CALIFORNIA
ENERGY
COMMISSION

Environmental Issues for Biomass Development in California

PIER COLLABORATIVE REPORT

PRELIMINARY DRAFT

December 2005
Contract 500-01-016

Prepared By:

Robert B. Williams

California Biomass Collaborative
Department of Biological and Agricultural Engineering
1 Shields Avenue
University of California
Davis, CA 95616

B.M. Jenkins
Executive Director

Contract No. 500-01-016

Prepared For:
California Energy Commission
Public Interest Energy Research (PIER) Program

Valentino Tiangco
Contract Manager

Martha Krebs
Deputy Director
ENERGY RESEARCH AND DEVELOPMENT DIVSION

B. .B. Blevins
Executive Director

Table of Contents

List of Figures

List of Tables

Introduction

This draft report describes results and findings from a workshop on Environmental Regulations and Implications for Biomass that was held by the California Biomass Collaborative on 9 November 2005. Several key issues emerged in panel presentations and subsequent break-out sessions discussing development within the three primary resource categories: agriculture, forestry, and municipal wastes. These common themes fall within three main topics;

- Regulation across multiple media

  This includes evaluation using full systems approaches (Lifecycle analysis)

- Greater reliance on regulation based on performance standards rather than prescriptive technology standards (as well as the need to identify and reduce conflicting regulations and overlapping jurisdiction).
- The need for transparent and independent proof-of-concept or validation projects for future permitting and regulation

In addition, the report discusses additional issues identified through the workshop and other activities. These include issues faced by agricultural operations in non-attainment air basins which are losing exemptions from air permitting. A contentious issue still being decided is the determination of VOC emission factors for confined animal feeding (CAFO) and other concentrated animal operations, especially dairies in the San Joaquin Valley.

Distributed generation issues are also discussed, especially in relation to technologies that are not currently regulated by local air districts. This generally applies to small capacity systems. With respect to biopower technologies, solid fuel combustion devices are already regulated in most (if not all) air districts in California and therefore would not be subject to DG permitting requirements. Reciprocating engines fueled by biogas are also generally already regulated by local districts (for engines larger than 50 hp, or about 37 kW), and would be exempt from DG permitting requirements as currently written.

There is also some discussion of biofuels benefits and drawbacks. Biofuels have greenhouse gas advantages but there is also potential criteria and/or VOC pollutant increases. Net energy and GHG advantages of ethanol depend on the process and source of biomass. Generally, net energy and GHG reduction potential is better for biodiesels than for ethanol fuels.

Forest issues discussed are mainly those related to wildfire emissions that may potentially be reduced if fuel thinning occurs on a large enough scale.

Finally, issues related to the MSW resource are discussed. These include certain long term environmental management issues associated with conventional sanitary or 'dry-tomb' landfills. Methane emissions are a significant environmental issue with MSW landfilling because of significant leaking that occurs even with modern gas collection systems. Other management options which treat (at least the biodegradable fraction) and stabilize the material before landfilling appear to be the best way to mitigate long term methane emissions problems faced with conventional landfilling. Improved environmental performance of modern waste to energy facilities are discussed as well as general results found by LCA of waste management options (these include cross or multi-media impact evaluation. More comprehensive life cycle assessments for integrated waste management as well as other biomass management strategies are needed to provide information for policy and regulation.

Workshop

A workshop on 'Environmental Regulations and Implications for Biomass' was held on 9 November, 2005 in Sacramento. Attendance included some 80 people with various expertise in environmental management and biomass development. The workshop structure consisted of an opening keynote address by Energy Commission Chair Joe Desmond, two morning informational panels, an afternoon keynote given by former CalEPA Secretary Winston Hickox, a set of three concurrent breakout sessions for participant input, followed by reports from the breakout and wrap-up and adjournment.[1]

The first morning panel consisted of representatives from state environmental agencies giving brief presentations on regulatory process background and state programs, strategies and concerns regarding biomass use and management environmental impacts. The second panel was composed of six speakers giving perspectives from industry, the environmental community, and a local agency. The speaker presentations as well as transcripts from all portions of the workshop except the break-out sessions are available at http://biomass.ucdavis.edu/pages/forum/workshops/workshop.html .

The facilitated breakout sessions were organized by biomass resource type (forest, agriculture, and municipal). Participants self-selected a breakout session to attend.

Participants were asked to address key environmental issues regarding the sustainable use and management of biomass[2] resource in the state. Questions to help prompt the discussion were distributed to the participants:

- Where are the knowledge gaps; are policies and regulations adequate and consistent (if not, which are not, and what suggestions are there for improvement)?
- What environmental issues need resolution to bring stakeholder groups closer to agreement on how to move forward?
- What research, development, and demonstration (RD&D) activities are required, if any?
- What efforts are needed to expedite improved management and utilization of biomass? How might we achieve more sustainable management and utilization earlier rather than later?

Participants were also given a set of three 'Resource Issue Matrices' to use for discussion guidance or reference. The resource matrices addressed one of the resource types (Forest, Agriculture, and Municipal) and attempted to list environmental issues and

[1] The workshop agenda is in the appendix and full proceedings are on line at http://biomass.ucdavis.edu.

[2] Biomass includes; biogenic fraction of municipal solid waste, municipal and food processor liquid wastes, food processor solid residues, agricultural residues (from crops and livestock), forest industry byproducts and residues, biomass from forest fuels reduction activities, purpose grown trees and crops for energy, fuels, and chemicals

impacts (pros and cons) resulting from resource management and commercial utilization of biomass subtypes within each of the main biomass categories (e.g., mill residues, logging slash, or thinnings from forest/range land fuels management for the forestry category).

After the breakout period, the groups reassembled and short reports were given by the facilitators highlighting the key points discussed.

Forest Resource Breakout Report

Mark Nechodom and Doug Wickizer facilitated the forest resource breakout group. Table 1 lists the key issues discussed in the forest resource breakout session.

Table 1. Key issues highlighted in the Forest Resource Breakout Report

There is real difficulty in siting demonstration projects that could be proof of concept for management strategies or devices that have complex relationships across multiple media. Because of the potential for new strategies or technologies to be out of compliance with respect to one emission type or regulation while showing promise for improved performance over conventional methods for a separate environmental issue, it is often difficult get RD&D projects on the ground, regardless of potential benefits if the system were to perform as expected. It is the uncertainty of the new systems that preclude even valid demonstration attempts. Therefore, alternative standards or allowances for pilot projects are recommended.
If we start managing forests to increase carbon sequestration, then other collateral environmental impacts must be considered (the point was that some of these have not been thought through yet).
Should biomass power plants be allowed to have higher emissions than from central station natural gas facilities because of the potential emission offsets from avoided wildfires? In other words, can biopower facilities receive credit for changing wildfire behavior?
Netting across multiple media, e.g., systems life-cycle assessment is important.
Internalize the externalities (economically)
Offset credit system for forest thinning, reduced prescribed burns and wildfire is difficult to implement by local air districts and reportedly, no offsets of this type are recognized by US EPA (per conversation w/ Placer County APCD)

Agriculture Resource Breakout Report

Steve Shaffer and Cynthia Cory facilitated the agriculture resource breakout group. The key points are listed below in the following three tables organized by type of concern [1)Knowledge gaps, policies, adequacy / consistency of regulations, 2)Research Development, Demonstration and Deployment (RDD&D) and 3) Issues and resolutions to bring stakeholders together]. Table 2 lists the key issues discussed in the forest resource breakout session.

Table 2. Key issues related to knowledge gaps, policies, regulations adequacy / consistency

Expand systems analysis approach to all utilization strategies (similar to LCA used in transportation modeling and other)
Take a portfolio approach for pollutants and GHG emissions (also called 'netting across media', or 'multimedia approach' ▪ Such an approach would need to take federal/state/local regulations into account and harmonized if needed for moving forward.
Process for consistent regulation implementation ▪ An example was mentioned where there may be differences in water regulation interpretation among different regional offices and staff. This brings up the issue of how to balance benefits of consistent regulations across regions vs. needs of regional board for the differences.
Need Incentives. Suggestions include, ▪ Farm commodity tax/fee with funds going to develop and implement technologies ▪ Green payment for a farm that goes above and beyond compliance - incentive to outperform the regulatory standard
Review criteria for offset credits (especially with respect to CAFOs) ▪ Disappearance of offset credits due to ban on burning – where are offsets going to come from ? ▪ Offset credit concept needs to be made 'achievable'
Set performance standards and allow industry to achieve them (rather than reliance on BACT)

Table 3. Key issues related to RDD&D

There is a need to conduct research in dedicated energy and bioproduct crops (i.e., saline tolerant biomass, algae) that would have lower environmental impact, be more easily managed or provide byproducts while mitigating some other environmental issue. ▪ Do a cropping / product systems pilot ▪ Investigate CAFO nutrient management by 'trapping' nutrients into biomass more efficiently (i.e., duckweed, water hyacinth, algae) to help close the nutrient loop. Perhaps allow for reduction in feed importation to the state.

Environmental verification pilot project "systems approach" ▪ Large scale environmental verification project is recommended (James Liebman at EPA, Cory and Shaffer) ▪ Fund a state-run model dairy technology proving ground, for example, where vendors come and demonstrate technology, quantify performance, etc.
Develop a menu of technologies that are economically viable and meet criteria and standards ▪ And/or just set performance standard (like the water boards do) rather than BACTs (as the air boards do).

Table 4. Key issues related to issues and resolutions to bring stakeholders together

Conduct comprehensive review of regulations as barrier to sustainability (cross media, portfolio approach to emissions and regulations)
Net metering and grid access/interconnection issues need to be truly addressed by PUC
AB 1090 (Matthews) -Conversion technology jurisdiction/waste hierarchy ▪ Consensus on the concept of conversion moving up in the waste hierarchy is not achieved ▪ Recognize that facilities are refineries, therefore feedstock is not waste and is instead an industrial/material input, obviating need for CIWMB regulation.

Municipal Resource Breakout Report

Ruth MacDougall and Brenda Smyth facilitated the municipal resource breakout group. The two following tables list key discussion issues according to 'high priority' in Table 5, and 'medium to high' in Table 6.

Table 5. Key issues rated as high priority from the Municipal resource breakout

Regulators should place a value on externalities as a way to offset other emissions and/or improve economics
Regulate on performance standards rather than regulations that prescribe technologies
The waste management hierarchy should be revised to include conversion technologies (CTs) as a resource recovery method (or at least create a new rung for CT elevated above landfill disposal)
If CT remains classified as disposal, then some amount of diversion credit should be allowable

The CEQA process (or environmental requirement) should prevail over public political pressure - set the environmental performance bar and stick to it. ▪ Set the bar high enough to preclude permitting by political decision
Material uses as a feedstock or a fuel for a CT should not be considered waste (falling out of the purvue of CIWMB). Otherwise treat the facility as a Non-Disposal Facility Element (NDFE)[3]
Support Research and Development and Demonstration (RD&D) projects to provide data and public education (Amazement Parks) ▪ At a minimum allow regulatory exclusions for RDD&D projects
Support renewable fuels mandate ▪ Apply a public goods charge to petroleum fuels Provide for a higher tariff for renewable electricity
Adopt a European type 'Landfill Directive' to ban untreated waste from landfills
ADC in landfills should not receive diversion credits

Table 6. Key issues rated as medium to high priority from the Municipal resource breakout

Increase source separation of wastes
Streamline permitting

Conclusions from the Workshop

Key issues that came up repeatedly in the panel presentations and were common to the break out sessions fall within three main topics:

- Regulation across multiple media
  - This includes evaluation using full systems approaches (Lifecycle analysis)
- Greater reliance on regulation based on performance standards rather than prescriptive technology standards (as well as the need to identify and reduce conflicting regulations and overlapping jurisdiction).
- The need for transparent and independent proof-of-concept or validation projects for future permitting and regulation

[3] See; http://www.ciwmb.ca.gov/LGCentral/Glossary.htm#NDFE or http://www.ciwmb.ca.gov/Regulations/Title14/ch9a63.htm#ch9ca6_4

Agriculture Resource Issues

Loss of air permit exemption for Agricultural Operations

SB 700 (Statutes of 2003)[4] eliminates stationary source permit exemptions for agricultural operations and requires air quality and air pollution control districts that are federal nonattainment areas to adopt and implement control measures to reduce emissions from agricultural practices, including confined animal facilities such as dairies and feedlots.[5] Agricultural operations whose air pollution emissions exceed one-half of the major source threshold for any criteria pollutant now require a permit to operate (operations that emit below the one-half threshold may still require a permit if the air district shows that those emissions contribute to a violation a state or federal ambient air quality standard.

CAFs and CAFOs (Dairy Issues)

For the purpose of regulating discharges to surface and ground waters, the Federal Clean Water Act (CWA) contains a definition large animal facilities based on their propensity to contribute to water pollution. The Federal CWA defines concentrated animal feeding operations (CAFOs) as animal feeding operations with more than 1000 animal units (AU= 1000 lb. live animal weight)[6], or 300 animal units if there is direct discharge to navigable waters, or if the facility is considered to be a significant contributor of pollutants to waters of the US by the appropriate authority (i.e., the regional waterboard).[7] Dairy cattle, generally larger than beef cattle, are equivalent to 1.4 AU which means a dairy with about 700 mature cows is a CAFO under the federal standard. The Santa Ana Regional Water Quality Control Board (State Water Region 8), which includes the Chino Basin, defines all dairies, heifer ranches, and calf nurseries in the region as CAFOs (regardless of size).[8]

For the use by local districts when developing rules to mitigate emissions from agricultural operations, including confined animal facilities (CAFs), AB 700 required the California Air Resources Board (CARB) to develop a definition for 'large' CAF's. The CARB approved definitions for large CAFs in June, 2005.[9]

---

4 SB 700: http://www.leginfo.ca.gov/pub/03-04/bill/sen/sb_0651-0700/sb_700_bill_20030922_chaptered.html

5 Jenkins, B. M. (2005). "Biomass in California: Challenges, opportunities, and potential for sustainable management and development." CEC-500-2005-160, California Biomass Collaborative.

6 The USDA 'Animal Unit' equals 1,000 pounds of live animal weight. The EPA uses the 40CFR/P122 definitions, i.e., 1 AU = 1 mature beef cow = 0.7 lactating or dry dairy cow = 55 turkeys =100 chickens, etc.

7 See http://www.setonresourcecenter.com/cfr/40CFR/P122_013.HTM

8 General waste discharge requirements for CAFOs within the Santa Ana Region; http://www.waterboards.ca.gov/santaana/pdf/tentative/TR8-2004-0055.pdf

9 (2005). 'Air Board sets stage for large dairy rules'. CARB News Release. Available at: http://www.arb.ca.gov/newsrel/nr062305.htm

For dairies in ozone non-attainment air basins, a large CAF has 1000 or more lactating cows. For dairies in attainment areas, a large CAF is a facility with 2000 or more lactating cows (support stock are not counted for purposes of the definition, but emissions from support stock must be accounted for in the permit to operate).[10]

The San Joaquin Valley and the South Coast air basins are both non-attainment for the federal 1-hour ozone standard and house about 93% of all California dairy animals. Using the 1000 lactating cow number for CAF determinant, 29% of dairies and 73% of animals in the San Joaquin Valley will be considered CAFs as well as 50% of dairies and 75% of animals in the South Coast air basin. Individual air districts are free to use more stringent CAF definitions[11]

Dairy VOC emissions

For the SJVAPCD, dairies (and other confined animal feeding operations) that emit more than 12.5 tons/yr of VOC will require air permits. The size of the dairy (in number of animals) that will trigger the requirement for an air permit has been a subject of litigation. The dispute is primarily over the VOC emission factor for dairy cattle used by CARB (12.8 lb./head/yr)[12] where the methane emissions data from an early study was misapplied and taken as VOC emissions and written into the emission inventory.[13]

The California ARB and SJVAPCD are funding ongoing investigations to determine air emissions from California dairies. Researchers from the University of California, California State University, Texas A&M, Iowa State, state agencies, and private consultants are engaged in several parallel measurement and modeling studies.

