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CALIFORNIA
ENERGY COMMISSION

Energy Research and Development Division

FINAL PROJECT REPORT

The Challenge of Retail Gas in California's Low-Carbon Future

Technology Options, Customer Costs, and Public Health Benefits of Reducing Natural Gas Use

Gavin Newsom, Governor
April 2020 | CEC-500-2019-055-F

PREFACE

The California Energy Commission's (CEC) Energy Research and Development Division manages the Natural Gas Research and Development program, which supports energy-related research, development, and demonstration not adequately provided by competitive and regulated markets. These natural gas research investments spur innovation in energy efficiency, renewable energy and advanced clean generation, energy-related environmental protection, energy transmission and distribution and transportation.

The Energy Research and Development Division conducts this public interest natural gas-related energy research by partnering with RD&D entities, including individuals, businesses, utilities, and public and private research institutions. This program promotes greater natural gas reliability, lowers costs, increases safety for Californians, and is focused in:

- Buildings End-Use Energy Efficiency.
- Industrial, Agriculture, and Water Efficiency.
- Renewable Energy and Advanced Generation.
- Natural Gas Infrastructure Safety and Integrity.
- Energy-Related Environmental Research.
- Natural Gas-Related Transportation.

The Challenge of Retail Gas in California's Low-Carbon Future is the final report for the future of natural gas project (PIR-16-011) conducted by Energy and Environmental Economics and the University of California, Irvine. The information from this project contributes to the Energy Research and Development Division's Natural Gas Research and Development Program.

For more information about the Energy Research and Development Division, please visit the CEC's research website (www.energy.ca.gov/research/) or contact the CEC at 916-327-1551.

ABSTRACT

This study evaluates scenarios that achieve an 80 percent reduction in California's greenhouse gas emissions by 2050 from 1990 levels, focusing on the implications of achieving these climate goals for gas customers and the gas system. Achieving these goals is not guaranteed and will require large-scale transformations of the state's energy economy in any scenario.

These scenarios suggest that building electrification is likely to be a lower-cost, lower-risk long-term strategy compared to renewable natural gas (RNG, defined as biomethane, hydrogen and synthetic natural gas, methane produced by combining hydrogen and carbon). Furthermore, electrification across all sectors, including in buildings, leads to significant improvements in outdoor air quality and public health. A key uncertainty is whether consumers will adopt electrification technologies at scale, regardless of their cost effectiveness.

In any low-carbon future, gas demand in buildings is likely to fall because of building electrification or the cost of RNG. In the High Building Electrification scenario, gas demand in buildings falls 90 percent by 2050 relative to today. In the No Building Electrification scenario, a higher quantity of RNG is needed to meet the state's climate goals, leading to higher gas commodity costs, which, in turn, improve the cost-effectiveness of building electrification.

The potential for large reductions in gas demand creates a new planning imperative for the state. Without a gas transition strategy, unsustainable increases in gas rates and customer energy bills could be seen after 2030, negatively affecting customers who are least able to switch away from gas, including renters and low-income residents.

Even in the High Building Electrification scenario, millions of gas customers remain on the gas system through 2050. Thus, this research evaluates potential gas transition strategies that aim to maintain reasonable gas rates, as well as the financial viability of gas utilities, through the study period.

Keywords: Natural gas, greenhouse gas emissions, climate change, renewable natural gas, electrification, equity, air quality and public health

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CHAPTER 1: Introduction

California has a long-standing commitment to reducing greenhouse gases (GHGs) and combating climate change. The state's original climate change mitigation goals, set during Governor Arnold Schwarzenegger's tenure in 2005, aimed to reduce emissions to 1990 levels by 2020 and reduce GHGs by 80 percent below 1990 levels by 2050 (EO S-03-05). The 2020 goal was codified into law in 2006 in Assembly Bill 32 (Núñez, Chapter 488, Statutes of 2006), while the 2050 goal remains an executive order.

A decade later, Governor Edmund G. Brown Jr. set a 2030 climate target for the state when he signed Senate Bill (SB) 32 (Pavley, Chapter 249) in 2016, requiring the state to reduce GHGs 40 percent below 1990 levels. In 2018, Governor Brown called for the state to achieve carbon neutrality by no later than 2045 (EO B-55-18). The carbon neutrality goal is in addition to the state's 80 percent reduction goal for GHG emissions.

