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Renewable natural gas in California: An assessment of the technical and economic potential☆

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ABSTRACT

Renewable natural gas has the potential to diversify and decarbonize natural gas as a transportation fuel. Biomethane, a subset of renewable natural gas, is produced from a range of waste sources that are distributed across the landscape with uneven access to natural gas infrastructure. Using a spatially explicit techno-economic model of renewable natural gas supply in California, we develop supply curves for producing renewable natural gas and delivering it to California's transportation fuels market in order to estimate the economic potential. The gross potential is 90 bcf per year (94.5 PJ/yr), which is larger than the 17 bcf per year (18 PJ/yr) of natural gas consumed as transportation fuel in California in 2016. Seventy-five percent of the resource is estimated to be economic if the value of existing policy credits are fully capitalized, resulting in 6.9 million Low Carbon Fuel Standard credits. Renewable natural gas provides an economically viable option for methane emission reduction for a quarter of dairy manure in the state. The results suggest that renewable natural gas can play a significant role in meeting low carbon fuel policies in California and that expansion of demand for natural gas in transportation is needed to fully realize this potential.

1. Introduction

Developing supplies of renewable natural gas (RNG) is attractive for several climate and energy policy goals. Current sources of methane emissions to the atmosphere, such as dairy manure and organic wastes in landfills, can be managed to reduce or capture the methane for beneficial use (Ramanathan and Xu, 2010). Diverting these methane emissions into energy consumption both displaces fossil gas combustion and releases carbon dioxide instead of methane with 27 fold reduction in climate forcing (IPCC, 2014). Renewable natural gas can provide substantial quantities of either renewable fuel for the transportation sector, pipeline gas or renewable electricity. By using local resources, the development of renewable natural gas supports energy independence and local economic development. Finally, new ultra-low NOx natural gas engines for medium and heavy-duty vehicles provide a low criteria air pollutant option for the sector, which when fueled by renewable natural gas is also a low carbon option provided methane leakage is limited (CARB, 2015a). Medium and heavy duty vehicles are an especially challenging sector for zero emission vehicles.

Renewable natural gas, also known as biomethane, is methane produced from organic resources, upgraded to acceptable standards and put to commercial use in the energy sector. Such resources include manure, food waste, landfill gas, wastewater treatment sludge, forest residues, agricultural residues, and the organic fraction of municipal solid waste (MSW). Landfill gas and biogas from existing wastewater treatment anaerobic digesters can be readily transformed into renewable natural gas through a combination of biogas cleaning and upgrading. Manures, residues and MSW require either anaerobic digestion with subsequent biogas cleaning and upgrading or gasification with methane synthesis.

The use of these resources is motivated by multiple benefits. Capturing and consuming methane that would otherwise be released to the atmosphere leads to decreasing both climate forcing and background tropospheric ozone concentrations (West et al., 2006). Dairy manures and landfills are responsible for 25% and 20%, respectively, of 2013 methane emissions in California (CARB, 2017b). Wastewater

Abbreviations: AD, Anaerobic Digestion; BCF, Billion Cubic Feet; BDT, Bone Dry Tons (United States); CARB, California Air Resources Board; CEC, California Energy Commission; CNG, Compressed Natural Gas; CPUC, California Public Utilities Commission; EPA, United States Environmental Protection Agency; GBSM, Geospatial Bioenergy Systems Model; LC, Levelized Cost; LCFS, Low Carbon Fuel Standard; mmBtu, Million British Thermal Units; MSW, Municipal Solid Waste; NO_x, Nitrogen Oxides; RFS, United States Renewable Fuels Standard; RNG, Renewable Natural Gas; TPY, Tons Per Year; WWTP, Wastewater Treatment Plant

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treatment plants were responsible for 4%. Reducing these sources of methane is a primary driver in California's policies that make RNG an attractive energy source. There are potential air quality benefits of diverting biogas into RNG where biogas is currently burned in internal combustion engines for power generation. Other benefits from the development of RNG resources include reducing landfill burden, as well as odor and pathogen control.

The transportation sector is a particularly interesting end-use for renewable natural gas due to growing natural gas vehicle demand and policies that provide large incentives for renewable and low carbon fuels. Additionally, transportation fuels generally have higher prices per unit of energy compared to other sectors, providing more economic incentive for alternatives like RNG. Natural gas vehicle demand in the United States has increased from 23.7 billion cubic feet (bcf) (24.8 PJ) to 41.2 bcf (43.2 PJ) from 2006 to 2016, a 73% increase (5.6% annual growth rate). California has the largest natural gas vehicle demand in the country with 45% of the total national demand and stronger growth over the same timeframe. Renewable natural gas can be delivered to vehicles either locally near the production facility or through long distance pipeline distribution. Local usage provides economic advantages where resources and demand coincide. Renewable natural gas transported in long distance pipelines enables access to all fueling locations that are needed to increase demand levels. Pipeline access also places the supplies into the larger market for natural gas, which diversifies potential demands and can reduce the financial risk to the RNG producer.