In Janurary, 2005, preliminary results from the research were presented.[14] The preliminary findings include those of Dr. Frank Mitloehner (UC Cooperative Extension) who reported about 3.8 lbs/cow/year of VOC come directly from the animal, mostly from rumination. Another 2.6 lbs/cow/y was measured from the fresh manure (up to 3 days old left in pen).

Dr. CE Schmidt, an independent consultant, conducted an extensive suite of flux-chamber measurements from 11 types of emitting surfaces at a flushed lane dairy in Merced County (e.g., manure piles, corrals, freestall and turnout areas, open feed storage, lagoons, etc.);

---

[10] Gaffney, P. (2005). "Initial statement of reasons for the confined animal facility definition." *Staff report*, California Air Resources Board. Available at: http://www.arb.ca.gov/regact/lcaf05/isor.pdf

[11] Ibid.

[12] Gaffney, P. 2004 update. Available at: http://www.arb.ca.gov/ei/areasrc/fullpdf/FULL7-6.PDF

[13] Benedict and Ritzman, (1938) determined CH_4 emission factor to be 160 lbs/cow/yr which was later mis-interpreted to be TOG emission factor. A 1980 EPA study determined that 8% of livestock TOG is reactive or ROG. 8% of 160 gives the 12.8 emission factor. Also see the discussion in the Gaffney, P. 2004 update, op. cit.

[14] Livestock emissions research symposium 26 January, 2005. Fresno, CA Proceedings available at; http://www.arb.ca.gov/ag/agadvisory/lersymp.htm

Over 40 flux chamber measurements were made with analysis for speciated reactive organic gases (ROGs or VOCs), ammonia/amines, total organic compounds, and methane. Schmidt's preliminary results indicate the VOC emission factor from dairy operation surfaces only (no cow belching, ruminating, etc.) ranges from 3.6 to 19 lbs/cow/year. The dominant ROG species is ethanol emitted from siled feed. Emissions from the wastewater lagoon were 'relatively' low.[15]

Using the preliminary data from Mitloehner for direct animal emissions and the range of VOC emissions derived from Schmidt's flux chamber measurements, total emission factor potentially ranges from 7.4 to 23.6 lbs/cow/year.

SJVAPCD Dairy VOC Emission Factor Determination

The Air Pollution Control Officer (APCO) for the San Joaquin Valley Air Pollution Control District was required to adopt a dairy emission factor by 1 July, 2005 (since extended to 1 August, 2005)[16]. As part of the settlement agreement, a Dairy Permitting Advisory Group (DPAG) was formed which was composed of representatives from the dairy industry, the research community, and the environmental community.

The DPAG submitted its' final recommendations on dairy emission factors to the APCO in May, 2005. The DPAG could not arrive at a consensus opinion in its' report and instead showed three emission factor recommendations derived from each of three factions among the stakeholders; the dairy industry, the University of California, and the environmental community.[17] The DPAG recommends 5.6, 13.3, and 38.2 lbs./cow-year for dairy facility VOC emission factor (see Table 7). The dairy industry recommends the lowest emission factor while the environmental community recommends the highest.

The APCO released a draft determination of dairy VOC emission factors which was discussed at a public workshop in July, 2005.[18] After receiving comments, a final report was issued 1 August, 2005.[19]

The draft dairy VOC emission determined by the APCO was **20.6** lbs/cow-yr and revised downward to **19.3** lbs/cow-yr in the final report (these are milking cows, not support animals that are usually at a dairy as well). This is significantly larger than the value currently used by CARB (12.8 lbs/cow-year). The report discusses the process used to

---

[15] See presentation by Schmidt in proceedings at; http://www.arb.ca.gov/ag/agadvisory/lersymp.htm

[16] (2004). "Settlement Agreement. Western United Dairymen, Alliance of Western Milk Producers v. San Joaquin Valley Air Pollution Control District." Fresno Superior Court.

[17] (2005). "Dairy Emissions Factors for Volatile Organic Compounds - Recommendations to the San Joaquin Valley Air Pollution Control Officer." *Final Report, 6 May, 2005*, Dairy Permitting Advisory Group. Available at: http://www.valleyair.org/busind/pto/dpag/DPA_%20EF_Report_Final.pdf

[18] Crow, D. L. (2005). "Draft Air Pollution Control Officer's Determination of VOC Emission Factors for Dairies." *27 June, 2005*, SJVAPCD. Available at: http://www.valleyair.org/Workshops/postings/7-11-05/APCO%20EF%20Report%20_June%2027%20%2005_.pdf

[19] Crow, D. L. (2005). "Air Pollution Control Officer's Determination of VOC Emission Factors for Dairies." Final Repot *1August, 2005*, SJVAPCD. Available at: http://www.valleyair.org/busind/pto/dpag/APCO%20Determination%20of%20EF_August%201_.pdf

arrive at the determination, which includes a line-item examination of the data for each type of on dairy operation and weighs the arguments behind the three different recommendations made by the DPAG (see Table 7). The APCO value is slightly higher than a simple average of the DPAG recommendations (DPAG average = 19.0).

Notable in the discussion by the APCO in his report are the comments given in the line-item evaluation (the line-items are the eight VOC constituents or dairy processes listed in Table 7). The APCO states that the best available data **underestimate** the emissions for each of the eight line-items. The expectation then is that as better data become available, the VOC emission factor will increase above the current 19.3 lbs/cow-yr.

This is an evolving issue. Besides the magnitude of the dairy VOC emission factor, there is debate over what compounds should be included in the VOC category.[20] SJVAPCD dairy and agricultural operations BACT determination is in process. The DPAG has issued draft report on dairy BACT [21], and the US EPA (Region 9)[22] and CARB are evaluating technologies and strategies for improved manure management addressing both water and air impacts.

[20] Capareda, S., Mukhtar, S., Shaw, B., Parnell, C., and Flocchini, R. (2005). "White Paper - Highly reactive volatile organic compound (HRVOC) emissions from CAFOs." Available at: http://caaqes.tamu.edu/white%20papers/RVOC_White_Paper32405_Final.pdf

[21] Dairy Permitting Advisory Group (2005). "Recommendations to the San Joaquin Valley Air Pollution Control Officer Regarding Best Available Control Technology for Dairies in the San Joaquin Valley" DRAFT Report. Available at: http://www.valleyair.org/busind/pto/dpag/dpag_idx.htm

[22] James Liebman, US EPA IX. Liebman.James@epamail.epa.gov

Table 7 Summary of DPAG recommendations and SJVAPCD determination for VOC emission factors from dairy.[23]

Constituent or process	Emissions (lb/hd-yr) Dairy Industry*	University of California*	NRDC*	SJVAPCD Determination†	SJVAPCD Comments†
1 Emissions from cows and feed in environmental chamber	2.7	3.4	4.3	1.4† (2.7)◊	Underestimate and further research is recommended
2 Amines from dairy processes	0.2	0.2	11.0	0.2	"
3 VOC emissions (except VFAs and Amines) from miscellaneous dairy processes	1.2	1.2	1.2	1.2	Clearly understimate of actual emissions, further work recommended
4 VOC emissions (except VFAs and Amines) from lagoons and storage ponds	1.0	1.0	1.0	1.0	Underestimate and further research is recommended
5 VFAs from dairy processes	0.5	7.5	17.0	15.5	Most probably represents an underestimate of VFA emissions. Futher research is needed
6 Phenols from dairy processes	0	0	2.6	TBD, >0	Insufficient data available but emissions are known to be greater than zero
7 Land application	NA	NA	1.0	TBD, >0	"
8 Feed storage, settling basins, composting, & manure disturbance	Included above or insignificant	NA	0.1	TBD, >0	"
Totals	5.6	13.3	38.2	**19.3**	

* Viewpoints 1, 2, and 3, from; (2005). "Dairy Emissions Factors for Volatile Organic Compounds - Recommendations to the San Joaquin Valley Air Pollution Control Officer." Final Report, 6 May, 2005, Dairy Permitting Advisory Group.

† Crow, D. L. (2005). "Air Pollution Control Officer's Determination of VOC Emission Factors for Dairies." Final Report. 1 August, 2005, SJVAPCD. Available at; http://www.valleyair.org/busind/pto/dpag/dpag_idx.htm

◊ Crow, D. L. (2005). "Draft Air Pollution Control Officer's Determination of VOC Emission Factors for Dairies." 27 June, 2005, SJVAPCD.

Dairy VOC emissions in the SJVAPCD

Dairy operations VOC emissions for the SJVAPCD can be estimated from the APCO August 1 emission factor and recent dairy cattle population estimates. Table 8 gives an estimate of dairy cattle numbers for the SJVAPCD by county using the California Biomass Collaborative 2005 resource estimate and a support animal to milk cow ratio given in the CARB report on large CAF definition.[24, 25]

[23] Williams, R. B. (2005). "Technology assessment for biomass power generation." *CEC PIER Contract 500-00-034*, Draft Final Report. SMUD ReGen program.

[24] Gildart, M., Williams, R. B., Yan, L., Aldas, R. E., Matteson, G., C., and Jenkins, B. M. (2005). "An Assessment of Biomass Resources in California." CEC PIER Contract 500-01-016, California Biomass Collaborative.

25 from Gaffney, P. (2005). "Initial statement of reasons for the confined animal facility definition." Staff report, California Air Resources Board. Available at: http://www.arb.ca.gov/regact/lcaf05/isor.pdf

Table 8. Dairy cows in the SJVAPCD

SJAPCD Counties	Milk Cows	Support Animals (0.7 x milk cows)*
San Joaquin	103,619	72,533
Stanislaus	178,420	124,894
Merced	237,854	166,498
Madera	63,934	44,754
Fresno	95,577	66,904
Kings	162,656	113,859
Tulare	442,853	309,997
Kern	121,147	84,803
Total Animals	1,406,060	984,242

*Support animal to milking cow ratio of 0.7 is taken from Gaffney (2005)

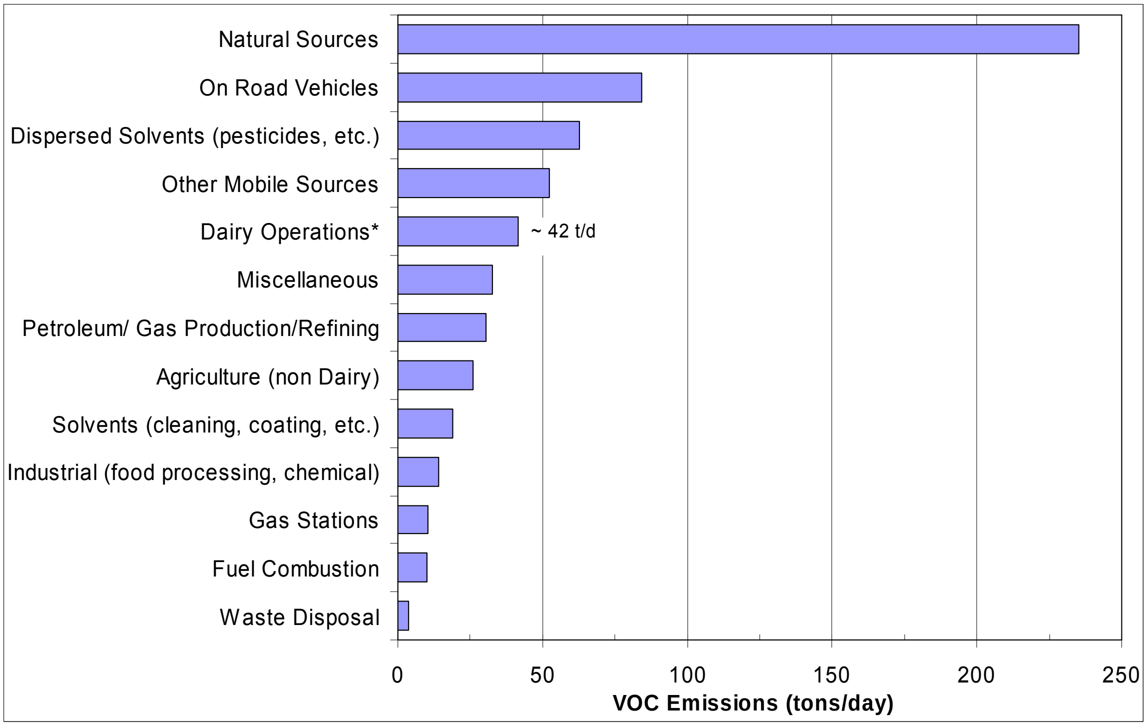
The APCO emission factor (19.3 lb/head/yr) applies to lactating milk cows. The CARB large CAF definition report recommends adjusting the emission factor to account for the whole dairy related herd by multiplying by 0.66. The dairy VOC estimate for the SJVAPCD is therefore;

[(1,406,000 + 984,000) head X (19.3lb/head/yr) X 0.66 whole herd adjust] =30.4 M lbs/yr

or 41.7 tons VOC per day.

Figure 1 displays VOC emissions by source type in the SJV air basin. Values for sources other than dairy operations is from CARB's online emissions inventory for 2005.[26] Total VOC emissions to the air basin are estimated to be 620 tons/day. Human caused emissions account for 62% of the basin's VOC emissions. Of these, dairy operations are the fourth largest contributor, behind on and off-road mobile and dispersed solvents sources, or about 7% of the total (Figures 1 and 2).

[26] CARB emission inventory can be accessed at; http://www.arb.ca.gov/app/emsinv/emssumcat.php



* based on SJVAPCD estimate of 2.4 million dairy cattle (lactating and support)

Figure 1. SJVAPCD VOC emissions by source type

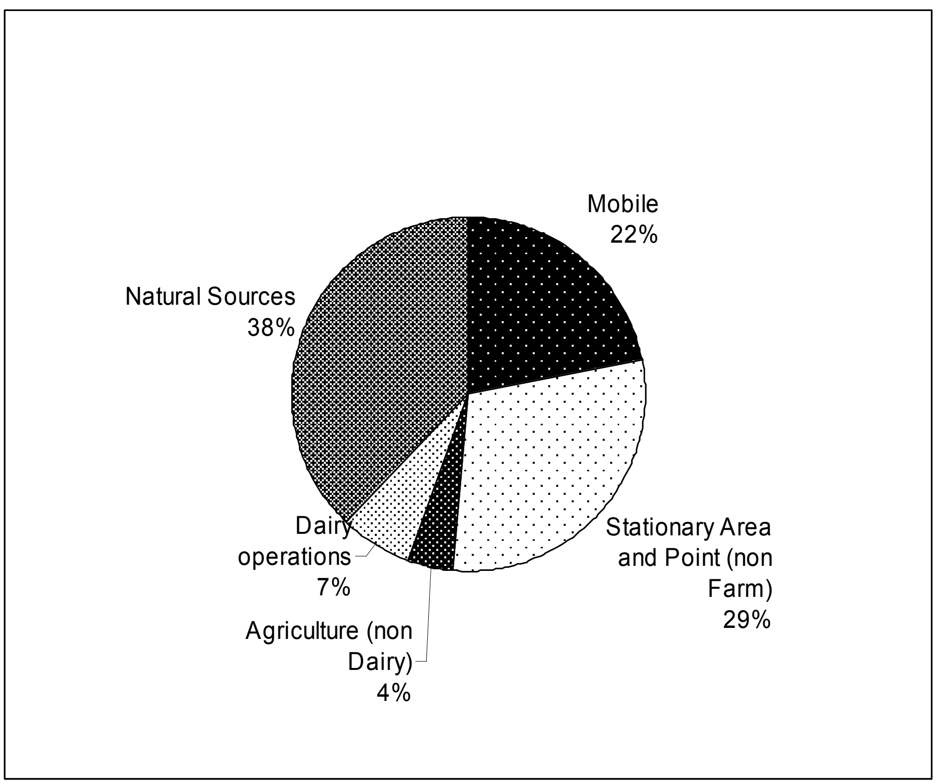


Figure 2. SJVAPCD VOC emission distribution by source (includes natural sources)

Water and Nutrient issues related to Dairies or CAFOs

To be added

Distributed Generation Definition and Emission Requirements

Senate Bill 1298 (Statutes of 2000)[27] set air emissions standards for distributed generation (DG) units within California that are otherwise exempt from existing local air district rules. The Bill defined DG simply as "electric generation located near the place of use." There is no size or technology specified in the definition. A practical definition might be that DG is generation that is intended for consumption at the generation site and/or generation that is connected to the local distribution system and not connected to the transmission system.

