

CALIFORNIA BIOFUEL GOALS AND PRODUCTION POTENTIAL

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ABSTRACT: Recent California legislation 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. Currently, nearly all gasoline in California contains 5.7% ethanol (annually, 3.3 GJ of ethanol is blended with 58 GJ gasoline). Using future fuel demand estimates and a set of blend rates or renewable fuels standards, in-state biofuel production needs were forecast. In addition, an assessment was made of crop land area that would be required to supply biofuel production with in-state resources. For ethanol, in-state production in 2010 would need to be about 0.69 GJ y⁻¹ for the E5.7 scenario, increasing to 1.5 GJ y⁻¹ by 2020 and 3.3 GJ y⁻¹ by 2050. For a 10% RFS (or E10 scenario), in-state production goals could be 1.2, 2.6, and 5.9 GJ y⁻¹ for 2010, 2020, and 2050 respectively. For renewable diesel, in-state production goals would vary from between 0.05 and 0.5 GJ y⁻¹ in 2010, to between 0.6 and 2.8 GJ y⁻¹ by 2050 (for B2 and B20 blend scenarios respectively). Shifting the current in-state grain and sugar crops to feedstock for fuels production could meet the 2010 E10 in-state goal but would be insufficient to meet projected demand beyond about 2012. Land area for oil crops required for biodiesel becomes exceedingly high above 5% RFS after 2020. Biofuels from in-state lignocellulosic resources (current residues plus 600,000 ha of energy crops) could potentially supply 9.1-12 GJ y⁻¹ ethanol or 6 to 8 GJ y⁻¹ gasoline or diesel equivalent. Competition for land will arise under high indigenous biofuel demands. Electricity and hydrogen may also contribute more substantially to transportation energy supply over the longer term. Utilization of lignocellulosic resources and continued research into improving sustainable yields and developing new products coupled with improved transportation efficiency to reduce fuel demand will be needed to satisfy long range targets. Reliable feedstock supply cost curves and economic modeling of biorefineries and their impacts in the California context are needed to improve understanding of the potential for an indigenous biofuel industry in the state and are part of current research efforts.

Keywords: liquid biofuels, resource potential, bio-energy policy

1 INTRODUCTION

Recent California legislation and executive branch policy may have substantial impact on the production and use of biofuels in the state. New legislation in California includes standards for reduced global warming emissions from vehicles (AB 1493 [1]), and establishment of a goal to reduce statewide GHG emissions to 1990 levels by 2020 (AB 32 [2]). In addition, AB 1007 [3] requires development by June 2007 of a state plan to increase the use of alternative fuels in the state (including biofuels).

Policies articulated by executive order set statewide GHG emission reduction targets for 2010, 2020, and 2050, set goals for in-state biofuels production and electricity generation from biomass, and established a goal to reduce the carbon intensity of transportation fuels which includes development of a low carbon fuel standard (LCFS).

Executive Order S-3-05 established the following GHG emission targets; "by 2010, reduce GHG emissions to 2000 levels; by 2020, reduce GHG emissions to 1990 levels; by 2050, reduce GHG emissions to 80 percent below 1990 levels" [4]. The 2020 target coincides with the target established in law by AB 32.

Executive Order S-06-06 and the Bioenergy Action Plan articulated goals for in-state share of biofuel production; by 2010, 20% of the state's biofuel consumption should be produced in-state, increasing to 40% by 2020, and 75% by 2050 [5],[6]. The biofuel production goals do not establish a renewable fuel standards (RFS) as they do not address actual biofuel usage.

Executive Order S-01-07 establishes a goal to reduce the "carbon intensity of California's transportation fuels by at least 10 percent by 2020", and calls for the implementation of a low carbon fuel standard (LCFS) as

an early action in implementing AB 32 [7]. The LCFS is under development.

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. Other pending legislation proposes an RFS for diesel consumed in the state (starting at 2% renewable diesel followed in two years by 5% renewable diesel content, SB 140, Kehoe) [8].

This paper analyzes the effect of a renewable fuels standard on projected biofuel consumption in California as well as needed in-state biofuel production capacity to satisfy the goals in Executive Order S-06-06 and the Bioenergy Action Plan.