This research project was defined before Governor Brown issued the 2018 carbon neutrality executive order, so the scenarios evaluated here focus on investigating futures that achieve a 40 percent reduction in GHGs by 2030 ("40 x 30") and an 80 percent reduction in GHG emissions by 2050 ("80 x 50"). To meet the state's carbon-neutrality target by 2045, it is safe to assume that most of the mitigation measures modeled here will be needed, as well as additional measures like negative emissions technologies that are not considered in this analysis. While more research is needed to understand the full scope and scale of actions needed to achieve carbon neutrality in California, the research findings presented here serve as a useful guidepost.

California's energy and climate policies extend beyond emissions targets. California law requires the state to achieve a 60 percent Renewables Portfolio Standard (RPS) by 2030 and meet 100 percent of retail sales from zero-carbon electricity by 2045 (SB 100, de León, Chapter 312, Statutes of 2018). Complementary to electric sector decarbonization goals are mandates and targets aimed at increasing the share of zero-emission vehicles on California roads. The state's energy transition also extends to the built environment. Recent legislation (AB 3232, Friedman, Chapter 373, Statutes of 2018) requires the California Energy Commission to examine strategies to reduce emissions from buildings 40 percent below 1990 levels by 2030. These and other policy mechanisms are moving California toward achievement of the state's long-term decarbonization requirements and targets.

This study evaluates and synthesizes the potential impacts of technology innovation, along with California's many long-term energy and climate policies, that are acting on the natural gas sector in California through 2030 and 2050. This research focuses particularly on impacts to retail gas delivered through the natural gas distribution system, the low-pressure system of pipelines that serve most homes and businesses in California. Other research (for example, Long, 2018; Ming, 2019) has evaluated the role of gas on the higher-pressure, bulk gas distribution system.

This project builds on recent studies pertinent to the future of the natural gas industry in California. These studies include recently completed California Energy Commission (CEC)

Electric Program Investment Charge - (EPIC) funded research into the impacts of climate change on temperature and hydroelectric availability in California, as well as the development of long-term scenarios of California's energy sector through 2050.

This study leverages Energy and Environmental Economics' (E3's) expertise in modeling long-term, low-carbon scenarios for the State of California using the California PATHWAYS model. In 2015, the CEC, California Public Utilities Commission (CPUC), California Air Resources Board (CARB) and California Independent System Operator (California ISO) engaged E3 in a joint effort to use the PATHWAYS model to develop statewide greenhouse reduction scenarios through 2050. E3 evaluated several low-carbon scenarios, including a "low-carbon gas" scenario that included the use of biomethane, hydrogen, and synthetic methane in buildings and industry, as well as the use of renewable compressed natural gas (CNG) in trucks. The PATHWAYS model has been further developed for use in CARB's Scoping Plan Update[1] and through support from the CEC's EPIC research program. However, none of those past studies have fully addressed the question of "what is the future of retail natural gas in California?"

The present study also builds on past work by synthesizing technical, economic, and achievable resource assessments of advanced biofuels and low-carbon technologies. Some of these studies had a high-level focus on the potential for synergies between natural gas and renewable electricity (Pless, 2015) without in-depth research on the potential advanced alternatives or the technical and economic aspects. Other studies had deep analysis of particular technologies (Melaina, 2013) or the potential feedstocks and conversion technologies without a focus on the potential for decarbonization of the natural gas system (DOE, 2016; McKendry, 2002).

This project builds on E3's 2018 report to the CEC titled *Deep Decarbonization in a High Renewables Future* (Mahone et al, 2018). That report modeled ten scenarios that all meet California's 2030 targets of a 40 percent reduction in GHGs below 1990 levels and an 80 percent reduction in GHGs below 1990 levels by 2050. A key finding of that study is that electrification is among the lower-cost, lower-risk strategies to decarbonize the buildings sector, given the cost and resource supply limitations associated with low-carbon gas. Informed by this approach, deep decarbonization in the buildings sector was recommended to avoid more expensive or speculative mitigation options elsewhere in the economy.

However, the 2018 study focused on economywide metrics[2] and did not evaluate in-depth what the implications of building electrification, or technology innovation in low-carbon gas technologies, would mean for the natural gas sector or natural gas customers in the state. This study takes a closer look at the distributional implications of building decarbonization in the context of the same 2030 and 2050 California GHG reduction targets. Of particular interest

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[1] California Air Resources Board. November 2017. *California's 2017 Climate Change Scoping Plan*, https://ww3.arb.ca.gov/cc/scopingplan/scoping_plan_2017.pdf.

