Renewable Natural Gas – hope or hype? Initial research into cost-effectiveness and market barriers

Benjamin Cheah, Verdant Associates, Kenai, AK

ABSTRACT

Renewable hydrogen or natural gas (RNG) is the industry's newest buzzword. But is it more than just a craze? Is RNG an effective tool in the fight against climate change and can it be utilized as a tool to help states like California meet their stringent self-imposed greenhouse gas reduction targets? How can RNG play into California's future as the state experiences increasing year-after-year threats from climate-induced disaster? A better understanding of the market barriers and cost-effectiveness of renewable natural gas will help policymakers in any jurisdiction design programs, RNG standards, and incentive mechanisms to encourage technologies that cost-effectively reduce greenhouse gas emissions. This paper presents findings from a cost-effectiveness analysis of an RNG standard for the country's largest gas utility and a California statewide market characterization and cost-effectiveness analysis of renewable natural gas for on-site generation.

As legislatures consider RNG requirements, market assessments and cost-effectiveness analyses can help shape public policies. Our market assessment found that biogas is an expensive fuel. Upfront costs combined with ongoing operations, maintenance, and fuel cleaning costs, as well as air quality permitting issues are all perceived barriers to an RNG future. Incentives, both at the state and federal level, can be leveraged to overcome some of these barriers.

Introduction

From fires to floods, climate change has fueled an increasing amount of severe weather events across the globe. California is at the forefront of tackling the ever-increasing climate crises, and along with its stringent greenhouse gas emission reduction goals, has passed pieces of legislation towards evaluating the potential for Renewable Natural Gas (RNG).

In 2018, California Senate Bill (SB) 1440 (Hueso, 2018) directed the California Public Utilities Commission (CPUC) to evaluate whether to establish goals or targets for RNG purchases by California's gas utilities. In November 2019, the CPUC issued the Assigned Commissioner's Scoping Memo and Ruling Opening Phase 4 of Rulemaking 13-02-008 addressing implementation of SB 1440. On December 6, 2019, the Energy Division hosted a technical workshop to discuss SB 1440 implementation. SB 1440 did not specify RNG cost-effectiveness metrics or benchmarks to compare RNG to other decarbonization options.

This paper discusses the potential for using RNG as a tool for combatting climate change and reducing emissions, either by replacing fossil natural gas or generating electricity. While this paper focuses on California, the findings can be extrapolated to other parts of the country. Verdant's findings are based on analysis performed for the commercial and industrial sector focusing on stationary generation equipment, and analysis on residential impacts comparing high and low efficiency gas appliances and electric appliances. The results are intended to present potential benchmarks to electrification and other decarbonization pathways.

Sources and Characteristics of Biogas

Biogas is a mixture of methane and other gases that are formed when organic material is decomposed anaerobically (in the absence of oxygen) or through gasification or pyrolysis (syngas). The organic matter can come from a variety of sources such as dairies, wastewater treatment plants (WWTP), landfills, and excess crop or forest residues. When this biogas is refined to pipeline quality it is often called biomethane, directed biogas, or RNG.[1] The resulting product is virtually identical to and can be used in place of natural gas (NG) but with the potential to reduce emissions and be carbon neutral or carbon negative. Figure 1 below presents an overview of the primary sources of biogas in California and some of the impacts of each source that is used.

The figure also describes the baseline methane requirement or the current standard practice in California for the different sources of biofuel. Most large WWTP and landfill biofuel sources in California are required to capture and destroy the methane produced, either through a process called flaring or through combustion. This destroys the methane but still produces CO_2. Dairies, smaller landfills, and smaller WWTPs don't typically have the equipment to perform this destruction, so the methane produced is typically released (or vented) into the atmosphere. As methane has a CO_2 equivalent (CO_2eq) value of 25 times that of CO_2 (CARB, 2021), venting methane into the atmosphere causes significant greenhouse gas (GHG) emissions.