The bill directed the California Air Resources Board (CARB) to issue electrical generating technology Best Available Control Technology (BACT) guidelines for the local air districts. The CARB issued a regulation defining a DG certification procedure and setting a time line for emissions requirements.[28] Essentially, the emissions requirements for DG are be equivalent to BACT levels for central station power plants in California at the earliest practical time. The CARB made a best effort estimate in 2001 and predicted the 'earliest practical time' would be January 2007 (See Table 9).[29]

Table 9. DG emission standards beginning January, 2007

Pollutant	Emission Standard (lb/MWh)
NOx	0.07
CO	0.10
VOCs	0.02
PM	Corresponding to natural gas with fuel sulfur content no more than 1 grain/100 scf

As of January, 2006, six devices have been certified by CARB to the 2007 DG standards (five are fuel cell systems and one is a 250 kW microturbine). So far, only devices fueled by natural gas have been certified.[30] Certification for devices fueled by other than natural gas has not progressed due in part to variability of other fuels (i.e., landfill, WWTP digester gas, dairy digester gas, and oil-field waste gases) and it's not decided yet how certification will proceed.[31] The term 'Waste gas' is used by CARB and the industry to refer generally to LFG, WWTP digester gas, and petroleum facility waste gases. SJVAPCD Rule 4702 (Internal Combustion Engines) defines waste gas as "untreated raw

[27] The chaptered version is available at; http://www.arb.ca.gov/energy/dg/sb1298bill20000927chaptered.htm

[28] CARB. Final regulation order- Establish a distributed generation certification program. Available at; http://www.arb.ca.gov/regact/dg01/finreg.pdf

[29] Mike Waugh, (2006). CARB Distributed Generation Working Group meeting, 27 January, 2006. Sacramento, CA

[30] See; http://www.arb.ca.gov/energy/dg/dg.htm (accessed January, 2006)

[31] Waugh, M. (2006). Op. Cit.

gas derived through a natural process" and specifically includes LFG and WWTP digester gas. The Rule 4702 wording seems to exclude other biogases. [32] For the state level certification program, it's not clear if other biogases (such as from dairy or MSW digesters) will be considered waste gas or a fuel gas. Synthesis and producer gas from gasification of solid or liquid fuels are also not currently recognized as a potential fuel for separate DG certification.

Senate Bill 1298 and the resulting CARB regulation apply only to electrical generation systems that are not already covered by existing local air district rules. In general, local air districts have existing standards for reciprocating engines (usually > 50 bhp), smaller gas turbines fueled by waste gas, and solid/liquid/gaseous fuelled boilers (which includes most biomass boilers). The DG emission limits generally apply to fuel cells, microturbines, and reciprocating engines below 50 bhp. Unless Senate Bill 1298 is changed, or individual local air districts enact more stringent BACT requirements for non-exempt devices, small (but > 50 bhp or 37 kW) biomass fueled facilities that use reciprocating engines or solid fuel combustion boilers will not need to meet the central power plant emission levels or the limits in Table 9. It is unclear at this time if gas turbines fueled by biogas or synthesis gas will be required to meet these central station emissions.[33]

[32] See section 3.34 of Rule 4702 at; http://www.valleyair.org/rules/currntrules/Rule_4702_0605.pdf

[33] Note; CARB was supposed to complete an electrical generation technology review by July, 2005 to determine what technologies will likely not meet the central station emission levels. As of early August, 2005, this review has not been issued.

Dairy Power Program and Stationary Engine Emissions

The Recent legislation (SBX1-5, Statutes of 2001) appropriated $10 million for assisting dairies in California with the installation of systems to create electricity from dairy wastes. This led to the establishment of the Dairy Power Production Program (DPPP) by the California Energy Commission to distribute the funds and to encourage the development of biologically based anaerobic digestion and biogasification ("biogas") electricity generation projects in the State. Objectives include developing commercially proven biogas electricity systems to help California dairies offset the purchase of electricity, and providing environmental benefits through reduction of air and ground water pollutants associated with storage and treatment of livestock wastes.

Approximately 14 dairies in California have been awarded grant monies for construction of digesters under the DPPP. This includes seven covered lagoon systems, six plug flow designs and a complete-mix reactor design.

Other than at one facility (Joseph Gallo Cottonwood Dairy, Arbuckle), it is believed that the engines installed in each DPPP project were exempt from air permits because they are considered agricultural operations and were installed before SB 700 took affect. Therefore, it is believed that none of the DPPP engines have had been tested for emissions (except for the Gallo Dairy)[34]. Without air permits, it is likely that many of the engines emit significant levels of NOx which is one reason for environmental groups opposition to use of more state money for dairy digester promotion, extension of net metering rules, and the renewable energy label the power receives.

CARB Engine BACT recommendation

As part of the distributed generation program, CARB has developed a set of recommendations for permitting reciprocating and gas turbine engines.35 Table 10 displays the range of emissions 'achieved in practice' for large reciprocating engines operating on 'waste' gas in California. The emissions are from actual measurement of engines fueled by landfill gas or waste-water treatment plant (WWTP) digester gas. The engines are all spark ignition and employed lean-burn or pre-stratified charge technology (for NOx reduction). The smallest engine in the data set was 260 brake-horsepower (bhp) with a capacity of 195 kWe. The largest was 4,235 bhp with a capacity of 3.1 MWe.

34 The engine at the Gallo Cottonwood Dairy is a 300 kW engine with a 2-way catalyytic converter for emission control. H2S in the fuel gas is scrubbed before the engine to preserver catalyst life. NOx was measured in 2004 at a level of 0.3 g/bhp-hr or one-half the limit. From SJVAPCD Source Test ATC #N-1660-7-0 (12/17/2004)

[35] (2002). "Guidance for the permitting of electrical generation technologies." California Air Resources Board, Sacramento. Available at; http://www.arb.ca.gov/energy/dg/dg.htm

Table 10. Emissions ‘achieved in practice’ from reciprocating engines fueled by biogas in California[36]

	(g/bhp-hr)	(lb/MW-hr)
NO_x	0.31 - 0.6	1 - 1.9
VOC	0.05 - 0.54	0.16 - 1.7
CO	1.5 - 3.9	4.7 - 12.1
PM	NA	NA

Tables 11 and 12 show California Air Resources Board (CARB) recommended best available control technology (BACT) for reciprocating engine and gas turbine (<3 MWe) distributed generation applications respectively. BACT emissions depend on the fuel type (waste gas or fossil fuel) and class of prime mover (turbine or reciprocating). The higher emissions allowed for biogas applications mainly reflect the fact that use of catalytic converters with biogas fuel is difficult and is not in routine practice. The ‘achieved in practice’ emissions (Table 10) fall below the recommended BACT levels except for CO.

Table 11. CARB recommended BACT emissions for reciprocating engines [37]

	'Waste gas' * fired			Fossil fuel fired		
	(g/bhp-hr)	(ppmvd)‡	(lb/MW-hr)	(g/bhp-hr)	(ppmvd)	(lb/MW-hr)
NO_x	0.6	50	1.9	0.15	9	0.5
VOC	0.6	130	1.9	0.15	25	0.5
CO	2.5	300	7.8	0.6	56	1.9
PM	NA	NA	NA	0.02	-	0.06

‡ ppmvd – parts per million by volume dry - values are approximate for reciprocating engines
* See discussion on meaning of ‘waste gas’ above

Table 12. CARB recommended BACT emissions for gas turbines < 3 MWe

	'Waste gas' * fired (any capacity)			Fossil fuel fired		
	(g/bhp-hr)	(ppmvd)	(lb/MW-hr)	(g/bhp-hr)	(ppmvd)	(lb/MW-hr)
NO_x		25	1.25		9	0.5
VOC		-	-		5	0.1
CO		-	-		10	0.4
PM		-	-			

* See discussion on meaning of ‘waste gas’ above

[36] Ibid.
[37] Ibid.

Efficiency Effects on Output Based NOx Emissions

In power systems, emission limits based only on concentration ignore the effect that conversion efficiency has on pollutant emission per unit of output energy (i.e., kWh or MWh). For a given concentration limit, less efficient conversion systems will have significantly larger emission rates (on an equal energy output basis) than more efficient devices (for reciprocating engine generating sets, the smaller capacities are typically less efficient).

Figure 3 shows reciprocating engine-genset NOx emission rate vs. conversion efficiency for a given exhaust concentration. For a system with 45% conversion efficiency and 65 ppm NOx in the exhaust, the NOx emission rate is about 1.9 lb/MWh of electricity produced [38] (this would be a large engine generator, lean-burn with perhaps 2 to 3 MWe capacity meeting the current SJVAPCD Rule 4702 engine limits for non-ag. operation stationary engines [39]). A system operating at 25% conversion efficiency with 65 ppm NOx concentration in the exhaust gas will emit at the rate of about 3.5 lb/MWh. The 25% efficient unit would need to have a NOx exhaust concentration of 35 ppm in order to emit at the same CARB recommended output based rate as the 45% efficient device emitting at 65 ppm (see Figure 4).

In the long term, the concentration-only based emission limits will be a disincentive to improved conversion efficiency. The California Air Resources Board as well as the US EPA and the Regulator Assistance Project recommend output based emissions regulations for power generation systems. [40,41,42]

---

38 Recall that the CARB BACT recommendation is 1.9 lb NOx/MWh for 'waste' gas fueled reciprocating engines.

39 Ag.. operation engines (AO) in Rule 4702 have more lenient NOx limits at 90 or 150 ppmv for rich and lean burn engines respectively. It could be argued that engines fueled by dairy digester gas operated by the farm qualify as AO engines. See; http://www.valleyair.org/rules/currntrules/Rule_4702_0605.pdf

40 (2002). "Guidance for the permitting of electrical generation technologies." California Air Resources Board, Sacramento. Available at; http://www.arb.ca.gov/energy/dg/dg.htm

41 See; http://www.epa.gov/chp/chp_support_tools.htm

42 (2002). "Model regulations for the output of specified air emissions from smaller-scale electric generation resources." The Regulatory Assistance Project, Montpelier, VT. Available at; http://www.raponline.org/Pages/Feature.asp?select=8

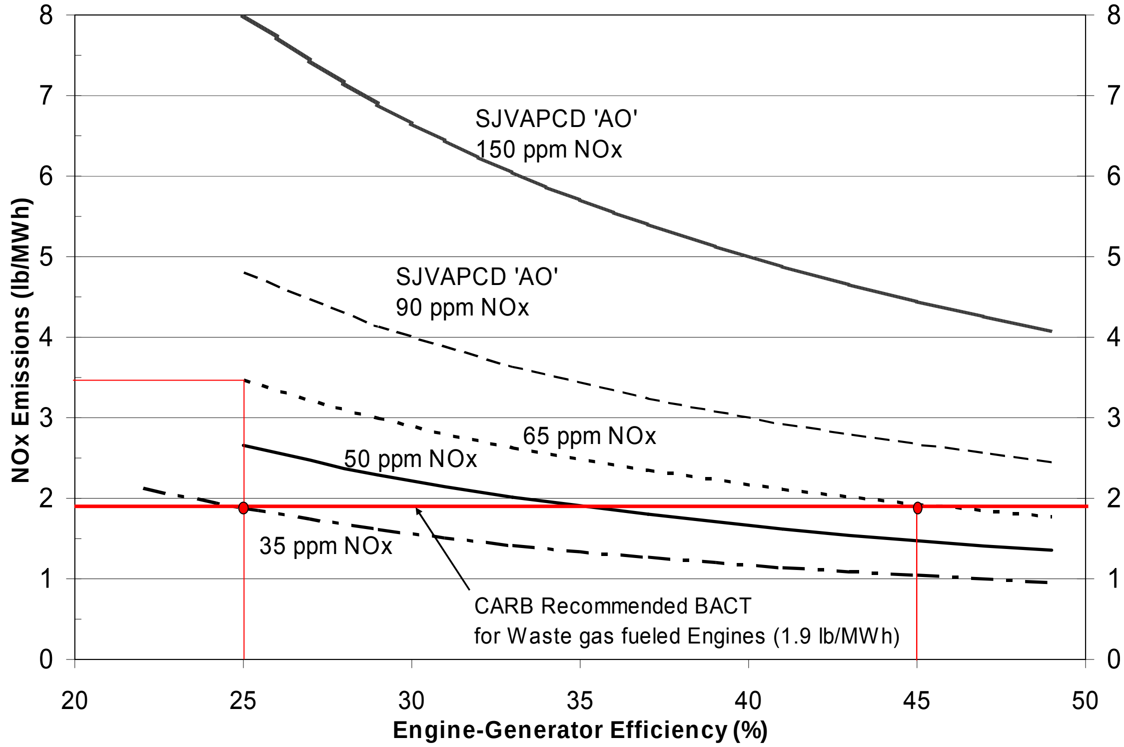


Figure 3. NOx emission rate vs. efficiency for given exhaust concentration (concentrations are at 15% O_2)

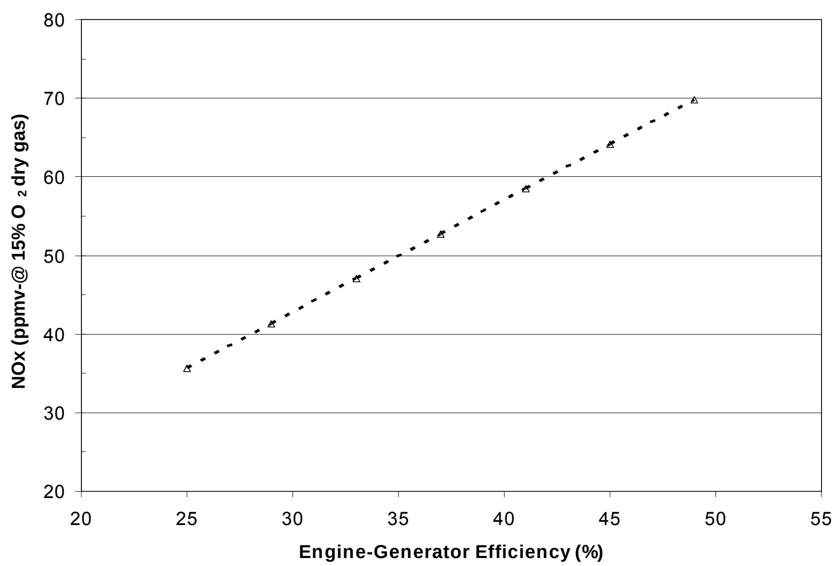


Figure 4. Maximum NOx concentration vs. efficiency for 1.9 lbs/MWh emission rate.

Elimination of agricultural open burning

SB 705 (Statutes of 2003)[43] eliminates agricultural open burning within the San Joaquin Valley Air Pollution Control District in phases beginning in 2005 with a complete ban effective by June, 2010. SB 705, in eliminating burning, also potentially eliminated emission credits applicable to open burning because the emissions are now no longer surplus. Operating permits of many of the existing solid fueled biomass facilities in the SJVAPCD require emission offsets that had been satisfied by consuming agricultural residues that otherwise would be open burned and receiving emission credits. Means to allow facilities to continue to operate without open burning emission credits offsets are now under consideration.[44]

SB 704 (Statutes of 2003)[45] established the Agricultural Biomass to Energy Program with funds up to $6 million redirected from the Renewable Resources Trust Fund. The program was funded only for FY 03-04. SB 704 was a companion bill intended to provide incentives for the alternative use of agricultural biomass no longer eligible for open burning in the San Joaquin Valley (imposed by SB 705). The program provided $10 per green ton subsidy for qualified agricultural biomass converted to energy between July 2003 and June 2004. The subsidy applied only to new agricultural biomass at least 10% above the five year average purchase amounts for the facility. SB 704 also repealed the former Agricultural Biomass-to-Energy Incentive Grant Program administered by the Department of Trade and Commerce through 2002.[46]

Forest Issues

The State Board of Forestry and Fire Protection lists 2.2 million acres as being at extreme risk of wildfire, and more than 15 million acres at very high risk.[47] On average since 1950, more than 250,000 acres of forest and rangeland have been affected by wildfire each year. Over the last five years the average annual area burned exceeds 500,000 acres in approximately 10,000 wildfires. Average annual wildfire-related costs in California for local, state, and federal agencies exceed $900 million per year. Expanding urban development in wildland-urban-interface areas creates increasing risk from fire. Drought and bark beetle infestations have exacerbated these problems in the southern regions of the state, contributing to the devastating fires there in the fall of 2003 that cost 22 lives. Reducing fuel loads in forests greatly reduce these risks, but produce large amounts of biomass needing disposal or utilization.