In addition, an assessment was made of crop land area that would be required to supply biofuel production with in-state resources to determine to overall potential for state resources to meet long term bioenergy demand.

2 CURRENT AND PROJECTED FUEL USE

2.1 Current fuel use in California

California currently consumes about 60 GJ y⁻¹ of gasoline and 11.4 GJ y⁻¹ of diesel (jet fuel consumption is approximately 11 GJ y⁻¹) [9].

Nearly all gasoline in California contains 5.7% ethanol by volume as an oxygenate, for octane enhancement, as well as to supplement the limited petroleum refining capacity. California ethanol use, therefore, is some 3.4 GJ y⁻¹ blended with gasoline. Ethanol consumption in the US in 2006 was 20.3 GJ [10].

Renewable or biodiesel consumption in the state is relatively small at about 15 MJ y⁻¹, representing about 0.1% of the 11.4 GJ y⁻¹ diesel market in the state [9].

2.1 Projected petroleum use in California

California is heavily dependent on road vehicles for personal transportation and goods movement. There are 21.9 million automobiles and 6 million commercial vehicles registered in the state, which equates to about 0.8 vehicles per person [11].

Total vehicle km traveled (VkmT) on state roads is about 525 billion. VkmT has been increasing roughly at the same rate as population for the past 15 years, but California state agencies are projecting VkmT to increase faster than population. By 2030, VkmT on California roads is predicted to increase by more than 60% (to more than 800 billion km y⁻¹). Extrapolating to 2050, VMT could be as high as 1100 billion km y⁻¹, more than twice what it is today [12] [13] (Figure 1).¹

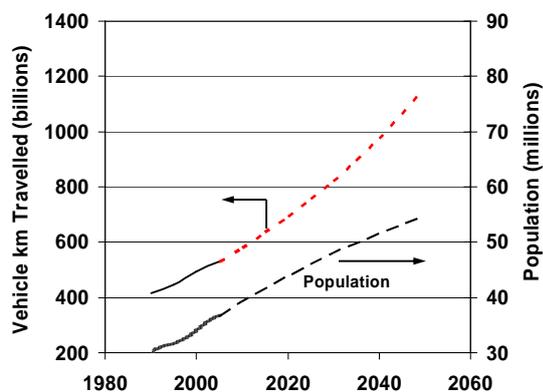


Figure 1: California vehicle km traveled and population projections [13],[14]

Annual gasoline usage is forecast to grow to between 60 and 70 GJ by 2025. Extrapolating to 2050, gasoline usage could be between 60 and 90 GJ y⁻¹ [12, 13] (Fig. 2) (see notes on fuel use modeling below)².

Diesel consumption is expected to grow from 19 to 25 GJ y⁻¹ by 2025 and could reach 36 GJ y⁻¹ by 2060 (Fig. 2).

¹ Note that these projections are speculative and mostly assume business as usual scenarios (low fuel prices, no significant change in fleet average fuel economy) and GHG reduction policy is not considered.

² The CEC VkmT and fuel consumption forecasts are from the California Energy Commission (CEC) and are based on the California conventional alternative fuels response simulator (CALCARS). The model uses forecasts and assumptions for population, household size, income levels, fleet average fuel economy, fuel prices, and composition of vehicle stock (e.g., growth in hybrid vehicle and light duty diesel proportion of fleet). The CEC based fuel prices on the EIA 2005 Energy Outlook which projected worst-case world oil price to be only \$48/barrel by 2025 and their reference-case price to be as low as \$30/barrel by 2025 (constant 2003 dollars). Therefore, the CEC worst-case retail fuel price was only \$2.49/gasoline equivalent gallon by 2025 (constant 2005 dollars). Fleet average fuel economy in the CEC forecast varied from 20.4 mpg to between 21.9 mpg (low fuel price, no GHG policy case) and 27.3 mpg (high fuel price w/ GHG policy)

3 BIOFUEL ESTIMATES

For this analysis, three biofuel blend rates for ethanol in gasoline are assumed; a). continuation of the current 5.7% statewide average (E5.7), b). a 10% RFS which assumes some combination of ethanol-gasoline blends such that the overall average is E10, and c). a 20% RFS (or E20 overall average).