	Daries (> 500 Cows)	WWTP	Landfill	Biomass
Description	• Large daries collect and store manure to breakdown and later use as fertilizer.	• Breakdown organic waste.	• Methane is collected via pipes.	• Organic material such as woodchips, orchard clippings, nut shells used to produce syngas.
Baseline Methane Requirement	• No requirement - typically vented (released into the atmosphere)	• Required to destroy the methane through combustion or flaring.	• Most landfills are required to destory the methane through combustion or flaring.	• No requirement - typically vented (released into the atmosphere)
Breakdown of Organic Matter	• Anerobic Digestion	• Anerobic Digestion	• Anerobic Digestion	• Gasification and Pyrolysis
Quantity of Known Systems Operating in California	• 799 dairies in California • 38 agricultural digesters producing, collecting, and using biogas for onsite generation • 12 projects using RNG for pipeline injection • over 100 additional planned for pipeline injection	• 242 WWTP in California • 154 known to have a digester to produce methane. • 112 believed to make beneficial use of the gas	• 405 landfills in California • 265 with methane collection • 15 believed to utilize pipeline injection	• 63 biomass generation plants in California • 25 producing, collecting, and using biogas for RNG

Figure 1. Primary Sources of Biogas or RNG in California

Biogas Management and Uses

If biogas is not flared, it can be used for further beneficial purposes such as pipeline injection or onsite electricity generation. Additionally, biogas may be used to fuel transportation. Biogas or RNG for transportation use often utilizes pipeline injection to transport RNG to the fueling station(s).

Pipeline injection. Biogas must meet NG pipeline standards for both heat content and purity before injecting into the NG distribution system. These requirements include removing CO_2 to increase heat content and potentially expensive filtering and treatment to remove compounds that are likely problematic such as hydrogen sulfide (H_2S), ammonia (NH_3), and siloxanes. Additionally, biogas needs to be pressurized to be at sufficient pressure to be injected into the gas pipeline. At this point, RNG becomes functionally identical to the Compressed Natural Gas (CNG) that flows through California's pipelines for use in customers' businesses and homes. The upgrading, cleanup, and pressurization equipment, plus the

[1] Throughout the rest of this report, biomethane, directed biogas, or RNG will be referred to as RNG.

connection to the pipeline and ongoing operations and maintenance, can be very expensive. The costs to clean up biogas itself can range between $500 - $1500/kW, with the cost of the pipeline interconnection itself adding up to several hundred dollars per kW (ICF, 2019).[2], not to mention the significant amounts of electricity required to even perform cleaning and pressurizing the gas. Some industry experts estimate that O&M alone for these processes can be as much as $20 per MMBtu. These costs result in RNG being substantially more expensive than NG. Once injected into the NG distribution network, the RNG co-mingles with fossil-based NG. The producers of RNG are paid by selling credits or through long term contracts. This gas can also be used for transportation and receive credits via California's Low Carbon Fuel Standard and the federal Renewable Fuel Standard.

Electricity generation. Biogas can also be used to generate electricity, either onsite or through RNG where the generator operator agrees to buy directed biogas from a producer. For onsite generation, the biogas still needs to be processed to remove many of the same impurities as for pipeline injection, but often the requirements for use in combustion are not as stringent as for injection into a pipeline. Most engines have requirements that are significantly less stringent than the California pipeline standard. Some reciprocating (or internal combustion) engines can tolerate nearly 1,000x more siloxanes (10 -100 mg/m3) than are allowed in California pipelines. Some microturbines, however, require fuel with a lower siloxane (0.01-0.1 mg/m3) content than California pipelines (Levin and Carder, 2018).

Transportation. While this paper does not specifically focus on biogas for transportation purposes, state incentive programs such as California's Low Carbon Fuel Standard (LCFS) and the federal Renewable Fuel Standard (RFS) cannot be ignored because they can influence the availability of biogas for other purposes. These standards are market-based programs with the goal of reducing the carbon intensity of transportation fuels. The demand driven by these programs could potentially compete for the supply of RNG available for stationary uses. According to the CARB's LCFS website, "The LCFS is designed to encourage the use of cleaner low-carbon transportation fuels in California, encourage the production of those fuels, and therefore, reduce GHG emissions and decrease petroleum dependence in the transportation sector. The LCFS standards are expressed in terms of the "carbon intensity" of gasoline and diesel fuel and their respective substitutes."