Renewable natural gas is not the only product that can be made from these biomass resources. Other fuels, such as renewable diesel, dimethyl ether, or ethanol could be produced from these same resources. Composting, biomass-based electricity and bioproducts are other potential uses. Carreras-Sospedra et al. (2016) suggests that conversion of biomass for renewable natural gas for vehicle use provides greater greenhouse gas reductions while having comparable emissions of criteria air pollutants compared with advanced electricity generation technologies. RNG with ultra-low NOx engines can serve an energy sector that has limited viable options for areas attempting to simultaneously improve air quality and achieve deep reductions in greenhouse gas emissions in the near term.

The State of California has a policy framework that is supportive of the development of renewable natural gas supplies. The state has recently implemented policies that mandate the reduction of short-lived climate pollutants including methane from landfills and dairies (California State Senate, 2016; CARB, 2015b), provide a market pull for low carbon fuels through the Low Carbon Fuel Standard (California Governor's Office, 2007), spur the development of natural gas vehicles for air quality and greenhouse gas purposes (California State Senate, 2014; CEC, 2016a; CARB, 2011), ensure access to pipeline infrastructure (California State Assembly, 2012), and provide monetary incentives to offset some portion of the interconnection costs (California State Assembly, 2016).

The result of this rich policy environment is a market with industries facing mandates for methane reductions and a high demand for carbon credits in the transportation. This creates opportunities for the development of a renewable natural gas industry that provides compliance for potential suppliers of methane and carbon credits for the transportation fuels market. Estimating the size of and participation in this new market requires understanding the economic incentive for potential suppliers of RNG. Spatial techno-economic models of potential suppliers of RNG can be used to develop supply curves for the industry, which estimate the quantity of RNG that can be supplied below a given price (Parker et al., 2010).

This study examines the technical and economic feasibility of producing large quantities of renewable natural gas fuels for use in transportation in California. The focus of the study is on the role in-state sources of renewable natural gas can play in compliance with California's Low Carbon Fuel Standard (LCFS) while reducing methane emissions from the waste and dairy sectors.

2. Background and literature review

Existing biomass resource assessments suggest that there is a substantial resource base in California and the United States that could be tapped to build a renewable natural gas industry in the state. The gross potential for renewable natural gas in California from all sources is 132.3 BCF (139 PJ) per year (Williams et al., 2015). Eliminating resources that are technically infeasible to capture, such as manure from pasture grazed animals, the resource is estimated at 90.3 BCF (95 PJ) per year (Williams et al., 2015). Of this total, 37.3 BCF (39 PJ) per year is currently being used for electricity, heat or pipeline gas production. Nationally, the resource potential is estimated at 855 BCF (898 PJ) per year (Saur and Milbrandt, 2014). Removing technically infeasible and resources currently being used or tied to a planned project, the available resource is reduced to 333 BCF (350 PJ) (Saur and Milbrandt, 2014). The potential is greater than 17 BCF (18 PJ) of natural gas use in transportation in California in 2016 but only 1.3% of total natural gas consumption. For reference, the 333 BCF (350 PJ) RNG potential for the United States is similar in scale to the demand for transportation fuels from refuse trucks (215 BCF or 226 PJ) and transit buses (104 BCF or 109 PJ) in the country in 2014 (US EIA, 2016). These are two of the vehicle sectors with highest natural gas market share. Four resources for renewable natural gas are analyzed in this paper: landfill gas, wastewater biogas, food and green waste and dairy manures.

Landfill gas is produced from the anaerobic degradation of organic matter in landfills. This landfill gas needs to be captured, cleaned and upgraded to produce renewable natural gas that can either be used directly in co-located fueling stations or injected into the natural gas pipeline to be used elsewhere. Current production of landfill gas is due to the waste in place in existing landfills, which will continue to produce methane at a declining rate for decades. Future landfill gas will also be impacted by the extent of diversion of degradable organic wastes. California has set goals of reducing organic waste in landfills by 50% of 2014 levels in 2020 and 75% in 2025. If achieved, this rapid removal of degradable wastes will result in declining landfill gas production. If no degradable waste were added to landfills, landfill gas supplies would decline at a rate of 2–5% per year depending on landfill conditions.

Food waste and yard waste, two major organic components of municipal solid waste, can be diverted from landfills to produce biogas in anaerobic digesters. The biogas requires cleaning and upgrading to produce renewable natural gas. The MSW digesters produce biogas from wastes faster, with a higher yield, with fewer contaminates and with lower methane losses to the environment compared to landfill gas. The resulting digestate can be used in compost production, keeping nutrients in the soil instead of the landfill. The diversion of food and yard wastes from landfills will reduce landfill gas production in the future. Given the composition of landfilled material (CIWMB, 2009) and the biomethane potential of waste components (Staley and Barlaz, 2009), food and yard waste represent 33% of the total biomethane potential of landfilled material in California.

The California Biomass Collaborative estimates that 1.2 million bone dry tons (bdt) per year of food and green wastes could be utilized if it can be economically separated from the waste stream (Williams et al., 2015). Exploiting this resource can be done in two ways – source separation and mixed digestion of a sorted waste stream. These resources are best suited for anaerobic digestion due to high moisture content and high biodegradability. The currently landfilled food waste and green waste represents 15 bcf (15.8 PJ) per year of renewable natural gas potential.

Biogas from wastewater treatment is produced in some wastewater treatment plants where anaerobic digesters are used. The biogas can be upgraded to produce RNG. Currently, much of this biogas is used to provide heat for the plant and/or electricity for the treatment plant and