---

[43] SB 705: http://www.leginfo.ca.gov/pub/03-04/bill/sen/sb_0701-0750/sb_705_bill_20030922_chaptered.html
[44] Jenkins (2005). op. cit.
45 SB 704: http://www.leginfo.ca.gov/pub/03-04/bill/sen/sb_0701-0750/sb_704_bill_20030922_chaptered.html
[46] Jenkins (2005). op. cit.
[47] Zimny, C. Fuel hazard reduction regulation: regulatory methods and rule language alternatives. State Board of Forestry and Fire Protection, Forest Practice Committee, Draft 26 April 2004, Sacramento, CA.

Concerns include environmental impacts from harvesting activities including soil erosion, damage to remaining trees, sediments from roads, and changes in quality of wildlife habitat. Despite apparent benefits, forest management technique remains controversial, especially where larger tree removals are proposed to economically support treatment operations. The federal Healthy Forest Initiative and the Healthy Forest Restoration Act are targeted towards reducing fuel loads and fire risk, with the intent of treating more than 19 million acres in the US by the end of 2006.[48]

Proper management of fuel stocks in forests to reduce catastrophic wildfires can reduce post-fire soil erosion and hydrologic and water-shed impacts.

Air pollution from agricultural and forest burning has long been an issue supporting bioenergy development. Emissions from wildfires have become increasingly so. Emissions of criteria pollutants from agricultural burning, range improvement fires, prescribed forest fires, and wildfires are listed in Table 13. Total emissions from wood-fired boilers in California are shown for comparison. Total tonnages are of course quite different, and emissions vary by season. Wildfire emissions occur primarily during the summer, with 97% of emissions occurring between May and October. Average aggregate annual wildfire emissions for exceed 1.1 million tons per year (Table 14)[49] For criteria pollutants, biomass power plants employing modern circulating fluidized bed boilers realize emission reductions for all species compared with agricultural burning (Table 14) although at present straw and other field crop residues are not used in California power plants because of problems with ash fouling. Emission reductions for wildland fires are similar. Biomass utilization results in substantial emission reductions for CO, hydrocarbons, and particulate matter compared to open fires. Emissions for all criteria pollutants from existing biomass boilers in the state amount to 0.1% of total statewide emissions, whereas agricultural, range, and prescribed forest fires account for 5% and wildfires 10% of total statewide emissions.

Economic and ecosystems losses due to intense wildfires have also stimulated interest in improving forest management and increasing wood utilization. Approximately 1 million housing units in California are within wildland-urban interface or wildland areas.[50] The total estimated replacement value is $107 billion for structures only. Between 1985 and 1994, an estimated 703 homes were lost annually to wildfire in California. The average loss per home burned is estimated at $232,000, and the average total annual loss for California is $163 million.

---

[48] USDA News Release No. 0036.05, 3 February 2005, http://www.healthyforests.gov/

[49] The value of 598,000 tons per year given in the California Fire Plan (California Fire Plan, 2004, http://www.fire.ca.gov/FireEmergencyResponse/FirePlan/appendixc_part1.html) has been updated by the California Air Resources Board.

[50] California Fire Plan, 2004, http://www.fire.ca.gov/FireEmergencyResponse/FirePlan/pdf/fireplan.pdf

Table 13. Air pollutant emissions from agricultural, range, and forest burning, wildfires, and wood-fired boilers, 2004 inventory (10 year annual average tons/day).[51]

	TOG	ROG	CO	NOx	SOx	PM	PM10	PM2.5	Total
Agricultural—Prunings	13.3	7.6	74	3.8	0.01	8.9	8.7	8.2	100
Agricultural—Field	20.5	11.7	142	1.8	0.18	17.2	16.9	16.2	182
Total Agricultural	33.8	19.3	216	5.6	0.19	26.1	25.6	24.37	282
Range Improvement	41.2	23.5	309	3.7		46.1	45.3	43.0	400
Forest Management	49.8	28.4	720	6		54.2	52.1	46.3	830
Total Ag, Range, Forest	124.8	71.2	1,245	15.3	0.19	126.4	123	113.7	1,512
Wildfires	273.0	128.4	2,482	79.38	24.46	362.0	253.4	215.0	3,221
Wood-fired boilers	0.83	0.37	24.49	5.05	0.48	1.12	1.12	1.04	32
Total Statewide	8,720	4,743	16,293	3,270	279	4,079	2,361	995	32,642

TOG=total organic gases, ROG=reactive organic gases, CO=carbon monoxide, NOx=oxides of nitrogen, SOx =oxides of sulfur, PM=total particulate matter, PM10=particulate matter of aerodynamic size class 10 μm and less, PM2.5=particulate matter of aerodynamic size class 2.5 μm and less.

Table 14. Emission factors (lb/MMBtu of fuel energy) for agricultural field crops, tree prunings, and circulating fluidized bed (CFB) boilers in California.[52]

	Average-Field	Average-Wood	Average-Ag	CFB	Ag/CFB
CO	7.96	4.77	6.89	0	2,963
NOx	0.33	0.41	0.36	0.06	6.36
SOx	0.04	0.01	0.03	0.01	2.9
ROG	0.85	0.53	0.74	--*	31,800
PM10	0.78	0.43	0.66	0.01	47.5

*$<2\times10^{-5}$.

[51] California Air Resources Board Emissions Inventory, 2004, http://www.arb.ca.gov/app/emsinv/emssumcat_query.php?F_YR=2004&F_DIV=0&F_SEASON=A&SP=2005&F_AREA=CA#9

[52] Jenkins, B.M. and S.Q. Turn. 1994. Primary atmospheric pollutants from agricultural burning: emission rate determinations from wind tunnel simulations. Paper No. 946008, ASAE, St. Joseph, MI. CFB emission factors derived from Grass, S.W. and B.M. Jenkins. 1994. Biomass fueled fluidized bed combustion: atmospheric emissions, emission control devices and environmental regulations. Biomass and Bioenergy 6(4):243-260.

Municipal Issues

Reducing waste disposal is also an important driver for biomass development. Approximately 1.5 million BDT of urban fuels, mostly wood, are separated from the waste stream and used as biomass fuel for power generation. Assembly bill 939 (1989), mandated a 50% solid waste diversion rate by 2000. This rate has not yet been achieved (Figure 5), and after reaching a peak of 48% in 2002 declined to 47% in 2003. The diversion accomplished to date has extended the projected lifetime of existing landfills, but total disposal has not decreased over the last ten years. Instead, increasing diversion is associated with increasing waste generation arising from state population growth and increasing per capita waste generation.[53]

An assessment conducted by the California Integrated Waste Management Board (CIWMB) in 2002 indicates a remaining 35 year landfill capacity.[54] The 43 permitted urban landfills in the state have a combined remaining lifetime of 12 years, while 132 non-urban sites have capacity for 66 years, including the Eagle Mountain and Mesquite landfills, which are not currently operating. If the latter two are excluded, non-urban fill capacity extends 22 years. The 17 landfills in the Los Angeles area have a lifetime of 9 years. Within the 2017 timeframe of the RPS, waste jurisdictions will need to make decisions regarding future waste disposal. These conditions have led the CIWMB[55] and a number of jurisdictions to investigate alternatives, including waste conversion. A key limitation in this regard is the current technology designations concerning waste transformation and conversion. Lack of diversion credit for many technologies creates a considerable economic disadvantage as jurisdictions are unwilling to support development that does not result in compliance under AB 939. The issue of conversion is also subject to contentious public debate and particular opposition to incineration and other thermochemical technologies. Despite these concerns, the resource value of biomass in solid waste constitutes a considerable potential for economic development and environmental improvement.

[53] Williams, R.B. and B.M. Jenkins. 2004. Management and conversion of organic waste and biomass in California. In: Van Swaaij, W.P.M., T. Fjallstrom, P. Helm, and A Grassi (eds), Second World Biomass Conference: Biomass for Energy, Industry, and Climate Protection, ETA-Florence and WIP-Munich, Vol. II:2374-2377

[54] CIWMB, 2002, Remaining landfill capacity in California, http://www.ciwmb.ca.gov/agendas/mtgdocs/2002/02/00007306.doc

[55] http://www.ciwmb.ca.gov/Organics/Conversion/

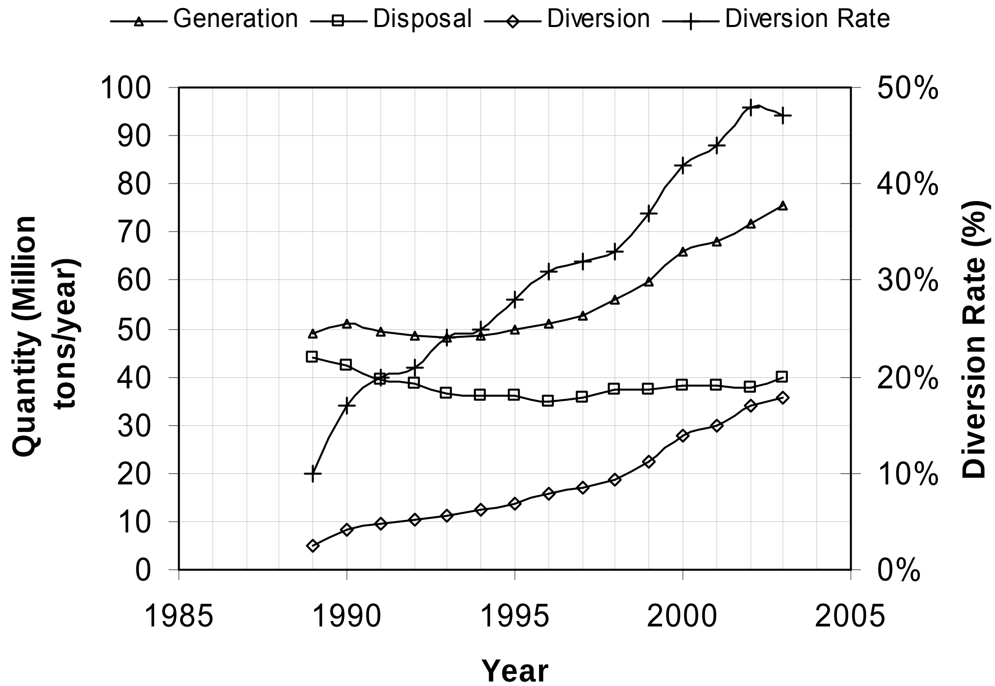


Figure 5. Solid waste generation, disposal, and diversion in California, 1989-2003.[56]

Some environmental performance aspects of existing waste management practices are well known while others are not (for example, the long-term consequences of dry-tomb landfill technology are uncertain). Established modern solid waste combustion with energy recovery facilities have well documented environmental performance

The current practice of landfilling half of the solid waste stream in California carries environmental consequences that must be addressed, including air emissions, water quality, hazardous waste containment, and nuisance factors

For MSW, conventional disposal is by landfill with some capture of the generated methane. Older landfills did not employ engineered low permeability liners for reducing leachate transport. Newer landfills are designed to restrict leachate leakage both during filling and after the landfill has reached capacity and ceased receiving material, but it is generally accepted that these systems will eventually fail with leachate intrusion into ground water. Short of monitoring leachate from closed landfills and then mining them to recover and treat or stabilize the material before groundwater contamination occurs, the only other means of ensuring stable waste disposal is to treat the material before landfilling or avoid landfilling altogether. Burning or biochemically stabilizing (composting or anaerobic digestion) waste are treatment options that are now required in Europe, and only MSW residues can be landfilled

[56] http://www.ciwmb.ca.gov/LGCentral/Rates/Diversion/RateTable.htm

The methane emissions from landfills are particularly important, since methane is a more potent greenhouse gas than carbon dioxide and since landfills represent the second largest source category of anthropogenic methane emissions behind the energy industry (see Table 15).

Methane emissions from US landfills for 1990 to 2002 are presented on a total mass basis in Table 15. Total landfill methane production increased over the period, but corresponding increases in landfill gas recovery led to about a 10% reduction in net methane emissions to the atmosphere. A majority of the landfill gas produced by active landfills in the state is converted to electricity, and comparisons of electrical capacities provide a good comparison of the level of control of methane emissions from landfills in the state. For the state, landfill gas that is either currently used for electricity production, is planned for electricity use, or is flared, represents approximately 305 MWe, while uncontrolled or vented landfills have a capacity of 31 MWe.[57]

Table 15. CH_4 Emissions from US landfills (Gg) [58]

Activity	1990	1996	1997	1998	1999	2000	2001	2002
MSW Landfills	11,599	13,520	13,802	14,047	14,385	14,659	14,954	15,221
Industrial Landfills	812	946	966	983	1,007	1,026	1,047	1,065
Recovered								
Gas-to-Energy	(824)	(1,360)	(1,618)	(1,938)	(2,177)	(2,376)	(2,630)	(2,748)
Flared	(478)	(2,059)	(2,390)	(2,692)	(2,750)	(2,764)	(3,146)	(3,325)
Oxidized▲	(1,111)	(1,105)	(1,076)	(1,040)	(1,047)	(1,055)	(1,022)	(1,021)
Total	9,998	9,942	9,685	9,360	9,419	9,491	9,202	9,192

Note: Totals may not sum due to independent rounding. ▲ oxidized in soil covering

Refer to the companion draft white paper titled "Biomass in Solid Waste in California: Utilization and Policy Alternatives" for a more complete discussion of environmental issues related to MSW in California

[57] Hackett, C. et. al.(2004), Evaluation of Conversion Technologies Processes and Products. Draft Final Report. University of California.

[58] United States Environmental Protection Agency (2004) "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2002. EPA report # EPA 430-R-04-003. US EPA, Washington, DC.

Valuing the Externalities or Life-Cycle Costing

It is generally accepted that resource use by society impacts the environment; impacts increase with population and standard of living. Paying full cost for products and services by the user or consumer at the point of purchase is a basic concept in economic theory for efficient allocation of resources (i.e., the market). Therefore, the idea of allocating full life-cycle costs to the product is not revolutionary. For renewable energy, it is perceived that there are positive environmental and social attributes that, if their values could be agreed upon, could be used to help finance the costs of alternative energy systems that otherwise could not compete with conventional sources. With respect to attempts to value the externalities associated with California biomass power, there is one known published study that systematically addresses the topic.[59]

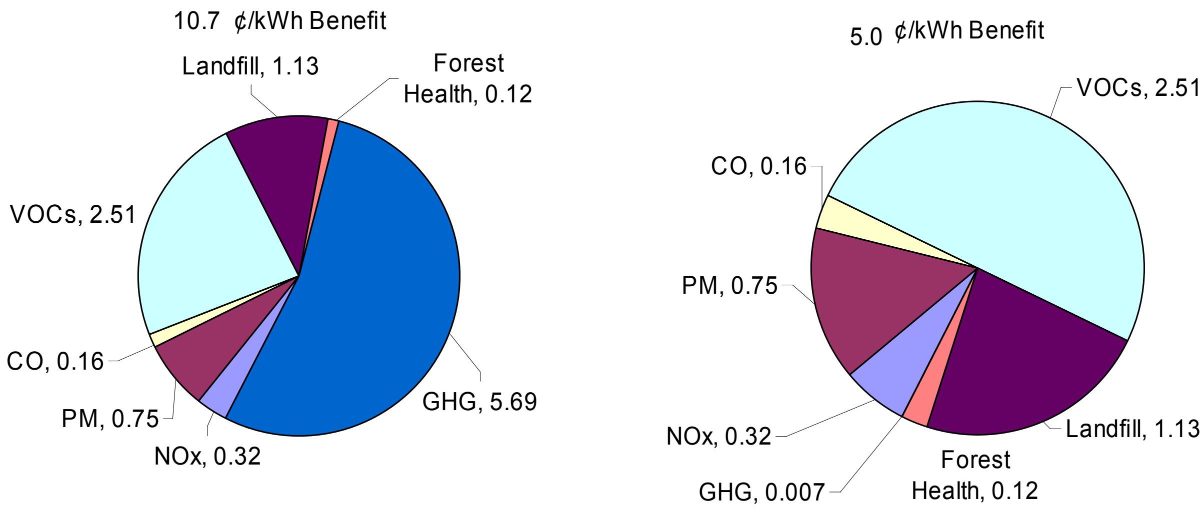
The study by Morris (2000) included an estimate for value of external benefits from biopower production in California. Economic values were assigned for emission factors and costs due to non-energy use or disposal (i.e., open burning, composting, landfill, forest floor spreading, etc.) for woody forest product wastes and agricultural and urban residues and then used to compare against emissions from biopower using the same amount of biomass or fuel. The net benefit being the difference in emission impact values for the energy vs. non-energy use of the biomass. The model calculated 10.7 ¢/kWh of external value provided by biopower. More than half this amount is due to the GHG reduction benefit which was estimated at 5.69 ¢/kWh (See Figure 6 A).

