facilities			0.70	1.47	2.79	4.53	7.36
Direct Fixed Capital (DFC), also called TIC				9.96	19.98	32.46	52.73
Engineering	DFC x MF	0.12		1.19	2.40	3.89	6.33
Construction	DFC x MF	0.13		1.29	2.60	4.22	6.85
Contractor & Legal	DFC x MF	0.08		0.80	1.60	2.60	4.22
Process/Project Contingency	DFC x MF	0.0412		0.41	0.82	1.34	2.17
Total Plant Cost (TPC)				13.65	27.40	44.50	72.30
AFUDC							
Total Plant Investment (TPI)				13.65	27.40	44.50	72.30
Land			0.60	2.21	3.83	5.80	11.61
Startup							
Total Capital Cost (TCC)				15.86	31.23	50.31	83.91
Contingency/TPI							
Working Capital	DFC x MF	0.05		0.68	1.37	2.23	3.61
Variable Operating Costs (million USD/yr)							
Feed				16.80	41.99	83.98	167.95
Utilities				0.62	1.16	2.32	4.64
Methanol				0.766	1.91	3.83	7.66
Catalysts and Chemicals				1.18	2.94	5.89	11.78
Total				19.36	48.01	96.01	192.02
Fixed Operating Costs (million USD/yr)							
Labor (SF from V-R)	DFC x MF	0.072	0.25	0.30	0.35	0.42	0.50
Maintenance (3% of A)			0.03	0.30	0.60	0.97	1.58
General Overhead (65% of labor + maint)			0.65	0.39	0.62	0.90	1.35
Direct Overhead (45% of Labor)			0.45	0.14	0.16	0.19	0.22
Insurance (0.5% of TIC)			0.005	0.08	0.16	0.25	0.42
Total				1.20	1.88	2.74	4.07

Table 96. China biodiesel capital and operating costs

Country	China	Code =	3				
Cost component	Units	Cost Factor	Scale Factor	China Biodiesel	China Biodiesel	China Biodiesel	China Biodiesel
Year $	$			2005	2005	2005	2005
Cost Index (2 = M&S, 3 = CE)			3	130.93	130.93	130.93	130.93
Plant Size	dry short ton/day			118	295	589	1,178
	dry tonne/day			107	267	534	1,068
Stream Factor	%			95%	95%	95%	95%
Feed	Dry short ton/yr			3.704E+04	9.259E+04	1.852E+05	3.704E+05
	GJ/short ton			3.592E+01	3.592E+01	3.592E+01	3.592E+01
	GJ/yr			1.331E+06	3.326E+06	6.653E+06	1.331E+07
Soy Oil Cost	USD/dt			**$ 829.62**	**$ 829.62**	**$ 829.62**	**$ 829.62**
	USD/gal			$ 3.18	$ 3.18	$ 3.18	$ 3.18
Biodiesel	gal/short ton			270.0	270.0	270.0	270.0
	GJ/yr			1.366E+06	3.416E+06	6.831E+06	1.366E+07
	gal/Stream day			3.181E+04	7.952E+04	1.590E+05	3.181E+05
	bbl/s stream day			7.574E+02	1.893E+03	3.787E+03	7.574E+03
	gal/yr			1.000E+07	2.500E+07	5.000E+07	1.000E+08
	Mil Gal/YR			**10**	**25**	**50**	**100**
Glycerin	ton/day			9.44	23.59	47.18	94.36
	ton/ton feed			0.080	0.080	0.080	0.080
	gal/yr			5.65E+05	1.41E+06	2.82E+06	5.65E+06
soy beans	ton/day			6.45E+02	1.60E+03	3.20E+03	6.40E+03
	bu/day			2.16E+04	5.37E+04	1.07E+05	2.14E+05
	bu/yr			6.734E+06	1.683E+07	3.367E+07	6.734E+07
	MM$/yr			64.31	160.77	321.54	643.08
Process Efficiency - to biodiesel	% HHV			102.7%	102.7%	102.7%	102.7%
Process efficiency - overall	% HHV						
Capital Cost (million USD)							
Caustic Refining			0.70	3.31	7.43	12.07	19.61
Feed Handling			0.70	0.17	0.32	0.51	0.83
Esterification			0.70	0.47	0.89	1.44	2.34
Separation			0.70	2.33	4.43	7.19	11.68
Biodiesel Post-Treatment			0.70	1.77	3.36	5.46	8.87
Glycerin Purification & MeOH Recovery			0.70	1.10	2.09	3.39	5.51
Storage Facilities			0.70	1.58	3.00	4.88	7.92
Direct Fixed Capital (DFC), also called TIC				10.72	21.52	34.95	56.78
Engineering	DFC x MF	0.12		1.29	2.58	4.19	6.81
Construction	DFC x MF	0.13		1.39	2.80	4.54	7.38
Contractor & Legal	DFC x MF	0.08		0.86	1.72	2.80	4.54
Process/Project Contingency	DFC x MF	0.0412		0.44	0.89	1.44	2.34
Total Plant Cost (TPC)				14.70	29.50	47.93	77.85
AFUDC							
Total Plant Investment (TPI)				14.70	29.50	47.93	77.85
Land			0.60	2.21	3.83	5.80	11.61
Startup							
Total Capital Cost (TCC)				16.91	33.33	53.73	89.46
Contingency/TPI							
Working Capital	DFC x MF	0.05		0.74	1.48	2.40	3.89
Variable Operating Costs (million USD/yr)							
Feed				30.73	76.82	153.63	307.27
Utilities				0.62	1.16	2.32	4.64
Methanol				0.766	1.91	3.83	7.66
Catalysts and Chemicals				1.18	2.94	5.89	11.78
Total				33.29	82.83	165.67	331.34
Fixed Operating Costs (million USD/yr)							
Labor (SF from V-R)	DFC x MF	0.072	0.25	0.78	0.92	1.09	1.30
Maintenance (3% of A)			0.03	0.32	0.65	1.05	1.70
General Overhead (65% of labor + maint)			0.65	0.72	1.02	1.39	1.95
Direct Overhead (45% of Labor)			0.45	0.35	0.41	0.49	0.58
Insurance (0.5% of TIC)			0.005	0.08	0.17	0.27	0.45
Total				2.26	3.16	4.29	5.98

Table 97. Colombia biodiesel capital and operating costs

Country	Colombia	Code =	6					
Cost component	Units	Cost Factor	Scale Factor	USA Biodiesel	Colombia Biodiesel	Colombia Biodiesel	Colombia Biodiesel	Colombia Biodiesel
Year $	$			2002	2005	2005	2005	2005
Cost Index (2 = M&S, 3 = CE)			3	110.63	130.93	130.93	130.93	130.93
Plant Size	dry short ton/day			118	118	295	589	1,178
	dry tonne/day			107	107	267	534	1,068
Stream Factor	%			95%	95%	95%	95%	95%
Feed	Dry short ton/yr			3.704E+04	3.704E+04	9.259E+04	1.852E+05	3.704E+05
	GJ/short ton			3.592E+01	3.592E+01	3.592E+01	3.592E+01	3.592E+01
	GJ/yr			1.331E+06	1.331E+06	3.326E+06	6.653E+06	1.331E+07
Soy Oil Cost	USD/dt			**$ 155.50**	**$ 155.50**	**$ 155.50**	**$ 155.50**	**$ 155.50**
	USD/gal			$ 0.60	$ 0.60	$ 0.60	$ 0.60	$ 0.60
Biodiesel	gal/short ton			270.0	270.0	270.0	270.0	270.0
	GJ/yr			1.366E+06	1.366E+06	3.416E+06	6.831E+06	1.366E+07
	gal/Stream day			3.181E+04	3.181E+04	7.952E+04	1.590E+05	3.181E+05
	bbl/s stream day			7.574E+02	7.574E+02	1.893E+03	3.787E+03	7.574E+03
	gal/yr			1.000E+07	1.000E+07	2.500E+07	5.000E+07	1.000E+08
	Mil Gal/YR			**10**	**10**	**25**	**50**	**100**
Glycerin	ton/day			12.61	12.61	31.53	63.06	126.12
	ton/ton feed			0.107	0.107	0.107	0.107	0.107
	gal/yr			7.55E+05	7.55E+05	1.89E+06	3.77E+06	7.55E+06
soy beans	ton/day			6.45E+02	6.45E+02	1.60E+03	3.20E+03	6.40E+03
	bu/day			2.16E+04	2.16E+04	5.37E+04	1.07E+05	2.14E+05
	bu/yr			6.734E+06	6.734E+06	1.683E+07	3.367E+07	6.734E+07
	MM$/yr			12.05	12.05	30.13	60.27	120.53
Process Efficiency - to biodiesel	% HHV			102.7%	102.7%	102.7%	102.7%	102.7%
Process efficiency - overall	% HHV							
Capital Cost (million USD)								
Caustic Refining			0.70	2.539	2.99	6.72	10.91	17.72
Feed Handling			0.70	0.128	0.15	0.29	0.46	0.75
Esterification			0.70	0.359	0.42	0.80	1.30	2.11
Separation			0.70	1.790	2.11	4.00	6.50	10.56
Biodiesel Post-Treatment			0.70	1.359	1.60	3.04	4.94	8.02
Glycerin Purification & MeOH Recovery			0.70	0.844	0.99	1.89	3.07	4.98
Storage Facilities			0.70	1.214	1.43	2.71	4.41	7.16
Direct Fixed Capital (DFC), also called TIC				8.23	9.69	19.44	31.58	51.31
Engineering	DFC x MF	0.12		0.99	1.16	2.33	3.79	6.16
Construction	DFC x MF	0.13		1.07	1.26	2.53	4.11	6.67
Contractor & Legal	DFC x MF	0.08		0.66	0.78	1.56	2.53	4.10
Process/Project Contingency	DFC x MF	0.0412		0.34	0.40	0.80	1.30	2.11
Total Plant Cost (TPC)				11.29	13.29	26.66	43.31	70.35
AFUDC								
Total Plant Investment (TPI)				11.29	13.29	26.66	43.31	70.35
Land			0.60	2.21	2.21	3.83	5.80	11.61
Startup								
Total Capital Cost (TCC)				13.50	15.50	30.49	49.11	81.96
Contingency/TPI								
Working Capital	DFC x MF	0.05		0.56	0.66	1.33	2.17	3.52
Variable Operating Costs (million USD/yr)								
Feed				5.76	5.76	14.40	28.80	57.59
Utilities				0.70	0.83	2.07	4.14	8.28
Methanol				0.87	1.024	2.56	5.12	10.24
Catalysts and Chemicals				1.33	1.57	3.94	7.87	15.74
Total				8.65	9.19	22.96	45.93	91.86
Fixed Operating Costs (million USD/yr)								
Labor (SF from V-R)	DFC x MF	0.072	0.25	0.596	0.45	0.56	0.67	0.80
Maintenance (3% of A)			0.03	0.25	0.29	0.58	0.95	1.54
General Overhead (65% of labor + maint)			0.65	0.55	0.48	0.75	1.05	1.52
Direct Overhead (45% of Labor)			0.45	0.27	0.20	0.25	0.30	0.36
Insurance (0.5% of TIC)			0.005	0.07	0.08	0.15	0.25	0.41
Total				1.73	1.50	2.30	3.22	4.63

Table 98. Summaries biodiesel summary yields, costs, and plant gate costs, 25 MM GPY