Cost Effectiveness Analysis

Decarbonizing our economy is increasingly important and understanding how to most efficiently do this is a key factor in succeeding in that goal. Historically, California energy policy has been tied to assessments of cost effectiveness through the Standard Practice Manual (SPM) tests of cost effectiveness. These tests include the following tests:

- **The Participant Cost Test (PCT)** is the measure of the quantifiable benefits and costs to the customer due to participation in the program.
- **The Ratepayer Impact Measure (RIM) Test** measures what happens to customer bills or rates due to changes in utility revenues and operating costs caused by the program.
- **The Total Resource Cost (TRC) Test** measures the net costs of a program as a resource option based on the total costs of the program, including both the participants and the utility's costs.
- **The Societal TRC (STRC)** is a variant of the TRC test that uses a lower societal discount rate.

[2] The ICF study references estimates that the cost of financing, constructing, and maintaining a pipeline of 1 mile will range from $1-5/MMBtu.

- **The Program Administrator (PA) Cost Test** measures the net costs of a program as a resource option based on the costs incurred by the PA (including incentive costs) and excluding any net costs incurred by the participants.

These SPM tests do not, however, directly assess how much it costs a homeowner, utility, or the state to avoid releasing a ton of carbon dioxide equivalent into the atmosphere. This is likely to be an increasingly important metric as decarbonization attracts increasing focus.

The benefits for the total resource cost (TRC), societal total resource cost (STRC), program administrator (PA), and ratepayer impact test (RIM) are largely composed of avoided cost savings while the participant cost test (PCT) benefits are largely bill savings.

This section describes results from our RNG cost effectiveness research in the commercial and industrial sectors followed by an analysis of the potential of RNG to help decarbonize California's residential building stock.

Commercial and Industrial Biogas Fueled Electricity Generation

Our research represents findings from over 400 distinct simulations based on combinations of customer renewable generation technologies, RNG or onsite biogas (OSB) fuel type, methane baseline, total installation costs, and incentive levels. As part of these scenarios, we considered the following:

- Resiliency adder incentives,
- Capacity factors,
- Baseline types,
- Digester costs,
- Grants and other incentives, and
- RNG costs.[3]

The technologies include multiple sizes of gas turbines, fuel cells, electric only fuel cells, IC engines, and microturbines. Avoided costs and emissions information are derived from the 2020 *California Avoided Cost Calculator* (ACC). The energy consumption bills are calculated using commercial rates for all California IOUs.

Avoided Cost Calculator

RNG fueled generation technologies are modeled as producing electricity that reduces the customer usage of power supplied from the grid. The electricity production is valued using the CPUC ACC. The ACC produces an avoided cost shape for an applicable climate zone. To assess the utility value of additional GHG reduction associated with technologies installed on a vented baseline, the GHG adder from the ACC was applied to the CO2e reduction associated with the reduction in methane emissions.

Total resource cost test. Simulations were grouped into four distinct scenarios – technologies with a flared baseline using RNG, those with flared baseline using OSB, those with a vented baseline using RNG, and those with vented baseline using OSB. The TRC analysis represents the cost-effectiveness from the joint perspective of the participant customer and the

[3] We present findings below using alternative compositions of RNG, where the RNG sources are landfills, dairies, wastewater treatment plants, and municipal solid waste. The carbon intensities of the various sources of RNG are derived from the above research and based on an assumption that the RNG is comprised of biofuel from 85% landfill, 8% dairy, 3.5% waste water treatment plants, and 3.5% municipal solid waste. The price of RNG is based on a combination of production costs for the different RNG sources, sourced from a recent report from the American Gas Foundation (ICF, 2019). This represents the average of the high and low production cost estimates. For dairies, the production cost estimates are multiplied by 1.5 due to dairies being able to extract higher prices due to the LCFS and their higher carbon values. The data adds on costs for Transportation & Public Purpose Program (PPP) charges, along with 2021 NG Rates for PG&E.

utility. The benefits for this test include the avoided cost value of the electricity produced and the GHG emissions reductions while the costs including program administrator non-incentive costs, participant measure costs, and increased fuel costs.

Figure 2 displays the distribution of TRCs calculated for the over 400 scenarios that were run. None of the scenarios run for technologies using a flared baseline[4] passed the minimum threshold TRC value of 1.0 to be considered cost-effective from a program standpoint. Systems with a vented baseline, however, were all found to be cost-effective based on the TRC test.