The large GHG reduction benefit results from the assumption that landfilling of 48% of the fuel would be the alternative (85% of the urban wood waste fuel and 60% of mill wastes are assumed to be landfilled in the alternative scenario). The LFG model used by Morris appears to allow 80% of the carbon in the landfilled wood to evolve as gas (CH4 and CO2) over an 80 -100 year period (i.e., 20% of the carbon in the wood remains sequestered). This is a very optimistic assumption for wood degradation in a landfill which is claimed by others to be an efficient means of carbon sequestration.[60] Literature values for expected wood degradation in landfills estimate that only 3 - 4% of the wood particle carbon is emitted as LFG over the long term (96-97% of the carbon is essentially sequestered).[61] When allowing only 4% of landfilled wood carbon to be emitted in Morris' model, the GHG reduction due to biopower is reduced by 88%, netting less than 1 ¢/kWh GHG benefit, all else being equal (Figure 6 B).

[59] Morris, G. (2000). "Biomass Energy Production in California: The case for a biomass policy initiative." NREL/SR-570-28805, NREL/SR-570-28805, Golden, CO.

[60] Skog, K. E., and Nicholson, G. A. (1998). "Carbon cycling through wood products: The role of wood and paper products in carbon sequestration." Forest Products Journal, 48(7-8), 75-83.

[61] Micales, J. A., and Skog, K. E. (1997). "The decomposition of forest products in landfills." International Biodeterioration & Biodegradation, 39(2-3), 145-158.



A (Morris, 2000)

B
(adjusted using different LFG assumptions)

Figure 6. Distribution of biopower external benefit from Morris (2000) [A], and with LFG from wood adjusted to literature values [B]

Brief Review from Europe

Saez (1998)[62] compared externalities for purpose grown biomass power vs. power from coal in Spain. The net CO2 emissions for the biomass cycle was assumed zero while for each kWh of biopower produced, 2.23 lbs. (1.015 kg) of CO2 from coal power was offset. Using CO2 emission reduction values of between, \$0.80 - \$16 t^{-1}, the external value of offsetting GHG in his analysis was between \$0.001 and \$0.02 kWh^{-1}.

Freppaz (2003)[63] modeled costs and emissions tradeoffs for using forest wood to replace 14% of thermal and electric energy in a Spanish community (offsetting an energy supply composed of oil, coal and natural gas). The GHG reduction from the biomass amounted to about 0.5 lb/ kWh (0.23 kg kWh-1) (heat or electricity). Freppaz did not model external costs.

Soderholm and Sundqvist (2003)[64] in a series of reviews, present results from more than 60 studies from the late 1980s through the 1990s. Figure 7 shows the ranges of external cost estimates for power generation arranged by energy source. The figure uses a logarithmic scale to present costs/kWh because the ranges are so large (i.e., external cost

---

[62] Saez, R. M., Linares, P., and Leal, J. (1998). "Assessment of the externalities of biomass energy, and a comparison of its full costs with coal." *Biomass & Bioenergy*, 14(5-6), 469-478.

[63] Freppaz, D., Minciardi, R., Robba, M., Rovatti, M., Sacile, R., and Taramasso, A. (2003). "Optimizing forest biomass exploitation for energy supply at a regional level." *Biomass & Bioenergy*, 26(1), 15-25.

[64] Soderholm, P., and Sundqvist, T. (2003). "Pricing environmental externalities in the power sector: ethical limits and implications for social choice." *Ecological Economics*, 46(3), 333-350

of coal power in the reviewed studies ranged from < 1¢/kWh to more than $10/kWh with the median at about 9¢/kWh). Biomass external costs ranged from less than zero to about 20 ¢/kWh, with the median around 5 ¢/kWh (external cost, not a benefit). Comparing to other fuels, the biomass external cost median is lower than coal or oil (implies lower net external costs for biomass). In this set of studies, the external cost medians for natural gas and nuclear are lower than for biomass. Assumptions vary widely for many of the studies so these so comparisons should be done with caution. The point is that valuing externalities is difficult and highly dependent on assumptions and assessment approach.

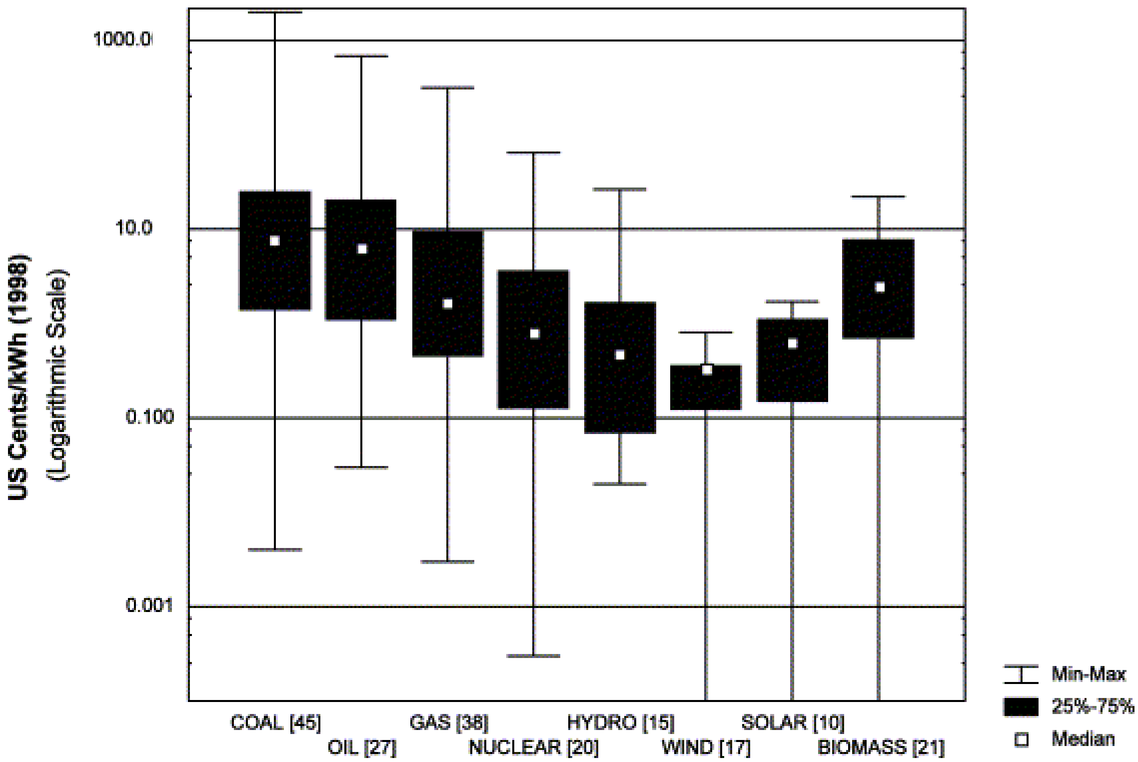


Figure 7. Range of external cost estimates in power generation (Sources [65], [66], [67])

In the early 1990's, Europe's "Fifth Environmental Action Program – Towards Sustainability" required that policy decisions take into account benefits and costs of action (or in-action) based on best available information. A multi-country collaboration that included over 50 teams from all EU-15 countries as well as initial participation by the US began in 1991 with the purpose of developing an accounting framework for

65 Ibid.

[66] Sundqvist, T., 2002. Power Generation Choice in the Presence of Environmental Externalities, Ph.D. Dissertation, Division of Economics, Luleå University of Technology, Sweden.

[67] Sundqvist T. and Söderholm P., 2002. Valuing the environmental impacts of electricity generation: a critical survey. *Journal of Energy Literature* **8** pp. 3–41.

assessing external costs of energy technologies. The report and methodology was delivered in 1995 and was called ExternE.[68]

A primary objective of ExternE program in Europe was to quantify various social costs associated with production and consumption of electricity from various fuel sources and to give science-based recommendations for pricing externalities. Current EU 'Community Guidelines for state aid for environmental policy' recommends a 5 Euro-cent/kWh (~ 6 US cent/kWh) adder for renewable electricity to compensate for external value.[69] Because of time horizon limitations in the model and uncertainties in external cost data, especially for large impact categories such as acidification or global warming, actual values for externalities are uncertain. Policy makers in the EU are responding to current environmental pressure without waiting for refinement of the cost data that would identify cost-optimal level of intervention (i.e., EU policy makers are using a precautionary approach).[70]

RECs and Tradeable RECs

Absent rigorous or agreed upon value adders for externalities, carbon credits, carbon taxes, or tradeable renewable energy credits may stand in or bridge until life-cycle costing is in place. Renewable energy credits (RECs) sometimes referred to 'unbundled' RECs are the renewable energy attributes of the power produced from the renewable energy source. Unbundled and tradable RECs allow the electricity to enter the grid as generic power and used by any load the grid operator (or utility) sees fit. The renewable attributes, RECS, are sold separately by the producer giving the purchaser rights to claim renewable energy use (i.e., the energy and the REC go to different buyers). This can effectively reduce wheeling charges and losses associated with transmitting unbundled renewable energy long distances.[71]

Currently, California RPS regulations do not allow tradeable RECs nor do they allow out of state renewable generation to qualify except if it generated near the border and connects to the western regional transmission system within California and delivers the electricity to California. Concerns related to RECs include the potential for double counting RECs (or complicating the tracking system) and reducing the need and/or incentive for in-state renewable generation. California could establish REC trading rules that allow only renewable energy generated in-state to be eligible or even assign fractional REC units to imported electricity.

---

[68] European Commission, 1995. Externalities of fuel cycles. European Commission, DG XII, Science, Research and Development, JOULE, ExternE Externalities of Energy, Vol. 2, Methodology. European Commission, Luxembourg, EUR 16521

[69] Community guidelines on state aid for environmental protection, OJ C 37, 3.2.2001. http://europa.eu.int/eur-lex/pri/en/oj/dat/2001/c_037/c_03720010203en00030015.pdf

[70] Krewitt, W. (2002). "External costs of energy--do the answers match the questions?: Looking back at 10 years of ExternE." *Energy Policy*, 30(10), 839-848.

[71] Pollak, D. (2005). "Tradable Renewable Energy Credits and the California Renewable Portfolio Standard." California Research Bureau - California State Library, Sacramento.

There are some 18 states plus the District of Columbia that have an RPS program and 14 of these have, or plan to implement, a REC trading program. Table 16 shows RPS eligibility restrictions (or delivery requirements) for states with RPS programs. Table 17 shows the range of prices fo RECs that were traded in some of the US markets in 2004. They ranged from less than 0.1 ¢/kWh to 5 ¢/kWh. The prices essentially were determined by REC supply and demand in the local markets.

Table 16. RPS eligibility restrictions in other states or regions (source [72])

Strict In-State Requirement	In-State Interconnection or Delivery Requirement	Unbundled from within Region OK with Energy Delivery to Region	Unbundled from Out of State Possible W/O Energy Delivery
HI			
MN			
AZ	AZ		
	CA		
	CO		
	NV		
	NM		
	NY		
	TX		
	WI		
		MA	
		ME	
		NJ	
		PA	
		RI	
		CT	CT
			DC
			MD

Table 17. .REC Prices in Selected Compliance Markets (Source [73])

State	2004 REC Price Range ($/MWh)	Noncompliance Penalty ($/MWh)
Maine	0.65 - 0.70	N/A
Texas	11 – 15	50
Connecticut	35 – 48	55
New Jersey	4.25 – 7.50	50
Massachusetts	40 - 49	51

[72] Ibid.
[73] Ibid.

Biofuels

Liquid biofuels represent a means to reduce reliance on petroleum feedstocks (the energy security argument) as well as reduce or moderate carbon emissions from the transportation sector (the global warming/climate change argument). There are potential social and economic benefits from jobs that would be created by a California biofuels industry.

Biofuels generally include ethanol and biodiesel. Ethanol is fermented from sugars from sugar beet or cane or derived from hydrolyzed starch (e.g., corn) or cellulose (e.g., wood, straw, stovers, paper, etc.). The lignocellulosic ethanol route is not yet commercial. Biodiesel usually refers to methyl or ethyl esters derived from vegetable oils or animal fats (soy and canola or rape oils are the primary sources used in commercial biodiesel production. Used cooking/fry oils can also be made into biodiesel.

Advanced or 'second generation' biofuels include those derived from solid biomass via a gasification-syngas-liquid route (aka Biomass to Liquids or BTL). Fischer-Tropsch diesel, dimethyl ether and methanol are possible through BTL processes. Lignocellulosic ethanol can be considered a 'second generation' biofuel. In energy scenarios that constrain fossil-carbon emissions, theses second generation biofuels are preferred because their lifecycle CO_2 emissions performance is much better than conventional biofuels (CO2 emission reduction compare to replaced fossil fuels of up to 90% versus the 30-50% of conventional biofuels). If BTL were developed to commercial scale, in the near term (2010) it would be competitive with oil price range of 60-100 $/barrel. In the 'far future'(2020-2030), second generation biofuels could be competitive at $40/barrel oil prices.[74]

Net Energy and GHG advantages of Ethanol

The degree to which ethanol fuel use in the transportation sector influences or reduces greenhouse gas (GHG) emissions depends on the ethanol production process and feed source. The amount of fossil energy required to produce a gallon of ethanol from corn grain in commercial facilities has decreased significantly due to improved corn yields and increased ethanol plant efficiencies.[75] There is continuing debate as to whether the net energy balance of corn derived ethanol production is positive or negative. Recent papers argue that lifecycle fossil energy inputs to corn ethanol production are larger than the useable energy in the fuel product.[76] [77] [78] Other than Pimentel and Patzek, there is general

---

[74] Wakker, A., Egging, R., van Thuijl, E., van Tilburg, X., Deurwaarder, E., de Lange, T., Berndes, G., and Hansson, J. (2005). "Biofuel and Bioenergy implementation scenarios. Final report of VIEWLS WP5, modeling studies." *ECN-RX--05-141*, Energy Research Center of the Netherlands. Available at; http://www.ecn.nl/library/reports/2005/rx05141.html

[75] Wang, M. (2005). "Updated energy and greenhouse gas emission results for fuel ethanol." *15th Intl. Symp. on Alcohol Fuels*, San Diego.

[76] Patzek, T. W. (2004). "Thermodynamics of the corn-ethanol biofuel cycle." *Critical Reviews in Plant Sciences*, 23(6), 519-567.

consensus in the literature that corn ethanol production yields positive net energy (though small (see Table 18). Others point out that the Pimentel and/or Patzek analyses utilize different boundary assumptions than are generally used in 'well to wheels' or 'well to tank' lifecycle analyses, and/or use outdate corn and ethanol productivity assumptions.[79 80]

The net energy ratios (ER, ratio of energy in product to fossil energy used in production) for ethanol from grain sources (corn and wheat) are generally greater than 1 (to about 1.8). Sugar cane ethanol has an ER of about 3.7 reflecting higher available sugar for fermentation per unit of fossil input. The net ER for gasoline is approximately 0.85, reflecting energy required for oil extraction, transport, and refining.