Technology	Units	USA	Argentina	Brazil	Canada	Caribbean Basin	China	Colombia	India	Mexico
Plant Size	MM gal/yr	25	25	25			25			
Yields										
Primary Product Yield	gal/ton soy oil	270	270	270			270			
	gal/ton soybeans	50	50	50			50			
	gal/bu soybeans	1.11	1.11	1.11			1.11			
By Product A										
Unit		Glycerin	Glycerin	Glycerin			Glycerin			
Yield unit										
Annual Yield	MM gpy	1.89	1.89	1.89			1.89			
Price unit	USD/gal	1.27	1.27	1.27			1.27			
MM USD/yr		2.4	2.4	2.4			2.4			
By Product B										
Unit		meal	meal	meal			meal			
Yield unit	ton/ton beans	0.7370	0.7370	0.7370			0.7370			
Annual Yield	tons	3.92E+05	3.92E+05	3.92E+05			3.92E+05			
Price unit	USD/ton	171.55	131.42	159.91			292.55			
Annual Cost	MM USD/yr	67.19	51.47	62.63			114.58			
Energy Inputs										
Electricity										
Cost	$/kWh	0.04	0.04	0.04			0.04			
Amount	kWh/yr	2.50E+06	2.50E+06	2.50E+06			2.50E+06			
Annual Cost	MM USD/yr	0.10	0.10	0.10			0.10			
Fuel										
Type		Methanol	Methanol	Methanol			Methanol			
Unit		gal	gal	gal			gal			
Amount	Mmgpy	1.14	1.14	1.14			1.14			
Cost	USD/unit	0.90	0.90	0.90			0.90			
Annual Cost	MM USD/yr	1.024	1.024	1.024			1.024			
Capital & Operating Costs										
Capital	MMUSD	30.64	32.62	31.23			33.33			
Operating w/o feed	MM USD/yr	11.55	11.35	10.5			11.87			
Feed										
Ton Soybean/year	ton/yr	5.31E+05	5.31E+05	5.31E+05			5.31E+05			
Cost soybeans	USD/bu	5.60	4.29	5.22			9.55			
Ton Beans/ton oil		5.427	5.427	5.427			5.427			
$ton oil/$ ton beans		2.345	2.345	2.345			2.345			
Unit	ton oil	9.79E+04	9.79E+04	9.79E+04			9.79E+04			
Cost/unit	USD/lb	0.24	0.184	0.224			0.409			
Rate	unit/day	357	357	357			357			
Beans yearly cost	MM USD/yr	99.20	75.99	92.47			169.17			
Product Plant Gate Cost										
Basis		USTL	10 yr SL	10 yr SL			9 yr SL			
Value	USD/gal	2.23	1.85	2.11			3.56			

Table 99. Summaries biodiesel summary yields, costs, and plant gate costs, 100 MM GPY

Technology	Units	USA	Argentina	Brazil	Canada	Caribbean Basin	China	Colombia	India	Mexico
Plant Size	MM gal/yr	100	100	100			100			
Yields										
Primary Product Yield	gal/ton soy oil	270	270	270			270			
	gal/ton soybeans	50	50	50			50			
	gal/bu soybeans	1.11	1.11	1.11			1.11			
By Product A										
Unit		glycerin	glycerin	glycerin			glycerin			
Yield unit										
Annual Yield	MM gpy	7.55	7.55	7.55			7.55			
Price unit	USD/gal	1.27	1.27	1.27			1.27			
MM USD/yr		9.59	9.59	9.59			9.59			
By Product B										
Unit		meal	meal	meal			meal			
Yield unit	ton/ton beans	0.7370	0.7370	0.7370			0.7370			
Annual Yield	tons	1.57E+06	1.57E+06	1.57E+06			1.57E+06			
Price unit	USD/ton	171.55	131.42	159.91			292.55			
Annual Cost	MM USD/yr	268.77	205.89	250.53			458.34			
Energy Inputs										
Electricity										
Cost	$/kWh	0.04	0.04	0.04			0.04			
Amount	kWh/yr	1.00E+07	1.00E+07	1.00E+07			1.00E+07			
Annual Cost	MM USD/yr	0.40	0.40	0.40			0.40			
Fuel										
Type		Methanol	Methanol	Methanol			Methanol			
Unit		gal	gal	gal			gal			
Amount	MM gpy	4.56	4.56	4.56			4.56			
Cost	USD/unit	0.90	0.90	0.90			0.90			
Annual Cost	MM USD/yr	4.10	4.10	4.10			4.10			
Capital & Operating Costs										
Capital	MMUSD	82.36	87.58	83.91			89.46			
Operating w/o feed	MM USD/yr	39.86	39.68	38.42			40.45			
Feed										
Ton Soybean/year	ton/yr	2.13E+06	2.13E+06	2.13E+06			2.13E+06			
Cost soybeans	USD/bu	5.60	4.29	5.22			9.55			
Ton Beans/ton oil		5.427	5.427	5.427			5.427			
$ton oil/$ ton beans		2.345	2.345	2.345			2.345			
Unit	ton	3.92E+05	3.92E+05	3.92E+05			3.92E+05			
Cost/unit	USD/lb	0.24	0.184	0.224			0.409			
Rate	unit/day	1428	1428	1428			1428			
Beans Yearly Cost	MM USD/yr	396.81	303.98	369.88			676.70			
Product Plant Gate Cost										
Basis		USTL	10 yr SL	10 yr SL			9 yr SL			
Value	USD/gal	2.11	1.72	2.00			3.42			

9 Renewable Diesel

Renewable diesel is produced by hydrotreating oil or grease containing fatty acids, e.g., soy oil, canola oil, palm oil, or yellow grease. There are a number of commercial hydrotreating processes. The process chosen is based on the UOP Unionfining and MQD Unionfining process (Hydrocarbon Processing 2004). In the Uniofining process oxygen is removed (deoxygenation) from the bio-oil by decarboxylation (rejecting oxygen as carbon dioxide) and hydrogenation (removing oxygen as water), producing an ultra-low sulfur diesel product. Figure 28 gives the process flow diagram for the hydrotreater. Feed and a hydrogen-rich gas are contacted with a regenerable hydrotreating catalyst in vessel one (1) at typical hydrotreating conditions, e.g., temperature of 350-400 °C, and 500-2000 psia, then reactor products and unreacted hydrogen are cooled and separated (2). The liquid product is stripped to remove light components and hydrogen sulfide (3), or fractionated to recover multiple liquid products. Table 100 gives a comparison of the material balances for production of renewable diesel and biodiesel (Arena et al. 2006). Table 101 presents a comparison of the properties of renewable diesel and biodiesel (Arena et al. 2006).

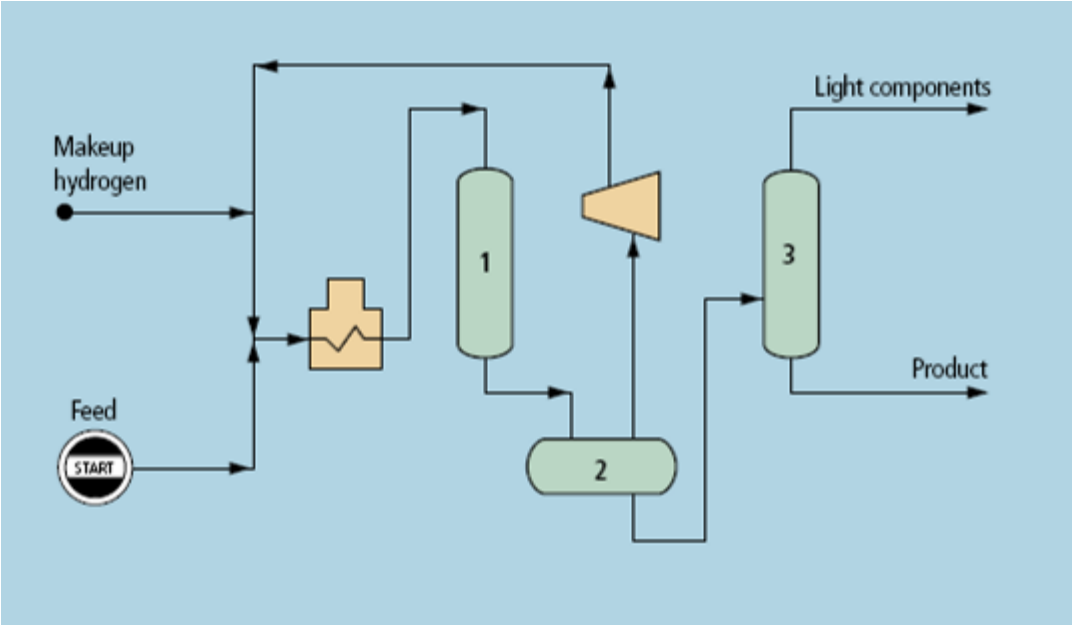


Figure 28. UOP LLC hydrotreating process flow diagram (Hydrocarbon Processing 2004)

Table 102 gives the capital and operating costs for the USA base case. In this analysis hydrogen is assumed to be purchased across the fence, so capital and operating costs associated with hydrogen production are not included. Figure 29 presents the USA case plant gate price breakdown for 0.24 USD/lb soy oil. Table 103 through Table 105give comparable costs for other countries. Table 106 and Table 107 give summary yields and cost information for 25 MM GPY and 100 MM GPY plants.

Table 100. Renewable diesel and biodiesel yields

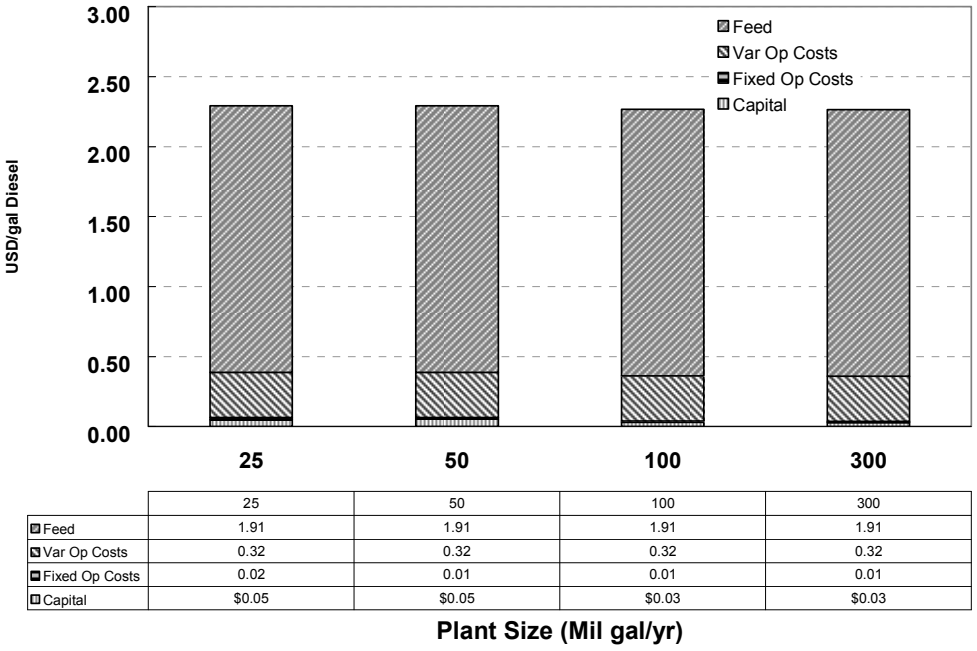
Feed	Biodiesel	Green diesel
% Oil or Grease	100	100
% H2		1.5-3.8
% methanol	8.7	
Products		
% water,C02		12-16
% Lt HC		2-5
% diesel	96	83-86
% glycerol	12	
Operating cost $/gal	.05	.025

Table 101. Renewable diesel and biodiesel properties

	Biodiesel (FAME)	Green diesel
%O	11	0
Density g/ml	.883	.78
Sulfur content	<10ppm	<10ppm
Heating Value (lower) MJ/kg	38	44
% change in NOx emission	+10	0 to -10
Cloud Point C	-5	-5 to -30
Distillation 10-90% pt	340-355	265-320
Cetane	50	80-90

