



December 5, 2014

The Honorable Janea Scott, Commissioner
California Energy Commission
1516 Ninth Street
Sacramento, CA 95814

Re: Comments on The 2014 Draft Integrated Energy Policy Report

Dear Commissioner Scott:

I am writing on behalf of the Bioenergy Association of California (BAC) to thank you and the Commission for the excellent *2014 Draft Integrated Energy Policy Report* (the "Draft IEPR"). The Draft IEPR's focus on the transportation sector is very timely and necessary to help California meet its greenhouse gas reduction, air quality, energy independence and other goals. The Draft IEPR is particularly helpful because it integrates the discussion and proposals for both greenhouse gas reduction and protection of air quality. Integrating these two important mandates and maximizing steps to achieve both is essential to their success. BAC supports many of the Draft IEPR's proposals to achieve these goals and recommends several additional areas for inclusion in the 2014 IEPR, described more fully below.

BAC is an association of more than fifty public agencies, local governments, private companies and others working to convert organic waste to energy, including transportation fuels, renewable electricity and pipeline biogas. BAC's public sector members include air quality, solid waste, wastewater and environmental protection agencies, as well as city and county governments. BAC's private sector members include bioenergy, solid waste, engine, technology, carbon, agriculture and other sectors involved in bioenergy development.

I. GENERAL COMMENTS ON THE 2014 DRAFT IEPR

The Draft IEPR provides a very helpful overview and discussion of the

transportation sector in California. Its presentation of the state of vehicle technologies, status of low carbon fuels, infrastructure development and other aspects of the transportation sector provide very helpful data, trends analysis and recommendations. BAC especially supports the following elements of the Draft IEPR:

A. Integration of Greenhouse Gas and Air Pollution Reduction Strategies.

The Draft IEPR very helpfully provides data and analysis of the relationship between greenhouse gas reduction and protection of air quality, and strategies to maximize both. As technologies improve and new, lower carbon fuels are introduced, it is particularly important for both the Energy Commission and the Air Board to continue to maximize reductions of both climate change and criteria pollutants and not to trade one goal for the other. Many strategies can achieve both.

B. Recognition that Biofuels Can Provide Immediate and Significant Emission Reductions.

BAC strongly supports the Draft IEPR's finding that biofuels will "play a critical role in reducing carbon emissions from the transportation sector and are a key element in the state's approach to a low-carbon transportation future."¹ As the Draft IEPR notes, electricity and hydrogen are longer term strategies to reduce greenhouse gas emissions whereas biofuels can provide immediate and significant reductions.²

C. Natural Gas Engines and Fuels On Track to Become Electric Vehicle Equivalent for Criteria Pollutants.

BAC agrees with the Draft IEPR that natural gas fuels and engines have the potential to "cost-effectively reduce carbon and criteria emissions from the on-road, heavy-duty trucking sector."³ [emphasis added] In other words, natural gas engines are on track to operate at emissions levels that are "electric vehicle equivalent."⁴ This finding is extremely important as both the Energy Commission and Air Board determine how to maximize both greenhouse gas and criteria pollutant reductions. Continuing to incentivize natural gas engines and fuels is a cost-effective way to reduce both types of emissions and, when the engines use biogas or a biogas blend, achieve the greatest greenhouse gas reductions.

D. Need to Address Pipeline Access and Cost Issues for Biogas.

As the Draft IEPR notes, biogas provides the lowest carbon fuels and yet pipeline access and costs are significant barriers to the increased use of biogas as a

¹ Draft IEPR at page 4.

² Id. at page 73.

³ Id. at page 117.

⁴ Id. at pages 95, 110 and 111.

transportation fuel. BAC agrees with the Draft IEPR that the state needs to find ways to reduce the costs of meeting new standards for pipeline biogas and pipeline interconnection in order to expand the use of biogas as a transportation fuel.⁵ As the Draft IEPR notes, “Cost-effective compliance methods or alternative funding for AB 1900 compliance must be found so that biogas can be transmitted via California’s vast natural gas pipeline infrastructure.”⁶ BAC recommends several strategies to reduce pipeline biogas costs and sources of funding, below, which should be allocated to pipeline biogas.

E. Need for Better Inter-Agency Coordination

BAC agrees with the Draft IEPR that increasing coordination between agencies is critical to maximize the benefits of the different greenhouse gas reduction and air quality protection goals. In particular, better coordination between the Commission, Air Resources Board and Public Utilities Commission would help to ensure that funding programs are coordinating to maximize impact and help meet new standards and legislative requirements.

F. Importance of Leveraging Funding for Clean, Low-Carbon Transportation

BAC strongly supports the recommendations to leverage various funding programs for transportation. Since several agencies now have funding from Cap and Trade revenues and other sources, it is important that agencies work together to agree on goals and strategies to maximize the impacts of those funds. At a minimum, the Climate Action Team, Interagency Bioenergy Working Group or other inter-agency team should ensure that Greenhouse Gas Reduction Funds (GGRF) are in fact allocated to projects that maximize greenhouse gas reductions and help to promote strategies in the AB 32 Scoping Plan Update. BAC is particularly concerned that the Air Board has prioritized criteria pollutant reductions over greenhouse gas reduction in the use of its GGRF funding, at least in the 2014-2015 budget. The Energy Commission and Air Board should coordinate much more closely on the use of GGRF and ARFVT funding for transportation. In addition, both agencies should coordinate with CalRecycle, CalFire, and the California Department of Food and Agriculture on the use of those agencies’ GGRF funds to maximize greenhouse gas reductions and clean fuels development from those funds.

G. Importance of Promoting a Technology Neutral Portfolio.

BAC agrees with the Draft IEPR that California should promote a portfolio of technologies and fuels⁷ to increase short-term and long-term benefits and to continue to reduce emissions from all technologies and fuels. A related tenet must be to remain technology neutral as vehicle technologies and fuels continue to evolve and improve. As the Draft IEPR notes, the biggest opportunity for near

⁵ Id. at pages 109 and 119.

⁶ Id. at page 109.

⁷ Draft IEPR at page 73.

term greenhouse gas reductions is from biodiesel, E85 ethanol, and natural gas blended with biogas.⁸ Longer term, electric and fuel cell vehicles will provide the a larger share of greenhouse gas reductions, but California needs both near- and long-term strategies, as well as strategies to reduce emissions in all vehicle classes. Given the wide range of vehicles and the different benefits and challenges for each sector, pursuing a technology neutral, portfolio approach is the most sensible strategy for California to achieve its clean transportation needs.