For diesel, renewable diesel blends of 2%, 5%, and 20% (B2, B5, and 20% RFS [B20]), respectively).

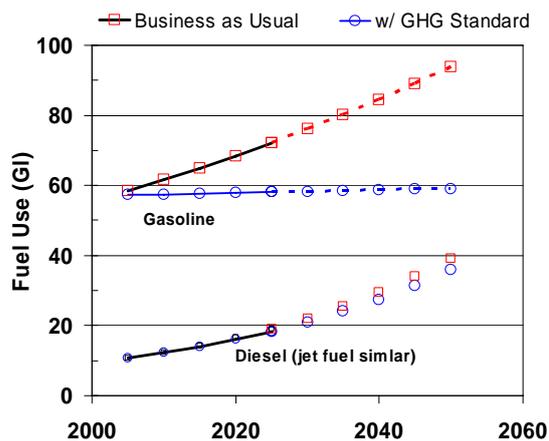


Figure 2: California petroleum fuel usage projections ³

3.1 Biofuel demand projections

Using the average of the projected gasoline and diesel demand (Figure 2), the future demand for biofuel is estimated for the three blend rates.

Ethanol demand between the years 2010 and 2050 is projected to grow from 3.5 to 4.4 GJ y⁻¹ (for the E5.7 case), from 6.2 to 7.9 GJ y⁻¹ (E10 case), and 12.8 to 16.4 GJ y⁻¹ (E20 case) (Table 1).

Table 1. Projected in-state ethanol demand (GJ y⁻¹)

Year	E5.7	E10	E20
2010	3.5	6.2	12.8
2020	3.7	6.5	13.5
2050	4.4	7.9	16.4

Demand for biodiesel between the years 2010 and 2050 is projected to grow from 0.05 to 0.56 GJ y⁻¹ (for the B2 case), from 0.12 to 1.4 GJ y⁻¹ (B5 case), and 0.49 to 5.7 GJ y⁻¹ (B20 case) (Table 2).

Table 2. Projected in-state biodiesel demand (GJ y⁻¹)

Year	B2	B5	B20
2010	0.05	0.12	0.49
2020	0.13	0.33	1.30
2050	0.56	1.41	5.65

3.2 In-state biofuel production goals

Based on policy goals for in-state shares of biofuel production, the in-state renewable gasoline (e.g., ethanol) production goal is expected to be between 0.7 and 2.6 GJ

³ Dashed lines are extrapolations beyond reference study time scales

for 2010 (for E5.7 and E20 scenarios respectively). By 2050 (assuming the petroleum demand projections above), the in-state ethanol production goal would be between 3.3 and 12 GI (E5.7 and E20 respectively) (Figure 3).

For renewable diesel (or biodiesel), in-state production goals for 2010 would be from 0.05 to 0.50 GI (for the B2 and B20 scenario respectively) growing to between 0.6 to 5.6 GI by 2050 (Figure 4).

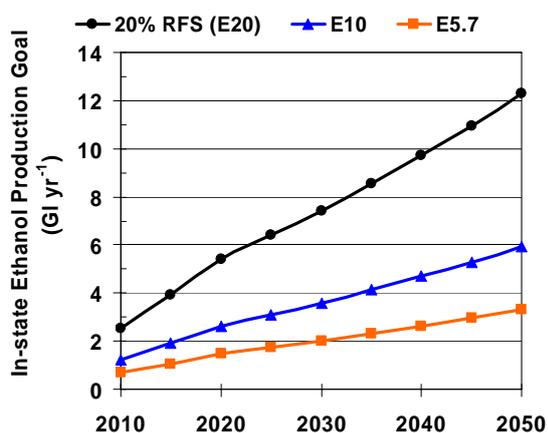


Figure 3: In-state production goals for renewable gasoline (as ethanol) for three blend scenarios

