ECONOMICS AND LIFE-CYCLE ANALYSIS OF LIGNOCELLULOSIC BIOFUEL PRODUCTION FROM ENERGY CANE

TEXAS A&M AGRILIFE EXTENSION

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Integrated Bioenergy Supply Chain System

Energy cane's desirable characteristics

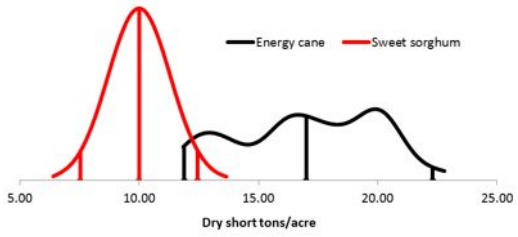
- High yield potential:
  - Sugar cane – 10 dry tons/acre
  - Energy cane – 17 dry tons/acre
- Potential low input requirement
- Wide geographic adaptability
- Non-competitive with food, feed or fiber crops
- Compared to sugar cane:
  - Lower concentrations of soluble sugars
  - Higher levels of fiber content

Feedstock production

- Two feedstock types for constant supply
  - Energy cane from October to April (possibly May)
  - Sorghum or napier grasses from June to September
- Production costs from extension budgets
  - Energy cane from District 12 in Texas
  - Sweet sorghum from Mississippi State Univ. study
- Grower's return over production costs
  - Depending on the region's returns from competing crops
- Harvest and hauling costs:
  - Energy cane from RGVSG, Inc.
  - Sweet sorghum from Texas A&M Univ. study

Yield risk component

- Feedstock yields
  - Energy cane – experimental plots historical data
    - Univariate empirical distribution
  - Sweet sorghum – no historical data
    - GRKS distribution: minimum, middle, maximum



Parameters for feedstock

Parameters	Units	Energy cane	Sweet sorghum
Expected yield	Dry short tons/acre	17	10
Production cost	$/acre	613	182
Production cost	$/dry short ton	36	18
Return to growers	Percent	20%	20%
Fixed harvest & haul cost	$/acre	92	0
Variable harvest & haul cost	$/dry short ton	10	29
Area harvested			
Hydrolysis	Acres	35,541	26,143
Gasification	Acres	27,879	20,507
Total production			
Hydrolysis	Dry short tons/year	610,000	261,429
Gasification	Dry short tons/year	478,490	205,067
Expected feedstock cost	$/dry short ton	58	51

Contractual agreements

- Farmers know the risk in current crops
  - Available regional information on historical yields and prices
  - Knowledge of regional weather patterns
- Farmers do not know the risk in feedstock
  - New varieties of common crops
  - No historical data on prices or a market price
- The plant has to offer a contract that provides:
  - Floor and floating price indexed with competing crops
  - Incentives for higher yields and quality of feedstock
  - Crop Insurance?

Biofuel conversion plant

- Limited information on economic feasibility of commercial size conversion facilities
- National Renewable Energy Laboratory (NREL) provides a vast literature on operating and capital expenses for different conversion technologies
- Conversion technologies:
  - Enzymatic hydrolysis – Humbird et al. (2011)
  - Gasification with FT synthesis – Swanson et al. (2010)

Plant parameters

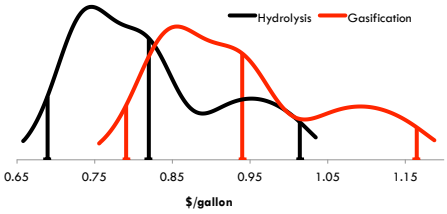
- Annual plant capacity (gallons or million BTUs)
- Average biofuel yield from feedstock
- By-product credits (yields and prices)
  - Excess electricity
- Fixed capital investment sources:
  - Equity generates dividends
  - Loan at a specified interest rate and period
- Stochastic ethanol and by-product prices

Parameters for conversion plant

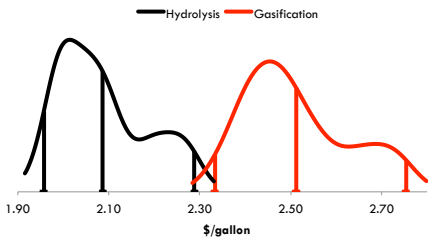
Parameters	Units	Hydrolysis	Gasification
Biofuel produced		Ethanol	Gasoline
By-products		Electricity	Electricity
Annual production	Gallons/year (MMBtu/year)	61 million (4.6 m)	42 million (4.8 m)
Biofuel yield	Gallons/dry ton (MMBtu/dt)	70 (5)	61 (7)
Annual feedstock demand	Dry short tons/year	871,429	683,607
Share of energy cane	Percent	70%	70%
Share of sweet sorghum	Percent	30%	30%
On-stream factor	Percent	96%	85%
Plant life	Years	30	20
Total Capital Investment (TCI)	$	455 million	605 million
Under loan (% of TCI)	$	273 million (60%)	363 million (60%)
Interest rate	Percent	8%	8%
Total cash costs	$/gallon ($/MMBtu)	2.14 (28.19)	2.61 (23.11)