Table 102. USA base case renewable diesel capital and operating costs

Country	USA	Code =	1				
Cost component	Units	Cost Factor	Scale Factor	USA Renewable Diesel	USA Renewable Diesel	USA Renewable Diesel	USA Renewable Diesel
Year $	$			2005	2005	2005	2005
Cost Index (2 = M&S, 3 = CE)			3	130.93	130.93	130.93	130.93
Plant Size	dry short ton/day			282	565	847	1,130
	dry tonne/day			256	512	769	1,025
Stream Factor	%			95%	95%	95%	95%
Feed	Dry short ton/yr			9.792E+04	1.958E+05	2.938E+05	3.917E+05
	GJ/short ton			3.592E+01	3.592E+01	3.592E+01	3.592E+01
	GJ/yr			3.518E+06	7.035E+06	1.055E+07	1.407E+07
Feed Cost - Soy oil	USD/dt			**$ 486.48**	**$ 486.48**	**$ 486.48**	**$ 486.48**
	Bbl/SD			1,753	3,505	5,258	7,010
Renewable Diesel	gal/short ton soybean oil			255.3	255.3	255.3	255.3
	gal/ton soybeans			47.0	47.0	47.0	47.0
Process Efficiency - to diesel	% HHV			92.3%	92.3%	92.3%	92.3%
Process Effciency - with hydrogen							
Diesel	gal/yr			2.500E+07	5.000E+07	7.500E+07	1.000E+08
	Mil Gal/YR			**25.00**	**50.00**	**75.00**	**100.00**
	tpy			8.127E+04	1.625E+05	2.438E+05	3.251E+05
	GJ/yr			3.248E+06	6.495E+06	9.743E+06	1.299E+07
	gal/Stream day			7.210E+04	1.442E+05	2.163E+05	2.884E+05
	bbl/s stream day			1,717	3,433	5,150	6,866
Electricity requirement	kWh/yr			6.077E+05	1.215E+06	1.823E+06	2.431E+06
Capital Cost (million USD)							
Process		0.9	0.70	3.73	6.07	8.06	9.85
			0.80				
TIC from Hydrocarbon Processing	2367	$/BPSD	0.70				
			0.85				
			0.65				
			0.65				
			0.65				
Utiliies - 10% assumed		0.1	0.70	0.41	0.67	0.90	1.09
			0.70				
Direct Fixed Capital (DFC), also called TIC				4.15	6.74	8.95	10.95
Engineering	DFC x MF	0.12		0.50	0.81	1.07	1.31
Construction	DFC x MF	0.13		0.54	0.88	1.16	1.42
Contractor & Legal	DFC x MF	0.08		0.33	0.54	0.72	0.88
Process/Project Contingency	DFC x MF	0.0412		0.17	0.28	0.37	0.45
Total Plant Cost (TPC)				5.69	9.24	12.27	15.01
AFUDC							
Total Plant Investment (TPI)				5.69	9.24	12.27	15.01
Land			0.60	2.21	2.21	2.82	3.76
Startup				0.00	0.00	0.00	0.00
Total Capital Cost (TCC)				7.90	11.45	15.09	18.77
Contingency/TPI							
Working Capital	DFC x MF	0.05		0.28	0.46	0.61	0.75
Variable Operating Costs (million USD/yr)							
Feed				47.64	95.27	142.91	190.54
Utilities (electricity)		0.04		0.02	0.05	0.07	0.097
Other				1.30	2.60	3.90	5.20
Hydrogen				6.75	13.50	20.25	27.00
Total				55.71	111.42	167.13	222.84
Fixed Operating Costs (million USD/yr)							
Labor (SF from V-R)	DFC x MF	0.0165	0.25	0.07	0.08	0.09	0.10
Maintenance (3% of A)			0.03	0.12	0.20	0.27	0.33
General Overhead (65% of labor + maint)			0.65	0.13	0.18	0.23	0.28
Direct Overhead (45% of Labor)			0.45	0.03	0.04	0.04	0.04
Insurance (0.5% of TIC)			0.005	0.04	0.06	0.08	0.09
Total				0.39	0.56	0.71	0.84



	25	50	100	300
Feed	1.91	1.91	1.91	1.91
Var Op Costs	0.32	0.32	0.32	0.32
Fixed Op Costs	0.02	0.01	0.01	0.01
Capital	$0.05	$0.05	$0.03	$0.03

Figure 29. USA plant gate price breakdown, soy oil at $0.24/gal

Table 103. Argentina renewable diesel, capital and operating costs

Country	Argentina	Code =	5				
Cost component	Units	Cost Factor	Scale Factor	Argentina Renewable Diesel	Argentina Renewable Diesel	Argentina Renewable Diesel	Argentina Renewable Diesel
Year $	$			2005	2005	2005	2005
Cost Index (2 = M&S, 3 = CE)			3	130.93	130.93	130.93	130.93
Plant Size	dry short ton/day			282	565	847	1,130
	dry tonne/day			256	512	769	1,025
Stream Factor	%			95%	95%	95%	95%
Feed	Dry short ton/yr			9.792E+04	1.958E+05	2.938E+05	3.917E+05
	GJ/short ton			3.592E+01	3.592E+01	3.592E+01	3.592E+01
	GJ/yr			3.518E+06	7.035E+06	1.055E+07	1.407E+07
Feed Cost - Soy oil	USD/dt			**$ 157.24**	**$ 157.24**	**$ 157.24**	**$ 157.24**
	Bbl/SD			1,753	3,505	5,258	7,010
Renewable Diesel	gal/short ton soybean oil			255.3	255.3	255.3	255.3
	gal/ton soybeans			47.0	47.0	47.0	47.0
Process Efficiency - to diesel	% HHV			92.3%	92.3%	92.3%	92.3%
Process Effciency - with hydrogen							
Diesel	gal/yr			2.500E+07	5.000E+07	7.500E+07	1.000E+08
	Mil Gal/YR			**25.00**	**50.00**	**75.00**	**100.00**
	tpy			8.127E+04	1.625E+05	2.438E+05	3.251E+05
	GJ/yr			3.248E+06	6.495E+06	9.743E+06	1.299E+07
	gal/Stream day			7.210E+04	1.442E+05	2.163E+05	2.884E+05
	bbl/s stream day			1,717	3,433	5,150	6,866
Electricity requirement	kWh/yr			6.077E+05	1.215E+06	1.823E+06	2.431E+06
Capital Cost (million USD)							
Process		0.9	0.70	4.01	6.51	8.65	10.58
			0.80				
TIC from Hydrocarbon Processing	2367	$/BPSD	0.70				
			0.85				
			0.65				
			0.65				
			0.65				
Utiliies - 10% assumed		0.1	0.70	0.45	0.72	0.96	1.18
			0.70				
Direct Fixed Capital (DFC), also called TIC				4.45	7.24	9.61	11.75
Engineering	DFC x MF	0.12		0.53	0.87	1.15	1.41
Construction	DFC x MF	0.13		0.58	0.94	1.25	1.53
Contractor & Legal	DFC x MF	0.08		0.36	0.58	0.77	0.94
Process/Project Contingency	DFC x MF	0.0412		0.18	0.30	0.40	0.48
Total Plant Cost (TPC)				6.11	9.92	13.18	16.12
AFUDC							
Total Plant Investment (TPI)				6.11	9.92	13.18	16.12
Land			0.60	2.21	2.21	2.82	3.76
Startup				0.00	0.00	0.00	0.00
Total Capital Cost (TCC)				8.32	12.13	16.00	19.88
Contingency/TPI							
Working Capital	DFC x MF	0.05		0.31	0.50	0.66	0.81
Variable Operating Costs (million USD/yr)							
Feed				15.40	30.79	46.19	61.59
Utilities (electricity)		0.04		0.02	0.05	0.07	0.097
Other				1.30	2.60	3.90	5.20
Hydrogen				6.75	13.50	20.25	27.00
Total				23.47	46.94	70.41	93.88
Fixed Operating Costs (million USD/yr)							
Labor (SF from V-R)	DFC x MF	0.0165	0.25	0.06	0.07	0.08	0.08
Maintenance (3% of A)			0.03	0.13	0.22	0.29	0.35
General Overhead (65% of labor + maint)			0.65	0.12	0.19	0.24	0.28
Direct Overhead (45% of Labor)			0.45	0.03	0.03	0.03	0.04
Insurance (0.5% of TIC)			0.005	0.04	0.06	0.08	0.10
Total				0.38	0.56	0.72	0.85

Table 104. Brazil renewable diesel capital and operating costs

Country	Brazil	Code =	2				
Cost component	Units	Cost Factor	Scale Factor	Brazil Renewable Diesel	Brazil Renewable Diesel	Brazil Renewable Diesel	Brazil Renewable Diesel
Year $	$			2005	2005	2005	2005
Cost Index (2 = M&S, 3 = CE)			3	130.93	130.93	130.93	130.93
Plant Size	dry short ton/day			282	565	847	1,130
	dry tonne/day			256	512	769	1,025
Stream Factor	%			95%	95%	95%	95%
Feed	Dry short ton/yr			9.792E+04	1.958E+05	2.938E+05	3.917E+05
	GJ/short ton			3.592E+01	3.592E+01	3.592E+01	3.592E+01
	GJ/yr			3.518E+06	7.035E+06	1.055E+07	1.407E+07
Feed Cost - Soy oil	USD/dt			**$ 453.47**	**$ 453.47**	**$ 453.47**	**$ 453.47**
	Bbl/SD			1,753	3,505	5,258	7,010
Renewable Diesel	gal/short ton soybean oil			255.3	255.3	255.3	255.3
	gal/ton soybeans			47.0	47.0	47.0	47.0
Process Efficiency - to diesel	% HHV			92.3%	92.3%	92.3%	92.3%
Process Effciency - with hydrogen							
Diesel	gal/yr			2.500E+07	5.000E+07	7.500E+07	1.000E+08
	Mil Gal/YR			**25.00**	**50.00**	**75.00**	**100.00**
	tpy			8.127E+04	1.625E+05	2.438E+05	3.251E+05
	GJ/yr			3.248E+06	6.495E+06	9.743E+06	1.299E+07
	gal/Stream day			7.210E+04	1.442E+05	2.163E+05	2.884E+05
	bbl/s stream day			1,717	3,433	5,150	6,866
Electricity requirement	kWh/yr			6.077E+05	1.215E+06	1.823E+06	2.431E+06
Capital Cost (million USD)							
Process		0.9	0.70	3.82	6.20	8.23	10.07
			0.80				
TIC from Hydrocarbon Processing	2367	$/BPSD	0.70				
			0.85				
			0.65				
			0.65				
			0.65				
Utiliies - 10% assumed		0.1	0.70	0.42	0.69	0.91	1.12
			0.70				
Direct Fixed Capital (DFC), also called TIC				4.24	6.89	9.15	11.19
Engineering	DFC x MF	0.12		0.51	0.83	1.10	1.34
Construction	DFC x MF	0.13		0.55	0.90	1.19	1.45
Contractor & Legal	DFC x MF	0.08		0.34	0.55	0.73	0.89
Process/Project Contingency	DFC x MF	0.0412		0.17	0.28	0.38	0.46
Total Plant Cost (TPC)				5.81	9.44	12.54	15.34
AFUDC							
Total Plant Investment (TPI)				5.81	9.44	12.54	15.34
Land			0.60	2.21	2.21	2.82	3.76
Startup				0.00	0.00	0.00	0.00
Total Capital Cost (TCC)				8.02	11.65	15.36	19.10
Contingency/TPI							
Working Capital	DFC x MF	0.05		0.29	0.47	0.63	0.77
Variable Operating Costs (million USD/yr)							
Feed				44.40	88.81	133.21	177.61
Utilities (electricity)		0.04		0.02	0.05	0.07	0.097
Other				1.30	2.60	3.90	5.20
Hydrogen				6.75	13.50	20.25	27.00
Total				52.48	104.95	157.43	209.91
Fixed Operating Costs (million USD/yr)							
Labor (SF from V-R)	DFC x MF	0.0165	0.25	0.03	0.03	0.04	0.04
Maintenance (3% of A)			0.03	0.13	0.21	0.27	0.34
General Overhead (65% of labor + maint)			0.65	0.10	0.16	0.20	0.24
Direct Overhead (45% of Labor)			0.45	0.01	0.02	0.02	0.02
Insurance (0.5% of TIC)			0.005	0.04	0.06	0.08	0.10
Total				0.31	0.47	0.61	0.74

