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STAFF WHITE PAPER

Senate Bill 1383, Renewable Gas Requirements: Challenges, Considerations, and Questions for Stakeholders to Address

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ABSTRACT

Although California's greenhouse gas emissions are primarily carbon dioxide (about 82 percent), short-lived climate pollutants (SLCPs) contribute a majority of the remaining fraction. SLCPs are powerful climate forcers that remain in the atmosphere for a much shorter time and are estimated to account for about 40 percent of climate forcing from pollution associated with human activities.

To address SLCPs, Senate Bill 1383 (Lara, Chapter 395, Statutes of 2016) requires the California Air Resources Board (CARB) to develop and enact a comprehensive short-lived climate pollutant strategy to reduce statewide emissions of methane by 40 percent, hydrofluorocarbon gases by 40 percent, and anthropogenic black carbon by 50 percent below 2013 levels by 2030. SB 1383 also requires the California Energy Commission, in consultation with the California Air Resources Board and California Public Utilities Commission (CPUC), to develop recommendations for development and use of renewable gas.

In response to these requirements, the Energy Commission will jointly host a workshop on June 27, 2017 with CARB and the CPUC. The primary workshop goal is to stimulate discussion and seek stakeholder input on developing and using renewable gas, including biogas and biomethane, for electricity production and transportation fuel.

From workshop discussions, the Energy Commission must identify cost-effective strategies consistent with existing state policies and climate change goals. The Energy Commission must also provide recommendations that consider priority end uses of renewable gas, including biomethane and biogas, and the interactions of these end uses with state policies.

Comments received from stakeholders will be considered when developing recommendations and will be included in the Energy Commission's *2017 Integrated Energy Policy Report* (IEPR) to meet the responsibilities stated in SB 1383.

Keywords: California Energy Commission, *Integrated Energy Policy Report*, short-lived climate pollutants, Senate Bill 1383, renewable gas, biomethane, biogas, electricity, transportation

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EXECUTIVE SUMMARY

Senate Bill 1383 (Lara, Chapter 395, Statutes of 2016) requires that by January 1, 2018, the California Air Resources Board (CARB) develop and enact a comprehensive short-lived climate pollutant (SLCP) strategy. The strategy would reduce statewide emissions of methane by 40 percent, hydrofluorocarbon gases by 40 percent, and anthropogenic black carbon by 50 percent below 2013 levels by 2030.

California will need significantly more development and use of renewable gas, including biogas and biomethane, to meet its goal of 40 percent reduction of methane below levels 2013 levels by 2030. Over the last 20 years, development of biogas to produce electricity and transportation fuel has occurred at some dairy farms, wastewater treatment plants, landfills, and organics recycling facilities.

Capture and use of methane will require the widespread development of renewable gas projects in California. State and local government permit agencies will need to increase their awareness of the opportunities and challenges that these projects face to help them carry out their responsibilities as growth occurs. Furthermore, consumers are not fully aware of the benefits and impacts. Government monitoring, evaluation, guidance and assistance will be required to address the unique nature of individual projects and host sites, electricity system interconnection, natural gas pipeline injection, and incentive support for a diversity of conversion technologies and market applications.

To achieve the significant SLCP targets of SB 1383, the major considerations and challenges outlined above will require additional discussion and work between government entities, utility companies, project developers, technology providers, site owners, and vehicle fleet owners. The Energy Commission is seeking feedback and has posed several important questions for stakeholder comment. Comments and findings from the June 27, 2017, Joint Agency Workshop on Renewable Gas will be included in the *2017 Integrated Energy Policy Report (IEPR*).

The Energy Commission issues this staff white paper to frame the discussion for the June 27, 2017, joint agency workshop in hope of encouraging public input to fill knowledge gaps and suggest conclusions. This staff white paper frames the opportunities and challenges to achieve the SB 1383 goals both from electricity generation and use of transportation fuels. It is meant to stimulate comments from relevant state agencies, federal, and local governments; gas and electric utilities; biogas host site owners; market forecasting experts; fuel and electricity project developers/operators; financial investors; vehicle and engine manufacturers; vehicle fleet owners; public interest organizations; and the public.

The Energy Commission will later issue a draft staff report as a supplement to this staff white paper, to provide a landscape of the current state of renewable gas feedstocks, technologies, and uses, as well as set a context for discussing cost-effectiveness, barriers, challenges, and opportunities.

CHAPTER 1: Introduction

Methane constitutes the largest of the short-lived climate pollutants (SLCPs) in terms of its total greenhouse gas contribution. Methane in particular has a global warming impact that is 25 times greater than carbon dioxide over 100 years and 72 times greater over 20 years. In 2014, 39.8 million metric tons carbon dioxide equivalent of methane gas was emitted in California from a variety of economic sectors. This is equivalent to more than 11.5 average sized coal-fired power plants.[1] Most of these methane emissions come from the natural biogenic decomposition of waste at livestock operations (such as dairies), food and urban waste facilities, wastewater treatment plants, and landfills.