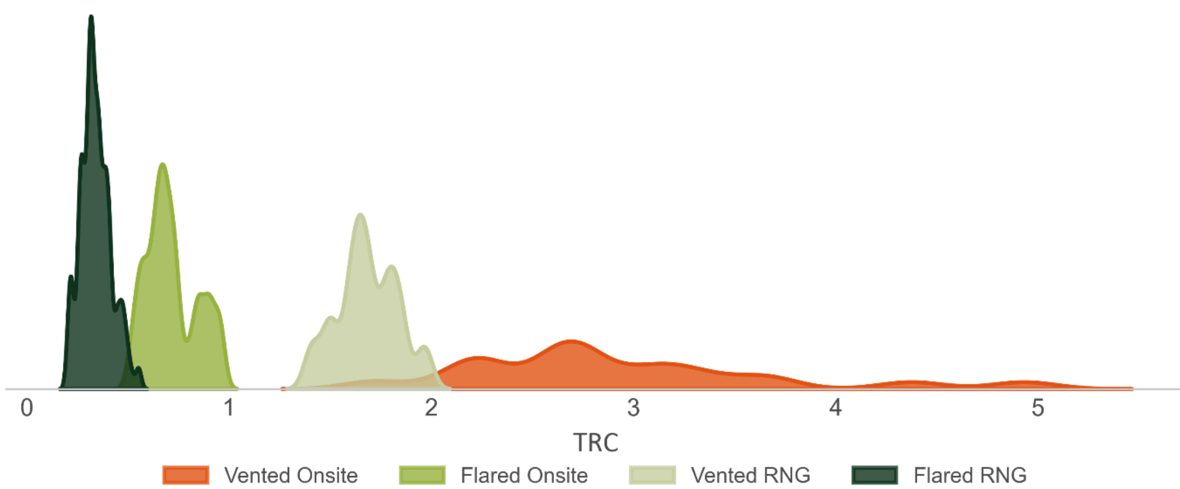

Figure 2. Distribution of TRC by RNG and Onsite Biogas and Vented and Flared Baseline for Different Scenario Analyses in 2020

While the technology type does play a little role in the range of TRCs for a given fuel type and baseline type, whether or not the technology is likely to be cost effective has is entirely to do with the benefits associated with the reduction in GHG emissions, due to the vented baseline type. As shown below in Figure 3, RNG-fueled fuel cells typically show lower TRC benefits than combustion technologies as they generally have higher O&M costs related to fuel cleaning and stack replacements. For technologies fueled by RNG and OSB with a flared baseline, the avoided costs are principally those associated with the participant customer producing electricity and foregoing the use of electricity supplied by the utility. For technologies fueled by OSB with a vented baseline, especially OSB at a dairy, the avoided cost includes the reduction in GHGs associated with the reduction in methane and any avoided cost savings associated with electricity production.

[4] Based on 2020 Avoided Costs

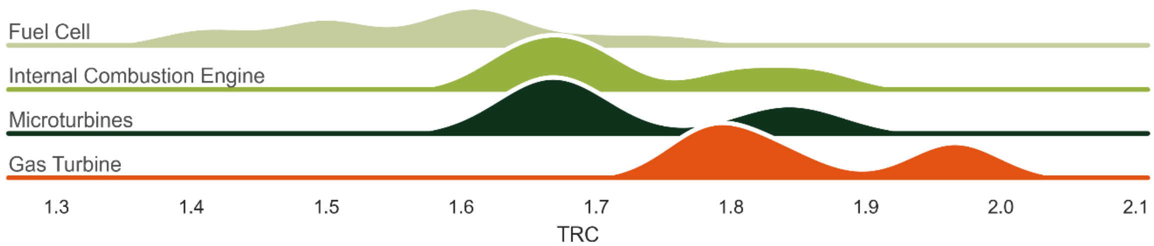

Figure 3. Distribution of TRC by Technology Type for Vented RNG Scenarios in 2020

Although Figure 2 above shows that Flared Onsite technologies were determined to not be cost effective in 2020, the future cost of carbon is expected to change that. Using the avoided costs estimated for 2030 we found that TRC estimates for Flared Onsite technologies may become cost-effective in the future, due to the increased cost of carbon. Figure 4 shows the comparison between 2020 results and 2030 results for the scenarios we ran for Flared Onsite technologies.