Table 105. China renewable diesel capital and operating costs

Country	China	Code =	3				
Cost component	Units	Cost Factor	Scale Factor	China Renewable Diesel	China Renewable Diesel	China Renewable Diesel	China Renewable Diesel
Year $	$			2005	2005	2005	2005
Cost Index (2 = M&S, 3 = CE)			3	130.93	130.93	130.93	130.93
Plant Size	dry short ton/day			282	565	847	1,130
	dry tonne/day			256	512	769	1,025
Stream Factor	%			95%	95%	95%	95%
Feed	Dry short ton/yr			9.792E+04	1.958E+05	2.938E+05	3.917E+05
	GJ/short ton			3.592E+01	3.592E+01	3.592E+01	3.592E+01
	GJ/yr			3.518E+06	7.035E+06	1.055E+07	1.407E+07
Feed Cost - Soy oil	USD/dt			**$ 829.62**	**$ 829.62**	**$ 829.62**	**$ 829.62**
	Bbl/SD			1,753	3,505	5,258	7,010
Renewable Diesel	gal/short ton soybean oil			255.3	255.3	255.3	255.3
	gal/ton soybeans			47.0	47.0	47.0	47.0
Process Efficiency - to diesel	% HHV			92.3%	92.3%	92.3%	92.3%
Process Effciency - with hydrogen							
Diesel	gal/yr			2.500E+07	5.000E+07	7.500E+07	1.000E+08
	Mil Gal/YR			**25.00**	**50.00**	**75.00**	**100.00**
	tpy			8.127E+04	1.625E+05	2.438E+05	3.251E+05
	GJ/yr			3.248E+06	6.495E+06	9.743E+06	1.299E+07
	gal/Stream day			7.210E+04	1.442E+05	2.163E+05	2.884E+05
	bbl/s stream day			1,717	3,433	5,150	6,866
Electricity requirement	kWh/yr			6.077E+05	1.215E+06	1.823E+06	2.431E+06
Capital Cost (million USD)							
Process		0.9	0.70	4.11	6.67	8.86	10.84
			0.80				
TIC from Hydrocarbon Processing	2367	$/BPSD	0.70				
			0.85				
			0.65				
			0.65				
			0.65				
Utiliies - 10% assumed		0.1	0.70	0.46	0.74	0.98	1.20
			0.70				
Direct Fixed Capital (DFC), also called TIC				4.57	7.42	9.85	12.05
Engineering	DFC x MF	0.12		0.55	0.89	1.18	1.45
Construction	DFC x MF	0.13		0.59	0.96	1.28	1.57
Contractor & Legal	DFC x MF	0.08		0.37	0.59	0.79	0.96
Process/Project Contingency	DFC x MF	0.0412		0.19	0.31	0.41	0.50
Total Plant Cost (TPC)				6.26	10.17	13.51	16.52
AFUDC							
Total Plant Investment (TPI)				6.26	10.17	13.51	16.52
Land			0.60	2.21	2.21	2.82	3.76
Startup				0.00	0.00	0.00	0.00
Total Capital Cost (TCC)				8.47	12.38	16.32	20.28
Contingency/TPI							
Working Capital	DFC x MF	0.05		0.31	0.51	0.68	0.83
Variable Operating Costs (million USD/yr)							
Feed				81.24	162.47	243.71	324.94
Utilities (electricity)		0.04		0.02	0.05	0.07	0.097
Other				1.30	2.60	3.90	5.20
Hydrogen				6.75	13.50	20.25	27.00
Total				89.31	178.62	267.93	357.24
Fixed Operating Costs (million USD/yr)							
Labor (SF from V-R)	DFC x MF	0.0165	0.25	0.08	0.09	0.10	0.11
Maintenance (3% of A)			0.03	0.14	0.22	0.30	0.36
General Overhead (65% of labor + maint)			0.65	0.14	0.20	0.26	0.30
Direct Overhead (45% of Labor)			0.45	0.03	0.04	0.05	0.05
Insurance (0.5% of TIC)			0.005	0.04	0.06	0.08	0.10
Total				0.43	0.62	0.78	0.92

Table 106. Renewable diesel summary yields, capital and operating costs, 25 MM GPY

	Units	USA	Argentina	Brazil	Canada	Caribbean Basin	China	Colombia	India	Mexico
Plant Size	MM gal/yr	25	25	25			25			
Yields										
Primary Product Yield	gal/ton soy oil	255.3	255.3	255.3			255.3			
	gal/ton soybeans	47.0	47.0	47.0			47.0			
	gal/bu soybeans	1.4	1.4	1.4			1.4			
By Product A										
Unit		meal	meal	meal			meal			
Yield unit	ton/ton beans	0.7370	0.7370	0.7370			0.7370			
Annual Yield	ton/yr	3.92E+05	3.92E+05	3.92E+05			3.92E+05			
Price unit	USD/ton	171.55	131.42	171.55			171.55			
MM USD/yr		67.19	51.47	67.19			67.19			
By Product B										
Unit										
Yield unit										
Annual Yield										
Price unit										
Annual Cost										
Energy Inputs										
Electricity										
Cost	$/kWh	0.04	0.04	0.04			0.04			
Amount	kWh/yr	2.43E+06	2.43E+06	2.43E+06			2.43E+06			
Annual Cost	MM USD/yr	0.024	0.024	0.024			0.024			
Fuel										
Type		Hydrogen	Hydrogen	Hydrogen			Hydrogen			
Unit		ton/ton feed	ton/ton feed	ton/ton feed			ton/ton feed			
Amount	lb/ton soy oil	76	76	76			76			
Cost	USD/MMBtu	14.92	14.92	14.92			14.92			
Annual Cost	MM USD/yr	6.75	6.75	6.75			6.75			
Capital & Operating Costs										
Capital	MMUSD	7.90	8.32	8.02			8.47			
Operating w/o feed	MM USD/yr	8.46	8.46	8.38			8.50			
Feed										
Amt soybeans/yr	ton/yr	5.31E+05	5.31E+05	5.31E+05			5.31E+05			
Cost soybeans	USD/bu	5.60	4.29	5.60			5.60			
T Beans/t soyoil	ton/ton	5.427	5.427	5.427			5.427			
$ ton oil/$ ton beans	USD/USD	2.345	2.345	2.345			2.345			
Unit	ton soy oil/yr	9.79E+04	9.79E+04	9.79E+04			9.79E+04			
Cost/unit	USD/lb	0.24	0.18	0.24			0.24			
Rate	unit/day	256	256	256			256			
Beans yearly cost	MM USD/yr	99.19	75.99	99.19			99.19			
Product Plant Gate Cost										
Basis		USTL	10 yr SL	10 yr SL			9 yr SL			
Value	USD/gal	2.29	1.85	2.16			3.64			

Table 107. Renewable diesel summary yields, capital and operating costs, 100 MM GPY

	Units	USA	Argentina	Brazil	Canada	Caribbean Basin	China	Colombia	India	Mexico
Plant Size	MM gal/yr	100	100	100			100			
Yields										
Primary Product Yield	gal/ton	255.3	255.3	255.3			255.3			
	gal/ton soybeans	47.0								
	gal/bu soybeans	1.4								
By Product A										
Unit		meal	meal	meal			meal			
Yield unit	ton/ton beans	0.7370	0.7370	0.7370			0.7370			
Annual Yield	tons	1.57E+06	1.57E+06	1.57E+06			1.57E+06			
Price unit	USD/ton	171.55	131.42	159.91			292.55			
MM USD/yr		268.80	205.92	250.56			458.39			
By Product B										
Unit		N/A	N/A	N/A			N/A			
Yield unit										
Annual Yield										
Price unit										
Annual Cost	MM USD/yr									
Energy Inputs										
Electricity										
Cost	$/kWh	0.04	0.04	0.04			0.04			
Amount	kWh/yr	2.43E+06	2.43E+06	2.43E+06			2.43E+06			
Annual Cost	MM USD/yr	0.097	0.097	0.097			0.097			
Fuel										
Type		Hydrogen	Hydrogen	Hydrogen			Hydrogen			
Unit		ton/ton feed	ton/ton feed	ton/ton feed			ton/ton feed			
Amount	lb/ton soy oil	76	76	76			76			
Cost	USD/unit	14.92	14.92	14.92			14.92			
Annual Cost	MM USD/yr	27.00	27.00	27.00			27.00			
Capital & Operating Costs										
Capital	MMUSD	18.77	19.88	19.1			20.28			
Operating w/o feed	MM USD/yr	33.13	33.15	33.03			33.22			
Feed										
Amt soybeans/yr	ton/yr	2.13E+06	2.13E+06	2.13E+06			2.13E+06			
Cost soybeans	USD/bu	5.60	4.29	5.22			9.55			
T Beans/t soyoil	ton/ton	5.427	5.427	5.427			5.427			
$ ton oil/$ ton beans	$/	2.345	2.345	2.345			2.345			
Unit	ton soybean oil/yr	3.92E+05	3.92E+05	3.92E+05			3.92E+05			
Cost/unit	USD/lb	0.24	0.18	0.22			0.40928571			
Rate	ton/day	1025	1025	1025			1025			
Beans yearly cost	MM USD/yr	396.85	304.02	369.92			676.78			
Product Plant Gate Cost										
Basis		USTL	10 yr SL	10 yr SL			9 yr SL			
Value	USD/gal	2.27	1.82	2.14			3.61			

10 Wheat Ethanol

The corn dry mill ethanol model was used to estimate capital costs, operating costs, and plant gate prices for ethanol from a wheat dry mill. The ethanol yield was estimated from Shapouri 2006, and DDG yield (0.37 ton DDG/ton wheat) from OECD 2006. The USA wheat price was taken from the USDA Wheat Yearbook (2007).

Table 108 gives the USA base case capital and operating cost summary. Figure 30 shows the breakdown of plant gate price for the USA as a function of plant size. Tables 109-111 give capital and operating costs for other countries. Table 112 and Table 113 give cost summaries for 25 and 100 MM GPY plants.