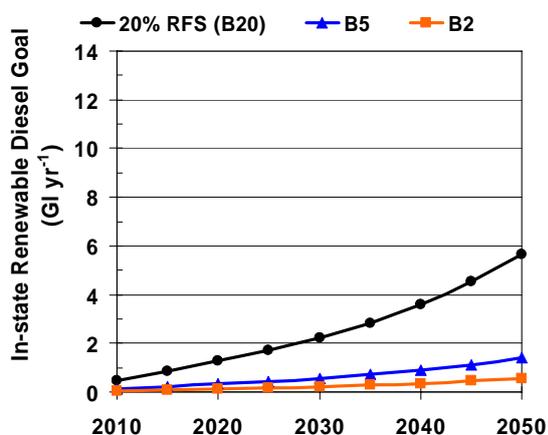


Figure 4: In-state production goals for renewable diesel for three RFS scenarios

4 CROP AREA REQUIREMENTS

4.1 Conventional ethanol production

Traditional food and feed crops are currently used for biofuel and bioenergy production. The vast majority of US ethanol production comes from Midwest grain corn. In 2005, about 14% of the US corn harvest was used to produce some 14.8 GI of ethanol equivalent to about 1.8% of US gasoline demand [15]. In 2006, some 18.5 GI of ethanol were produced from about 18% of the US corn crop [10], [16]. Corn crop planted area for 2007 is the largest since 1944 and is 15% larger than the 2006 crop (the increase is offset by reductions in soy, cotton, and rice plantings) [17].

The non-fermentable solids, or distillers' grains, from corn ethanol fermentation is used for cattle feed and is an important source of income for the US bioethanol industry.

In Europe, cereal grain crops and sugar beets are used in bioenergy production. This is primarily for biogas from anaerobic digestion which is used for renewable electricity and renewable compressed natural gas vehicle fuel.

Coproduct credits are important to the overall economic feasibility and energy balance of corn ethanol facilities in the US. Midwest facilities commonly dry distillers grains prior to marketing. In California, feeding of wet distillers grains is more commonly proposed. Controlling ethanol and other VOC emissions from these feedstuffs will be important to the success of these operations in California.

4.2 US crop area requirements

Approximately 18% (5.7 million ha) of the 2006 US corn crop was used for ethanol production [10, 16]. According to Hill et al., (2006) [15], the US corn harvest could yield about 28 billion gallons of ethanol (about 13% of US gasoline demand). To supply all of the US gasoline demand from corn derived ethanol, about 230 million ha would be required, well in excess of available land for corn [18].

4.3 California crop area requirements: ethanol

California's diverse agricultural sector includes many starch and sugar crops that could be used for bioethanol feedstocks. Grown currently for food and feed (and driven by markets in the long-term), existing California crops with the largest potential for conventional bioethanol production are rice, wheat, corn, barley, sorghum, and oat grain crops and sugar beets. These crops together accounted for more than 450,000 ha harvested in 2005 (which is about 12.7% of all irrigated cropland in the state) (Table 3).

The potential ethanol production represented by the 2005 California harvest from these crops is about 1.3 GI [approximately 0.9 GI gasoline equivalent](Table 3). With the exception of rice, these grain and sugar crops had been cultivated in much larger amounts at various times since 1950. For example, in 1954, 770,000 ha of barley was harvested and 525,000 ha of wheat was harvested in 1981.

Table 3. California starch and sugar crops and ethanol potentials.

	Yield (Mg ha ⁻¹)	Ethanol Yield (l ha ⁻¹)	2005 harvest (1000 ha)	Ethanol Potential (MI y ⁻¹)	
				2005 Crop	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

*There are about 3.6 million ha under irrigation in California. Sources [18-20]

If the current grain and sugar crops in the state were

diverted from food and feed production to conventional ethanol production, it could meet the 2010 in-state goal for ethanol for the E10 or 10% RFS scenario (about 1.3 GJ of ethanol potential from 461,000 ha harvested) (Table 3).

To meet in-state production goals for ethanol using only corn from California would require between 342,000 and 1.26 million ha by 2020 and between 777,000 and 2.86 million ha by 2050 for E5.7 and E20 scenarios respectively (Table 4). The 2050 land use estimate approaches the total 3.6 million ha of irrigated crop land in California.