To help address these greenhouse gas emissions, Senate Bill 1383 (Lara, Chapter 395, Statutes of 2016) set forth requirements to control certain SLCPs in California. The bill expanded the California Air Resources Board's (CARB's) SLCP Reduction Strategy that had been established under Senate Bill 605 (Lara, Chapter 523, Statutes of 2014). It directed CARB to develop a comprehensive SLCP strategy in coordination with other state agencies. In addition, emissions for three SLCPs have to be reduced below 2013 levels by 2030 as follows: 40 percent for methane, 40 percent for hydrofluorocarbon gases, and 50 percent for anthropogenic black carbon.

The capture, conversion, and use of these renewable sources of methane for energy are an opportunity to reduce SLCP emissions while displacing high carbon emitting fuels and providing a beneficial use. Of all the United States, California is estimated to have the highest potential to generate this renewable methane, also known as biogas, biomethane, or renewable natural gas.[2]

Potential uses for biogas include combusting for process heating or process steam, electricity generation, fuel for natural gas vehicles, or injection into natural gas pipelines. Biogas can also be converted into renewable hydrogen for use in fuel cell electric generators, fuel cell electric vehicles, energy storage, and a multitude of other applications.

California has produced electricity and transportation fuels from renewable gas, biogas, and biomethane for nearly 20 years. Even though fewer than 50 fuel production plants are operating today, significant opportunities for growth will be stimulated by the combined

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1 Assumes nationally averaged coal-fired power plant size of 760 MW. United States Environmental Protection Agency, Greenhouse Gases Equivalencies Calculator - Calculations and References. Accessed June 5 2017, https://www.epa.gov/energy/greenhouse-gases-equivalencies-calculator-calculations-and-references.

2 National Renewable Energy Laboratory, Biogas Potential in the United States, October 2013, Available at http://www.nrel.gov/docs/fy14osti/60178.pdf.

synergy of government policies, regulations, incentives, technological progress, and beneficial market changes.

The combined technical potential from all biomethane sources (animal manure, food waste, wastewater treatment plants, organic diversion of waste from landfills, and landfills) could produce up to 2.1 billion diesel gallons equivalent (DGE) per year of transportation fuel. That is nearly 7,000 megawatts (MW) of electricity if fully captured as an energy source. Furthermore, studies completed by the University of California at Davis[3] and ICF[4] evaluated the economic potential to convert waste residues to renewable gas, biogas, and biomethane. These studies concluded that based on today's policies and market circumstances, growth projections could range from 670 million DGE to 1.0 billion DGE per year.

Challenges, however, impede the further propagation and development of biogas, biomethane, and renewable gas projects in California. This staff paper is designed to highlight opportunities, challenges, and barriers to overcome in achieving the SB 1383 goals, both from electricity generation and use of transportation fuels.

Four renewable gas areas of consideration relating to SB 1383 requirements have been identified. They are discussed in Chapters 2–5. An overview of each chapter subject area is described order to provide a framework deriving specific considerations and questions that need resolution. Chapter 6 reconfigures the same questions based on topics discussed by separate stakeholder panels at the June 27, 2017, Joint Agency Workshop on Renewable Gas.

The Energy Commission will be soliciting stakeholder input and the public comment to fill knowledge gaps and suggest potential solutions to identified problems. Comments received from the public, along with contributions from stakeholders, will be included in the *2017 IEPR* to consider in carrying out SB 1383 responsibilities. The information will also be used in publishing an Energy Commission staff report on renewable gas.

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3 Jaffe, Amy Myers, Rosa Dominguez-Faus, Nathan C. Parker, Daniel Scheitrum, Justin Wilcock, Marshall Miller (2016) *The Feasibility of Renewable Natural Gas as a Large-Scale, Low Carbon Substitute*. Institute of Transportation Studies, University of California, Davis, STEPS Program, Institute of Transportation Studies, June 2016.

4 ICF (2017). *Economic Impacts of Deploying Low NOx Trucks Fueled by Renewable Natural Gas.* Available at https://static1.squarespace.com/static/53a09c47e4b050b5ad5bf4f5/t/590767ce59cc68a9a761ee54/1493657553202/ICF_RNG+Jobs+Study_FINAL+with+infographic.pdf.

CHAPTER 2: Legislative, Regulatory, and Program Administration Considerations

California will need significantly more development and use of renewable gas, including biogas and biomethane, to meet its goal of 40 percent reduction of methane below 2013 levels by 2030. Over the last 20 years, development of biogas to produce electricity has occurred at some dairy farms, wastewater treatment plants, landfills and waste diversion facilities. Use of biomethane as a transportation fuel has recently increased substantially. Much of the fuel used in natural gas trucks and buses comes from out-of-state imports delivered through interstate natural gas pipelines. In-state development of renewable gas from waste residue through both existing and new, emerging conversion technologies has just begun to produce transportation fuels. All of this early market development has been stimulated by government actions in the form of regulations, incentives, policies, and executive orders by Governor Edmund G. Brown Jr. Yet widespread growth is dependent on greater consistency, alignment, guarantee of program longevity, and maybe reconfiguration of a combination of government programs and policies to attract a substantial increase in private investment in renewable gas.