Starch and sugar based ethanol feedstocks and processes can not utilize a large proportion of the plant biomass (the lignocellulosic fraction) directly for ethanol production. Sugar mills generally use the bagasse (cane residue after sugar extraction) for boiler fuel, which improves energy extraction but US corn ethanol facilities generally do not use any of the remaining corn plant for fuel in the facility (distiller's grains are used for animal feed).

Ethanol processes that utilize cellulosic feedstocks yield much more ethanol on an energy input basis (Table 18 and Figure 8). There is ongoing research into developing improved enzymes that can hydrolyze cellulosic biomass for ethanol production.

Table 18. Net energy values for ethanol from different feedstocks

Feedstock	Net Energy Ratio (MJ/ fossil MJ)	Net Energy Btu/gal	Fossil use Btu/gal	Reference
Corn	0.78	-15,019	99,119	9
Corn	0.86	-14,213	98,313	9 (w/ energy content corrections)
Corn	1.2	13095	71,005	1 - 3
Corn	1.8	36154	47,946	1 - 3
Wheat (grain)	1.2	14,017	70,083	5
Wheat (grain)	1.6	31,538	52,563	5
Casava	1.5	28,465	55,635	4
Sugar Cane (Brazil)	3.7	61,370	22,730	6
Cellulosic	5	67,280	16,820	8
Cellulosic	8	73,588	10,513	7

References:

1) Shapouri H, Duffield JA, Wang M. The energy balance of corn ethanol: an update. Agricultural Economic Report 813, US Department of Agriculture, Washington, DC, USA, 2002.
2) Kim, S., and Dale, B. E. (2005). "Environmental aspects of ethanol derived from no-tilled corn grain: nonrenewable energy consumption and greenhouse gas emissions." Biomass & Bioenergy, 28(5), 475-489.
3) Wang, M. "Updated energy and greenhouse gas emission results for fuel ethanol." 15th Intl. Symp. on Alcohol Fuels, San Diego.
4) Hu, Z. Y., Fang, F., Ben, D. F., Pu, G. Q., and Wang, C. T. (2004). "Net energy, CO2 emission, and life-cycle cost assessment of cassava-based ethanol as an alternative automotive fuel in China." Applied Energy, 78(3), 247-256.
5) Stumborg, M. A., Zentner, R. P., and Coxworth, E. (1996). "Energy balance of wheat conversion to ethanol." Bioenergy '96: Partnerships to Develop and Apply Biomass Technologies, Tennessee Valley Authority, Nashville.
6) Dias de Oliveira, M. E., Vaughan, B. E., and Rykiel, E. J. J. (2005). "Ethanol as Fuel: Energy, Carbon Dioxide Balances, and Ecological Footprint." BioScience, 55(7), 593-602.
7) Wang presentations
8) Sheehan - NREL
9) Pimentel, D. (2003). "Ethanol Fuels: Energy balance, economics, and environmental impacts are negative." Natural Resources Research, 12(2), 127-134.

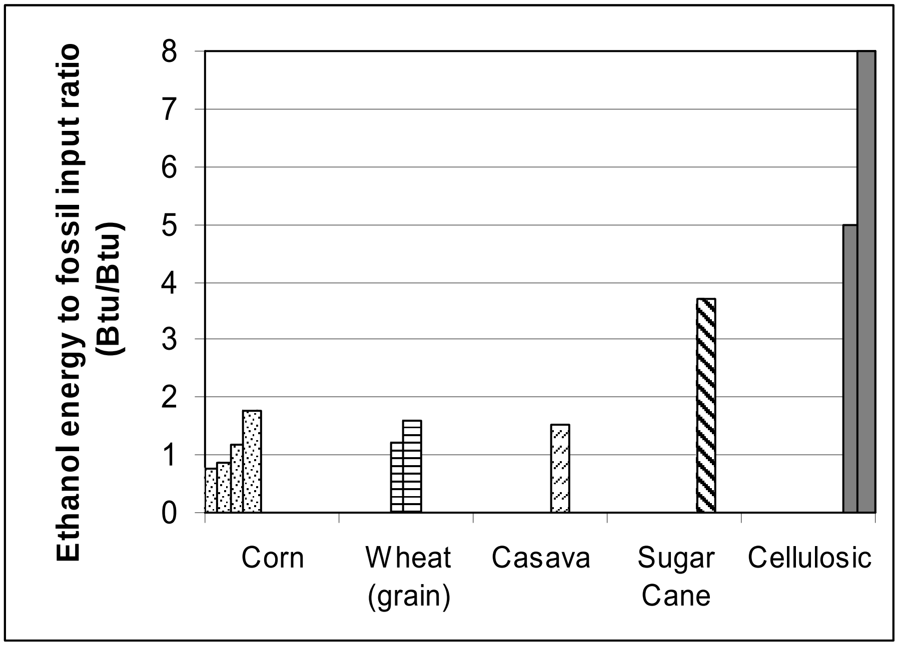


Figure 8. Net energy ratios for ethanol from several feedstocks

Wang (2005) presents results from 'well to wheels' lifecycle analysis of light-duty vehicles fueled with ethanol from corn and cellulose feedstocks at two different blend concentrations (E10 and E85).[81] Wang uses the Greenhouse gases, Regulated Emissions, and Energy use in Transportation (GREET) model developed at Argonne National Lab.[82] Figure 9 displays GREET model results for lifecycle GHG reductions when ethanol is used to displace gasoline. The figure shows percent GHG reduction compared to gasoline-only fuels. E10 using corn-derived ethanol marginally reduces net GHG emissions. Corn derived E85 reduces GHG emissions by about 20%. Cellulosic derived E85 exhibits 55-65% lifecycle GHG reductions. [83] All else being equal, cellulose derived ethanol is some three times more effective at reducing GHG emissions compared to corn ethanol.

[81] Wang, M. (2005) Op. cit.

[82] The GREET model is downloadable from this site; http://www.transportation.anl.gov/software/

[83] Spatari, S., Zhang, Y., and MacLean, H. L. (2005). "Life Cycle Assessment of Switchgrass- and Corn Stover-Derived Ethanol-Fueled Automobiles." *Environ. Sci. Technol.*, 39(24), 9750-9758.

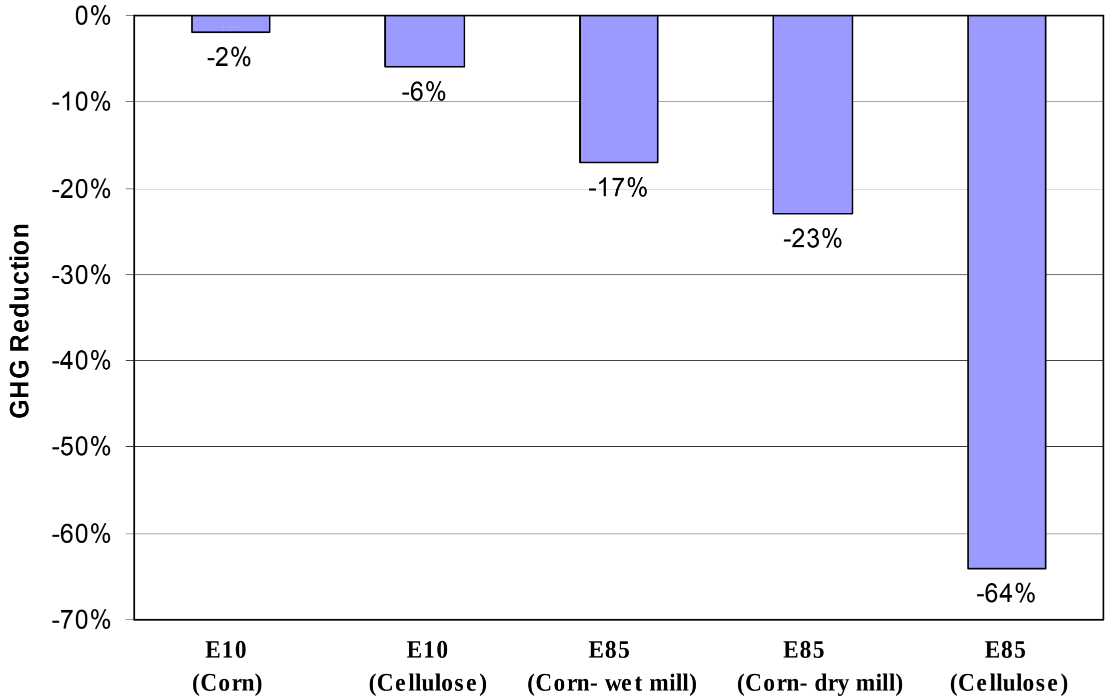


Figure 9. Reductions in per-mile GHG emissions when ethanol blend displaces gasoline [84]

Net Energy and GHG advantages of Biodiesel

Transesterification of vegetable or animal oils (triglycerides) using methanol is depicted in the following equation:

$$\underset{\text{(Triglyceride)}}{C_3H_5(OOCR)_3} + \underset{\text{(Methanol)}}{3CH_3OH} \xrightarrow{CH_3ONa \text{ (Sodium Methoxide)}} \underset{\text{(Methyl Ester)}}{3RCOOCH_3} + \underset{\text{(Glycerine)}}{C_3H_5(OH)_3}$$

The net energy ratios of oil crop biodiesels are higher than that for corn ethanol approaching the energy ratio for the sugar cane ethanol system (Table 19) .

[84] Wang, M. (2005) Op. cit.

Table 19. Net energy values for oils and biodiesels

Feedstock	Net Energy Ratio (MJ/ fossil MJ)	Net Energy Btu/gal	Fossil use Btu/gal	Reference
Petroleum Diesel	0.88	-18,914	157,614	138,700 (Btu/gal)
Rape Methyl Ester (RME)	1.9	65,700	73,000	1
Rape Ethyl Ester (REE)	2.2	75,655	63,045	1
Soy Methyl Ester (SEE)	3.2	95,356	43,344	2
Rapeseed oil (straight)	3.3	96,670	42,030	1

References;

1) Janulis, P. (2004). "Reduction of energy consumption in biodiesel fuel life cycle." *Renewable Energy*, 29(6), 861-871.

2) Sheehan, J., Camobreco, V., Duffield, J., Graboski, M. S., and Shapouri, H. (1998). "Life Cycle Inventory of Biodiesel and Petroleum Diesel for Use in an Urban Bus." *NREL/SR-580-24089*, Final Report. National Renewable Energy Laboratory.

Lifecycle CO2 emissions from biodiesel in trucks and transit buses have been modeled extensively. [85] [86] [87] [88] [89] In general, lifecycle GHG emissions reductions when biodiesel replaces petroleum diesel are approximately 1.5%, 15%, and 67% for vegetable oil methyl ester B2, B20, and B100 respectively. GHG reduction using animal fat derived B20 and B100 are 19% and 96% respectively (See Table 20 and Figure 10). The larger GHG reduction from animal fat biodiesel is due to the fact that fossil energy embedded in the animal fat (or waste cooking oils) is not attributed to the biodiesel production chain (it's attributed to the food production that created the fat/oil waste).

[85] Sheehan, J., Camobreco, V., Duffield, J., Graboski, M. S., and Shapouri, H. (1998). "Life Cycle Inventory of Biodiesel and Petroleum Diesel for Use in an Urban Bus." NREL/SR-580-24089, Final Report. National Renewable Energy Laboratory.

[86] Beer, T., Grant, T., Brown, R., Edwards, J., Nelson, P., Watson, H., and Williams, D. (2000). "Life-Cycle Emissions Analysis of Alternative Fuels for Heavy Vehicles- Stage 1." CSIRO Atmospheric Research Report C/0411/1.1/F2, Australian Greenhouse Office.

[87] (2002). "Assessment of Biodiesel and Ethanol Diesel Blends, GHG Emissions, Exhaust Emissions, and Policy Issues." Levelton Engineering & (S&T)2 Consultants for Natural Resources Canada.

[88] Beer, T., Grant, T., Williams, D., and Watson, H. (2002). "Fuel-cycle greenhouse gas emissions from alternative fuels in Australian heavy vehicles." Atmospheric Environment, 36(4), 753-763.

[89] MacLean, H. L., Lave, L. B., Lankey, R., and Joshi, S. (2000). "A life-cycle comparison of alternative automobile fuels." Journal of the Air & Waste Management Association, 50(10), 1769-1779.

Table 20. Lifecycle CO_2 emissions from biodiesel fuel systems

Fuel	Life Cycle Fossil CO2	Units	Vehicle Type	Fuel efficiency assumption	% Fossil CO2 change from Petroleum Diesel	Source
Petroleum Diesel	633.3	(g CO2/bhp-h)	Transit Bus	7.5 MJ/bhp-hr	-	1
B20 (Soyoil/methanol)	534.1	(g CO2/bhp-h)	↓	↓	-16	1
B100 (Soyoil/methanol)	136.5	(g CO2/bhp-h)	↓	↓	-78	1
Petroleum Diesel	1640	g/km	Transit Bus	22 MJ/km	-	2
B20 (Soybean/methanol)	1350	g/km	↓	↓	-18	↓
B100 (Soybean/methanol)	708	g/km	↓	↓	-57	↓
E95 (wood)	817	"	↓	↓	-50	↓
E95 (straw)	678	"	↓	↓	-59	↓
Petroleum Diesel	2224	g/mile	Not specified	1700 g/mile tailpipe CO2 emissions		3
B2 (Canola)	2194	↓	↓	↓	-1.3	↓
B2 (Soyoil)	2194	↓	↓	↓	-1.3	↓
B2 (Animal Fat)	2182	↓	↓	↓	-1.9	↓
B2 Average	**2190**	↓	↓	↓	**-1.5**	↓
B20 (Canola)	1936	↓	↓	↓	-12.9	↓
B20 (Soyoil)	1939	↓	↓	↓	-12.8	↓
B20 (Animal Fat)	1811	↓	↓	↓	-18.6	↓
B20 Average	**1895**	↓	↓	↓	**-14.8**	↓
B100 (Canola)	733	↓	↓	↓	-67.0	↓
B100 (Soyoil)	748	↓	↓	↓	-66.4	↓
B100 (Animal Fat)	86	↓	↓	↓	-96.1	↓
B100 Average	**522**		↓	↓	**-76.5**	

References:

1).Sheehan, J., Camobreco, V., Duffield, J., Graboski, M. S., and Shapouri, H. (1998). "Life Cycle Inventory of Biodiesel and Petroleum Diesel for Use in an Urban Bus." NREL/SR-580-24089, Final Report. National Renewable Energy Laboratory.

2).Beer, T., Grant, T., Brown, R., Edwards, J., Nelson, P., Watson, H., and Williams, D. (2000). "Life-Cycle Emissions Analysis of Alternative Fuels for Heavy Vehicles- Stage 1." CSIRO Atmospheric Research Report C/0411/1.1/F2, Australian Greenhouse Office.

3) (2002). "Assessment of Biodiesel and Ethanol Diesel Blends, GHG Emissions, Exhaust Emissions, and Policy Issues." Levelton Engineering & (S&T)2 Consultants for Natural Resources Canada.