Table 4: Starch/sugar crop area requirements for in-state ethanol production goals (thousand ha)

	Corn (1000 ha)			Sugar Beet (1000 ha)		
	E5.7	E10	E20	E5.7	E10	E20
2010	161	287	594	85	152	314
2020	342	609	1261	181	322	667
2050	777	1382	2864	411	731	1514

For the same scenarios and goals, sugar beet crop area would be about half of that required for corn. In the case of an integrated biorefinery that utilizes corn grain as well as the lignocellulosic portions of the plant (the stover), required land area would be about 60% of that for an industry that utilizes only the corn grain.

4.4 California crop area requirements: biodiesel

Soybeans are not suited for California’s climate and, except as imports, are not a viable in-state source of biodiesel although at present they constitute the major feedstock for biodiesel production in the US. Safflower is grown in California and is a potential source for oil feedstock. Canola, though not grown extensively in California, could be another potential oil seed crop, especially for remediation of salt affected lands in the state [21].

Crop area requirements to meet in-state goals for conventional biodiesel production are similar to those for conventional ethanol.⁴ Oil crop land area required varies from about 53,000 to 524,000 ha for the 2010 goal, between 139,000 and 1.39 million ha for the 2020 goal, and from 600,000 to 6 million ha by 2050 depending on blend-rate (B2 or B20) (Table 5). Oil seed crop area for indigenous biodiesel production is exceedingly high. Biodiesel crop acreage is based on oil seed yield of 2.24 Mg ha⁻¹ with 40% seed oil content and about 94% oil extraction efficiency. This gives a biodiesel yield of about 935 l ha⁻¹.

⁴ Conventional biodiesel means a biofuel from transesterification of plant oils suitable for use in compression ignition (diesel) engines. Conventional ethanol production means bioethanol fermented from starch and sugar crops. Advanced biofuels will be produced from lignocellulosic components of plant material through thermochemical and biochemical processes.

Table 5: Oil seed crop requirements to meet in-state production goals for conventional biodiesel (thousand ha)

Year	B2	B5	B20
2010	53	131	524
2020	139	347	1387
2050	602	1505	6020

5 CALIFORNIA LIGNOCELLULOSIC ETHANOL POTENTIAL

Lignocellulosic derived ethanol offers several advantages over ethanol produced from sugar/starch feedstocks. These include the potential for higher per acre ethanol yields and lower agronomic inputs for purpose-grown energy crops, improved product life-cycle environmental performance, GHG balances and net-energy ratios, the potential to utilize marginal and out of production lands which reduces competition with food crops, and the potential to utilize the diverse and large existing lignocellulosic biomass residue streams found in urban waste, forest thinnings, and agricultural residues.

As the US will not be able to make enough biofuels (e.g., bioethanol) from conventional feedstocks (starch and sugar sources) to substantially reduce petroleum imports or lower GHG emissions from the transportation sector, lignocellulosic routes to biofuels will be needed [15, 22, 23].

Existing lignocellulosic resources in California include forest operation and wood product residues, urban mixed paper, wood, and green wastes currently landfilled, and certain crop and agricultural residues. Technically recoverable amounts are estimated to be about 23 to 27 dry Tg y⁻¹ (Figure 5).

Energy crops, such as switchgrass,⁵ grown specifically for ethanol feedstock on 600,000 ha of idle or marginal lands could add another 6 to 12 dry Tg y⁻¹.

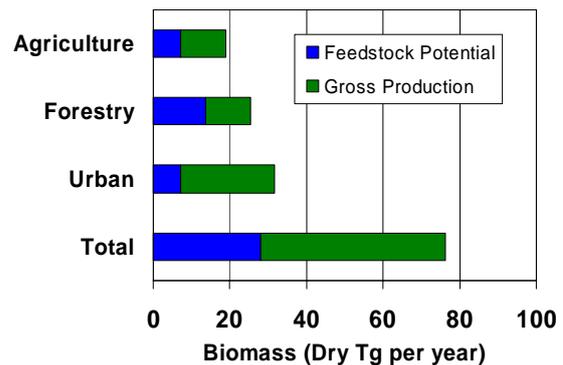


Figure 5: Total annual residue biomass in California and estimated technically recoverable feedstock potential [24]

⁵ Switchgrass is used as an example and may not be the preferred crop for California although field experiments are beginning. The best mix of energy crops that are agronomically and otherwise sustainable in California is the subject of on-going and proposed research.