Consideration 2-1: Uncertainties of current electricity and low-carbon transportation polices do not fully address risks and may not fully stimulate widespread development and use of renewable gas.

From a financial perspective, renewable gas projects suffer when government program incentives are interrupted or terminated. Incentive offerings may need to extend over multiple fiscal years to create project financial stability and develop commercial demonstrations. Once a project is operating, it is also important that post-permit regulatory conditions are stable without new regulations becoming substantial risks for the projects.

Questions:

- What regulatory changes are needed to ensure government programs, such as the Low Carbon Fuel Standard (LCFS), Renewable Fuel Standard (RFS), and federal tax credits, will continue without disruptive changes?
- How can California Environmental Quality Act (CEQA) reviews and permitting processes be more accommodating and transparent for renewable gas projects?
- How can California more effectively use federal programs (for example, RFS)?
- Which factors are more subject to volatility or uncertainty, and what actions are needed to mitigate vulnerabilities?

Consideration 2-2: Problems arising from regulatory and funding agency coordination may not be obvious or self-evident.

Renewable gas demonstration projects can be influenced by the coherence of regulatory and funding programs. These programs exist at federal, state, and local levels. Conflicts can arise when agencies manage overlapping programs. Positive outcomes are more likely when individual agency strategies are coordinated and aligned.

Questions:

- Are there substantial problems that need to be addressed?
- Is there a role for regulations implementing SB 1383 to play in addressing these problems?
- What problems for renewable gas project proponents arise from lack of agency coordination?
- Are there any existing conflicts between regulatory or funding programs that substantially plague renewable gas project proponents?
- Should emerging technology projects have less funding priority than anaerobic digester projects?

Consideration 2-3: Alignment of existing California state, regional, and local air quality district regulations and incentives can more efficiently reduce short-lived climate pollutants.

Positive outcomes are more likely when individual agency strategies are coordinated and aligned.

Questions:

- How do state government agencies track the progress of biomethane/biogas/renewable gas development and use? How do they evaluate the need to continue, coordinate, or reconfigure government programs in the context of programs/activities conducted by other government agencies and private investment in projects?
- What types of data are needed to monitor and maximize the development and use of biomethane/biogas/renewable gas and optimize government activities to achieve 40 percent reduction of short-lived climate pollutants (SLCP) by 2030?

Consideration 2-4: Renewable gas project developers face many obstacles: obtaining funding, determining business models and compiling economic data, conducting project designs, selecting technology, obtaining all needed permits, constructing the project, operating the project, and partnering with people and entities in long-term contracts that are essential to project success.

Questions:

- What can be done to assist project developers in their efforts?
- How would project proponents rank their most urgent needs for assistance from funding agencies?
- How can funding and regulatory agencies help resolve utility interconnectivity problems experienced by project proponents?
- How can funding and regulatory agencies help applicants secure partnering in long-term contracts?
- Do project developers need assistance from funding and regulatory agencies? On what topics or processes?

Consideration 2-5: Current California policies and programs do not fully address the potential of new, emerging conversion technologies to reduce short-lived climate pollutants.

Appendix A discusses various production pathways and end uses.

Questions:

- What key factors (such as incentives, technology advances, business maturity) are required to be in place to achieve 2030 SLCP targets in California?
- What actions does California need to take to achieve the SB 1383 SLCP goals and account for the views of utilities, investors, electricity generators, fuel developers, host site owners, vehicle manufacturers, vehicle fleet owners, environmental justice and public interest organizations, and local governments?
- Are there opportunities to promote technology diversity, for example gasification or pyrolysis, as well as different phases of development, such as renewable gas research, development, and commercialized use?
- What project enhancements or additional benefits can emerging technologies provide?

Consideration 2-6: Widespread development of renewable gas projects will require an increase in public outreach and awareness.

Greater public support for funding of renewable gas demonstration projects would be desirable. Such support might be achieved through more public outreach regarding project existence, benefits, and goals toward which projects contribute.

Questions:

- What roles do federal agencies and local governments play in evaluating and supporting the development and use of biogas, biomethane, and renewable gas as a source of electricity or transportation fuel?
- Are there environmental justice or environmental impact concerns?

CHAPTER 3: Market and Economic Feasibility

In-state biomethane, biogas, and renewable gas not only compete with out-of-state renewable gas supplies, but also with other types of energy (such as other renewable electricity and fossil fuels). Competition exists with production costs (for example, labor, regulatory, capital, or technology development costs) and revenue (such as energy prices, economic incentives, and other revenue streams like tipping fees or by-product revenues). Examining the market and determining measures to enhance a project's economic feasibility is key to achieving the goals of SB 1383. To illustrate economic feasibility, Appendix B aggregates cost and revenue information from types of projects in each submarket. Please note, data are limited, and more input from the industry is needed.