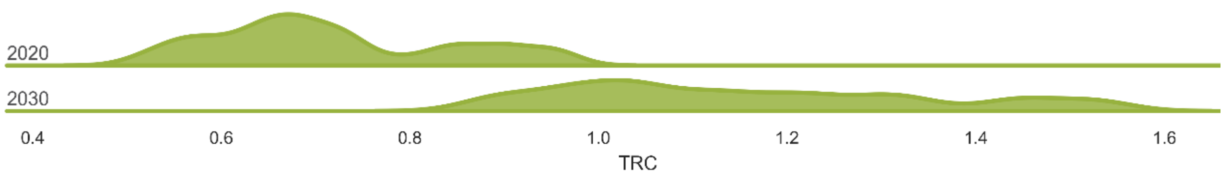

Figure 4. Distribution of 2020 versus 2030 TRC Estimates for Flared Onsite Scenarios

Participant cost test. The Participant Cost Test (PCT) evaluates the cost-effectiveness of renewably fueled generation technologies from the participating customer's point of view. The PCT benefits are the bill savings associated with the electricity produced by the technologies, rebates or incentives, reductions in taxes, and the investment tax credit (ITC). The change in the customer's total tax liability may be a benefit or a cost in the PCT. If the installation of the technology leads to a reduction in taxes, the reduction is treated as a benefit whereas an increase in taxes, is an increase in costs. The PCT costs (shown below in Figure 5), include the measure costs, the increase in fuel costs to run the generator, and increases in taxes.

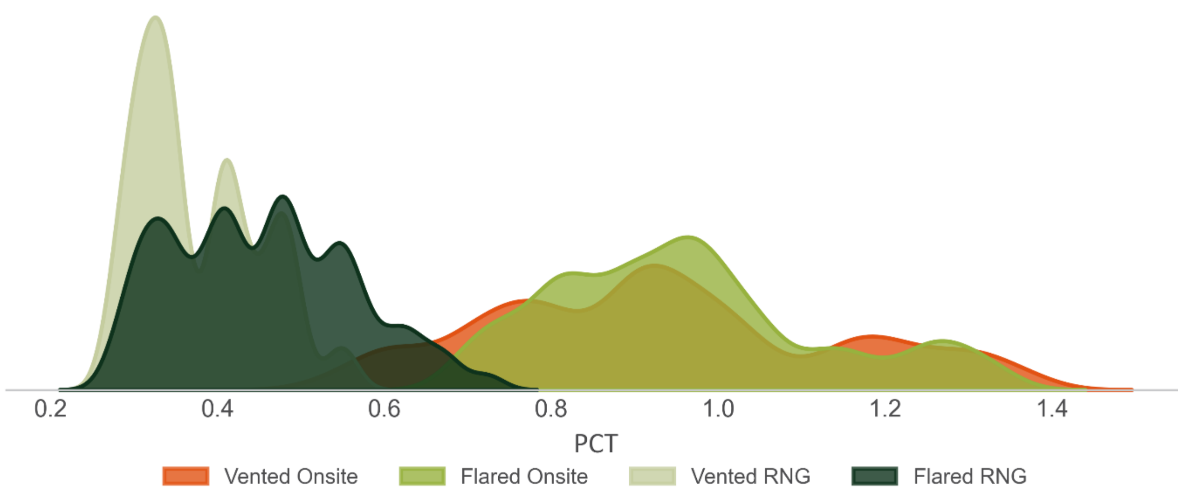

Figure 5. Distribution of PCT by RNG and Onsite Biogas and Vented and Flared Baseline in 2020

The PCT and TRC graphs show some similarities but also substantial differences when comparing the cost-effectiveness of these technologies. Both the PCT ratio and the TRC ratio find that technologies fueled by RNG have lower test results than the same technology configuration fueled by OSB. In both the PCT and the TRC the increased cost of fueling the technology is a cost in the test, contributing to lower cost-effectiveness values for the PCT and the TRC. The vented versus flared baseline, however, has substantially different impacts on the PCT than the TRC. The baseline of methane capture, venting versus flaring, does not impact the value of the bill savings, incentive received, or tax implications for the participant customer and therefore does not impact the PCT benefits. The larger GHG reduction associated with the vented compared to the flared baseline does not increase the value of the cost-effectiveness test to the participant unlike what was found in the TRC test.