Table 108. USA base case wheat ethanol capital and operating costs

Country	USA	Code =	1				
Cost component	Units	Cost Factor	Scale Factor	USA Wheat Ethanol	USA Wheat Ethanol	USA Wheat Ethanol	USA Wheat Ethanol
Year $	$			2005	2005	2005	2005
Cost Index (2 = M&S, 3 = CE)			3	130.93	130.93	130.93	130.93
Plant Size	dry short ton/day			772	1,545	3,091	6,179
	dry tonne/day			700	1,402	2,804	5,606
Stream Factor	%			95%	95%	95%	95%
Feed	Dry short ton/yr			2.676E+05	5.359E+05	1.072E+06	2.143E+06
	GJ/short ton			1.698E+01	1.698E+01	1.698E+01	1.698E+01
	GJ/yr			4.542E+06	9.098E+06	1.820E+07	3.638E+07
Feed Cost	USD/dt			$ 113.33	$ 113.33	$ 113.33	$ 113.33
Yield (gal/Dry US Ton)							
Ethanol	gal/short ton			93.3	93.3	93.3	93.3
DDGs	dry ton/ton			0.37	0.37	0.37	0.37
Process Efficiency - to ethanol	% HHV			48.8%	48.8%	48.8%	48.8%
Process efficiency - overall	% HHV						
Ethanol	gal/yr			2.497E+07	5.002E+07	1.000E+08	2.000E+08
	Mil Gal/YR			**25.0**	**50.0**	**100.0**	**200.0**
	tpy			8.278E+04	1.658E+05	3.316E+05	6.630E+05
	GJ/yr			2.216E+06	4.438E+06	8.875E+06	1.774E+07
	gal/Stream day			7.202E+04	1.442E+05	2.885E+05	5.768E+05
	bbl/s stream day			1.715E+03	3.434E+03	6.869E+03	1.373E+04
DDGs	dry ton/yr			9.900E+04	1.983E+05	3.965E+05	7.928E+05
Wheat Density	lb/bu			60.0	60.0	60.0	60.0
Wheat Density	$/bu			**3.40**	**3.40**	**3.40**	**3.40**
Wheat HHV	Btu/lb			8.05E+03	8.05E+03	8.05E+03	8.05E+03
	MMBtu/ton			1.61E+01	1.61E+01	1.61E+01	1.61E+01
Capital Cost (million USD)							
Feed Handling			0.70	1.95	3.17	5.15	8.36
Saccharification			0.70	1.61	2.63	4.27	6.93
Fermentation			0.70	3.53	5.75	9.34	15.16
Distillation			0.70	3.91	6.37	10.34	16.80
Solid/Syrup Separation			0.70	8.63	14.04	22.80	37.03
Storage/Load out			0.70	1.09	1.77	2.88	4.67
Wastewater Treatment			0.70	0.52	0.85	1.37	2.23
Air compressor			0.70	0.10	0.16	0.26	0.43
Steam Gen & Cooling Water			0.70	1.37	2.23	3.61	5.87
Direct Fixed Capital (DFC), also called TIC				22.72	36.95	60.02	97.48
Engineering	DFC x MF	0.12		2.73	4.43	7.20	11.70
Construction	DFC x MF	0.13		2.95	4.80	7.80	12.67
Contractor & Legal	DFC x MF	0.08		1.82	2.96	4.80	7.80
Process/Project Contingency	DFC x MF	0.0412		0.94	1.52	2.47	4.02
Total Plant Cost (TPC)				31.15	50.66	82.30	133.66
AFUDC							
Total Plant Investment (TPI)				31.15	50.66	82.30	133.66
Land			0.60	2.21	3.35	5.08	10.16
Total Capital Cost (TCC)				33.36	54.01	87.38	143.82
Contingency/TPI							
Working Capital	DFC x MF	0.05		1.56	2.53	4.11	6.68
Variable Operating Costs (million USD/yr)							
Feed				30.32	60.73	121.47	242.84
Nat Gas, GJ/y	8.51E+05	6.33	USD/GJ	5.39	10.79	21.59	43.16
Electricity, kWh/y	2.01E+07	0.05	$/kWh	1.01	2.01	4.03	8.05
Catalysts and Chemicals, Misc				1.79	3.59	7.17	14.34
Total				38.51	77.12	154.25	308.38
Fixed Operating Costs (million USD/yr)							
Labor (SF from V-R)	DFC x MF	0.0255	0.25	0.58	0.69	0.82	0.97
Maintenance (3% of A)			0.03	0.68	1.11	1.80	2.92
General Overhead (65% of labor + maint)			0.65	0.82	1.17	1.70	2.53
Direct Overhead (45% of Labor)			0.45	0.26	0.31	0.37	0.44
Insurance (0.5% of TIC)			0.005	0.17	0.27	0.44	0.72
Total				2.51	3.55	5.13	7.59

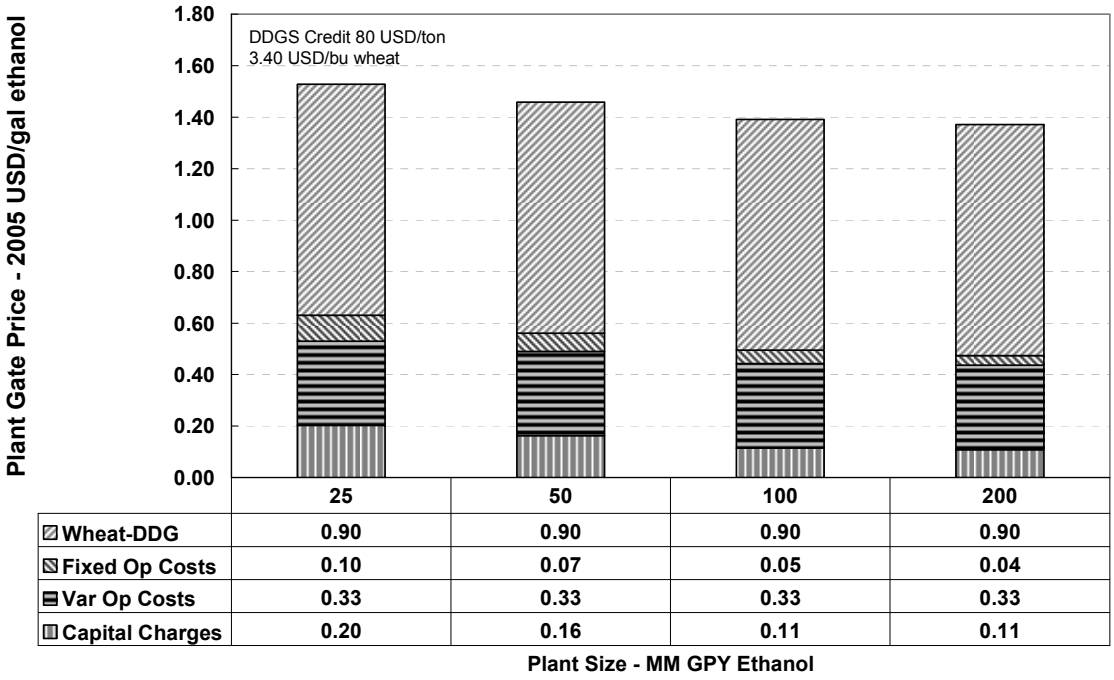


Figure 30. Plant gate price components, USA base case wheat ethanol

Table 109 . Argentina wheat ethanol capital and operating costs

Country	Argentina	Code =	5				
Cost component	**Units**	**Cost Factor**	**Scale Factor**	**Argentina Wheat Ethanol**	**Argentina Wheat Ethanol**	**Argentina Wheat Ethanol**	**Argentina Wheat Ethanol**
Year $	$			2005	2005	2005	2005
Cost Index (2 = M&S, 3 = CE)			3	130.93	130.93	130.93	130.93
Plant Size	dry short ton/day			772	1,545	3,091	6,179
	dry tonne/day			700	1,402	2,804	5,606
Stream Factor	%			95%	95%	95%	95%
Feed	Dry short ton/yr			2.676E+05	5.359E+05	1.072E+06	2.143E+06
	GJ/short ton			1.698E+01	1.698E+01	1.698E+01	1.698E+01
	GJ/yr			4.542E+06	9.098E+06	1.820E+07	3.638E+07
Feed Cost	USD/dt			$ 92.67	$ 92.67	$ 92.67	$ 92.67
Yield (gal/Dry US Ton)							
Ethanol	gal/short ton			93.3	93.3	93.3	93.3
DDGs	dry ton/ton			0.37	0.37	0.37	0.37
Process Efficiency - to ethanol	% HHV			48.8%	48.8%	48.8%	48.8%
Process efficiency - overall	% HHV						
Ethanol	gal/yr			2.496E+07	5.000E+07	9.999E+07	1.999E+08
	Mil Gal/YR			**25.0**	**50.0**	**100.0**	**199.9**
	tpy			8.275E+04	1.657E+05	3.315E+05	6.627E+05
	GJ/yr			2.215E+06	4.436E+06	8.872E+06	1.774E+07
	gal/Stream day			7.199E+04	1.442E+05	2.884E+05	5.765E+05
	bbl/s stream day			1.714E+03	3.433E+03	6.866E+03	1.373E+04
DDGs	dry ton/yr			9.900E+04	1.983E+05	3.965E+05	7.928E+05
Wheat density	lb/bu			60.0	60.0	60.0	60.0
Wheat density	$/bu			**2.78**	**2.78**	**2.78**	**2.78**
Wheat HHV	Btu/lb			8.05E+03	8.05E+03	8.05E+03	8.05E+03
	MMBtu/ton			1.61E+01	1.61E+01	1.61E+01	1.61E+01
Capital Cost (million USD)							
Feed Handling			0.70	2.09	3.40	5.53	8.97
Saccharification			0.70	1.73	2.82	4.58	7.44
Fermentation			0.70	3.80	6.17	10.03	16.28
Distillation			0.70	4.20	6.84	11.10	18.03
Solid/Syrup Separation			0.70	9.27	15.07	24.48	39.77
Storage/Load out			0.70	1.17	1.90	3.09	5.02
Wastewater Treatment			0.70	0.56	0.91	1.48	2.40
Air compressor			0.70	0.11	0.17	0.28	0.46
Steam Gen & Cooling Water			0.70	1.47	2.39	3.88	6.30
Direct Fixed Capital (DFC), also called TIC				24.40	39.67	64.45	104.67
Engineering	DFC x MF	0.12		2.93	4.76	7.73	12.56
Construction	DFC x MF	0.13		3.17	5.16	8.38	13.61
Contractor & Legal	DFC x MF	0.08		1.95	3.17	5.16	8.37
Process/Project Contingency	DFC x MF	0.0412		1.01	1.63	2.66	4.31
Total Plant Cost (TPC)				33.45	54.40	88.37	143.52
AFUDC							
Total Plant Investment (TPI)				33.45	54.40	88.37	143.52
Land			0.60	2.21	3.35	5.08	10.16
Total Capital Cost (TCC)				35.66	57.75	93.45	153.68
Contingency/TPI							
Working Capital	DFC x MF	0.05		1.67	2.72	4.42	7.18
Variable Operating Costs (million USD/yr)							
Feed				24.79	49.66	99.32	198.56
Nat Gas, GJ/y	8.51E+05	6.33	USD/GJ	5.39	10.79	21.59	43.16
Electricity, kWh/y	2.01E+07	0.05	$/kWh	1.01	2.01	4.03	8.05
Catalysts and Chemicals, Misc				1.79	3.59	7.17	14.34
Total				32.98	66.05	132.10	264.10
Fixed Operating Costs (million USD/yr)							
Labor (SF from V-R)	DFC x MF	0.0255	0.25	0.49	0.58	0.70	0.83
Maintenance (3% of A)			0.03	0.73	1.19	1.93	3.14
General Overhead (65% of labor + maint)			0.65	0.80	1.15	1.71	2.58
Direct Overhead (45% of Labor)			0.45	0.22	0.26	0.31	0.37
Insurance (0.5% of TIC)			0.005	0.18	0.29	0.47	0.77
Total				2.42	3.48	5.12	7.69