II. RECOMMENDATIONS ON THE 2014 DRAFT IEPR

BAC supports many of the findings in the Draft IEPR, but urges the Commission to expand the recommendations in several areas to address those findings. In particular, we urge the Commission to add the following recommendations:

A. Chapter One

BAC urges the Commission to add specific recommendations to:

- Coordinate with ARB and the CPUC to develop a transparent matrix of the different regulations and incentives to reduce both greenhouse gas emissions and criteria pollutants and how each regulation and incentive promotes each goal;
- Develop a long-term, inter-agency strategy to maximize both greenhouse gas emissions and criteria pollutants and ensure that current incentives are focused on greatest reductions;
- Define what the terms “zero emission” and “near zero emission” mean and whether they always refer to the same (criteria pollutant) emissions;
- Ensure that current incentive programs are technology neutral and that GGRF funding maximizes greenhouse gas reductions (or, at a minimum, does not ignore the lowest carbon transportation fuels)

B. Chapter Two

BAC urges the Commission to add specific recommendations to:

- Include coordination with, and leveraging of, the gas sector’s cap and trade revenues, which are separate from the revenues included in the State Budget and which are approximately \$150 million in 2015;
- Allocate a portion of the gas sector cap and trade revenues to production and pipeline distribution of biogas;
- Leverage funding for organic waste diversion (CalRecycle), dairy digesters (CDFA) and other cap and trade revenues to produce biogas for transportation

⁸ Id.

- fuels;
- Ensure that a portion of the Air Board's GGRF funds goes to biogas for transportation fuel use and as the renewable source of hydrogen;
- Coordinate ARB and CEC funding to promote biogas development that is co-located with hydrogen fueling stations to meet the requirements of SB 1505 as cost-effectively as possible;
- Coordinate with CalRecycle on the implementation of AB 1826 (Chesbro, 2014) and AB 1594 (Williams, 2014), which require the diversion of organic waste and will provide additional feedstock for biogas production;
- Leverage local funding and opportunities with ports and public agencies such as wastewater, solid waste and transit agencies to produce biogas and co-locate that production with natural gas and hydrogen fueling stations.

C. Chapter Five

BAC urges the Commission to include recommendations to:

- Develop a statewide strategy to optimize biogas production that is co-located with hydrogen fueling stations by identifying potential biogas production sites that are near fleets and fueling stations and incentivizing their joint development;
- Fund research to identify strategies to reduce the costs of compliance with new pipeline biogas standards, pipeline interconnection and other barriers to pipeline biogas injection, which is required by AB 1900 (Gatto, 2012).

III. SPECIFIC EDITS AND CORRECTIONS TO THE 2014 DRAFT IEPR

In addition to the recommendations above, BAC requests that the Commission make the following specific corrections to the Draft IEPR:

A. Biogas Potential (page 116)

Since testifying before the Commission in June, BAC has revised its estimate of the fuels potential from organic waste. The revision is based on corrections from UC Davis, which provided the underlying data, and because UC Davis only included 67 percent of the municipal organic waste in its estimates. With the passage of AB 1826 and AB 1594, BAC believes it is more accurate and more consistent to use 100 percent of the technically available organic waste across all sectors to calculate the fuels potential (the UC Davis estimate includes 100 percent of the technically available waste in other feedstock categories). The underlying data and analysis are included in the report that BAC recently released, *Decarbonizing the Gas Supply: Why California Needs a Renewable Gas Standard*, which is attached to these comments.

BAC would, therefore, like to correct the fuels potentials cited in the Draft IEPR on page 116 as follows:

- The total fuels potential from organic waste is 2.5 billion gge (not 2.1 billion dge) per year.
- Currently landfilled organic wastes could produce 684 (not 492) million gge of carbon negative transportation fuels.

B. Correct name of BAC (page 117)

Please correct BAC's name in footnote 177 on page 117. The correct name is Bioenergy Association of California, not Biogas Association of California.

C. Update Draft IEPR to include statutes of 2014 (page 122)

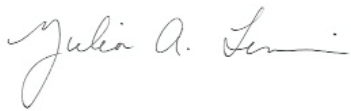
The Draft IEPR includes a helpful discussion of the relationship between organic waste diversion and production of the lowest carbon fuels, but should be updated to include two new statutes related to organic waste diversion that were enacted in 2014:

- AB 1826 (Chesbro) requires recycling of commercial organic waste; and
- AB 1594 (Williams) phases out the recycling credit for greenwaste that is used as landfill cover.

These new statutes will increase feedstock for biogas production and increase the need for coordination between the Commission and CalRecycle.

We thank the Commission for the opportunity to comment on the Draft IEPR. With the recommendations and corrections above, it will provide an outstanding framework for California's transportation sector.

Sincerely,



Julia A. Levin
Executive Director

Attachment: *Decarbonizing the Gas Sector: Why California Needs a Renewable Gas Standard*, November 2014, Bioenergy Association of California.



Decarbonizing The Gas Sector: Why California Needs A Renewable Gas Standard

November 2014



Authors: Julia Levin,
Katherine Mitchell,
and Henry Swisher



BioenergyCA.org



Acknowledgements

This paper would not have been possible without the work of Rob Williams and his team at the University of California, Davis, who provided the assessment of biomass resources and fuels potential on which much of this paper is based. Their ongoing analyses have been instrumental in the state's understanding of biomass resources.

The authors also wish to thank Rashaël Parker of Sierra Energy for her help throughout the development and design of this paper. Her guidance and contributions were invaluable.

Except where otherwise noted, the authors are solely responsible for the content of this paper.

About the Bioenergy Association of California

The Bioenergy Association of California (BAC) is a non-profit association of more than 50 public agencies, private companies, local governments, environmental groups and others working to promote sustainable bioenergy development. BAC focuses on community-scale projects that convert organic waste to energy, including renewable electricity, transportation fuels and pipeline gas. For more information about BAC, visit: www.bioenergyca.org.



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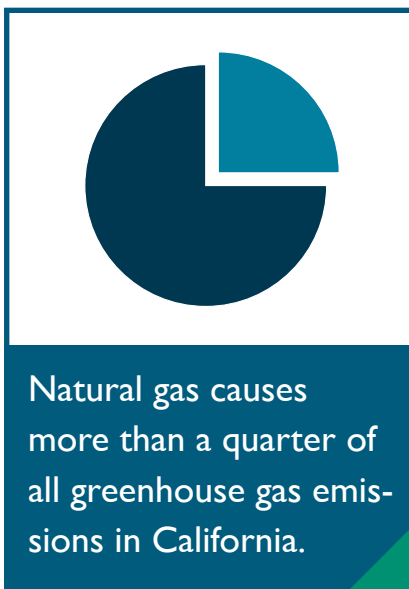
Executive Summary

California uses more than 2 trillion cubic feet of natural gas per year and that amount is going up.¹ Natural gas provides more than half of the state's electricity, heating and cooling, and a growing share of transportation fuels. Although cleaner and cheaper than other fossil fuels, natural gas is a major source of greenhouse gas emissions, air and water pollution. In addition, California imports 91 percent of its gas, making the state vulnerable to supply and price fluctuations and costing more than \$9 billion per year in lost revenues and jobs.²

Renewable gas provides a cleaner, safer and more sustainable alternative to fossil fuel gas. Made from organic waste, renewable gas can replace fossil fuel gas and provide many other benefits. Most importantly, renewable gas can:

- Cut greenhouse gas emissions by millions of tons per year;
- Produce renewable electricity that is available 24/7;
- Provide the lowest carbon transportation fuels;³
- Cut fossil fuel use, air and water pollution;
- Reduce landfilling by millions of tons per year;
- Reduce catastrophic wildfire;
- Protect ratepayers by diversifying California's gas supply; and
- Produce two to six times as many jobs as fossil fuel power.