While the TRC test does show that technologies with vented baselines are beneficial from a societal standpoint, none of these same scenarios are cost effective to the participant. Implementation of the vented on-site technologies would be idea candidates for increased incentives, especially for technologies seeing TRC ratios that ranged well above 2.

Residential Impacts

As California seeks to reduce GHG emissions from homes, RNG could be a near term solution to reduce emissions without building electrification's need to replace gas appliances. Our analysis describes the estimated impacts of RNG on GHG emissions and customer utility bills for residential heating and water heating measures. The section presents bill impacts and carbon emission comparisons for electric heating and water heating equipment compared to baseline and high efficiency gas heating and water heating (WH) equipment.[5] The gas equipment findings are presented for both NG and a 20% RNG/80% NG mixture.[6]

The analysis uses estimates of electricity and gas usage gathered from the *Database for Energy Efficiency Resources* (DEER) and from the *Building Energy Optimization Tool* (BeOpt), an engineering simulation software. The measure cost information is from the DEER. Avoided costs and emissions information are derived from the 2021 *California Avoided Cost Calculator* (ACC). The energy consumption bills are calculated using residential PG&E utility rates for 2021.

Greenhouse gas emissions analysis of RNG in the residential sector. Our investigation of residential RNG included analysis of the average annual CO_2 emissions for heating and water heating technologies fueled by RNG, NG, and electricity. This allows comparison to building electrification efforts. One significant difference between the use of RNG versus electrification is that RNG does not require customers to replace natural gas-powered appliances with efficient electrical ones, potentially allowing for a faster near-term reduction in building emissions.[7] Note that this analysis focused only on a single set of electricity and gas rates in PG&E territory.[8]

Figure 6 below presents the average yearly CO_2 emissions for the HPWH using the carbon intensity from the 2021 ACC.[9] The CO_2 emissions from the tankless and storage WH, and baseline and high

[5] We compare a 50-gallon Heat Pump Water Heater (HPWH) to a 50-gallon gas storage WH and tankless WH, and a HP furnace to an 80-AFUE and a 92-AFUE condensing gas furnace.

[6] The calculator developed for this research compares a HPWH, an instantaneous and relatively efficient gas water heater, and a NG storage WH. The inputs used for this paper use data from the DEER database, when available.

[7] In California, the 2019 RASS study notes that only 6% of water heaters are electric, indicating there is still significant resistance to converting to electric.

[8] The analysis is based on a PG&E electric rate of E-TOU-D and a gas rate of GR.

[9] The average annual CO_2 emissions is the lifecycle estimate of emissions divided by the EUL of the equipment.

efficiency furnaces are presented assuming the measures are fueled by NG or 20 percent RNG. We assume that within the next 5-10 years, 20 percent RNG will be more widely available.

