Ethanol Production Potential and Costs from Lignocellulosic Resources in California

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Abstract

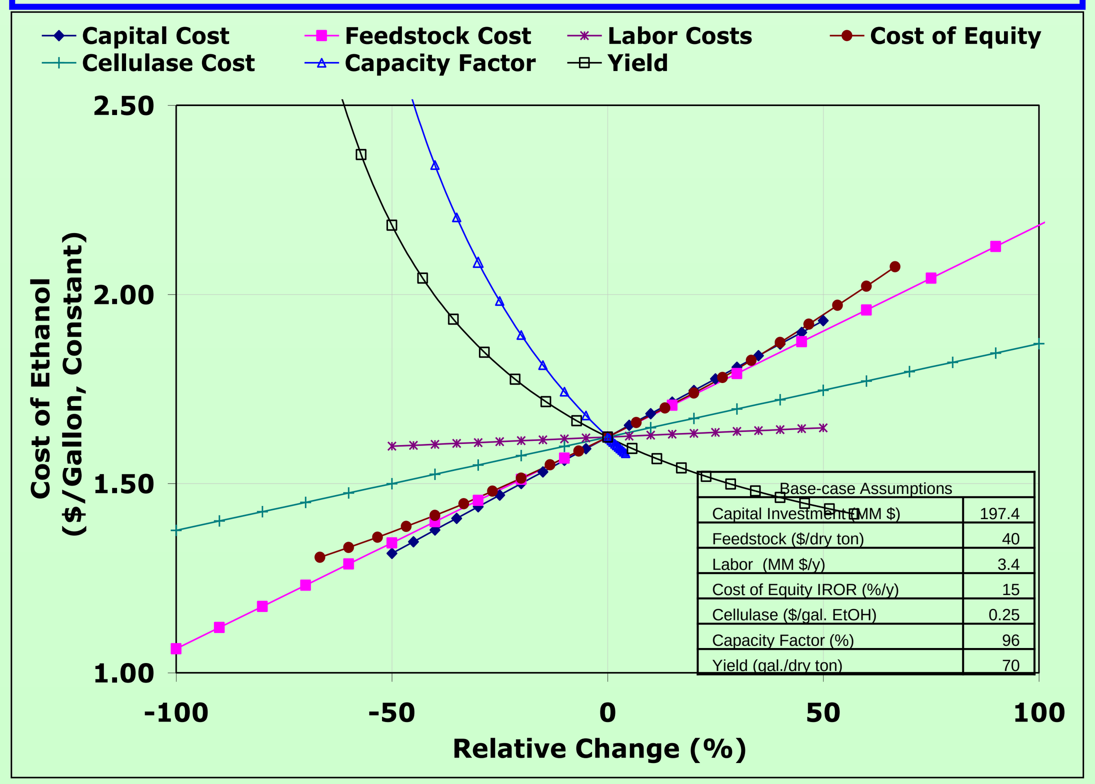
Recent California legislation and policy is likely to have substantial impact on the production and use of biofuels in the state. These new policies include standards for greenhouse gas (GHG) vehicle emissions and carbon content in the fuel, statewide reduction of GHG to 1990 levels by 2020 and goals for in-state biofuels production. The in-state biofuels production goals are: by 2010, 20% of state's biofuel consumption should be produced in-state, increasing to 40% by 2020, and 75% by 2050. Though none of these current laws and policies establish alternative fuel or biofuel usage requirements (such as a renewable fuel standard or RFS), they are likely to increase the use of biofuels in the state. California reformulated gasoline currently contains 5.7% ethanol which represents a 3.4 Gl y-1 market. Current in-state fuel ethanol production capacity is approximately 265 Ml y-1 from imported corn grain, surplus beverage sugars, and cheese whey. Although grain and sugar crops constitute a large share of California's agricultural production, they are not currently used for in-state fuel ethanol production. Various plans exist for increasing starch and sugar production, including the introduction of sugar cane into the southern interior valleys of the state, but lignocellulosic feedstocks are much more abundant in the state and likely to remain the dominant biomass available for biofuel production. Furthermore, ethanol derived from these resources should realize lower lifecycle greenhouse gas (GHG) emissions compared with ethanol from grain. Based on resource assessments conducted for the state, lignocellulosic ethanol production potential from California was estimated at about 6.9 Gl y-1 from 23 Tg y-1 of agricultural residues, forest thinnings, and woody and paper material in the municipal solid waste (MSW) landfill stream and another 2.3 – 5.1 Gl y-1 could be produced from 600,000 ha of energy crops. A California lignocellulosic ethanol facility could produce ethanol for about $0.44 per liter assuming delivered feedstock cost of $44 Mg-1 (dry basis), 292 liter Mg-1 yield, enzyme costs of $0.066 l-1 ethanol, and plant capital cost of $0.76 per liter-annual-capacity.

Cost projections for a Lignocellulosic Ethanol facility in California

Costs used in revenue requirement calculation

	(US$/litre)	(US M$/year)
Feedstock Cost ($44 Mg-1 (dry))	0.151	39.6
Cellulase	0.067	17.5
Labor (includes Administration)	0.013	3.4
Maintenance	0.009	2.3
Insurance/Property Tax	0.007	1.8
Other Operating Exp.	0.030	7.8
Total non Fuel Expenses	0.125	32.8
Total Operating Expenses	**0.276**	**72.4**
Equity Recovery	0.140	36.8
Taxes	0.048	12.5
Electricity Revenue	-0.032	-8.3
Revenue Requirement	0.433	113.3

Cost Sensitivity Analysis



Using cost factors derived from studies by the National Renewable Energy Laboratory, ethanol production cost from a 265 Ml y^{-1} facility using co-current dilute acid prehydrolysis and enzymatic hydrolysis of lignocellulosic feedstocks in California is estimated to be $0.43 l^{-1} in the near to midterm (3- 8 years) if the technology is sufficiently commercialized.