California could produce almost 300 billion cubic feet of renewable gas per year just from organic waste --the waste from food and food processing, livestock, agriculture, yard waste, construction debris and other wood waste, soiled paper and forest biomass. Instead of landfilling or burning that waste, California could use it to generate enough renewable electricity to power 2 to 3 million homes or to generate 2.5 billion gallons of clean, ultra-low carbon



Organic waste can produce enough renewable gas to replace $\frac{3}{4}$ of all the diesel used by motor vehicles in California.

transportation fuels.

California has adopted several policies to promote biogas, but their implementation has

1 California Energy Commission (CEC), 2014, Overview of Natural Gas in California. *CEC Energy Almanac*. <http://energyalmanac.ca.gov/naturalgas/overview.html>.

2 Based on \$4 per MMBtu x 2,405,520,000 MMBtu (2,313 billion scf of natural gas).

3 California Air Resources Board, 2014 Look-Up Table, available at: <http://www.arb.ca.gov/fuels/lcfs/2a2b/2a-2b-apps.htm>.

Biogas generates 2 to 6 times as many jobs per megawatt as fossil fuel gas.

been slow and they do not provide the long-term certainty needed for biogas to compete with the historically low cost of natural gas. In order to capture the many benefits of biogas, California needs a statewide policy to expand the biogas market enough to drive down costs and become self-sustaining.

California needs a Renewable Gas Standard (RGS). An RGS would require a small but increasing percentage of the state's gas to be renewable. Modeled after the state's Renewable Portfolio Standard, which has doubled renewable electricity in just over a decade, the RGS would require an increasing percentage of renewable gas, beginning with just 1 percent in 2020 and gradually increasing to 10 percent in 2030. This modest but steady increase in the renewable gas market will provide enormous benefits to public health and safety, the environment and the economy.

It is time for California to diversify and decarbonize its gas supply. It is time for a Renewable Gas Standard.



Los Angeles County Sanitation Districts produce 80 MW of renewable electricity from wastewater and landfill biogas, saving \$19 million in electricity costs and cutting GHG emissions by about 325,000 metric tons per year.

I. Introduction

California is a global leader in the fight against climate change. The state has adopted dozens of policies to increase renewable energy, energy efficiency, recycling, carbon sequestration and more. In the electricity sector, California has adopted a Renewable Portfolio Standard (RPS) to increase renewable energy and decrease greenhouse gas emissions. In the transportation sector, California has adopted a Low Carbon Fuel Standard (LCFS) to reduce greenhouse gas emissions

Nearly half of all new natural gas fired power plants built in the U.S. in 2013 were built in California.

and diversify fuel supplies. Surprisingly, however, California has not adopted a policy to decarbonize or diversify the gas sector, which causes more than one-quarter of all greenhouse gas emissions in the state.⁴

California will not be able to meet its long-term greenhouse gas reduction goals without reducing emissions from the gas sector. Yet California's natural gas use has been increasing in recent years and is likely to continue to do so given the rapid increase in gas fired power plants and the historically low price of natural gas.

Reducing emissions from California's gas sector will require a comprehensive statewide policy focused on decarbonizing and diversifying California's gas supply. This paper presents the rationale for a statewide gas strategy, beginning with an overview of the natural gas sector in California, then presenting the potential production and benefits of renewable gas – especially biogas generated from organic waste – and proposing the framework for a Renewable Gas Standard that would require a gradual but increasing percentage of California's gas to be renewable gas.

II. The Natural Gas Sector In California

California uses more than two trillion cubic feet of natural gas per year and gas use continues to increase (Table I).⁵ Most natural gas is used in the residential, industrial, commercial and electric sectors, with just a small fraction used as transportation fuel.

Natural gas is used to generate more than half of California's electricity supply⁶ and the majority

4 Based on 2012 usage of natural gas, 2.313 trillion cubic feet emits 125.8 million metric tons of CO₂ equivalent emissions (based on the US Energy Information Agency conversion factor of 54.4 kg CO₂e / 1,000 cf of natural gas). http://www.eia.gov/environment/emissions/co2_vol_mass.cfm. California's total GHG emissions are 458 MMT CO₂e. California Air Resources Board, "Greenhouse Gas Inventory for 2000-2012 – by Category as Defined in the 2008 Scoping Plan," available at: www.arb.ca.gov/cc/inventory/inventory.htm.

5 CEC, footnote 1.

6 U.S. Energy Information Administration (US EIA). California generates 8115 GWh from natural gas out of a total of 15,083 GWh used in 2014. <http://www.eia.gov/state/?sid=CA#tabs-4>.

of its home heating and hot water.⁷ It is also used for cooking and various industrial purposes. Natural gas use in California is highly seasonal, increasing in the winter for space heating and in the summer to generate electricity for air conditioning.⁸

Table 1 – Natural Gas Use in California (2010-2012)

Natural Gas End Use (billion cubic feet/year)	2010	2011	2012
Electricity Generation	922	796	1032
Industrial	548	559	577
Residential	509	518	485
Commercial	199	201	201
Natural Gas Vehicles	18	16	17
Total Natural Gas Demand	2,196	2,091	2,313

Source: California Energy Commission, 2014

California continues to add new natural gas fired power plants at a fast pace. In 2013, nearly half of all new natural gas power generation in the United States was built in California.⁹ And more than half of new power generation in California came from natural gas, more than all new renewable energy sources combined.¹⁰

The California Public Utilities Commission has jurisdiction over 150,000 miles of utility-owned natural gas pipelines, which transported 82 percent of the total amount of natural gas delivered to California's gas consumers in 2012¹¹. Residential and small commercial customers, referred to as "core" customers, account for



Sierra Energy's gasification facility on Fort Hunter Liggett will help the U.S. Army to meet its energy security and military preparedness goals.

7 CEC, footnote 1.

8 CEC, footnote 1.

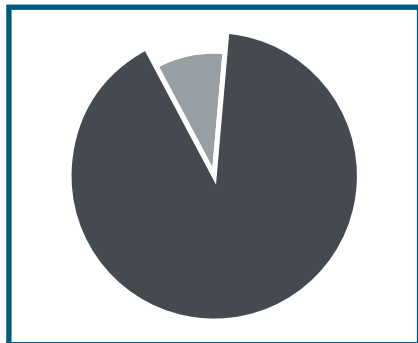
9 US EIA, <http://www.eia.gov/todayinenergy/detail.cfm?id=15751>.