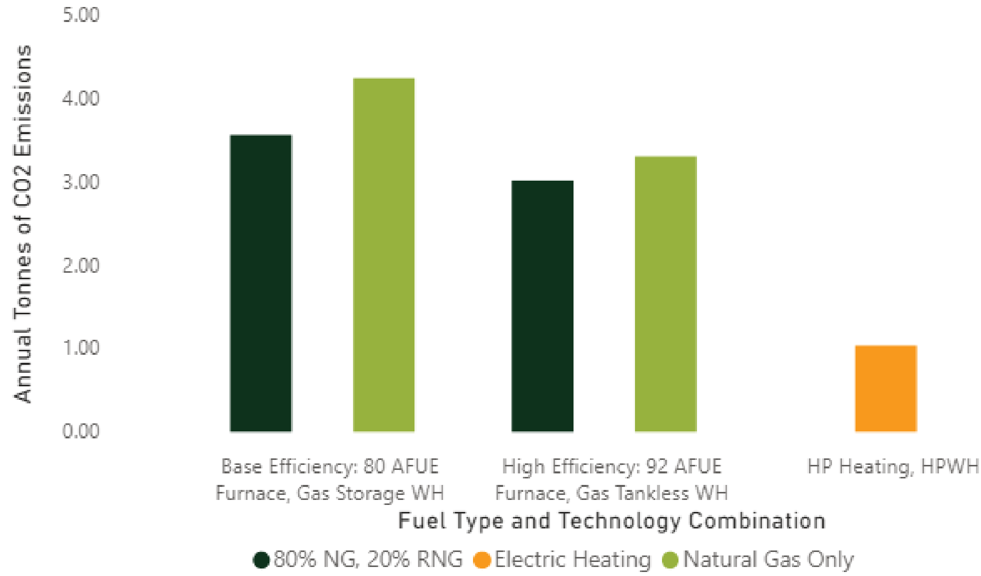

Figure 6. Tonnes of CO_2 Emissions

Figure 6 clearly illustrates the potential for high efficiency technologies (like tankless water heating or high AFUE furnaces) to reduce GHG emissions relative to the base efficiency furnace or storage water heater. The NG fueled high efficiency equipment estimated yearly GHG emissions are 3.31 tonnes while the NG baseline efficiency equipment emissions are approximately 28 percent higher at 4.25 tonnes. The emissions from the NG fueled high efficiency equipment are estimated to be 7 percent lower than the emissions from the 20 percent RNG fueled baseline equipment.

However, the electric HP heating and water heating equipment combination have the potential to significantly reduce GHG emissions relative to the NG and RNG fueled high efficiency equipment and to make a substantial reduction in emissions relative to the base efficiency heating and water heating equipment. When using the 2021 ACC's carbon intensity, the electric HP equipment is estimated to produce close to a third of the GHG emissions than the high efficiency equipment fueled by 20 percent RNG.

Residential bill impacts. California's GHG goals depend on households choosing technologies and fuels with a lower carbon intensity. The utility bills associated with electric, NG, and RNG measures will play an important role in households choosing to switch to electric or RNG fueled measures.

Figure 7 illustrates the estimated first year utility bills for homes with heat pump heating and water heating, and those with baseline efficiency NG heating and water heating equipment, and those with high efficiency NG heating and water heating. This compares the bill impacts of those customers using solely electricity for heating and water heating, those using solely NG, and those using 20% RNG for heating and water heating. The figure illustrates that the annual customer utility bill for the high efficiency NG heating and water heating equipment is the smallest of the three technology options. If a customer chooses the base efficiency storage NG heating and water heating equipment, their estimated annual utility bill increases roughly 18 percent. Comparing the high efficiency options for NG heating and water heating clearly illustrates the impact of installing a high efficiency equipment on utility bills. Transitioning from 100% NG to fuel composed of 80% NG and 20% RNG is estimated to increase the annual utility bills 21 percent relative to the 100% NG alternative).