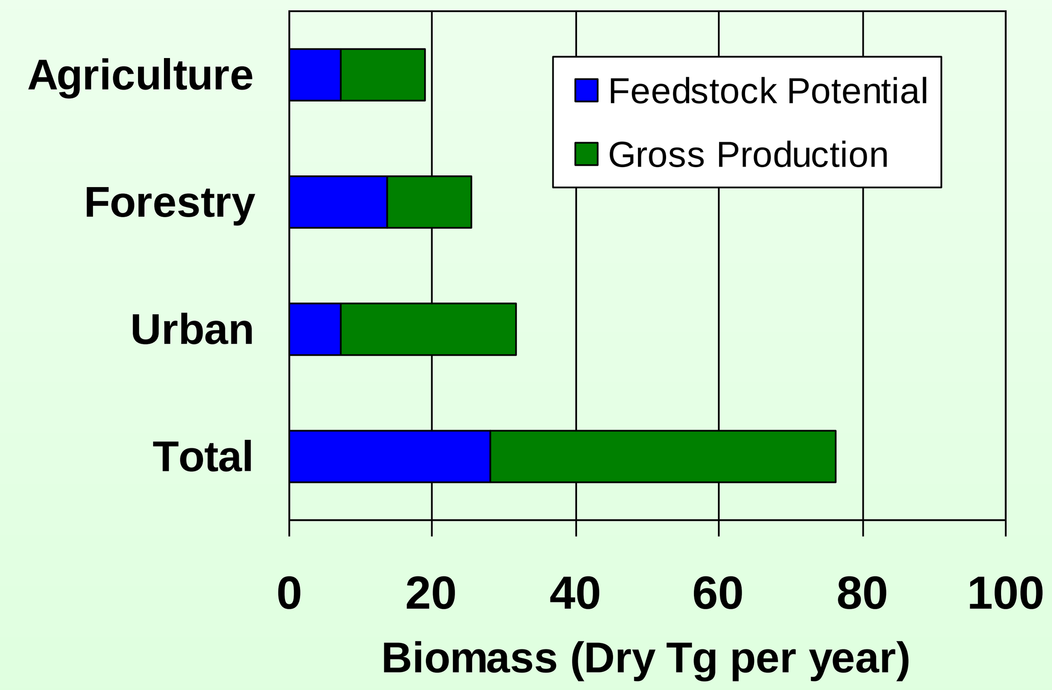
Delivered feedstock cost for this analysis was assumed to be $44 Mg^{-1} (dry) ton and cellulase enzyme cost to be $0.066 l^{-1} ethanol. Capital cost is $200 million ($0.755 l^{-1} annual-capacity). The project internal rate of return is 15%.

In-state Resources

California starch & sugar crops and ethanol potentials.

	Yield (Mg ha^{-1})	Ethanol Yield (l ha^{-1})	2005 harvest (1000 ha)	Ethanol Potential (Ml y^{-1}): 2005 Crop	Ethanol Potential (Ml y^{-1}): Historical Max. Crop
Rice	9.0	3321	213	708	799
Wheat	5.2	1964	149	295	1071
Corn	10.8	4293	45	193	651
Sugar beets	78.5	8138	18	144	1155
Barley	3.1	786	24	19	609
Sorghum	5.4	2151	4	9	367
Oats	2.9	702	8	6	64
Totals			**461***	**1373**	**4717**

The existing starch and sugar crop in California could produce some 1.37 GL y^{-1} of ethanol. This would require all these crops to shift from food production.



There are approximately 27 dry Tg y^{-1} of lignocellulosic materials potentially available in the state.

California lignocellulosic ethanol potential*

Biomass Source		Potential Feedstock (dry Tg y^{-1})	Potential Ethanol (Ml y^{-1})	Potential Ethanol (Ml y^{-1}, gasoline equivalent)
Current Lignocellulosic Residues in California		**22.6**	**6,855**	**4,561**
600,000 ha Dedicated Energy Crop				
Low Yield (11.2 dry Mg ha^{-1}, 334 l Mg^{-1})		6.8	2,270	1,514
High Yield (20.2 dry Mg ha^{-1}, 418 l Mg^{-1})		12.2	5,110	3,407
State potentials with existing residues & 600,000 ha energy crop	**Low Yield**	**29**	**9,138**	**6,076**
	---------------------------*Range*---------------------------			
	High Yield	**34.5**	**11,977**	**7,968**

*Assumes a conservative ethanol yield of 292 liters per dry tonne (Mg) for field/seed crops, orchard and vine prunings and removals, and forest and range thinnings. Assumes 334 liters per dry tonne (Mg) for landfilled paper and woody/green wastes available for utilization. Nearly 70% of the state estimate is due to the large potential for forest and rangeland thinnings. Estimate assumes no competition for the resource such as biopower, mulch, compost, etc.

Total ethanol production from in-state lignocellulosic feedstock, including 600 kha of energy crops could approach between 9.1 and 12 Gl y^{-1}

(between 6.1 and 8 Gl y^{-1} of gasoline equivalent or 10-13% of current gasoline use)