10 Id.

11 California Public Utilities Commission (CPUC), Overview of Natural Gas Sector. <http://www.cpuc.ca.gov/PUC/energy/Gas/natgasandCA.htm>.

approximately a third of the natural gas delivered by California utilities in 2012.¹² Large consumers, like electricity generators and industrial customers, referred to as “noncore” customers, accounted for two-thirds of the natural gas delivered by California utilities in 2012.¹³ Most of California’s small customers purchase natural gas from the utilities, while most large consumers purchase natural gas directly from producers and natural gas marketers.¹⁴

As a transportation fuel, natural gas is cleaner than diesel or gasoline. It is an important means to reduce air pollution and greenhouse gas emissions, especially from heavy duty vehicles such as trucks, buses, construction equipment and off-road vehicles. In the South Coast Air District, for example, vehicle emissions are the largest source of smog-forming NOx emissions, constituting seven of the ten largest sources of NOx emissions in the region.¹⁵ In fact, more than 90 percent of Southern California’s NOx emissions are from the combustion of gasoline and diesel by motor vehicles.¹⁶ Replacing those petroleum fuels with natural gas can reduce NOx emissions by 50 percent and may be able to reduce NOx emissions as much as 90 percent in the future.¹⁷ Natural gas can also reduce greenhouse gas emissions by 23 percent from diesel powered vehicles and by 28 percent from gasoline powered vehicles.¹⁸



California imports 91% of the gas that it uses, costing the state more than \$9 billion per year.

Natural gas is cleaner and cheaper than petroleum based fuels, but it is still a fossil fuel with a number of economic and environmental drawbacks. On the economic side, California has to import 91 percent of the natural gas that it uses from other states and Canada (Table 2).¹⁹ This means that California is sending nearly \$9 billion per year out of state to purchase natural gas.²⁰ The loss to California’s economy is much greater than that because California is also losing the

12 Id.

13 Id.

14 Id.

15 Henry Hugo, Assistant Deputy Executive Officer, South Coast Air Quality Management District, June 23, 2014 Presentation to the CEC, slides 3 and 4.

16 Gladstein, Neandross & Associates, Pathways to Near-Zero-Emission Natural Gas Heavy-Duty Vehicles, May 19, 2014, at p. 16. http://www.gladstein.org/pdfs/On-Road_Pathways.PDF.

17 Id at p. 9.

18 Todd Campbell, Clean Energy, June 23, 2014 Presentation to the California Energy Commission, slide 3.

19 California Gas and Electric Utilities’ California Gas Report: Issues 2004-2013. http://www.pge.com/pipeline/library/regulatory/cgr_index.shtml; CEC Energy Almanac, Table 2, http://energyalmanac.ca.gov/naturalgas/natural_gas_supply.html.

20 Based on \$4 per MMBtu x 2,405,520,000 MMBtu (2,313 billion scf of natural gas).

jobs, economic development, tax revenues and other economic multipliers that go with dollars spent on energy production. Importing 91 percent of California's gas supply, which is used to produce the majority of California's electricity supply, also leaves California vulnerable to market manipulation. California paid heavily for this vulnerability in the 2001-2002 energy crisis, when out-of-state gas traders manipulated the market and cost California ratepayers billions of dollars.

Table 2 - California Natural Gas Supply
Percentage of Supply by Region

	2008	2009	2010	2011	2012
California	13	12	12	11	9
Canada	19	21	23	19	16
Southwest US	46	43	41	32	35
Rocky Mountains	22	22	24	38	40
TOTAL	100	100	100	100	100

Source: California Energy Commission, 2014

Public health and environmental impacts add to the costs of natural gas. Natural gas is responsible for more than one-quarter of all greenhouse gas emissions in California – about 125 million tons of carbon dioxide equivalent emissions per year.²¹ Natural gas is responsible for 90 percent of the greenhouse gas emissions from California's electricity sector.²² Natural gas exploration, drilling and combustion have additional environmental and public health impacts.

While natural gas is cleaner and less expensive than diesel and gasoline, it provides far fewer benefits than renewable gas.

III. Renewable Gas Potential And Benefits

California can generate substantial quantities of renewable gas to reduce greenhouse gas emissions, diversify the gas sector and provide many other benefits. Renewable gas made from organic waste in California can provide more than 10 percent of the state's total gas supply

21 Based on California's 2012 gas consumption of 2.313 trillion cubic feet of gas and US EIA's emissions conversion factor of 54.5 kg of CO₂ per 1,000 scf of natural gas, emissions from California's gas sector were 125.8 MMT CO₂e in 2012. www.eia.gov/environment/emissions/CO2_vol_mass.cfm. California's total GHG emissions in 2012 were 458.7 MMT CO₂e. California Air Resources Board (CARB), "Greenhouse Gas Inventory for 2000-2012 – by Category as Defined in the 2008 Scoping Plan," available at: www.arb.ca.gov/cc/inventory/inventory.htm.

22 Id.

with technologies that are proven and widely deployed. In the future, renewable gas may also be generated from renewable power, further expanding renewable gas supplies.

What is Renewable Gas?

Renewable gas can be produced from biological (organic) material or renewable electricity.

Biogas

The California Energy Commission defines biogas as anaerobic digester gas, landfill gas and any other gas derived from an eligible biomass feedstock.²³ Biogas can be produced from anaerobic digestion (the decomposition of organic material in the absence of oxygen) or biomass conversion. Organic waste sources include food and food processing waste; fats, oils and grease (FOG); yard and other green waste; forest and wood waste; dairy and agricultural waste; biosolids and gas from wastewater treatment; and landfill gas.

Biomass conversion is defined by California law as “the production of heat, fuels, or electricity by the controlled combustion of, or the use of other noncombustion thermal conversion technologies on, the following materials, when separated from other solid waste:

- (1) Agricultural crop residues.
- (2) Bark, lawn, yard, and garden clippings.
- (3) Leaves, silvicultural residue, and tree and brush pruning.
- (4) Wood, wood chips, and wood waste.
- (5) Nonrecyclable pulp or nonrecyclable paper materials.”²⁴

Noncombustion thermal conversion technologies such as gasification and pyrolysis use direct or indirect heat in a controlled oxygen environment to convert biomass materials into biogas. In addition to thermal conversion there are also chemical and biological conversion methods for creating biogas from biomass.

Gas Produced From Renewable Electricity

In addition to biogas, renewable gas can be produced from renewable electricity, converting intermittent renewables like wind and solar to baseload, renewable power. This form of renewable gas is created by using wind or solar power to split water into hydrogen and oxygen, and then combining CO₂ with the hydrogen to create methane.²⁵ Although not yet deployed in California,



This CR&R facility in Southern California will produce 4 million diesel gallons per year from 320,000 tons of organic waste, the largest project of its kind in the U.S.

23 “*Renewables Portfolio Standard Eligibility, Seventh Edition*,” at page 116, adopted by the California Energy Commission, April 2013. Publication number CEC-300-2013-005-ED7-CMF

24 California Public Resources Code section 40106(a), enacted by Senate Bill 498 (Lara, 2014).

25 <http://www.dena.de/en/projects/renewables/power-to-gas-strategy-platform.html>

“power to gas” is being developed in Germany and the United Kingdom to convert intermittent renewables to baseload power and to provide a renewable form of methane.