Table 6: California lignocellulosic ethanol potential* [25]

Biomass Source	Potential Feedstock	Potential Ethanol	
	(dry Tg y⁻¹)	(Ml y⁻¹)	(Ml y⁻¹, gasoline equivalent)
Field and Seed	2.1	606	397
Orchard/Vine	1.6	473	314
Landfilled Mixed paper	3.6	1211	806
Landfilled wood & greenwaste with ADC	2.4	818	545
Forest thinnings	12.9	3748	2498
Totals- Current 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 600,000 ha energy crop	Low Yield	29	9,138
	----- Range -----		
	High Yield	34.5	11,977

*Assumes a conservative ethanol yield of 292 liters per dry tonne (Mg) for field and 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 considered to be available for utilization. Nearly 70% of the state estimate is due to the large potential for forest and rangeland thinnings. The estimate assumes no competition for the resource such as biopower, mulch, compost, etc.

Potential ethanol production from cellulosic residues in California could be as much as 6.9 Gl. Energy crops could add another 2.3 to 5.1 Gl of ethanol potential depending on crop and ethanol yield. Total ethanol production from in-state lignocellulosic feedstock material could approach between 9.1 and 12 Gl (between 6.1 and 8 Gl of gasoline equivalent or 10-13% of current gasoline use; see Table 6).⁶

6 DISCUSSION

Depending on the future demand for biofuel in California, the ability for in-state feedstocks to meet in-state biofuel production goals will be quite challenging. Future demand is highly uncertain and depends on how recent and pending GHG policies, fuel carbon standards, and potential renewable fuel mandates are implemented.

The current grain and sugar crop harvest in the state could meet a 2010 goal for ethanol production in the E10 or 10% RFS scenario, using about 13% of California's irrigated cropland. Using only corn for the 2010 E10 goal would require about 8% of California irrigated land.

Crop area requirements to meet in-state goals for conventional biodiesel production are similar to those for conventional ethanol. To meet potential 2010 in-state biodiesel goals, about 1.5 to 15% of the state's irrigated cropland would be required, though oil crops could be grown on some non-irrigated lands or on marginal lands with access to irrigation.

A combination of feedstocks based on using 10% of the current California starch/sugar production, 1/3 of the existing lignocellulosic residue, and 200,000 ha of purpose-grown cellulosic energy crops for ethanol could

produce about 3.2 Gl y⁻¹ of ethanol (Table 7), which is enough to meet the in-state goal for E5.7 through 2050 (~3.3 Gl y⁻¹), or the E20 case through about 2013. The 0.19 Gl y⁻¹ of biodiesel production portrayed in the scenario is sufficient to meet the B2 goal for 2020, and the B5 goal for 2010.

Many other scenarios are possible. Reliable feedstock supply cost curves and economic modeling of biorefineries and their impacts in the California context are needed to improve understanding of the potential for an indigenous biofuel industry in the state.

Table 7. A multi-feedstock scenario for a biofuel industry in California.

Scenario Component	Biofuel (Gl y ⁻¹)
10% of current starch/sugar crop for ethanol	0.14
1/3 Lignocellulosic Residue (~ 7.5 Tg y ⁻¹)	2.29
200,000 ha energy crop	0.80
Ethanol Total	3.23
200,000 ha oil seed crop (biodiesel)	0.19

A large amount of crop and product shifting would need to occur in order for California to produce or divert significant starch/sugar feedstocks to an indigenous biofuel industry. Agricultural land rents (costs) in California are generally much higher than in the US Midwest due to high value specialty crop production. In addition, a large share of California agriculture depends on irrigation through the summer dry season. Commodity sugar and starch production in the state is not as competitive as elsewhere in the US. Despite these considerations, there remains good potential for sustainable energy crop production to contribute to soil remediation, greenhouse gas reductions, and other environmental benefits.