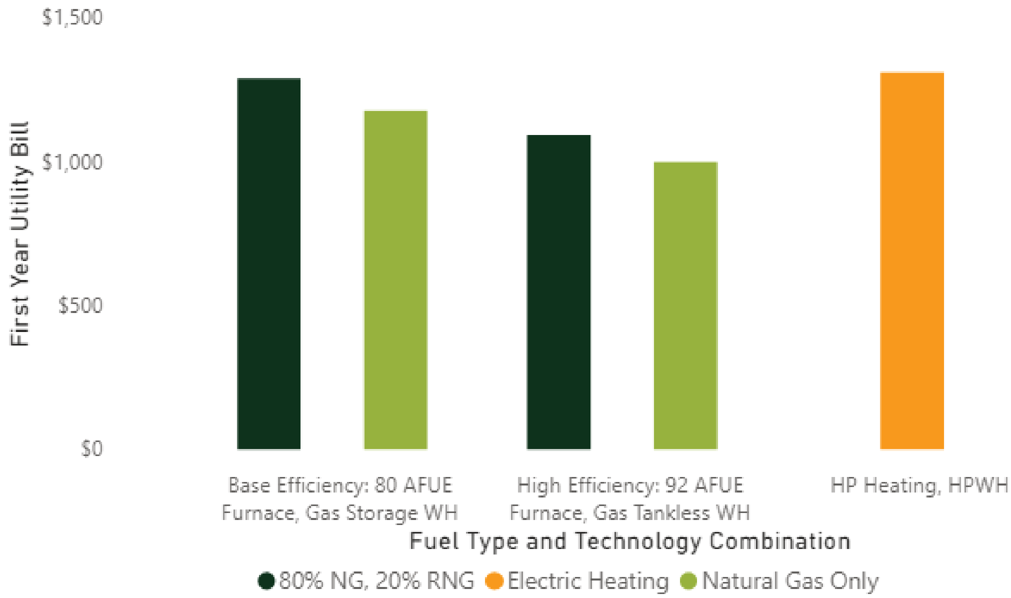

Figure 7. First Year Utility Bills

Using solely electric heating and water heating, the annual electric bill is larger than the high efficiency gas alternatives, as well as the baseline NG alternative. However, the annual electric bill is slightly lower than the baseline NG/RNG fuel mixture.[10]

Verdant Findings and Recommendation

Encouraging high efficiency technologies and lower carbon intensities in both electricity and RNG has the potential to contribute to California's progress to a low carbon future. The electrification measures (heat pump water heaters and heat pump HVAC) contribute to larger GHG reductions than the RNG measures with 20% RNG/80% NG fuel. High efficiency NG and RNG measures reduce GHGs, utility bills, and have a low cost of GHG reductions relative to commonly installed base efficiency gas measures. Uncertainty in future costs, utility rates, and the carbon intensity of electricity and NG/RNG, reinforces the importance of California choosing all viable paths toward carbon reduction in the short and medium term. Other findings based on our research include:

- **Baseline Considerations:** Vented baselines (i.e., dairies) show significantly higher TRC benefit cost ratios than flared baselines. This is consistent with earlier analyses, but as California moves towards a cleaner grid and increases the cost of carbon to society, these differences increase. While systems with a vented baseline display a high value to society (TRC test results are greater than 1.0), they can best monetize the increased benefit of destroying methane through the LCFS. The wide difference between the TRC and PCT benefit cost ratios indicates that increasing the incentives available to dairies, or any other biogas generators that can be shown to destroy methane that would have otherwise been released to the atmosphere, would be beneficial to both participants and society.

[10] In reviewing costs from DEER (DEER 2021) and the Measure Cost Study (Itron, 2014), upfront costs for HP Water Heaters are about 27% than those for Natural Gas Tankless Water Heaters, but about 35% more expensive than Natural Gas Storage Water Heaters. Heat Pump Furnaces are almost 40% cheaper than both baseline and high efficiency Furnaces. However, these upfront costs don't take into account the expected useful life (EUL) of the units. Heat Pump Water Heaters have an EUL of 10 years whereas their natural gas counterparts have an EUL of 20 years. Similarly, HP Furnaces have a an EUL of 15 years, while the Natural Gas Furnaces have an EUL of 20 years.

- **Future versus Immediate Benefits:** Although biogas generators with a flared baseline in 2020 do not exhibit TRC benefit cost ratios above 1, most onsite systems with a flared baseline are estimated to exceed a TRC benefit cost ratio of 1 by 2030. This indicates that incentivizing these systems in the future will provide a cost-effective benefit to society.
- **Effect of Transportation Programs:** The supply of RNG may be affected by transportation programs such as the LCFS. This program offers substantial credits, especially for dairies and other sources with negative carbon intensities by destroying methane. Verdant has found in other work that many dairies are layering the LCFS with other programs to maximize potential incentives.
- **Variability of Inputs and Assumptions:** The reduction of GHGs associated with residential water heating and heating measures will require interested parties to review the measure energy usage and costs and the utility bill and associated GHG impacts. Additionally, if this guidance is to be considered outside of California, avoided costs based on local jurisdictions should be examined.
- **Sources of RNG:** In addition to changes in grid emissions, RNG costs and carbon intensities have potentially significant impacts on costs and benefits from the use of RNG. Landfill-sourced RNG will tend to be cheaper but also have a higher carbon content than RNG sourced from sites like dairies with negative carbon intensities. Finally, different utility rates or climate zones could also change the results of the analysis presented here.

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