Considerations identified in this chapter cover market demand, supply, and business models. Market demand is dependent on regulations that stimulate future demand. Demand growth will create a greater potential for investment and greater opportunities for the use of renewable gas. From the market supply perspective, investments in renewable gas production capacity depends on profitability in term of stable revenue sources (such as Renewable Fuel Standard and Low Carbon Fuel Standard credits) or competitive production technology (such as capital and running costs). Economies of scale may be another consideration since small-scale projects (such as small dairies and wastewater treatment plants) are less competitive in the market than larger ones.

Finally, the business model for running renewable gas projects is critical. Appropriate partnership for a project can help to lower transaction costs and minimize project risks. Finding a solution to encourage strategic partnerships under different circumstances can be an important step to improving a project's economic feasibility.

Consideration 3-1: Assured policy measures that stimulate demand (or use of) renewable gas can ensure a future market.

The unclear future about market demand will cause hesitation among investors. Addressing some of the previous issues may stimulate demand and create a potential for growth and reveal opportunities for the use of renewable gas.

Questions:

- What key factors (such as incentives or regulations) are required to be in place to stimulate future demand of renewable gas and achieve 2030 short-lived climate pollutant targets in California?
- How can utilities preserve or maintain consumer affordability?
- What is needed to increase the number of vehicle product offerings and vehicle volume sales to achieve SB 1383 goals?

- Is there sufficient customer demand in California for electricity and transportation fuel produced from renewable gas, biogas, and biomethane? Will the electricity and transportation fuel outcomes be affordable for customers?

Consideration 3-2: Unclear and uncertain economic feasibility for each submarket can impede policy implementation.

Project location (availability of pipeline injection or grid interconnection), project size, feedstock source, or business model can be critical factors for a project's economic feasibility. However, detailed information about project costs and revenue sources is limited due to possible confidential business data. (Please refer to Appendix B for cost/revenue data for each submarket). The information gap may impede investment and increase difficulty in accessing the cost-effectiveness of policies. More input of economic information is needed and may provide the necessary background needed for policy implementation.

Questions:

- What key factors (such as incentives in capital, production, or regulations) are required to be in place to encourage more supply?
- How is market growth sequence or progress of steps evolving for each submarket seen, and what government actions are needed at each step in terms of supply?
- How much growth of energy development and use is projected for each submarket, such as dairy and livestock, food waste and organic diversion, wastewater treatment, landfill gas, and agricultural/forestry/urban woody biomass residue?
- What efforts are planned for disadvantaged communities to take advantage of the developments of biogas, biomethane, and renewable gas?
- What is your view of the potential for growth and appetite for private investment in any of these submarket sectors for either power generation or transportation fuels in California?
- Is total capital investment needed to achieve the SB 1383 goals in the realm of possibility from private capital sources with government supporting actions?

Consideration 3-3: Need for analysis on successful business models.

Appropriate business models and partnerships for a project can help reduce the risk of project failure, lower the transaction costs, and ultimately enhance the economic feasibility of the project.

Questions:

- What are the near-term opportunities for transportation?
- What key ingredients are needed to stimulate and maintain private investment in these types of projects? What can government do to support, complement, and accelerate achieving these key ingredients?

- What do fleet owners/managers need to see to make commitments and purchase/lease vehicles that can use biogas, biomethane, and renewable gas as a fuel?

CHAPTER 4: Feedstock Resources

The majority of California's methane emissions come from the natural biogenic decomposition of organic wastes at livestock operations (such as dairies), food and urban waste facilities, wastewater treatment plants, and landfills. Dairies typically store manure in large open lagoons which emit methane as the manure decomposes. Food and urban waste facilities, such as material recovery facilities and transfer stations, receive and either separate or temporarily store municipal waste before being sent to landfills or diverted for another use. These organic materials may emit methane as they degrade. At wastewater treatment plants, anaerobic digesters that produce methane may be included in the treatment system as a means to reduce the amount of residual solids that need to be landfilled. The organic material in landfills then continues to biodegrade, releasing methane over decades.

The capture, conversion, and use of renewable methane emissions for energy production are an opportunity to reduce short-lived climate pollutant (SLCP) emissions while displacing fuels with high greenhouse gas life-cycle emissions and providing a beneficial use. However, there are challenges regarding the ability to cost-effectively collect, secure, and pre-process these wastes.

Consideration 4-1: Estimates vary on the current inventory of resources available for renewable gas production.

Questions:

- How much growth of renewable gas development is expected for each feedstock type: (1) dairy and livestock waste; (2) food waste and organic diversion, (3) wastewater treatment, (4) landfill gas, and (5) wood wastes from agriculture, forest, and urban biomass residue?
- What is the current status of renewable gas imports into California?
- From what sources is California receiving renewable gas imports?
- What is the volume and potential of new gas use moving forward?
- How does potential renewable gas production in California vary with different processing technologies (for example, anaerobic digestion, gasification)?

Consideration 4-2: Balancing regulatory mandates and incentives.