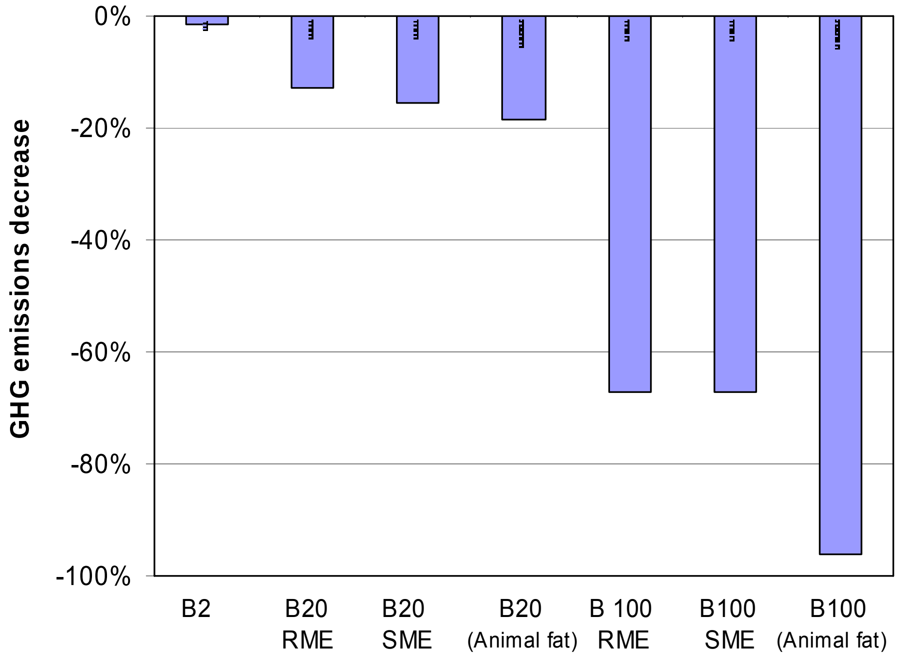


Figure 10. Reductions in lifecycle GHG emissions when biodiesel displaces gasoline

Issues in use of ethanol as a motor fuel

Biofuels were once synonymous with 'clean' burning fuels, but modern engines and emissions control technology, combined with reformulated petro-fuels have essentially leveled the field with respect to regulated emissions.[90]

The primary environmental issue with ethanol mixtures in gasoline is the increased evaporative emissions (hydrocarbon emissions) that results. The increase in evaporative emissions is driven by the increased permeability of ethanol fuel mixtures through the vehicle's fuel system soft components.

Furthermore, Reid vapor pressure (RVP), increases for EtOH concentrations between 0 and about 50 volume% which exacerbates the permeation issue. For ethanol-in-gasoline concentrations greater than 50%, the RVP is less than that of straight gasoline (See Figure 11).

[90] Keese, W. J. (2004). "*Expanding opportunities for biofuels*." Keynote Address, Biofuels Workshsop and Trade Show, Western and Pacific Region.

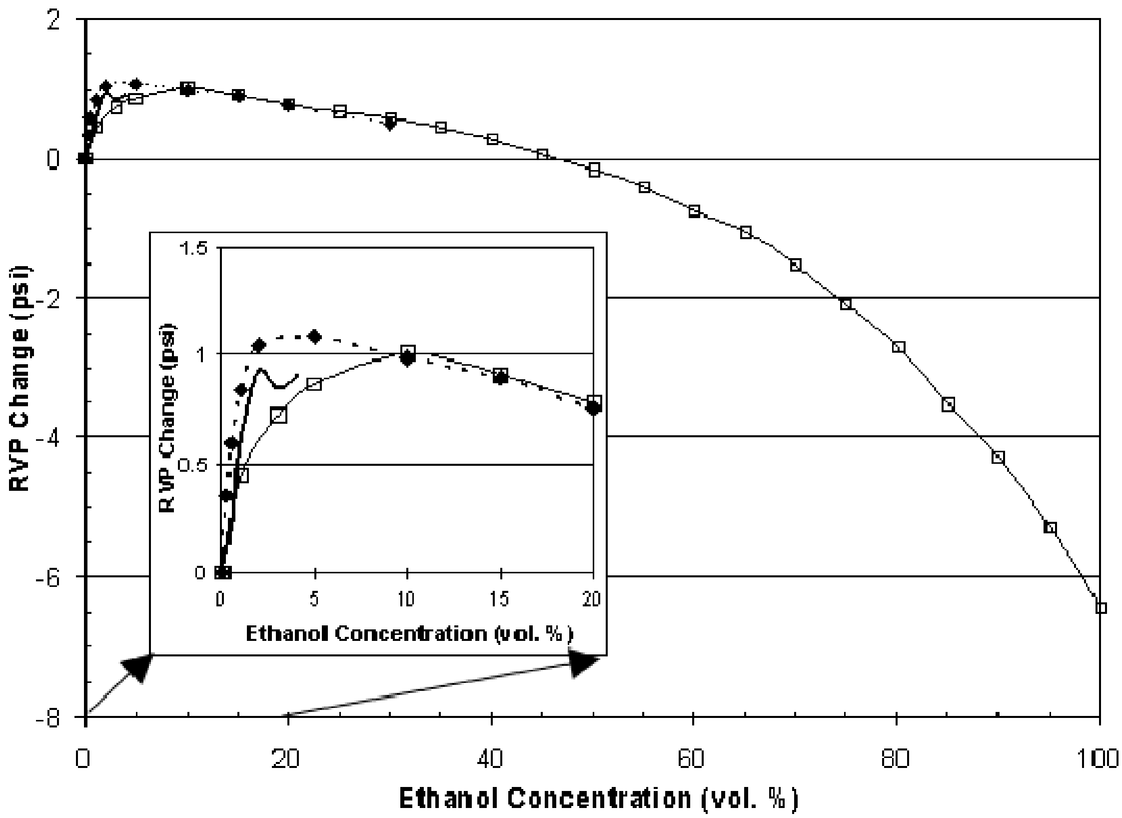


Figure 11. Vapor pressure vs. ethanol concentration in gasoline [91] [92] [93]

E85 has significantly lower RVP which tends to counteract the permeability problem but cold starts and cold weather drivability are concerns with E85. Co-mingling of high ehtanol blends straight gasoline can increase evaporative and permeation emissions.

Criteria Pollutants from ethanol fuels

NOx emissions increase about 3% for low ethanol blends (e.g., 5.7% volume blend that yields the 2% oxygen mass for oxygenated gasoline). Furthermore, NOx emissions may increase above 6% ethanol blends.[94] [95] [96]

---

[91] French, R., and Malone, P. (2005). "Phase equilibria of ethanol fuel blends." *Fluid Phase Equilibria*, 228-229, 27-40.

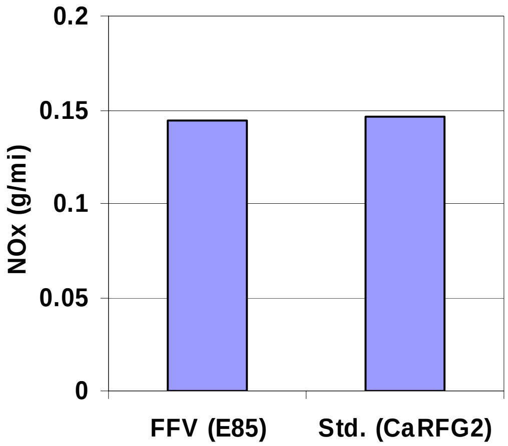
[92] Pumphrey, J. A., Brand, J. I., and Scheller, W. A. (2000). "Vapour pressure measurements and predictions for alcohol-gasoline blends." *Fuel*, 79(11), 1405-1411.

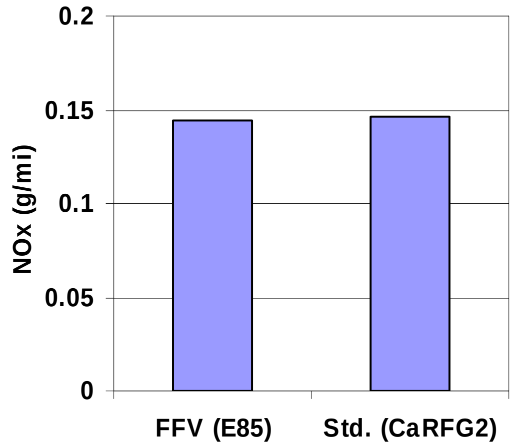
[93] Aulich, T., and Richter, J. (1999). "Addition of nonethanol gasoline to E10 - Effect on Volatility." University of North Dakota, Energy & Environmental Research Center, Grand Forks.

[94] (2005). "A summary of the Staff's assessment regarding the effect of ethanol in California gasoline on emissions - Review Draft." California Air Resources Board.

[95] McCormack, M. (2005). "The Outlook for Ethanol Use in California Transportation Fuels - Policy Drivers, Challenges and Opportunities." Presentation at World AG Expo, Tulare.

CO emissions generally decrease with increased ethanol concentrations (except for during cold start situations).





Predictive model update

CARB and stakeholders are updating the transportation emissions 'predictive model' to account for potential emission impacts from high ethanol blends. [97] Accounting for impacts of toxic emissions may be added to the predictive model.

Toxic Emissions

Ethanol fuel blends have higher emissions of formaldehyde and acetaldehyde than gasoline only fuel. However, ethanol fuel blends have significantly lower emissions of benzene and 1,3-butadiene. The overall aggregate toxic emissions of ethanol blends are lower than straight gasoline fuels (Table 21 and Figure 12)

While the E85 emissions have the highest total toxic aggregate emissions, they are ranked second lowest by weighted toxic equivalent (acetaldehyde has low toxicity and

[96] He, B.-Q., Jian-Xin Wang, Hao, J.-M., Yan, X.-G., and Xiao, J.-H. (2003). "A study on emission characteristics of an EFI engine with ethanol blended gasoline fuels." *Atmospheric Environment*, 37(7), 949-957.

[97] Perez, P. (2004). "Policy Drivers and Challenges for Ethanol Use in Transportation and Production in Calfornia." Presentation at Rice Straw Products Expo 2004, Sacramento. http://www.energy.ca.gov/ethanol/documents/2004-08-09_PEREZ_ETHANOL.PDF

contributes very little to the weighted toxic equivalent). The two M85 fuels had the highest toxicity of the group due to comparatively large formaldehyde emissions. Note the relatively low toxicity of CNG emissions.

Table 21. Vehicle lifetime toxic exhaust emissions for several fuels (g/140,000 miles) [98]

	Benzene	1,3-Butadiene	Formaldehyde	Acetaldehyde	Aggregate Toxics (sum)	CMU -Equivalent Toxicity[f] Aggregate (grams of sulfuric acid)
Conventional Gasoline	1820	210	350	126	2506	1575
CaRFG2[a]	840	126	336	84	1386	927
M85(CG)[b]	420	14	1526	28	1988	1961
M85(RFG)[c]	420	14	2394	70	2898	2925
E85(CG)[d]	252	28	574	3472	4326	812
CNG[e]	14	4	56	28	102	72

a) California Reformulated Gasoline -Phase 2
b) 85% (vol) methanol in conventional gasoline
c) 85% (vol) methanol in CaRFG2
d) 85% (vol) ethanol in conventional gasoline
e) Compressed natural gas
f) Carnegie Mellon University Equivalent Toxicity (Horvath et.al., 1995)

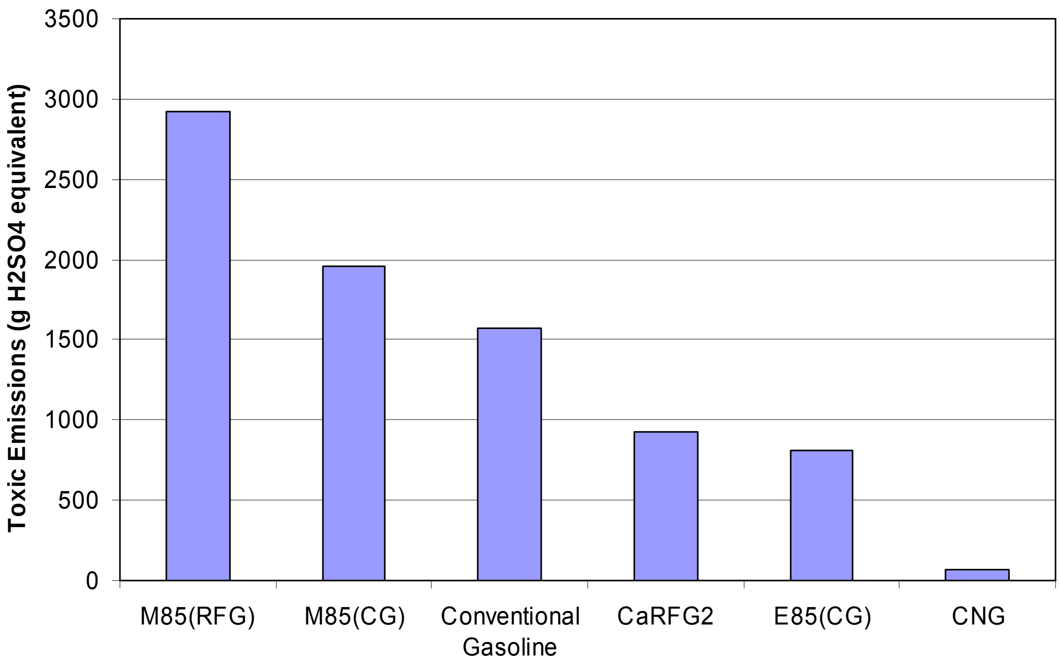


Figure 12. Toxic-equivalent lifetime emissions for several fuels [99]

[98] Winebrake, J. J., Wang, M. Q., and He, D. Q. (2001). "Toxic emissions from mobile sources: A total fuel-cycle analysis for conventional and alternative fuel vehicles." *Journal of the Air & Waste Management Association*, 51(7), 1073-1086..
[99] Adapted from (Winebrake et al., 2001)

Notes on toxic emissions study

Using emission factors from a CRC dynamometer study[100] and a vehicle lifetime of 225 300 km (140,000 miles), criteria, toxics and GHG emissions were modeled for a variety of gasoline and alternative fuels [101]. The results for toxic emissions are summarized in Table 21 and Figure 12. Table shows expected lifetime toxic emissions for production vehicles (early 1990s vintage) that had been optimized for the respective fuel. The sum of the emissions of the four compounds is labeled ‘Aggregate Toxics’. An equivalent toxic aggregate was computed using the Carnegie Mellon University Equivalent Toxicity weighting method (shown in equivalent grams of sulfuric acid; see [102]).

Issues using biodiesel as a motor fuel

Engines fueled with biodiesel (neat or blends) have lower PM, CO, hydrocarbon, soot, and other toxics emissions at the tailpipe compared to straight petroleum diesel. However NOx emissions increase which is a potential problem for widespread use of biodiesels in California. Reducing biodiesel NOx emissions is an active area of research.

- Reduces PM and toxic emissions
- Biodiesel can be used with no engine modification

Lifecycle and tailpipe emissions of biodiesel relative to petroleum diesel from the 1998 NREL biodiesel lifecycle study are shown in Figures 13 and 14 respectively.[103] Note that the emissions are calibrated for commercial transit bus engines available in 1994. If the comparison were updated using current engines, emissions controls, and petroleum diesel, then the differences shown would be reduced. Nevertheless, the trends would be similar.

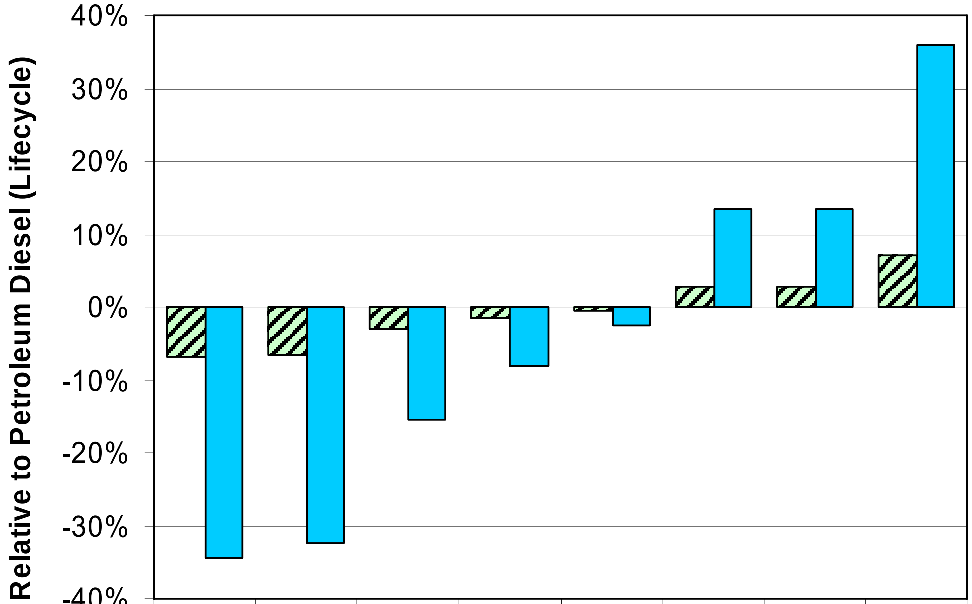
Note that while NOx is the only increased emission from biodiesel at the tailpipe, on a lifecycle basis, HCl and hydrocarbon emissions (HC) are increased for biodiesel fuel production and consumption. The increase in lifecycle HC emissions for biodiesel in the NREL study is due to large hexane emissions at the soybean crushing facility. Relative lifecycle NOx emissions for biodiesel are greater than the relative tailpipe emissions due to upstream processes for biodiesel (soybean growing, harvesting, transport, processing) having more NOx emissions than the petroleum diesel upstream processes.