Although this paper focuses on biogas, the potential for gas produced from renewable electricity should also be explored.

Potential for Biogas Development in California

California could generate more than 10 percent of its total gas consumption – 284 billion cubic feet of gas per year - from organic waste. If all technically available organic waste were converted to biogas, it would be equivalent to 2.5 billion gasoline gallon equivalents (gge) of transportation fuels or nearly 7,000 megawatts of renewable power (Table 3 and Appendix B).²⁶

Table 3 - Estimated Annual Biomass Residue Amounts and Fuel Potential for California

Feedstock	Amount Technically Available (Bone Dry Tons or Billion Cubic Feet)	Potential Fuels Production (Million gasoline gallon equivalents gge)
Agricultural Residue (lignocellulosic)	5.4 M BDT	272 gge
Animal Manure	3.4 M BDT	170 gge
Fats, Oils and Greases	207,000 tons	56 gge
Forestry and Forest Product Residue	14.2 M BDT	710 gge
Landfill Gas	106 BCF	457 gge
Municipal Solid Waste (67% of food, leaves, grass fraction)	1.2 M BDT	106 gge
Municipal Solid Waste (67% of lignocellulosic fraction)	7.0 M BDT	350 gge
Waste Water Treatment Gas	11.8 BCF	66 gge
Fuel Potential		2,187 gge

Compiled by Rob Williams, University of California, Davis, April 2014 (revised 19 May, 2014).²⁷

26 CEC 2008, “*An Assessment of Biomass Resources in California, 2007, 2010 and 2020*,” at p. iii, finding that the technical potential of biomass is 6,800 megawatts in 2020. The fuels potential is based on the assessment by UC Davis in Table 3 and Appendix B that using 67% of diverted organic waste and other biomass residues can produce 2.187 billion gasoline gallon equivalents of fuel. Using 100% of diverted organic waste plus the other organic waste and residues can produce 2.5 billion gasoline gallon equivalents of fuel.

27 Williams, R. B., B.M. Jenkins and S. Kaffka (California Biomass Collaborative). 2014. An Assessment of Biomass Resources in California, 2012 – DRAFT. Contractor Report to the California Energy Commission. PIER Contract 500-11-020. For an explanation of Notes and Sources, see the full table and notes in Appendix B.

The Benefits of Biogas

Increasing biogas use would provide many economic, environmental, public health and safety benefits to California. Most importantly, increasing biogas in California will:

- Provide immediate and significant greenhouse gas reductions;
- Produce low carbon fuels, renewable electricity and energy storage;
- Increase energy independence and fuel diversity;
- Produce jobs and economic development in every region of the state;
- Leverage private sector investment of three to four times as many dollars;
- Reduce air and water pollution, environmental justice impacts and landfilling;
- Increase recycling; and
- Reduce wildfire risks and impacts.

A Renewable Gas Standard could cut California's GHG emissions by more than 10 million metric tons of CO₂e per year.

Above all, biogas provides immediate and significant greenhouse gas reductions. Replacing just ten percent of California's natural gas with renewable gas would reduce GHG emissions by 12.6 million metric tons from fossil fuel displacement alone.²⁸ The actual emissions reduction

would be much greater due to upstream reductions in black carbon (from reduced wildfire) and methane emissions from dairies and other uncapped sources.



Clean Energy Renewable Fuels is selling 100,000 gallons per day of its renewable biogas, called Redeem, to California customers. Redeem has 90% lower GHG emissions than diesel.

In the fuels sector, biogas provides the lowest carbon fuels - or transportation of any kind – currently available, lower carbon per mile than electric or fuel cell vehicles (Table 4).²⁹ Renewable gas can also provide a renewable source of hydrogen for use in hydrogen fuel cells, either for electricity production or as

28 Calculated using US EIA's emissions conversion factor of 54.5 kg of CO₂ per 1,000 scf of natural gas. www.eia.gov/environment/emissions/CO2_vol_mass.cfm. California's 2012 gas consumption of 2.313 trillion scf, of natural gas in 2012 emits 125,827,200 metric tons of CO₂ equivalent emissions. 10% of those emissions is 12.6 MMT CO₂e.

29 CARB Look-Up Table, footnote 3.

a transportation fuel. When renewable gas is used to displace diesel, it can significantly reduce toxic air contaminants, particulate matter and other air pollutants.

Table 4 - Carbon Intensity of Transportation Fuels(grams CO₂e per megajoule energy)

Transportation Fuel	Carbon Intensity
Gasoline	99.18
Diesel	98.3
Biodiesel from Midwest soy beans	83.25
Corn ethanol	74.70 to 120.99
Natural Gas	68
Sugarcane ethanol	58.4 to 78.94
Hydrogen Fuel Cell Vehicles	39.42
Electric vehicles	30.80
Renewable Diesel	19 to 39
Landfill gas	11.26 to 15.56
Dairy Biogas	13.45
Wastewater biogas (large facilities)	7.89
Biogas from food and green waste	- 15

Source: California Air Resources Board May 2014 Look-Up Table³⁰

In the electricity sector, increasing the use of biogas can help California meet its renewable energy goals, especially as California increases renewable electricity beyond 33 percent. Biogas can provide renewable electricity that is available 24/7 and can easily ramp up and down to complement wind and solar power, which are only available intermittently. Bioenergy helps to fill in supply when solar and wind are not available, enabling California to increase its renewable energy portfolio at much lower cost and with greater grid stability.³¹



California Bioenergy's project at New Hope Dairy generates renewable electricity for the Sacramento Municipal Utility District (SMUD).

³⁰ Id.

³¹ Energy and Environmental Economics, January 2014, Investigating a Higher Renewables Portfolio Standard in California. http://www.ethree.com/public_projects/renewables_portfolio_standard.php.

In addition to the overall benefits of bioenergy, each bioenergy sector provides specific benefits, summarized in Table 5 below:

Table 5 – Sector Specific Benefits of Bioenergy

Sector	GHG Reduction (Million metric tons MMT)	Benefits
Diverted Municipal Organic Waste	5-10 MMT CO ₂ e / year (not including fossil fuel displacement)	<ul style="list-style-type: none"> • Reduced landfill waste • Revenue and/or energy for local governments • Production of organic fertilizers
Landfill Gas	6.77 MMT CO ₂ e / year (not including fossil fuel displacement)	<ul style="list-style-type: none"> • Reduced pollution and environmental justice impacts from fossil fuels
Livestock Waste	6 MMT CO ₂ e / year (not including fossil fuel displacement)	<ul style="list-style-type: none"> • Reduced odor, air and water pollution • Revenue for dairies • Production of organic fertilizer
Agricultural Waste	Estimate not yet available	<ul style="list-style-type: none"> • Reduced air pollution from open field burns • Production of organic fertilizer and soil amendments
Wastewater Treatment Biogas	3 MMT CO ₂ e / year (not including fossil fuel displacement)	<ul style="list-style-type: none"> • Produce revenue and/or energy for local governments • Production of organic fertilizer and soil amendments
Forest Waste	Can reduce GHG emissions from wildfire by 65 percent or more	<ul style="list-style-type: none"> • Protect health and safety • Reduce air pollution • Protect infrastructure and forest ecosystem • Save hundreds of millions in annual wildfire damages • Provide energy and/or revenues to rural communities

Source: Bioenergy Investment Plan, compiled by BAC in 2014

Organic waste can provide enough renewable gas to power 2 to 3 million homes in California.