Assembly Bill 1594 (Williams, Chapter 719, Statutes of 2014), mandates that as of January 1, 2020, the use of green material as alternative daily cover for landfills will no longer constitute diversion through recycling and will, instead, be considered disposal. At the same time, SB 1383 establishes targets to achieve a 50 percent reduction in the level of the statewide disposal of organic waste from the 2014 levels by 2020 and a 75 percent reduction by 2025, along with a 20 percent improvement in edible food recovery by 2025. SB 1383 also targets reductions in methane emissions from livestock manure management operations and dairy manure management operations by up to 40 percent below the dairy sector's and livestock sector's 2013 levels by 2030. Municipalities, waste haulers, dairies, and other groups are seeking alternative methods for organics disposal. Methods considered include converting waste to electricity or fuel.

Questions:

- What is the current and expected market movement and uptake of waste-to-energy projects based on California organics diversion and SLCP reduction regulations, with and without additional monetary incentives?
- How will future methane emissions from landfills be impacted by California organics diversion and SLCP reduction regulations?

Consideration 4-3: Accessibility and movement costs may limit the cost-effectiveness of waste and biogas collection.

Certain wastes, such as dead forest residues, may be difficult to access due to restrictive terrain and limited road access. Waste resources may also be dispersed across a wide area and have a high cost to transport. In other instances, existing biogas production sites may be too small to economically develop an end use. Such sites include small wastewater treatment plants and small dairies.

Questions:

- How can geographically dispersed and largely inaccessible feedstock for biogas resources be cost-effectively gathered or used? Entities of concern include wood waste and biogas from small facilities.
- How can facility operations be scaled to meet feedstock availability (for example, a community-scale gasifier to manage locally-produced wood waste and small scale mill residue in rural communities)?
- What are current and future opportunities for central and distributed processing?
- How can economic and physical limitations of gathering and harvesting be incorporated into project planning or the development of policies?

Consideration 4-4: Barriers to securing long-term feedstock supply agreements.

Securing a long-term feedstock supply agreement can be difficult unless partnering with an existing waste hauler, collector, or municipality. Stable feedstock contracts are commonly needed to attract private financing.

Questions:

- How can longer feedstock supply agreements be negotiated? What partnerships are needed?

CHAPTER 5: Distribution and End Use

Potential uses for biogas include combustion to produce process heating or process steam, electricity generation, or fuel for natural gas vehicles. Biogas can also be converted into renewable hydrogen for use in fuel cell electric generators, fuel cell electric vehicles, energy storage, and a multitude of other applications. Depending on the type of energy product, it can be distributed and delivered to its end market either by tanker truck, through natural gas pipelines, or via the electricity grid.

Consideration 5-1: More information is needed about users and use rates for biomethane, biogas, and renewable gas.

Questions:

- What are the future prospects of biomethane, biogas, and renewable gas in producing electricity compared to transportation fuel?
- What are the future prospects of using biomethane, biogas, and renewable gas with different vehicle technologies (for example, compressed natural gas, dimethyl ether, hydrogen)?
- Are there examples of biomethane, biogas, and renewable gas exceeding onsite needs? If so, by how much and what is done with the excess?
- What are the near-term, opportunities for alternative transportation end uses?

Consideration 5-2: Gas and electric utility interconnection can be a costly and lengthy process for renewable gas projects.

Methods to increase market access by distributing renewable gas to offsite end users are increasingly being pursued. This is especially true when production begins to exceed onsite demand, or when production facilities are sited at stranded/isolated feedstock sources such as in rural areas. Interconnection with gas and electric utility infrastructure can be a costly and lengthy process for renewable gas projects. Guidance or assistance, along with government support, can address this challenge; however, utility companies and regulators must balance gas quality with system safety and reliability.

Questions:

- How do utility companies plan to reduce short-lived climate pollutants?
- How do utility companies plan to address increasing renewable gas products?
- What actions have utility companies taken, or plan to take, to assure that natural gas infrastructure are reliable, safe, and meet leakage requirements?

- How will the emergence and success in the development and use of biomethane, biogas, and renewable gas affect the operation of utility companies?
- What steps could utility companies take to facilitate biomethane pipeline injection and electricity interconnection? Potentials steps include lower costs for project proponents, streamlined review processes, and expedited responses.
- What is the renewal cycle time of entering into or modifying existing contracts/purchase agreements?

Consideration 5-3: Projects face risks due to adverse economies of scale.

Questions:

- At what size are renewable gas projects significantly impacted by economies of scales? Are they different for various feedstocks?
- What can and should be done to mitigate handicaps experienced by renewable gas projects of various sizes?

CHAPTER 6: Panel Discussions

During the June 27, 2017, Joint Agency Workshop on Renewable Gas, seven panels of designated participants and a moderator will meet to discuss specified topics related to renewable gas.

The topics are:

1. Overview of California policies, programs and regulations related to SB 1383 responsibilities
2. Potential to develop biomethane, biogas and renewable gas to produce electricity and transportation fuels in California
3. Utility strategies to reduce short-lived climate pollutants
4. Progress, success, lessons learned from existing projects
5. Emerging technologies and market opportunities
6. Market maturity, business models and factors that attract private project financing
7. Demand, vehicle fleets, and other factors

Each panel will be asked a series of questions to address opportunities and challenges relating to generation and use of renewable gas. Participants from government, industry and nongovernmental organizations will provide insights and comments. Each agency will consider participant contributions in responding to its SB 1383 responsibilities.