[100] Auto/Oil Air Quality Improvement Research Program. *Dynamometer Study of Off-Cycle Exhaust Emissions*; Technical Bulletin No. 19; Coordinating Research Council: Atlanta, GA, 1996.

[101] MacLean, H. L., and Lave, L. B. (2000). "Environmental Implications of Alternative-Fueled Automobiles: Air Quality and Greenhouse Gas Tradeoffs." Environ. Sci. Technol., 34(2), 225-231.

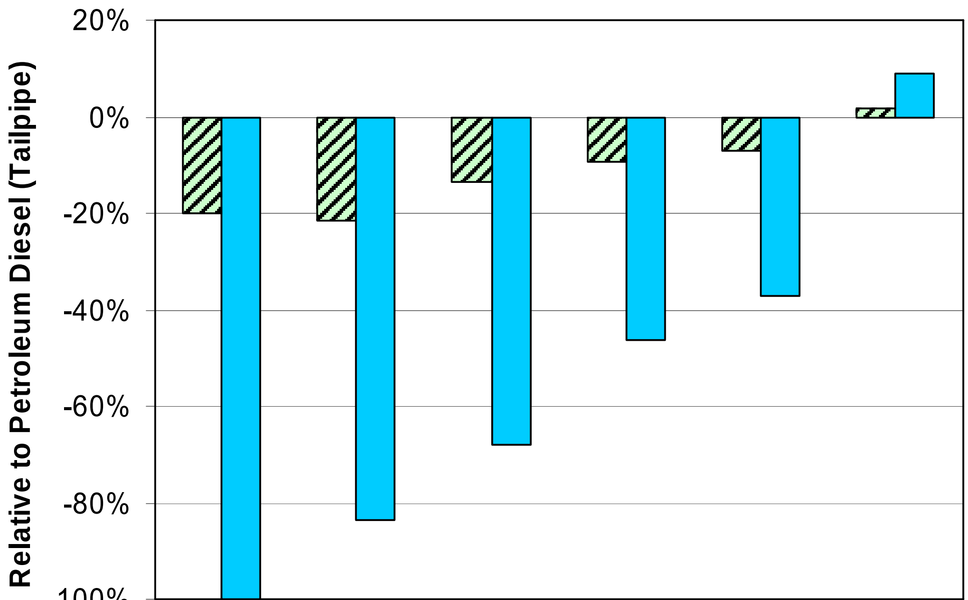
[102] Horvath, A., Hendrickson, C. T., Lave, L. B., McMichael, F. C., and Wu, T. S. (1995). "Toxic Emissions Indexes for Green Design and Inventory." *Environmental Science & Technology*, 29(2), A86-A90.

[103] Sheehan, J., Camobreco, V., Duffield, J., Graboski, M. S., and Shapouri, H. (1998). "Life Cycle Inventory of Biodiesel and Petroleum Diesel for Use in an Urban Bus." *NREL/SR-580-24089*, Final Report. National Renewable Energy Laboratory.



	CO	PM	HF	SOx	CH4	NOx	HCl	HC
B20	-7%	-6%	-3%	-2%	-1%	3%	3%	7%
B100	-35%	-32%	-16%	-8%	-3%	13%	14%	36%

Figure 13. Relative Lifecycle Emissions of biodiesel compared to petroleum diesel (Sheehan, et al., 1998)



	SOx	Soot	PM10	CO	NMHC	NOx
B20	-20%	-21%	-14%	-9%	-7%	2%
B100	-100%	-83%	-68%	-46%	-37%	9%

Figure 14. Relative Tailpipe Emissions of biodiesel compared to petroleum diesel (Sheehan, et al., 1998)

Appendix (matrices, workshop agenda and handout)

		Resource Category	Application/Management Practice	Pro	Con	Regulatory/Policy Issue	Key Issues & Recommendations
Forestry	Non-product Management	**Forestland and Shrubland Fuels Management**	• Prescribed burn • Air Curtain burner • Wildfire • Treat/Leave in place • Treat Material/Remove	• Protects old growth trees • Sequester carbon in plants & soils • Higher soil stability • Reduced need for roads • Free Mulch	• Air emissions from fires • Water pollution due to post-fire soil erosion • Loss of 'original' habitat type • Infestations and spread of disease • Air and water pollution • Accelerated GHG production if left on site.	• Rural homesite wildfire setback requirements	• Undo complex Forest Practice definitions
Forestry	Non-product Management	**Logging Slash**	• Open burn • Air-curtain burners • Land spreading • Air Curtain Burner • Free mulch	• Improves soil health • Larger landfills control CH4, VOC	• Air emissions from fires .Water pollution due to post-fire soil erosion • NOX emissions, loss of energy potential	• Burn permits • WDR • LF air permit requirements	
Forestry		**Removal, transport, and processing**	• Felling, trimming, grinding • Hauling • Processing, grinding	• Reduce risk of catastrophic wildfire • Protection from disease • Protect old-growth trees • Return to "original" habitat • Processed biomass appropriate for many uses	• Forest-road building, erosion problems • Potential for loss of habitat • Emissions from harvesting & thinning equipment • Emissions from transport • Emissions from processing plant • Traffic and environmental justice siting issues	• Healthy Forest Initiative • CA Prop. 40 (CFIP – 15 Sierra Nevada Counties) • Watershed management • Spotted owl habitat/endangered species requirements	
Forestry	Commercial Utilization	**Forestland and Shrubland Fuels Management**	<<ALL: • Heat • Power generation • Bio-fuels • GHG cap and trade program • Engineered wood and other wood products • Mill Residue	• Displace use of fossil fuels • Reduce GHG and other emissions • Closed-cycle carbon management	• Accelerated GHG release • Emissions of criteria air pollutants (NOX, PM) • Generates ash or other solid residue	• Local air district emission limits (NOx, offsets, PM, etc) • DG emission requirements (SB 1298) • Ethanol and biodiesel emission regulations • Waste Discharge Requirement for land applying/disposing ash • Noise Ordinances • Industrial Landuse restrictions • Need alternative compliance stds. for pilot or demo projects.	• Citing of demonstration projects • Potential reg. impacts under carbon regulation • Air quality compliance if no trade offs instituted • Risk rating need to be included in mgt. decision • Allow achievement of overall higher environ/econ gains to compensate for air quality impacts
Forestry	Commercial Utilization	**Logging Slash**	• Landfill with Gas Recovery (very little forest residue is landfilled)	• Protection of mature/old-growth trees • Some engineered products have greater strength, 7	• Impacts from increased use of binders and glues in engineered wood products	• Building Standards may limit some materials • Indoor air quality • Limited number of burn days	• Fuel moisture impacts permit and use for electricity production

		Resource Category	Application / Manag e-ment Practice	Pro	Con	Regulatory / Policy Issue	Key Issues & Recommendations
Agriculture	Non-product Management	**Crop Residues**	• Soil incorporation • Open burn	• Soil Quality - Incorporation o Maintain Fertility o Reduce erosion o • Wild life habitat – Flooding fields o Rice fields provide migratory bird habitat • Carbon sequestration in soil	• Disease and weeds from soil incorporation o Increased herbicide & fungicide use • Emissions from soil incorporation operation • Run-off of chemicals, ammonia, etc. • Emissions from decomposition of material left in field • GHG emissions from cultivation (e.g., rice fields) Emissions from burning – NOx, PM, VOC	• Open burning likely to continue restrictions • AB 1378 (1991) Reduce rice straw burning • SB 704 (2003) $10/ton for ag. residue (1 yr. only) • SB 705 (2003) Eliminate ag burning in the SJ Valley • SB 700 (2003) Ag. Ops. no longer exempt from air regulations	
		Manure	• Land application • Digester with flare	• Can add organic material and nutrients to soil	▪ CAFOs o Air emissions; feed, barns, lagoons, manure storage o Water emissions; salts, N, P management for ground water protection	▪ Water regulations (please specify) ▪ Digester air permit requirements	
		Processing Residues	• Land application • Landfill with flare • Digester with flare • Discharge to sewer • Other Treat/discharge	• Can add organic material and nutrients to the soil	• Minimally treated food-processor residues may add contaminants to soil • Emissions of NOx, CO	▪ Water regulations ▪ LF air permit requirements	
	Commercial Utilization	**Crop Residues**	<<ALL: • Heat • Power generation • Biofuels • Bioproducts	▪ Reduce fossil carbon emissions from creation of renewable products o Heat and power o Transportation fuels o Chemicals and materials	▪ Increase in some emissions (e.g., NOx and other products of combustion from energy recovery) ▪ Potential negative ground water impact	▪	▪ Can restrictive NOx limits be offset somewhat by credit for energy production or for reduction of other CAFO emissions? ▪ Local Air district rules for engines, turbines ▪ DG emission requirements (potentially)
		Manure		▪ Reduction in other CAFO air emissions (VOC, NH3, other??) ▪ Reduction in CH4 emissions (lagoons, straw in fields over winter) ? ▪ Potential positive ground water impact ▪ CAFO Water emissions; salts, N, P management for ground water protection	▪ Increase in some emissions (e.g., NOx and other products of combustion from energy recovery) ▪ Potential negative ground water impact ▪	▪ AB 1007 (2005) CEC to develop plan for alternative transportation fuels	
		Processing Residues		▪ Reduced ground water impact from improved discharge quality	▪		
		Dedicated Crops			▪ Downstream (secondary) emissions from biofuels		

		Resource Category	Application / Management Practice	Pro	Con	Regulatory / Policy Issue	Key Issues & Recommendations
Municipal / Urban Wastes or Residues	Non-product Management	**Municipal Solid Wastes**	• Landfill with flare	• Carbon sequestration (plastics and some biomass won't degrade in landfill) • Most landfills control emissions & discharges (but not completely) • Significant material is currently recycled or recovered	• Increased material to landfill due to increased population & affluence o Air Emissions from landfills (fugitive CH4, and some VOC) o Long term leachate & ground water issues o Fossil carbon required to manufacture material that ends up in waste o 23 Mt biomass disposed annually (40 Mt all solid waste)	• Have essentially reached AB 939 diversion requirements (if waste statistics are accurate), yet total disposal increases, per capita disposal has been stagnant for ~10 years. • Landfilling untreated MSW is often considered poorest environmental option • EJ issues in siting new landfills	• Change to disposal based management (rather than diversion based) • Ban untreated waste from landfill (ala EU Landfill Directive)
		Waste-water	• Digester with flare • Aerobic processing	• Decreases landfill and spreading	• Localized emissions of NOx, CO		
		Biosolids	• Land application • Landfill with flare	• Can provide organic material and nutrients to the soil • See above landfill issues	• Can add contaminants to the soil • Can create odours, nuisance, flies • Emissions of NOx, CO	• Kern County land application ban	
	Commercial Utilization	**Municipal Solid Wastes**	• Reuse & Recycle • Heat • Power generation • Biofuels • Compost & other products • Landfill with Gas Recovery • Co-digestion with other feedstocks	• Reduce material flow to landfill and/or stabilize before landfilling o GHG emission reductions o Reduced harmful leachate potential o Increased recovery for recycling, fuel, products • Reduce fossil carbon emissions from creation of renewable products o Heat and power o Transportation fuels o Chemicals and materials • Concentrate heavy metals and salts (pro or con?)	• NOx, PM, VOC, and other air emissions from processing facilities • HAP and Dioxin/Furan emissions from CTs not well understood • Potential solid/liquid discharge • Environmental performance 7 •	• AB 2770 (2002) Technology Definition (CTs) • AB 1090 (current) Waste Hierarchy (make conversion = recovery), diversion credit, definitions • AB 1007 (2005) CEC to develop plan for alternative transportation fuels	
		Source-Separated Wastes					
		Waste-water	• Heat • Power generation • Biofuels	• GHG emission reductions • Fossil fuel replacement	• Stationary and/or mobile emissions associated with biomethane use		
		Biosolids	• Heat • Power generation • Biofuels • Compost/other products • Landfill with Gas Recovery				

California Biomass Collaborative Workshop on
Environmental Regulations and Implications for Biomass Management in California
9 November, 2005
CalEPA Building, 1001 I St., Sacramento (Sher Auditorium)

Agenda

Audio Link* available at: http://www.ciwmb.ca.gov/Broadcast/

Time	(min)			
8:00		Check In		
8:30	5	Welcome/Introduction	**Bryan Jenkins**	California Biomass Collaborative
8:35	25	Morning Keynote	**Joe Desmond**	Chair, California Energy Commission
9:00		**Panel 1** State Environmental Agencies- Key Environmental Challenges - Programs and strategies to reduce impacts in meeting environmental goals		
		Moderator	**Rob Williams**	Biomass Collaborative
9:00	15	Regulatory /CEQA process	**Paul Richins**	CEC
9:15	15	Air	**Dean Simeroth/Bev Werner**	CARB
9:30	15	Water	**John Menke**	SWRCB
9:45	15	Solid Waste	**Fernando Berton**	CIWMB
10:00	15		**Discussion**	
10:15	15	Bioenergy Interagency Working Group	**Susan Brown**	California Energy Commission
10:30	15	**BREAK**		
10:45		**Panel 2** Perspectives; Industry – Local Agency - Environmental Community		
		Moderator	**Pat Sullivan**	SCS Engineers
10:45	10	Industry-Power	**Phil Reese**	CBEA
10:55	10	Industry-Fuels	**Necy Sumait**	Arkenol
11:05	10	Industry-Conversion Technologies	**Kay Martin**	BioEnergy Producers Association
11:15	10	Public Agency	**Ed Wheless**	LA San District
11:25	10	Environmental Community	**Alan Dusault**	Sustainable Conservation
11:35	10	Environmental Community	**Luke Tonachel**	NRDC
11:45	15		**Discussion**	
12 - 1		**Break for Lunch (on your own)**		
1:15	30	Afternoon Keynote (Moderator: Toni Symonds, State Controller's Office)	**Winston Hickox**	CalPers/CalStrs Fund: Clean Technology Initiative
1:45		Introduction to Breakout Sessions—Scope and Directions	Rob Williams	Collaborative
2:00		Breakout Sessions (3) by Resource	Forest / Agriculture	Municipal
3:30		Reports from Breakout Sessions	Session Facilitators	
4:20		Summary/Wrap-up		
4:30		**Adjourn**		

* During the workshop, discussion questions can be emailed to: auditorium@calepa.ca.gov

Workshop Goal

The principal goal of the workshop is to obtain stakeholder input on environmental issues facing future sustainable management and development of biomass in the state as part of a roadmap design process.

We Want Your Input

Please tell us your view. If you didn't have a chance to be heard at the breakout session, or you have more to add, please put use this form and get it back to us (biomass@ucdavis.edu or post);

California Biomass Collaborative
Biological & Agricultural Engineering
University of California
1 Shields Avenue
Davis, CA 95616-5924

Your name (not required)______________________and/or Affiliation________________

What are the **KEY** environmental issues regarding the sustainable use and management of biomass* resource in the state? [Use back side of sheet if needed]

- Where are the knowledge gaps; are policies and regulations adequate and consistent (if not, which are not, and what suggestions are there for improvement)?

- What environmental issues need resolution to bring stakeholder groups closer to agreement on how to move forward?

- What research, development, and demonstration (RD&D) activities are required, if any?

- What efforts are needed to expedite improved management and utilization of biomass? How might we achieve more sustainable management and utilization earlier rather than later?

---

* Biomass includes; biogenic fraction of municipal solid waste, municipal and food processor liquid wastes, food processor solid residues, agricultural residues (from crops and livestock), forest industry byproducts and residues, biomass from forest fuels reduction activities, purpose grown trees and crops for energy, fuels, and chemicals.