IV. Policy Framework For Renewable Gas

California has adopted several policies to promote biogas development, reduce landfilling of organic waste and increase renewable fuels. To date, these policies have achieved mixed results. Recent funding programs are helping to spur new biogas projects, but many of the recent regulatory policies have yet to be implemented, are prohibitively expensive, or do not provide enough certainty to attract the investment necessary to expand the biogas market. Several key policies are summarized below; a more complete description of the policy framework for biogas is included in Appendix A.

- **The 2012 Bioenergy Action Plan**, adopted by nine state agencies and Governor Brown's Office, details 55 separate actions that state agencies should take to increase bioenergy. Agencies are at varying stages of implementing these actions, the most important of which were codified in SB 1122 and AB 1900.
- **SB 1122 (Rubio, 2012)** requires utilities to procure 250 megawatts from small-scale bioenergy facilities. The California Public Utilities Commission (CPUC) is more than a year late in adopting the rules to launch this important program.
- **AB 1900 (Chesbro, 2012)** requires the CPUC to set new standards for pipeline biogas injection and to allocate the costs of meeting those standards. The CPUC has adopted the most stringent standards in the United States and has not yet completed the cost allocation phase of the proceeding.
- **The Low Carbon Fuel Standard (LCFS).** The Air Resources Board has adopted carbon intensity values for most sources of biogas, which is helping to incentivize new development. ARB needs to reevaluate some of its earliest carbon intensity analyses and adopt one for forest biomass based fuels. The program also needs to provide long-term certainty about the value of LCFS credits in order to increase market investment.



Methane generated at Waste Management's Altamont Landfill is converted to 13,000 gallons a day of renewable fuel used in WM trucks.

- **The Electricity Program Investment Charge (EPIC)** funds clean electricity R&D, technology deployment, and market facilitation. The California Energy Commission has allocated more than \$37 million to bioenergy projects in 2014, but it is not clear how much will be allocated to bioenergy in future years.
- **The Alternative and Renewable Fuel and Vehicle Technology Program.** The Energy Commission allocated \$18 million to biomethane based transportation fuels, out of a total of \$100 million available in 2014, even though organic waste based fuels are the lowest carbon fuels or transportation available.
- **Cap and Trade Revenues.** California's 2014–2015 Budget allocated cap and trade revenues to organic waste diversion and dairy digesters, but did not allocate any cap and trade revenues to biogas based transportation fuels, renewable hydrogen from biogas, forest biomass facilities or biogas from wastewater treatment facilities.

The policies described above are helping to launch a handful of new biogas projects in California, but they are not sufficient to grow a self-sustaining biogas industry. Some, such as SB 1122, are far behind the implementation schedule required by statute. Others, such as the LCFS program, do not provide the long-term certainty required to attract industry-wide investment. The biogas sector needs an effective regulatory framework and greater long-term certainty to reach the level of market penetration that will drive down costs and enable biogas to compete with the historically low cost of natural gas.

Achieving the potential production and benefits that biogas can provide in California will require a sector-wide policy to decarbonize and diversify California's gas supply.



CleanWorld's facility in Davis converts organic waste and landfill gas to 5.6 GWh of renewable energy and cuts GHG emissions by 13,500 tons per year.

V. Why A Renewable Gas Standard Makes Sense

California has a number of policies and funding programs to promote biogas development, but lacks the coordinated framework to significantly increase renewable gas production and distribution. Overcoming market barriers, especially low natural gas prices and utility resistance, will require a sector-wide approach that guarantees a biogas market in California, just as the state's

Renewable Portfolio Standard (RPS) guarantees a market for renewable electricity. Adopting a Renewable Gas Standard (RGS) that is phased in slowly with appropriate cost and other controls will help California meet its greenhouse gas reduction and clean energy goals.

California's RPS Works

California's RPS has been hugely successful in expanding renewable electricity generation. When the RPS was first adopted in 2002, renewable energy constituted only 10 percent of California's electricity supply, leaving the state overly dependent on natural gas and highly vulnerable to market manipulation by out-of-state gas traders. Thanks to the RPS, renewable sources now provide more than 20 percent of California's electricity supply and are on track to provide 33 percent by 2020.

The first RPS legislation, SB 1078, specified the many reasons to adopt a renewable portfolio standard:

- To increase the diversity, reliability, public health and environmental benefits of California's energy mix;
- To promote stable energy prices, protect public health, improve environmental quality, stimulate sustainable economic development, create new employment opportunities, and reduce reliance on imported fuels; and
- To reduce air pollution and improve public health throughout the state by reducing the burning of fossil fuels and associated environmental impacts.³²



San Jose's facility can convert 90,000 tons of waste to 1.6 MW of renewable electricity. The facility was developed by Zero Waste Energy Development Company and is part of the city's zero waste by 2022 plan.

A Renewable Gas Standard would achieve these same goals for the gas sector: significant reductions in air pollution and greenhouse gas emissions, increased fuel diversity and reliability, increased job and economic opportunities, protection of public health and the environment, and reduced reliance on fossil fuels.

32 SB 1078 (Statutes of 2002), adding Public Utilities Code section 399.11.

Designing a Renewable Gas Standard

Just as the RPS has driven the development of renewable electricity in California, a Renewable Gas Standard (RGS) will drive development of renewable gas. Like the RPS, it will be important to design an RGS that sets appropriate timelines, price protections and other measures to ensure that the RGS maximizes benefits while minimizing ratepayer impacts. A California RGS should include the following elements:

Phase-in and Percentage Requirement

Technically, renewable gas could provide more than 10 percent of California's total gas consumption.³³ Phasing in a lower percentage over several years will minimize ratepayer impacts and allow the industry and the market to develop in a more stable manner.

Recommendation:

- 1% RGS by 2020
- 3% RGS by 2023
- 5% RGS by 2025
- 10% RGS by 2030

Who Must Comply with the RGS?

The RGS should apply to all retail sellers of natural gas. Initially, it should apply to all gas sales under the jurisdiction of the California Public Utilities Commission (CPUC), which oversees the distribution of 82 percent of all gas consumed in California. It should apply to both the utilities, which own and sell about a third of the gas that they distribute, and to gas providers that sell more than two-thirds of the gas directly to large gas customers.

The RGS could be applied to publicly owned utilities and other gas providers on the same timeline or phased in at a later date.

Price and Market Protections

Given the very small percentages and gradual phase-in of the RGS, the impact on ratepayers should be negligible. Nonetheless, it will be important to include price and



Phoenix Energy uses wood and agricultural waste to generate renewable power in Merced County.