Table 110. Canada wheat ethanol capital and operating costs

Country	Canada	Code =	7				
Cost component	Units	Cost Factor	Scale Factor	Canada Wheat Ethanol	Canada Wheat Ethanol	Canada Wheat Ethanol	Canada Wheat Ethanol
Year $	$			2005	2005	2005	2005
Cost Index (2 = M&S, 3 = CE)			3	130.93	130.93	130.93	130.93
Plant Size	dry short ton/day			772	1,545	3,091	6,179
	dry tonne/day			700	1,402	2,804	5,606
Stream Factor	%			95%	95%	95%	95%
Feed	Dry short ton/yr			2.676E+05	5.359E+05	1.072E+06	2.143E+06
	GJ/short ton			1.688E+01	1.698E+01	1.698E+01	1.698E+01
	GJ/yr			4.516E+06	9.098E+06	1.820E+07	3.638E+07
Feed Cost	USD/dt			$ 102.00	$ 102.00	$ 102.00	$ 102.00
Yield (gal/Dry US Ton)							
Ethanol	gal/short ton			93.3	93.3	93.3	93.3
DDGs	dry ton/ton			0.37	0.37	0.37	0.37
Process Efficiency - to ethanol	% HHV			49.0%	48.8%	48.8%	48.8%
Process efficiency - overall	% HHV						
Ethanol	gal/yr			2.496E+07	5.000E+07	9.999E+07	1.999E+08
	Mil Gal/YR			**25.0**	**50.0**	**100.0**	**199.9**
	tpy			8.275E+04	1.657E+05	3.315E+05	6.627E+05
	GJ/yr			2.215E+06	4.436E+06	8.872E+06	1.774E+07
	gal/Stream day			7.199E+04	1.442E+05	2.884E+05	5.765E+05
	bbl/s stream day			1.714E+03	3.433E+03	6.866E+03	1.373E+04
DDGs	dry ton/yr			9.900E+04	1.983E+05	3.965E+05	7.928E+05
Wheat density	lb/bu			60.0	60.0	60.0	60.0
Wheat density	$/bu			**3.06**	**3.06**	**3.06**	**3.06**
Wheat HHV	Btu/lb			8.00E+03	8.05E+03	8.05E+03	8.05E+03
	MMBtu/ton			1.60E+01	1.61E+01	1.61E+01	1.61E+01
Capital Cost (million USD)							
Feed Handling			0.70	2.54	4.13	6.70	10.89
Saccharification			0.70	2.10	3.42	5.56	9.03
Fermentation			0.70	4.61	7.49	12.17	19.76
Distillation			0.70	5.10	8.29	13.47	21.88
Solid/Syrup Separation			0.70	11.25	18.29	29.71	48.25
Storage/Load out			0.70	1.42	2.31	3.75	6.09
Wastewater Treatment			0.70	0.68	1.10	1.79	2.91
Air compressor			0.70	0.13	0.21	0.34	0.55
Steam Gen & Cooling Water			0.70	1.78	2.90	4.71	7.65
Direct Fixed Capital (DFC), also called TIC				29.60	48.14	78.20	127.01
Engineering	DFC x MF	0.12		3.55	5.78	9.38	15.24
Construction	DFC x MF	0.13		3.85	6.26	10.17	16.51
Contractor & Legal	DFC x MF	0.08		2.37	3.85	6.26	10.16
Process/Project Contingency	DFC x MF	0.0412		1.22	1.98	3.22	5.23
Total Plant Cost (TPC)				40.59	66.01	107.23	174.15
AFUDC							
Total Plant Investment (TPI)				40.59	66.01	107.23	174.15
Land			0.60	2.21	3.35	5.08	10.16
Total Capital Cost (TCC)				42.80	69.36	112.31	184.31
Contingency/TPI							
Working Capital	DFC x MF	0.05		2.03	3.30	5.36	8.71
Variable Operating Costs (million USD/yr)							
Feed				27.29	54.66	109.32	218.56
Nat Gas, GJ/y	8.51E+05	6.33	USD/GJ	5.39	10.79	21.59	43.16
Electricity, kWh/y	2.01E+07	0.05	$/kWh	1.01	2.01	4.03	8.05
Catalysts and Chemicals, Misc				1.79	3.59	7.17	14.34
Total				35.47	71.05	142.10	284.10
Fixed Operating Costs (million USD/yr)							
Labor (SF from V-R)	DFC x MF	0.0255	0.25	0.97	1.16	1.38	1.64
Maintenance (3% of A)			0.03	0.89	1.44	2.35	3.81
General Overhead (65% of labor + maint)			0.65	1.21	1.69	2.42	3.54
Direct Overhead (45% of Labor)			0.45	0.44	0.52	0.62	0.74
Insurance (0.5% of TIC)			0.005	0.21	0.35	0.56	0.92
Total				3.72	5.16	7.32	10.64

Table 111. China wheat ethanol capital and operating costs

Country	China	Code =	3				
Cost component	Units	Cost Factor	Scale Factor	China Dry Mill Ethanol	China Dry Mill Ethanol	China Dry Mill Ethanol	China Dry Mill Ethanol
Year $	$			2005	2005	2005	2005
Cost Index (2 = M&S, 3 = CE)			3	130.93	130.93	130.93	130.93
Plant Size	dry short ton/day			772	1,545	3,091	6,179
	dry tonne/day			700	1,402	2,804	5,606
Stream Factor	%			95%	95%	95%	95%
Feed	Dry short ton/yr			2.676E+05	5.359E+05	1.072E+06	2.143E+06
	GJ/short ton			1.698E+01	1.698E+01	1.698E+01	1.698E+01
	GJ/yr			4.542E+06	9.098E+06	1.820E+07	3.638E+07
Feed Cost	USD/dt			$ 159.00	$ 159.00	$ 159.00	$ 159.00
Yield (gal/Dry US Ton)							
Ethanol	gal/short ton			93.3	93.3	93.3	93.3
DDGs	dry ton/ton			0.37	0.37	0.37	0.37
Process Efficiency - to ethanol	% HHV			48.8%	48.8%	48.8%	48.8%
Process efficiency - overall	% HHV						
Ethanol	gal/yr			2.496E+07	5.000E+07	9.999E+07	1.999E+08
	Mil Gal/YR			**25.0**	**50.0**	**100.0**	**199.9**
	tpy			8.275E+04	1.657E+05	3.315E+05	6.627E+05
	GJ/yr			2.215E+06	4.436E+06	8.872E+06	1.774E+07
	gal/Stream day			7.199E+04	1.442E+05	2.884E+05	5.765E+05
	bbl/s stream day			1.714E+03	3.433E+03	6.866E+03	1.373E+04
DDGs	dry ton/yr			9.900E+04	1.983E+05	3.965E+05	7.928E+05
Wheat density	lb/bu			60.0	60.0	60.0	60.0
Wheat density	$/bu			**4.77**	**4.77**	**4.77**	**4.77**
Wheat HHV	Btu/lb			8.05E+03	8.05E+03	8.05E+03	8.05E+03
	MMBtu/ton			1.61E+01	1.61E+01	1.61E+01	1.61E+01
Capital Cost (million USD)							
Feed Handling			0.70	2.14	3.49	5.66	9.20
Saccharification			0.70	1.78	2.89	4.69	7.62
Fermentation			0.70	3.89	6.33	10.28	16.69
Distillation			0.70	4.31	7.01	11.38	18.48
Solid/Syrup Separation			0.70	9.50	15.45	25.09	40.75
Storage/Load out			0.70	1.20	1.95	3.17	5.14
Wastewater Treatment			0.70	0.57	0.93	1.51	2.46
Air compressor			0.70	0.11	0.18	0.29	0.47
Steam Gen & Cooling Water			0.70	1.51	2.45	3.98	6.46
Direct Fixed Capital (DFC), also called TIC				25.00	40.66	66.05	107.27
Engineering	DFC x MF	0.12		3.00	4.88	7.93	12.87
Construction	DFC x MF	0.13		3.25	5.29	8.59	13.95
Contractor & Legal	DFC x MF	0.08		2.00	3.25	5.28	8.58
Process/Project Contingency	DFC x MF	0.0412		1.03	1.68	2.72	4.42
Total Plant Cost (TPC)				34.28	55.75	90.57	147.09
AFUDC							
Total Plant Investment (TPI)				34.28	55.75	90.57	147.09
Land			0.60	2.21	3.35	5.08	10.16
Total Capital Cost (TCC)				36.49	59.10	95.65	157.25
Contingency/TPI							
Working Capital	DFC x MF	0.05		1.71	2.79	4.53	7.35
Variable Operating Costs (million USD/yr)							
Feed				42.54	85.20	170.41	340.70
Nat Gas, GJ/y	8.51E+05	6.33	USD/GJ	5.39	10.79	21.59	43.16
Electricity, kWh/y	2.01E+07	0.05	$/kWh	1.01	2.01	4.03	8.05
Catalysts and Chemicals, Misc				1.79	3.59	7.17	14.34
Total				50.73	101.60	203.19	406.24
Fixed Operating Costs (million USD/yr)							
Labor (SF from V-R)	DFC x MF	0.0255	0.25	0.64	0.77	0.91	1.08
Maintenance (3% of A)			0.03	0.75	1.22	1.98	3.22
General Overhead (65% of labor + maint)			0.65	0.91	1.29	1.88	2.80
Direct Overhead (45% of Labor)			0.45	0.29	0.34	0.41	0.49
Insurance (0.5% of TIC)			0.005	0.18	0.30	0.48	0.79
Total				2.77	3.92	5.66	8.37

Table 112. Wheat ethanol summary yields, capital and operating costs, 25 MM GPY

Ethanol-Wheat Dry Mill	Units	USA	Argentina	Brazil	Canada	Caribbean Basin	China	Columbia	India	Mexico
Plant Size	MM gal/yr	25	25		25		25			
Yields										
Primary Product Yield	gal/ton	93.3	93.3		93.3		93.3			
By Product A		DDG	DDG		DDG		DDG			
Unit		ton	ton		ton		ton			
Annual Yield		9.90E+04	9.90E+04		9.90E+04		9.90E+04			
Price unit		80	80		80		80			
MM USD/yr		7.92	7.92		7.92		7.92			
By Product B										
Unit										
Annual Yield										
Price unit										
Annual Cost	MM USD/yr									
Energy Inputs										
Electricity										
Cost	$/kWh	0.05	0.05		0.05		0.05			
Amount	kWh/yr	2.01E+07	2.01E+07		2.01E+07		2.01E+07			
Annual Cost	MM USD/yr	5.39E+00	5.39E+00		5.39E+00		5.39E+00			
Fuel										
Type		Nat Gas	Nat Gas		Nat Gas		Nat Gas			
Unit		GJ	GJ		GJ		GJ			
Amount		8.51E+05	8.51E+05		8.51E+05		8.51E+05			
Cost	USD/unit	6.33	6.33		6.33		6.33			
Annual Cost	MM USD/yr	5.39	5.39		5.39		5.39			
Capital & Operating Costs										
Capital	MMUSD	33.36	35.66		42.80		36.49			
Operating w/o feed	MM USD/yr	10.69	10.6		11.9		10.96			
Feed										
Unit		ton								
Cost/unit	USD/unit	113.33	92.67		102.00		159.00			
	USD/bu	3.40	2.78		3.06		4.77			
Rate	tonne/day	700	700		700		700			
Yearly Cost	MM USD/yr	30.32	24.79		27.29		42.54			
Product Plant Gate Cost										
Basis		USTL	10 SL		10 SL		10 SL			
Value	USD/gal	1.53	1.31		1.49		2.03			

Table 113. Wheat ethanol summary yields, capital and operating costs, 100 MM GPY

Ethanol-Wheat Dry Mill	Units	USA	Argentina	Brazil	Canada	Caribbean Basin	China	Columbia	India	Mexico
Plant Size	MM gal/yr	100	100		100		100			
Yields										
Primary Product Yield	gal/ton	101.8	101.8		101.8		101.8			
By Product A										
Unit		DDG	DDG		DDG		DDG			
Yield unit		ton	ton		ton		ton			
Annual Yield		7.93E+05	7.93E+05		7.93E+05		7.93E+05			
Price unit		80.00	80.00		80.00		80.00			
MM USD/yr		63.42	63.42		63.42		63.42			
By Product B										
Yield unit										
Annual Yield										
Price unit										
Annual Cost	MM USD/yr									
Energy Inputs										
Electricity										
Cost	$/kWh	0.05	0.05		0.05		0.05			
Amount	kWh/yr	8.04E+07	8.04E+07		8.04E+07		8.04E+07			
Annual Cost	MM USD/yr	4.02	4.02		4.02		4.02			
Fuel										
Type		Nat Gas	Nat Gas		Nat Gas		Nat Gas			
Unit		GJ/yr	GJ/yr		GJ/yr		GJ/yr			
Amount		3.40E+06	3.40E+06		3.40E+06		3.40E+06			
Cost	USD/unit	6.33	6.33		6.33		6.33			
Annual Cost	MM USD/yr	21.67	21.67		21.67		21.67			
Capital & Operating Costs										
Capital	MMUSD	87.38	93.45		112.31		85.65			
Operating w/o feed	MM USD/yr	73.13	37.9				38.44			
Feed										
Unit	tonne/day									
Cost/unit	USD/unit	113.33	92.67		102.00		159.00			
	USD/bu	3.40	2.78		3.06		4.77			
Rate	unit/day	2804	2804		2804		2804			
Yearly Cost	MM USD/yr	121.47	99.32		109.32		170.41			
Product Plant Gate Cost										
Basis		USTL	10 SL		10 SL		10 SL			
Value	USD/gal	1.39	1.20		1.31		1.89			

11 Palm Oil Biodiesel

The palm oil biodiesel estimates were made assuming that yields are equal to yields from soybean oil. The soybean spreadsheet was modified to an oil basis instead of a soybean basis. The capital and operating cost estimate for the Caribbean Basin is given in Table 114; and Colombia is given in Table 115. Cost summaries for 25 and 100 MM GPY plants are given in Table 116 and Table 117.