Probability distribution of costs

Feedstock cost

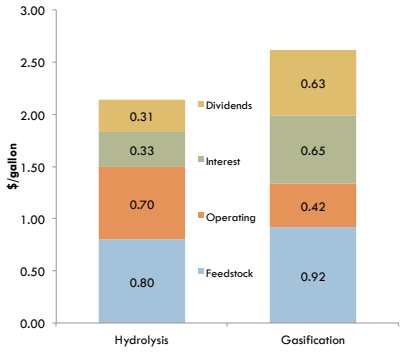


Total cash cost with by-product credit

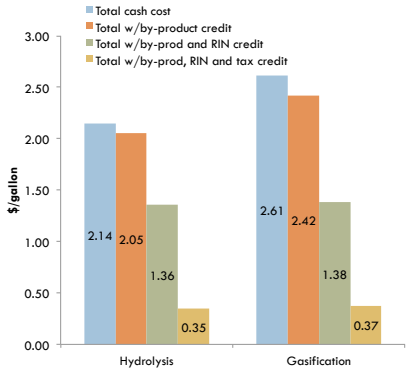


Expected cash cost overview

Expected cash cost distribution



Expected cash cost with different credits



Returns to growers and costs

Percent over production costs	20%	30%	40%	50%
Feedstock cost ($/dry short ton)	**56.34**	**59.38**	**62.43**	**65.48**
Production cost with return ($/dry short ton)	36.55	39.60	42.64	45.69
Variable harvest and hauling cost ($/dry short ton)	16.03	16.03	16.03	16.03
Fixed harvest and hauling cost ($/dry short ton)	3.76	3.76	3.76	3.76
Feedstock cost for hydrolysis($/gal)	**0.80**	**0.84**	**0.88**	**0.93**
Total cost with by-product credit for hydrolysis ($/gal)	**2.05**	**2.09**	**2.14**	**2.18**

Sensitivity analysis

Economic success → Prob(NPV > 0) > 95%

Hydrolysis AEO 2013 – reference

Energy cane yield (dry short ton/acre)

Ethanol yield (gallon/dry ton)	10	15	17	19	20
40	0%	0%	2%	4%	6%
50	1%	13%	24%	41%	49%
60	9%	50%	66%	80%	86%
70	32%	78%	**91%**	96%	97%
75	42%	86%	95%	98%	99%
80	53%	93%	97%	99%	99%
90	67%	97%	100%	100%	100%

Gasification AEO 2012 – high oil price

Energy cane yield (dry short ton/acre)

Ethanol yield (gallon/dry ton)	10	17	30	40
30	0%	1%	7%	14%
40	1%	7%	30%	44%
50	5%	20%	52%	64%
61	12%	**42%**	69%	80%
70	21%	54%	81%	89%
80	32%	67%	88%	91%
90	42%	74%	91%	94%
100	51%	83%	93%	95%
110	60%	87%	95%	97%

Thank you

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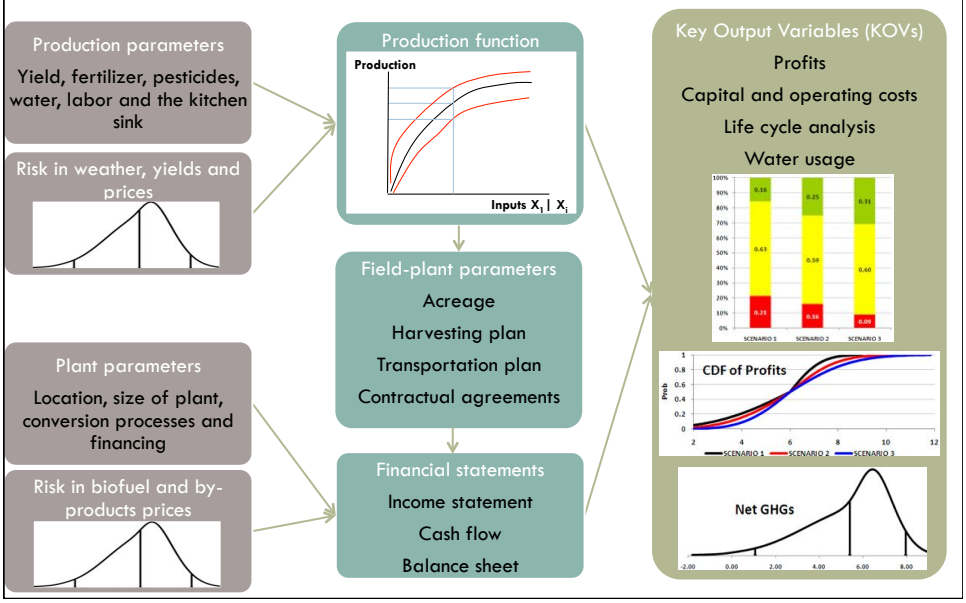
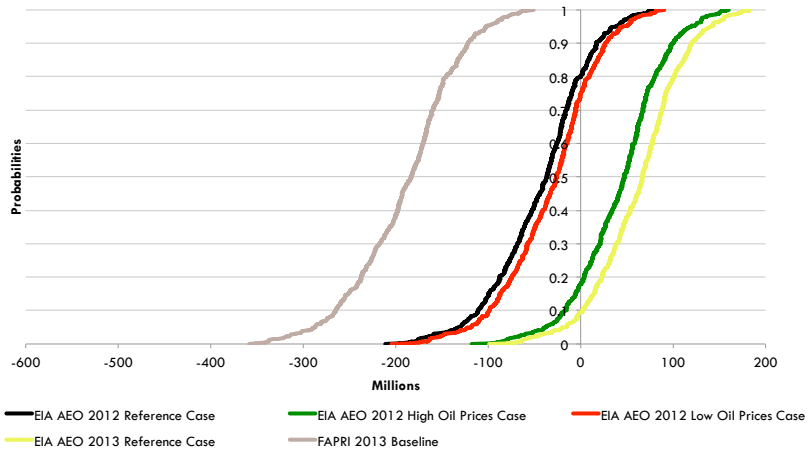
BIOSIM model



Net present value of hydrolysis



Net present value of gasification