³³ Assuming biogas production from all organic waste sources of 284 billion scf/year and total natural gas consumption of 2.3 trillion scf/year.

market protections with appropriate off-ramps to protect ratepayers and the market. Allowing utilities to bank compliance and/or borrow against future compliance may also help to reduce costs.

Additionality and Ratepayer Benefits

To maximize the benefits for California ratepayers and the public, eligible biomethane under the RGS should be subject to the requirements of AB 2196, which sets forth eligibility requirements for biomethane under the RPS.³⁴

AB 2196 limits RPS eligible biomethane to biomethane from new projects that are either: 1) used for onsite generation; 2) delivered via a dedicated pipeline; or 3) if delivered via a common carrier pipeline, provide specified environmental benefits to California.



Victor Valley Wastewater Authority produces 9 million kilowatt hours and avoids landfilling 1,400 tons of waste per year.

VI. Conclusion

It is time for California to accelerate the development of renewable gas. The technologies are proven and the benefits are enormous. Adopting a Renewable Gas Standard will help California to achieve its greenhouse gas reduction, clean energy and energy independence goals. It will also protect public health and safety, reduce environmental justice impacts, and create jobs and economic development.

A renewable gas standard will accelerate biogas development by guaranteeing a market and encouraging the most cost-effective projects with the greatest benefits. By ramping up slowly and with ratepayer protections, it can provide maximum benefits to the grid and the transportation sector without risk to ratepayers or the public.

It is time for a Renewable Gas Standard.

³⁴ Public Utilities Code section 399.12.6.

Policy Framework for Bioenergy in California

Executive Order S. 06-06 and Senate Bill 1505

Governor Schwarzenegger issued Executive Order S. 06-06 in 2006 to increase production of biofuels and biopowered electricity. That Order calls for:

- 20 percent of California's RPS target to come from biomass generation by 2020; and
- 40 percent of the biofuels that California uses to be produced in-state by 2020 and 75 percent to be produced in-state by 2050.

SB 1505, enacted in 2006, requires that one-third of the hydrogen used in publicly funded hydrogen fueling stations be generated from renewable sources. SB 1505 declared that it is "the intent of the Legislature that the state board work with other relevant state agencies on the production of hydrogen, with an emphasis on hydrogen produced from renewable resources, as part of a strategy to reduce the state's dependence on petroleum, achieve the state's greenhouse gas emission reduction targets, and improve air quality for the state's residents."

2012 Bioenergy Action Plan

In 2012, the Brown Administration significantly updated and expanded the state's Bioenergy Action Plan to promote bioenergy development, both biogas and biomass. The 2012 Bioenergy Action Plan was adopted by nine state agencies including the Governor's Office to:

- Increase environmentally and economically sustainable energy production from organic waste;
- Encourage development of diverse bioenergy technologies that increase local electricity generation, combined heat and power facilities, renewable natural gas, and renewable liquid fuels for transportation and fuel cell applications;
- Create jobs and stimulate economic development, especially in rural regions of the state; and
- Reduce fire danger, improve air and water quality, and reduce waste.

The 2012 Bioenergy Action Plan was intended to identify the technical, regulatory and financial barriers to bioenergy development and state actions to address those barriers. While some state agencies have worked to streamline permitting or otherwise promote bioenergy development, progress has been slow and far too limited.

Assembly Bills 1900 and 2196

In 2012, California enacted AB 1900 (Gatto) and AB 2196 (Chesbro) to promote the in-state production and distribution of biomethane. AB 2196 significantly limits the eligibility of out-of-state biomethane under California's RPS while AB 1900 is intended to promote the in-state production and use of biomethane. As AB 1900 states, the bill is intended:

"To meet the energy and transportation needs of the state, the com-

mission shall adopt policies and programs that promote the in-state production and distribution of biomethane. The policies and programs shall facilitate the development of a variety of sources of in-state biomethane.”

AB 1900 also requires the California Public Utilities Commission (CPUC) to identify impediments to biomethane procurement, offer solutions to address those impediments, and adopt pipeline access rules that ensure “nondiscriminatory open access to its gas pipeline system.”

The CPUC has completed the first phase of the AB 1900 rulemaking, in which it adopted new standards for pipeline biomethane to protect public health, pipeline safety and heating (energy) value of the gas. The standards are without doubt the most stringent pipeline biomethane standards in the United States. They include requirements for testing, monitoring and controlling 17 constituents of concern, as well as a heating content requirement that, taken together, are virtually cost-prohibitive. Meeting the 990 Btu heating requirement alone may double the cost of pipeline biomethane. Without other incentives or biogas purchase requirements, AB 1900 will not achieve its purpose of promoting and facilitating biogas development in California.

Senate Bill 1122

In 2012, California also enacted SB 1122 (Rubio), which requires the utilities to purchase 250 megawatts of renewable electricity generated from organic waste. SB 1122, which has been added to California’s existing feed-in tariff program for distributed scale renewables (SB 32), requires the investor owned utilities (PG&E, Southern California Edison and SDG&E) to purchase energy from small-scale (3 MW and smaller) bioenergy facilities. SB 1122 requires that the 250 megawatts be made up of:

- 110 megawatts generated from food and food processing waste, wastewater treatment, diverted municipal organic waste and codigestion;
- 90 megawatts generated from dairy and other agricultural waste; and
- 50 megawatts generated from forestry waste.

The CPUC is more than a year behind in adopting the specific program rules to implement SB 1122. A staff proposal issued in the Fall 2013 suggested some helpful changes to the existing feed-in tariff (ReMAT) program, but left open a number of issues that are critical to the successful implementation of SB 1122. Those issues include the minimum number of bidders required in each feedstock category, the required location of facilities, penalty and inflation adjustment provisions, a method to ensure that all sectors can participate in the program, and other issues.

Transmission and Pipeline Access

Interconnection to both pipelines and electric lines is a significant barrier to biogas development in California. Bioenergy projects must be able to connect to the transmission or pipeline grid to be able to export renewable electricity or biogas for use offsite. As mentioned in section B, the new standards for pipeline biomethane will be cost-prohibitive without additional subsidies, utility purchase requirements or other policies to make the standards feasible. In addition to the

biomethane standards themselves, pipeline interconnection can be a significant cost of biogas project development, sometimes as much as 20 to 30 percent of total project costs. California's investor-owned utilities charge anywhere from two to ten times as much for pipeline interconnection as utilities in other states.

Connecting bioenergy projects to the electricity transmission grid is no easier. Bioenergy project developers can receive wildly different cost estimates for similar interconnection projects, or even for the same interconnection project. Although the CPUC has provided a timeline and process for interconnection, developers cannot rely on utility timelines, cost estimates or technical requirements, all of which increase biogas project costs and risks substantially.

Funding Programs

Numerous state funding programs exist to help support new bioenergy projects. They are moving the industry forward, although not at the rate necessary to meet the state's low carbon fuels, waste diversion and other goals.