Questions for each panel are listed below.

Panel 1: Overview of California Policies, Programs and Regulations Related to SB 1383 Responsibilities

1. How do you track the progress of biomethane/biogas/renewable gas development and use? How do you evaluate the need to continue, coordinate or re-configure government programs in the context of programs/activities conducted by other government agencies and private investment in projects?
2. What types of data are needed to monitor and maximize the development and use of biomethane/biogas/renewable gas and optimize government activities to achieve 40 percent reduction of short-lived climate pollutants (SLCPs) by 2030?

Panel 2: Potential to Develop Biomethane, Biogas and Renewable Gas to Produce Electricity and Transportation Fuels in California

1. How much growth of energy development and use from renewable gas, biogas and biomethane do you expect for each submarket (for example, dairy and livestock, food waste and organic diversion, waste water treatment, landfill gas and agricultural/forestry, and urban woody biomass residue)?
2. What key factors (such as incentives, regulations, technology advances, and business maturity) are required to be in place to achieve 2030 SLCP targets in California?
3. What are the prospects to use biomethane, biogas and renewable gas for the growth of electricity generation compared to transportation fuel?
4. Which factors are more subject to volatility or uncertainty and what actions are needed to mitigate vulnerabilities?
5. How do you see a market growth sequence or progress of steps evolving for each submarket and what government actions are needed at each step?
6. How soon would you expect substantial market growth for each submarket?

Panel 3: Utility Strategies to Reduce Short-Lived Climate Pollutants

1. How does your utility plan to address the need to reduce short-lived climate pollutants?
2. What actions have you taken or plan to take to reassure that the natural gas system and pipelines are reliable, safe and minimize leakage?
3. How will the emergence and success in the development and use of biomethane, biogas and renewable gas affect the future direction and operation of your utility?
4. What steps could you take to enhance biomethane pipeline injection through lower costs, expedited construction times or other actions?
5. What efforts do you plan so disadvantaged communities can take advantage of the development of biogas, biomethane and renewable gas?

Panel 4: Progress, Success, Lessons Learned From Existing Projects

1. How would you characterize the success of your project and key ingredients for success?
2. What is the potential to replicate your progress throughout the state?
3. What challenges might interrupt continuing successful operation or impede expansion or the development of additional projects for any of the following areas:
   a. Technology development
   b. Project location
   c. Pipeline injection
   d. Business model

    e. Project financing
    f. Institutional/regulatory
    g. Demand and vehicle availability
    h. Related infrastructure
4. How much and what type of government action (regulation, incentives, other actions) is needed to achieve the SB 1383 SLCP goals?

Panel 5: Emerging Technologies and Market Opportunities

1. How would you characterize the promise of your fuel/technology and what steps are required to achieve commercial availability?
2. What challenges might interrupt development and commercialization of your fuel/technology for any of the following areas:
    a. Technology development
    b. Project location
    c. Pipeline injection
    d. Business model
    e. Project financing
    f. Institutional/regulatory
    g. Demand and vehicle availability
    h. Related infrastructure
3. What type of government action is required to support development and use of emerging fuels and technologies?
4. Can cost data be provided to the Energy Commission to support the cost-effectiveness and economic viability of your fuel/technology?

Panel 6: Market Maturity, Business Models and Factors That Attract Private Project Financing

1. What is your view of the potential for growth and appetite for private investment in any of these submarket sectors for either power generation or transportation fuels in California?
2. What key ingredients are needed to stimulate and maintain private investment in these types of projects? What can government do to support, complement and accelerate achieving these key ingredients?
3. Is total capital investment needed to achieve the SB 1383 goals in the realm of possibility from private capital sources with government supporting actions?

Panel 7: Demand, Vehicle Fleets and Other Factors

1. What is needed to increase the number of vehicle product offerings and vehicle volume sales to achieve SB 1383 goals?
2. What do fleet owners/managers need to see to make commitments and purchase/lease vehicles that can use biogas, biomethane and renewable gas as a fuel?
3. Is there sufficient customer demand in California for electricity and transportation fuel produced from renewable gas, biogas and biomethane?
4. What roles do federal agencies and local governments play in evaluating and supporting the development and use of biogas, biomethane and renewable gas as a source of electricity or transportation fuel?
5. What actions do you recommend the State of California take to achieve the SB 1383 SLCP goals and account for the views of utilities, investors, electricity generators, fuel developers, host site owners, vehicle manufacturers, vehicle fleet owners, environmental justice and public interest organizations, and local governments?

CHAPTER 7: Public Comment

For feedback on the issues and questions posed in this staff paper, oral comments will be accepted during the June 27, 2017, Joint Agency Workshop on Renewable Gas at the California Energy Commission. Written comments can be submitted to the Dockets Unit by 5:00 p.m. on July 11, 2017. Written comments will also be accepted at the workshop. All written comments will become part of the public record. Please refer to the Notice of Joint Agency Workshop on Renewable Gas.