Table 114. Caribbean basin palm oil biodiesel capital and operating costs

Country	Caribbean	Code =	9				
Cost component	**Units**	**Cost Factor**	**Scale Factor**	**Caribbean Palm Oil Biodiesel**	**Caribbean Palm Oil Biodiesel**	**Caribbean Palm Oil Biodiesel**	**Caribbean Palm Oil Biodiesel**
Year $	$			2005	2005	2005	2005
Cost Index (2 = M&S, 3 = CE)			3	130.93	130.93	130.93	130.93
Plant Size	dry short ton/day			118	295	589	1,178
	dry tonne/day			107	267	534	1,068
Stream Factor	%			95%	95%	95%	95%
Feed	Dry short ton/yr			3.704E+04	9.259E+04	1.852E+05	3.704E+05
	GJ/short ton			3.592E+01	3.592E+01	3.592E+01	3.592E+01
	GJ/yr			1.331E+06	3.326E+06	6.653E+06	1.331E+07
Palm Oil Cost	USD/dt			**$ 275.00**	**$ 275.00**	**$ 275.00**	**$ 275.00**
	USD/gal			$ 1.06	$ 1.06	$ 1.06	$ 1.06
Biodiesel	gal/short ton			270.0	270.0	270.0	270.0
	GJ/yr			1.366E+06	3.416E+06	6.831E+06	1.366E+07
	gal/Stream day			3.181E+04	7.952E+04	1.590E+05	3.181E+05
	bbl/s stream day			7.574E+02	1.893E+03	3.787E+03	7.574E+03
	gal/yr			1.000E+07	2.500E+07	5.000E+07	1.000E+08
	Mil Gal/YR			**10**	**25**	**50**	**100**
Glycerin	ton/day			12.61	31.53	63.06	126.12
	ton/ton feed			0.107	0.107	0.107	0.107
	gal/yr			7.55E+05	1.89E+06	3.77E+06	7.55E+06
Process Efficiency - to biodiesel	% HHV			102.7%	102.7%	102.7%	102.7%
Process efficiency - overall	% HHV						
Capital Cost (million USD)							
Caustic Refining			0.70	3.39	7.62	12.38	20.11
Feed Handling			0.70	0.17	0.32	0.53	0.86
Esterification			0.70	0.48	0.91	1.48	2.40
Separation			0.70	2.39	4.54	7.37	11.98
Biodiesel Post-Treatment			0.70	1.82	3.45	5.60	9.10
Glycerin Purification & MeOH Recovery			0.70	1.13	2.14	3.48	5.65
Storage Facilities			0.70	1.62	3.08	5.00	8.12
Direct Fixed Capital (DFC), also called TIC				10.99	22.06	35.84	58.21
Engineering	DFC x MF	0.12		1.32	2.65	4.30	6.99
Construction	DFC x MF	0.13		1.43	2.87	4.66	7.57
Contractor & Legal	DFC x MF	0.08		0.88	1.76	2.87	4.66
Process/Project Contingency	DFC x MF	0.0412		0.45	0.91	1.48	2.40
Total Plant Cost (TPC)				15.07	30.25	49.14	79.82
AFUDC							
Total Plant Investment (TPI)				15.07	30.25	49.14	79.82
Land			0.60	2.21	3.83	5.80	11.61
Startup							
Total Capital Cost (TCC)				17.28	34.08	54.94	91.43
Contingency/TPI							
Working Capital	DFC x MF	0.05		0.75	1.51	2.46	3.99
Variable Operating Costs (million USD/yr)							
Feed				10.19	25.46	50.93	101.85
Utilities				0.83	2.07	4.14	8.28
Methanol				1.024	2.56	5.12	10.24
Catalysts and Chemicals				1.57	3.94	7.87	15.74
Total				13.61	34.03	68.06	136.11
Fixed Operating Costs (million USD/yr)							
Labor (SF from V-R)	DFC x MF	0.072	0.25	0.68	0.85	1.01	1.20
Maintenance (3% of A)			0.03	0.33	0.66	1.08	1.75
General Overhead (65% of labor + maint)			0.65	0.65	0.98	1.36	1.92
Direct Overhead (45% of Labor)			0.45	0.30	0.38	0.46	0.54
Insurance (0.5% of TIC)			0.005	0.09	0.17	0.27	0.46
Total				2.05	3.05	4.18	5.87

Table 115. Colombia palm oil biodiesel capital and operating costs

Country	Colombia	Code =	6				
Cost component	**Units**	**Cost Factor**	**Scale Factor**	**Colombia Palm Oil Biodiesel**	**Colombia Palm Oil Biodiesel**	**Colombia Palm Oil Biodiesel**	**Colombia Palm Oil Biodiesel**
Year $	$			2005	2005	2005	2005
Cost Index (2 = M&S, 3 = CE)			3	130.93	130.93	130.93	130.93
Plant Size	dry short ton/day			118	295	589	1,178
	dry tonne/day			107	267	534	1,068
Stream Factor	%			95%	95%	95%	95%
Feed	Dry short ton/yr			3.704E+04	9.259E+04	1.852E+05	3.704E+05
	GJ/short ton			3.592E+01	3.592E+01	3.592E+01	3.592E+01
	GJ/yr			1.331E+06	3.326E+06	6.653E+06	1.331E+07
Palm Oil Cost	USD/dt			**$ 406.00**	**$ 406.00**	**$ 406.00**	**$ 406.00**
	USD/gal			$ 1.56	$ 1.56	$ 1.56	$ 1.56
Biodiesel	gal/short ton			270.0	270.0	270.0	270.0
	GJ/yr			1.366E+06	3.416E+06	6.831E+06	1.366E+07
	gal/Stream day			3.181E+04	7.952E+04	1.590E+05	3.181E+05
	bbl/s stream day			7.574E+02	1.893E+03	3.787E+03	7.574E+03
	gal/yr			1.000E+07	2.500E+07	5.000E+07	1.000E+08
	Mil Gal/YR			**10**	**25**	**50**	**100**
Glycerin	ton/day			12.61	31.53	63.06	126.12
	ton/ton feed			0.107	0.107	0.107	0.107
	gal/yr			7.55E+05	1.89E+06	3.77E+06	7.55E+06
Process Efficiency - to biodiesel	% HHV			102.7%	102.7%	102.7%	102.7%
Process efficiency - overall	% HHV						
Capital Cost (million USD)							
Caustic Refining			0.70	2.99	6.72	10.91	17.72
Feed Handling			0.70	0.15	0.29	0.46	0.75
Esterification			0.70	0.42	0.80	1.30	2.11
Separation			0.70	2.11	4.00	6.50	10.56
Biodiesel Post-Treatment			0.70	1.60	3.04	4.94	8.02
Glycerin Purification & MeOH Recovery			0.70	0.99	1.89	3.07	4.98
Storage Facilities			0.70	1.43	2.71	4.41	7.16
Direct Fixed Capital (DFC), also called TIC				9.69	19.44	31.58	51.31
Engineering	DFC x MF	0.12		1.16	2.33	3.79	6.16
Construction	DFC x MF	0.13		1.26	2.53	4.11	6.67
Contractor & Legal	DFC x MF	0.08		0.78	1.56	2.53	4.10
Process/Project Contingency	DFC x MF	0.0412		0.40	0.80	1.30	2.11
Total Plant Cost (TPC)				13.29	26.66	43.31	70.35
AFUDC							
Total Plant Investment (TPI)				13.29	26.66	43.31	70.35
Land			0.60	2.21	3.83	5.80	11.61
Startup							
Total Capital Cost (TCC)				15.50	30.49	49.11	81.96
Contingency/TPI							
Working Capital	DFC x MF	0.05		0.66	1.33	2.17	3.52
Variable Operating Costs (million USD/yr)							
Feed				15.04	37.59	75.19	150.37
Utilities				0.83	2.07	4.14	8.28
Methanol				1.024	2.56	5.12	10.24
Catalysts and Chemicals				1.57	3.94	7.87	15.74
Total				18.46	46.16	92.32	184.63
Fixed Operating Costs (million USD/yr)							
Labor (SF from V-R)	DFC x MF	0.072	0.25	0.45	0.56	0.67	0.80
Maintenance (3% of A)			0.03	0.29	0.58	0.95	1.54
General Overhead (65% of labor + maint)			0.65	0.48	0.75	1.05	1.52
Direct Overhead (45% of Labor)			0.45	0.20	0.25	0.30	0.36
Insurance (0.5% of TIC)			0.005	0.08	0.15	0.25	0.41
Total				1.50	2.30	3.22	4.63

Table 116. Palm oil biodiesel summary yields, capital and operating costs, 25 MM GPY

	Units	USA	Argentina	Brazil	Canada	Caribbean Basin	China	Colombia	India	Mexico
Plant Size	MM gal/yr					25		25		
Yields										
Primary Product Yield	gal/ton palm oil					270		270		
By Product A						glycerin		glycerin		
Unit										
Yield unit										
Annual Yield	MM gpy					0.755		0.755		
Price unit	USD/gal					1.27		1.27		
MM USD/yr						2.4		2.4		
By Product B										
Unit										
Yield unit										
Annual Yield										
Price unit										
Annual Cost										
Energy Inputs										
Electricity										
Cost	$/kWh					0.04		0.04		
Amount	kWh/yr					2.50E+06		2.50E+06		
Annual Cost	MM USD/yr					0.10		0.10		
Fuel										
Type						Methanol		Methanol		
Unit						gal		gal		
Amount	Mmgpy					1.14		1.14		
Cost	USD/unit					0.90		0.90		
Annual Cost	MM USD/yr					1.024		1.024		
Capital & Operating Costs										
Capital	MMUSD					34.08		30.49		
Operating w/o feed	MM USD/yr					11.62		10.87		
Feed										
	USD/ton					275.00		4.06E+02		
	ton/yr					92590		92590		
	MM USD/yr					25.46		37.59		
Product Plant Gate Cost										
Basis						10% SL		10% SL		
Value	USD/gal					1.58		2.02		

Table 117. Palm oil biodiesel summary yields, capital and operating costs, 100 MM GPY

	Units	USA	Argentina	Brazil	Canada	Caribbean Basin	China	Colombia	India	Mexico
Plant Size	MM gal/yr					100		100		
Yields										
Primary Product Yield	gal/ton soy oil					270		270		
By Product A						glycerin		glycerin		
Unit										
Yield unit						7.55		7.55		
Annual Yield	MM gpy					1.27		1.27		
Price unit	USD/gal					9.59		9.59		
MM USD/yr										
By Product B										
Unit										
Yield unit	ton/ton beans									
Annual Yield	tons									
Price unit	USD/ton									
Annual Cost	MM USD/yr									
Energy Inputs										
Electricity										
Cost	$/kWh					0.04		0.04		
Amount	kWh/yr					1.00E+07		1.00E+07		
Annual Cost	MM USD/yr					0.40		0.40		
Fuel										
Type						Methanol		Methanol		
Unit						gal		gal		
Amount	MM gpy					4.56		4.56		
Cost	USD/unit					0.90		0.90		
Annual Cost	MM USD/yr					4.10		4.10		
Capital & Operating Costs										
Capital	MMUSD									
Operating w/o feed	MM USD/yr					91.43		81.96		
Feed						40.13		38.89		
Feed										
	USD/ton									
	ton/yr					275		406		
	MM USD/yr					3.70E+05		3.70E+05		
						101.85		150.37		
Product Plant Gate Cost										
Basis						10% SL		10% SL		
Value	USD/gal					1.44		1.91		

12 Summary Comparisons

Figure 31 and Figure 32 present comparisons of the plant gate price of ethanol from three biomass sources–sugar cane, corn, and bagasse. For sugar cane, Figure 31, plant gate prices are primarily impacted by feedstock costs; the fraction of PGP representing feedstock ranges from 61% in the Caribbean to 78% in Mexico. There are small variations in capital and non-feedstock operating costs between countries. Comparable trends are seen for ethanol from corn dry mills, Figure 32. Again, capital and non-feedstock PGP contribution variations are small between countries. Feedstock has the largest contribution to PGP, and shows the most variation between countries. Feedstock cost percentages range from 46% in Canada to 66% in Brazil.