Funding for Electricity and Gas Projects

EPIC. The California Public Utilities Commission created the Electricity Program Investment Charge (EPIC) in 2011 to provide funding for clean energy development. EPIC created an electricity ratepayer surcharge that will generate approximately \$350 million in clean energy funding for the years 2015-2017. That funding is allocated as follows:

- \$152 million for Applied Research and Development;
- \$145 million for Technology Demonstration and Deployment, at least 20 percent of which must go to bioenergy projects; and
- \$53 million for Market Facilitation.

The EPIC program, like the former Public Goods Charge on electricity, is a very important opportunity to promote biogas projects and bioenergy more generally.

PIER. In addition to the EPIC program to promote clean electricity, the California Energy Commission also administers the Public Interest Natural Gas Research Program, also known as the PIER Natural Gas Program. The program allocates up to \$62 million per year for natural gas related research and demonstration.

SGIP. The California Public Utilities Commission (CPUC) also administers a funding program to support projects that generate electricity for onsite use, known as the Self-Generation Incentive Program (SGIP). Created in 2001 as a response to the California Energy Crisis, SGIP funds distributed generation projects, combined heat and power, and energy storage. It provides incentives ranging from \$1.13 to \$1.83 per watt, including a biogas adder of \$1.62/watt.

Funding from Cap & Trade Proceeds

As part of California's Global Warming Solutions Act (AB 32), California adopted a market

mechanism known as Cap & Trade that gives regulated entities more flexibility in meeting their greenhouse gas emission targets. Regulated entities can: 1) reduce their emissions by the required amount; 2) purchase carbon offset credits; and/or 3) purchase emission allowances that are auctioned off by the state. The auctions held so far have generated more than \$1 billion dollars. In the 2014-2015 budget, the State allocated funding in several categories that may support biogas development:

- \$25 million to CalRecycle for projects to reduce organic waste and promote recycling;
- \$15 million to the California Department of Food and Agriculture for dairy digester projects and other greenhouse gas reduction measures;
- \$42 million to CalFire for forest conservation, wildfire reduction and urban forestry; and
- \$200 to the Air Board for fuel cell and electric vehicle technology. As noted in Section A. above, one-third of the hydrogen used in these fuel cell fueling stations must come from renewable sources, ie biogas.

CalRecycle has already issued a Request for Proposals for its 2014-15 funding. It received more than \$115 million in proposals for the \$20 million it allocated to organic waste diversion.

Funding for Alternative Fuels

The Alternative and Renewable Fuel and Vehicle Technology Program, also known as AB 118, provides approximately \$100 million per year in grants to promote clean fuels and vehicles. Administered by the California Energy Commission, the program divides the funding between natural gas, electric, fuel cell and renewable fuel vehicles, alternative fuels production and infrastructure. While the mix of technologies and fuels that receive AB 118 funding is more diverse than the current allocation of Cap & Trade revenues for clean vehicles, it is still disproportionately focused on fuel cell, electric, natural gas and other fuels that provide substantially lower greenhouse gas reductions than biogas generated from organic waste.

Estimated Annual Biomass Residue Amounts and Fuel Potential for California (with Notes and Sources)

Compiled by Rob Williams, University of California, Davis[‡]

Feedstock	Amount Technically Available (Bone Dry Tons or Billion Cubic Feet)	Biomethane Potential (billion cubic feet)	Biofuel Potential	
			(Million gasoline gallon equivalent gge)	PJ (LHV basis) [§]
Agricultural Residue (Lignocellulosic)	5.4 M BDT ^a	-	272 ^h	32.7
Animal Manure	3.4 M BDT ^a	19.7 ^a	170 ⁱ	12.3
Fats, Oils and Greases	207,000 tons ^b	(assume conversion to biodiesel)	56 ⁱ	6.7
Forestry and Forest Product Residue	14.2 M BDT ^a	-	710 ^h	85.4
Landfill Gas	106 BCF ^a	53 ^f	457 ⁱ	55.0
Municipal Solid Waste (67% of food, leaves, grass fraction)	1.2 M BDT ^c	12.3 ^g	106 ⁱ	12.8
Municipal Solid Waste (67% of lignocellulosic fraction)	7.0 M BDT ^d	-	350 ^h	42.1
Waste Water Treatment Gas	11.8 BCF ^e	7.7 ^k	66 ⁱ	7.9
Total		93	2,187	263

* Diesel gallon equivalents can be estimated by multiplying gge by 0.89

Notes and Sources:

M BDT = million bone dry (short) tons, PJ = petajoule = 10¹⁵ joules

BCF = billion cubic feet

a. Williams, R. B., B. M. Jenkins and S. Kaffka (California Biomass Collaborative). 2014. An Assessment of Biomass Resources in California, 2012 – DRAFT. Contractor Report to the California Energy Commission. PIER Contract 500-11-020.

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- b. From: Wiltsee, G. (1999). Urban Waste Grease Resource Assessment: NREL/SR-570-26141. Appel Consultants, Inc. 11.2 lbs./ca-y FOG and California population of 36.96 million. Biodiesel has ~9% less energy per gallon than petroleum diesel.
- c. Technical potential assumed to be 67% of amount disposed in landfill (2012).
- d. 67% of mixed paper, woody and green waste and other non-food organics disposed in landfill (2012), (waste characterization and disposal amounts are from: <http://www.calrecycle.ca.gov/Publications/Detail.aspx?Publication-ID=1346> and <http://www.calrecycle.ca.gov/lgcentral/GoalMeasure/DisposalRate/Graphs/Disposal.htm>)
- e. From EPA Region 9; Database for Waste Treatment Plants
- f. Assumes 50% methane in gas
- g. Assumes VS/TS= 0.83 and biomethane potential of 0.29g CH₄/g VS (food waste) & VS/TS = 0.9 w/ BMP= 0.143g CH₄/g VS (leaves. Grass)
- h. Using 50 gge per dry ton (75 gallons EtOH per dry ton) yield. See, for example: Anex, R. P., et al. (2010). Techno-economic comparison of biomass-to-transportation fuels via pyrolysis, gasification, and biochemical pathways. [Article]. Fuel, 89, S29-S35. doi: 10.1016/j.fuel.2010.07.015
- i. ~116 ft³ methane is equivalent to 1 gge (983 Btu/scf methane and 114,000 Btu/gallon gasoline, lower heating value basis)
- j. 7.5 lbs FOG/ gallon biodiesel. Biodiesel has ~9% less energy per gallon than petroleum diesel, gives 50 M gallons diesel equivalent. 1 dge = 1.12 gge
- k. Assumes 65% methane in gas. §
- ‡ Compiled by Rob Williams, University of California, Davis. April 2014 (revised 19 May, 2014). Source material: Williams, R. B., B. M. Jenkins and S. Kaffka (California Biomass Collaborative). 2014. An Assessment of Biomass Resources in California, 2012 – DRAFT. Contractor Report to the California Energy Commission. PIER Contract 500-11-020.