The workshop will be structured to describe the policy, technology, and market context for renewable gas and highlight opportunities and challenges to achieve the SB 1383 goals both from electricity generation and use of transportation fuels. The workshop will include comments and presentations from the staff of each relevant state agency as well as federal and local governments. In addition to government agencies, comments will be taken from private and public entities, including gas and electric utilities, biogas host-site owners, market forecasting experts, fuel and electricity project developers/operators, financial investors, vehicle and engine manufacturers, vehicle fleet owners, and public interest organizations. Workshop findings will be included in the *2017 IEPR* to consider in carrying out SB 1383 responsibilities.

Appendix A: Production Pathways and End Uses

Methane and hydrogen gas are the simplest hydrocarbon compound and the most basic molecule in the universe, respectively. As such, there are many ways in which they can be renewably produced and used. Table 1 lists several methods for producing biogas/biomethane and renewable hydrogen, while Table 2 lists several energy-related end uses for these renewable gases.

Table 1: Renewable Gas Production Pathways

Biogas/Biomethane	Renewable Hydrogen
Anaerobic Digestion	Fermentation
Gasification / Pyrolysis	Gasification / Pyrolysis
Renewable Hydrogen Methanation	Biogas Reformation
	Electrolysis
	Artificial Photosynthesis

Source: California Energy Commission

Table 2: Renewable Gas End Uses for Energy

Biogas/Biomethane	Renewable Hydrogen
Heat / Steam Production	
Electricity Generation (Reciprocating Engines, Microturbines, Fuel Cells)	Electricity Generation (Fuel Cells)
CNG/LNG Vehicle Fuel	Hydrogen Vehicle Fuel
Injection into Natural Gas Pipelines	Energy Storage / Grid Balancing (via Injection into Natural Gas Pipelines)
Conversion to Liquid Hydrocarbon Fuels	Conversion to Liquid Hydrocarbon Fuels
	(Bio-)Oil Refining

Source: California Energy Commission

Appendix B:
Project Cost Effectiveness

Energy Commission staff gathered information from in-state facilities to assess the estimated costs for producing renewable gas. These plants included those producing renewable gas from dairy waste, organic waste diverted from landfills, wastewater, landfill gas, and gasification facilities to produce fuels for transportation use and electricity generation. This section includes an estimated range of costs for the production facilities, fueling stations, differential costs of natural gas (CNG) trucks compared to diesel trucks, interconnection into a natural-gas pipeline, and electricity generation equipment and utility interconnection (Tables 3, 4, and 5). Additional data are needed to better assess the costs associated with the various biomethane project types, especially for dairy and wastewater biomethane projects and in terms of producing transportation fuel. Additional data are also needed to assess the cost for gasification in terms of producing transportation fuel, and to further refine cost estimates for all potential end uses of syngas. This section also includes estimates of the various revenue streams that biomethane projects are able to capitalize on (Table 6).

Table 3: Production Facility Capital Cost Ranges by Type

	Capital Cost Range (million $) For Million Gallons (DGE) per Year Capacity							
	Food/Urban/ Municipal Solid Waste[5]		Dairy		Wastewater		Landfill	
	Low	High	Low	High	Low	High	Low	High
Organics Collection, Separation, and Processing Equipment	$1.20	$2.70	N/A	N/A	N/A	N/A		
Digester Technology	$8.75	$13.1	N/A	N/A	N/A	N/A		
Gas Collection System							$0.23	$1.7
Biogas Clean Up Equipment	$2.50	$3.75	N/A	N/A	N/A	N/A	$1.8	$4.7
Facility Engineering, Construction, and Permits	$15.0	$22.6	N/A	N/A	N/A	N/A	$1.6	$2.5
Subtotal Cost	*$28.0*	*$42.2*	*N/A*	*N/A*	*N/A*	*N/A*	*$3.6*	*$8.9*
Contingency (7 percent)	$1.97	$2.95	N/A	N/A	N/A	N/A	$0.25	$0.62
Biomethane Plant TOTAL COST	*$30.1*	*$45.2*	*N/A*	*N/A*	*N/A*	*N/A*	*$3.8*	*$9.5*

Source: California Energy Commission

5 Reflects cost range for different types and sizes of biomethane production plants designed to produce RNG for transportation fuels from organic waste diverted from landfills. Includes regional, centralized plants with modular units and organic waste delivered to the plant location for both onsite vehicle use and interconnection to a natural gas pipeline. Also includes smaller community-scale biomethane production plants to fuel vehicles onsite and not to connect to the natural gas pipeline.