⁶ Ethanol is not the only biofuel that can be made from lignocellulosic biomass. Butanol, mixed alcohols, Fischer-Tropsch liquids, and others can serve as gasoline and diesel fuel replacements.

7 SUMMARY AND CONCLUSIONS

Recent California legislation is likely to have substantial impact on the production and use of biofuels in the state. These new policies include

- standards for reduced global warming emissions from vehicles,
- establishment of a goal to reduce statewide GHG emissions to 1990 levels by 2020,
- development of a state plan to increase the use of alternative fuels including biofuels,
- goals for in-state biofuels production and increased power generation from biomass,
- a goal to reduce the carbon intensity of transportation fuels, and
- development of a low carbon fuel standard (LCFS).

However, none of these current laws and policies establishes alternative fuel or biofuel usage requirements (such as a renewable fuel standard or RFS)..

California currently consumes about 60 GJ y⁻¹ of gasoline which includes about 3.4 GJ y⁻¹ of ethanol. Some 11.4 GJ y⁻¹ of diesel fuel is consumed but only about 15 MJ y⁻¹ is biodiesel.

There are nearly 28 million registered vehicles in the state that, combined, travel some 525 billion km annually. Vehicle km traveled is projected to grow 60% by 2030.

Annual gasoline usage is forecast to grow to between 60 and 70 GJ by 2025. Extrapolating to 2050, gasoline usage could be between 60 and 90 GJ y⁻¹.

Diesel consumption is expected to grow from 19 to 25 GJ y⁻¹ by 2025 and could reach 36 GJ y⁻¹ by 2060.

Ethanol demand between the years 2010 and 2050 is projected to grow from 3.4 to 4.4 GJ y⁻¹ (for the E5.7 case), and 12.8 to 16.4 GJ y⁻¹ (E20 case).

Demand for biodiesel between the years 2010 and 2050 is projected to grow from 0.05 to 0.56 GJ y⁻¹ (for the B2 case), and 0.49 to 5.7 GJ y⁻¹ (B20 case).

Based on policy goals for in-state shares of biofuel production; 20% of demand by 2010, 40% by 2020, and 75% by 2050, the in-state ethanol production goal is expected to be between 0.7 and 2.6 GJ for 2010 (for E5.7 and E20 scenarios respectively) and 3.3 and 12 GJ (E5.7 and E20 respectively) by 2050.

In-state production goals for renewable diesel would be from 0.05 to 0.50 GJ (for the B2 and B20 scenario respectively) in 2010 growing to between 0.6 to 5.6 GJ by 2050.

Existing in-state starch and sugar crops could provide up to about 1.3 GJ y⁻¹ (~0.9 GJ gasoline equivalent), if shifted from feed or food use. This could meet the 2010 in-state goal for ethanol for the E10 or 10% RFS scenario.

Oil crop land area required varies from about 53,000 to 524,000 ha for the 2010 goal, and between 139,000 and 1.39 million ha for the 2020 goal. For 2020, this represents 4 to 40% of the irrigated land in California.

Existing technically recoverable lignocellulosic resources in California are estimated to be about 23 to 27 dry Tg y⁻¹. Energy crops grown specifically for ethanol feedstock on 600,000 ha of idle or marginal lands could add another 6 to 12 dry Tg y⁻¹.

Potential ethanol production from cellulosic residues in California could be as much as 6.9 GJ. Energy crops

could add another 2.3 to 5.1 GJ of ethanol potential depending on crop and ethanol yield. Total ethanol production from in-state lignocellulosic feedstock material could approach between 9.1 and 12 GJ y⁻¹.

Competition for land will arise under high indigenous biofuel demands. Utilization of lignocellulosic resources and continued research into improving sustainable yields and developing new products along with improvements in transportation system efficiency will be needed to satisfy the long range targets. Reliable feedstock supply cost curves and economic modeling of biorefineries and their impacts in the California context are needed to improve understanding of the potential for an indigenous biofuel industry in the state and are part of ongoing research.

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