Figure 33 shows a comparison for cellulosic ethanol from bagasse. The USA PGP assumes a high cost for bagasse, $35/ton, which is a value equal to that assumed in modeling for woody feedstocks. At this time there is no USA supply curve for bagasse. For the USA case feedstock represents 35% and capital 40%. For other countries, the bagasse cost estimates were estimated from the ORNL report, and represent between 11% (Caribbean Basin), and 23% (Colombia).

Figure 34 shows a comparison of biodiesel PGPs for both biodiesel from soybeans and from palm oil. PGPs are primarily a function of feedstock cost.

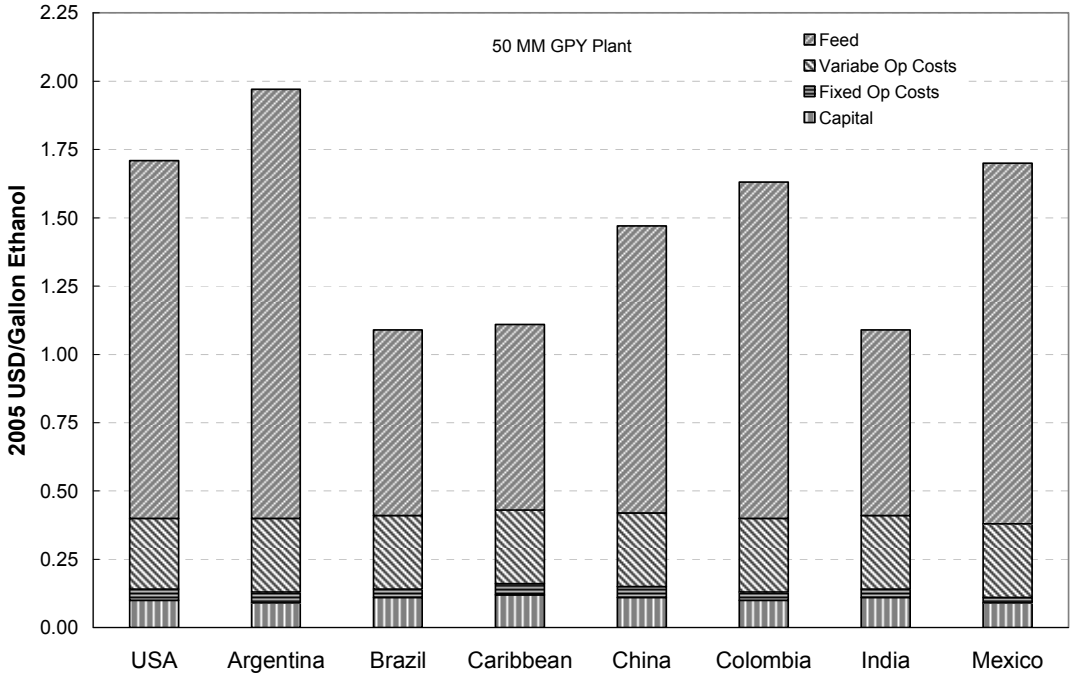


Figure 31. Comparison of sugar cane ethanol plant gate price

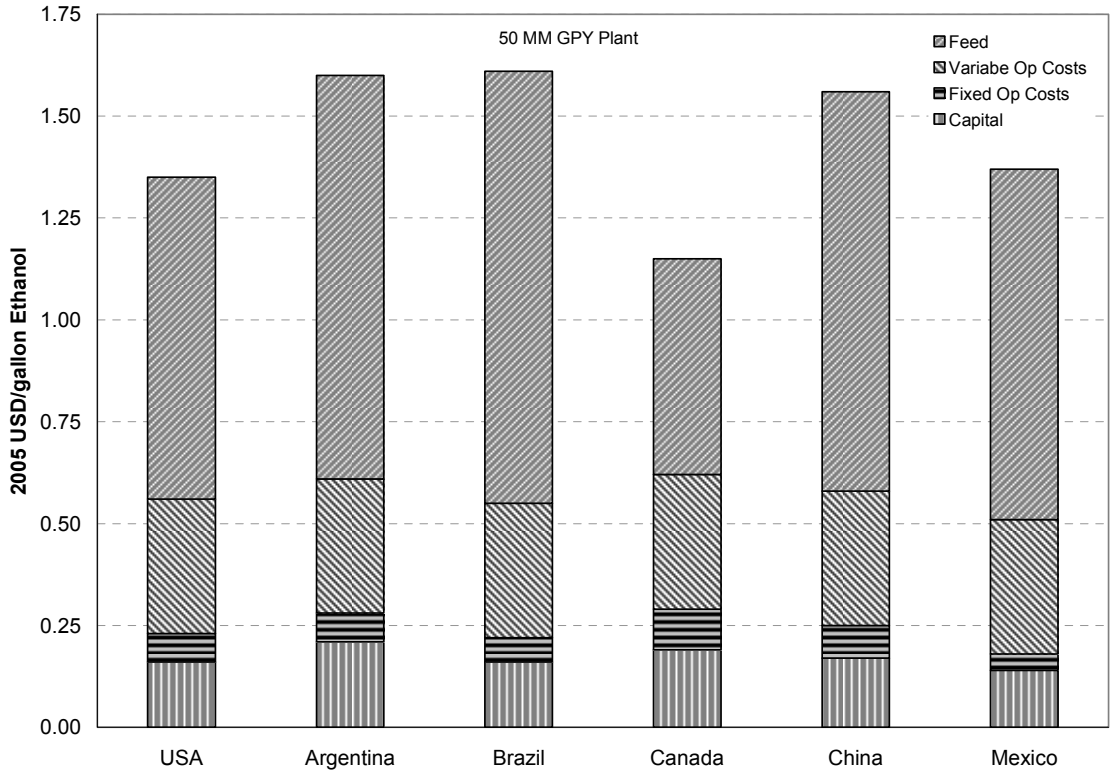


Figure 32. Comparison of corn dry mill ethanol plant gate prices

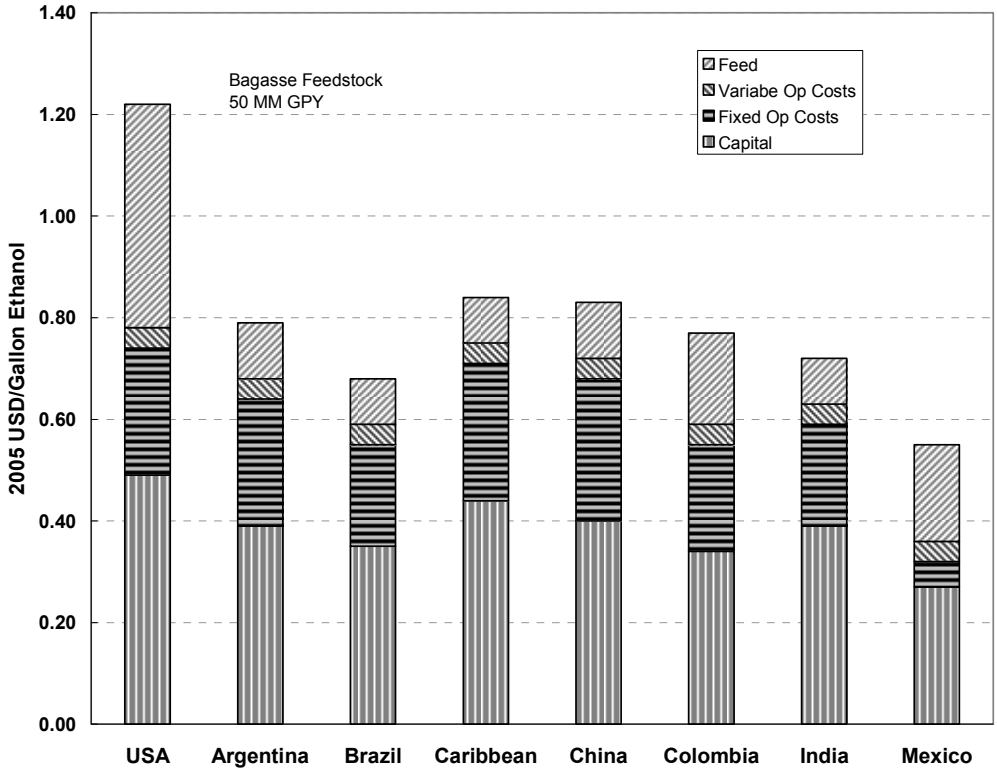


Figure 33. Comparison of cellulosic ethanol (TC) plant gate prices

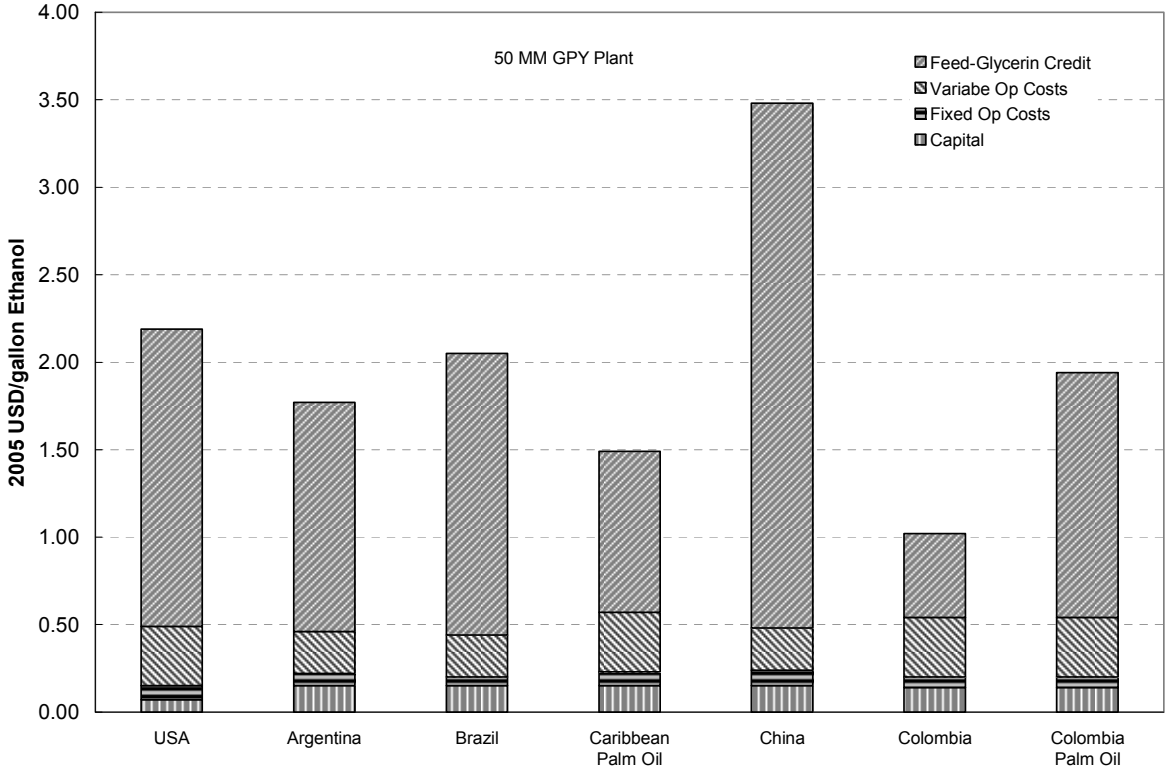


Figure 34. Comparison of biodiesel plant gate prices

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