Table 4: Gasification Facility Capital Cost Ranges

	Capital Cost Range ($) For kWh Per Year Capacity	
	Low (Large-Scale)	High (Small-Scale)
Feedstock Handling Equipment	$0.02	$0.07
Gasifier Unit	$0.15	$0.25
Syngas Clean Up Equipment	$0.02	$0.21
Methanation Unit[a]	N/A	N/A
Fischer-Tropsch System[b]	N/A	N/A
Facility Engineering, Construction and Permits	N/A	N/A
Subtotal Cost	$0.70	$1.60
Contingency (7 percent)	$0.05	$0.11
Biomethane Plant TOTAL COST	$0.75	$1.61

[a] Only required when biomethane is the desired product
[b] Only required when liquid hydrocarbon-based fuel is the desired product
Source: California Energy Commission

Table 5: Capital Cost Ranges for Biomethane End Uses

		Capital Cost Range ($) for Million Gallons (DGE) per Year Capacity *Unless otherwise stated	
		Low (Large-Scale)	High (Small-Scale)
Vehicle Fuel	CNG Fueling Station[6]	$950,000	$1,600,000
	100 Vehicle Differential Cost (for refuse trucks)[7]	$4,000,000	$10,000,000
Pipeline Injection	Biogas Gathering Lines (for centralized cleaning)	$1,600,000	$2,000,000
	Biogas Conditioning/Upgrading Equipment	$1,850,000	$8,000,000
	Natural Gas Pipeline Interconnect[8]	$1,000,000	$4,500,000
Electricity Generation	Electricity Generator (Stationary Reciprocating Engine, Microturbine, Fuel Cell)	$0.15 per kWh/yr $1,300,000/MW	$0.90 per kWh/yr $6,800,000/MW
	Electricity Interconnect*	$0.01 per kWh/yr $89,000/MW	$0.09 per kWh/yr $733,000/MW

Source: California Energy Commission

6 CNG fast-fill and slow-fill capabilities.

7 Cost range of $40,000 -$100,000 differential for each natural gas truck compared to equivalent diesel truck model.

8 Cost range to complete pipeline interconnect for 1 million diesel gallon equivalents (DGE) per year production plant capacity at a central regional plant. Assumes additional production modules at a central regional plant should not require significant new pipeline interconnection costs.

Table 6: Biomethane Facility Revenue

		Revenue Range Low	Revenue Range High	Current Incentives Revenue (End of May 2017)
CNG Vehicle Fuel	CNG Sales or Fuel Savings ($/DGE)	$1.70	$2.80	
	RFS D5 RIN Credits ($/DGE)[9] Or [RFS D3 RIN Credits ($/DGE)][10]	$1.25 [$3.62]	$2.01 [$4.63]	$1.65 [$4.27]
	Cellulosic Waiver Credits ($/DGE)[11] *cannot be earned with RFS D3 RINs, but can with D5 RINs	$0.76	$3.31	$3.31
	LCFS Credits ($/DGE)[12]	$0.20	$6.09	$0.63 - $3.50
Hydrogen Vehicle Fuel	Hydrogen Sales ($/kg) [$/DGE]	$10 [$11]	$18 [$20]	
	RFS D5 RIN Credits ($/DGE) [9, 13] Or [RFS D3 RIN Credits ($/DGE)][10,13]	$1.27 [$3.68]	$2.05 [$4.70]	$1.68 [$4.33]
	Cellulosic Waiver Credits ($/DGE)[11] *cannot be earned with RFS D3 RINs, but can with D5 RINs	$0.76	$3.31	$3.31
	LCFS Credits ($/DGE)[14]	$0.56	$4.10	$1.87 - $2.43
Electricity	Electricity PPA ($/kWh)	$0.067	$0.12	
	SGIP ($/W)[15]	$1.00	$1.20	$1.20
	Energy Savings	$0.09	$0.20	
General	Tipping Fee (for accepting feedstock material)	$35/ton	$112/ton	
	Biosolids Compost / Soil Amendment Sales	$10/ton	$16/ton	
	Liquid Fertilizer Sales	TBD	TBD	

Source: California Energy Commission

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9 Assume 2016 – 2017 current year (2017) D5 RIN credit price range of $0.76 to $1.22/RIN.

10 Assume 2016 – 2017 current year (2017) D3 RIN credit price range of $2.19 to $2.80/RIN.

11 Cellulosic Waiver Credits may only be earned if choosing to receive D5 RIN credits in lieu of D3 RIN credits. The Cellulosic Waiver Credit price per credit is $2.00 for 2017, $1.33 for 2016, $0.64 for 2015, and $0.49 for 2014.

12 Assume LCFS historical credit range of $22 to $122/MT-$CO_2$e, biomethane CI range of 30.92 to -272.97 gCO_2e/MJ, diesel CI of 98.44 gCO_2e/MJ for 2017, and EER of 1.0 for compression-ignition engines.

13 One kilogram of hydrogen can earn 1.5 RIN credits, based upon calculations from Section §80.1415 of the Renewable Fuel Standard.

14 Assume LCFS historical credit range of $22 to $122/MT-$CO_2$e, hydrogen CI range of 47.73 to -12.65 gCO_2e/MJ, California reformulated gasoline CI of 95.02 gCO_2e/MJ for 2017, and EER of 2.5 for light-duty fuel cell electric vehicles.

15 Step 1 through Step 3 of the *2017 Self-Generation Incentive Program Handbook*, including $0.60/watt biogas adder.