[2] A total resource cost perspective captures the net costs of California's energy system relative to a reference scenario. This metric includes expenditures on infrastructure (for example, power plants, trucks, heating, ventilation, and air-conditioning [HVAC] equipment) and fuels (for example, jet fuel, biodiesel, renewable natural gas). This perspective does not, however, capture potential distributional implications of different GHG mitigation options on customers.

are the impacts of building decarbonization strategies on households' energy bills and the gas utilities themselves.

This project examines several aspects of strategies to decarbonize buildings in an economywide context. This examination included working with UC Irvine to look into a range of costs for renewable natural gas; a detailed analysis of the gas utility financials and rate impacts of low-carbon scenarios (for example, using a gas utility revenue requirement model); an examination of the consumer bill effects that follow; and an examination of potential gas system transition strategies.

This project asks three main research questions:

1) What are the technology options and potential costs to reduce GHG emissions from natural gas consumption in California?
2) What are the natural gas rate and utility bill implications of different strategies to reduce GHG emissions from natural gas use in California?
3) What are the air quality benefits and human health implications of different electrification and decarbonization strategies?

Technical Advisory Committee and Public Comments

The preparation of this report benefited from a wide range of inputs and perspectives throughout the study development and presentation of draft findings. The Technical Advisory Committee (TAC) members for this project listed in Appendix B represent a wide and diverse range of viewpoints on the topics covered by this research. More than 30 unique comments were filed as part of the public comment period on the draft study results, including comments from more than 200 Sierra Club members. In addition to written comments, many public comments were provided verbally in the staff workshop on June 6, 2019, and filed with the CEC in response to the draft report. Overall, the key areas of discussion and disagreement include:

- The pace and urgency of electrifying buildings as a decarbonization strategy.
- The availability and cost of biomass resources to produce biofuels as an alternative to rapid electrification in buildings.
- The availability and cost of hydrogen as an alternative to rapid electrification in buildings.
- The impact of wildfires and wildfire liability on the future cost and reliability of electricity.

This report does not represent a consensus document on these issues, and many areas of disagreement remain. However, the researchers have seriously considered all the comments provided by stakeholders and have responded to some of these comments directly in this report and to other comments in a "frequently asked questions" document in Appendix A.

Methods

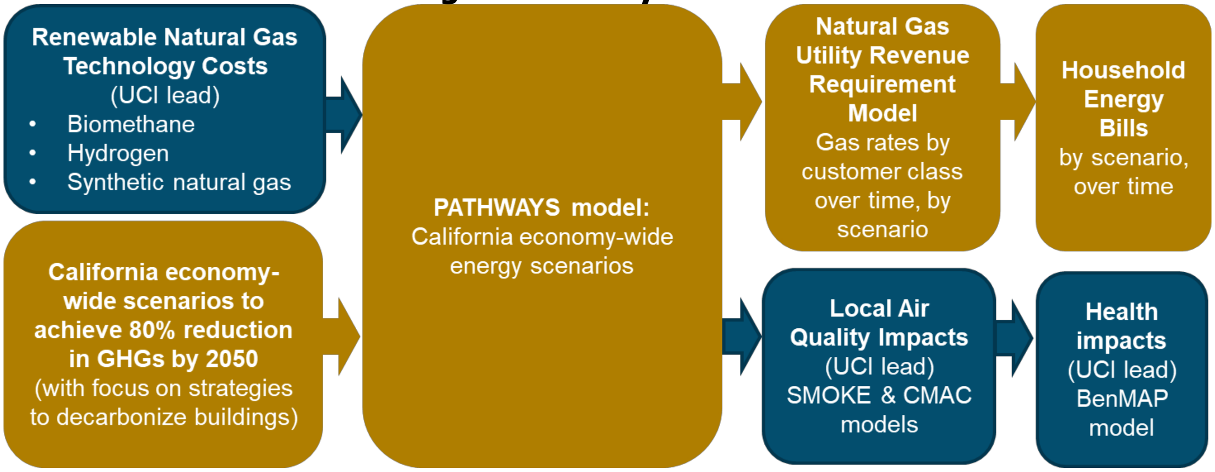
This research involved several phases of analysis steps, as illustrated in the figure below.

First, E3 worked with the University of California, Irvine (UCI) APEP (Advanced Power and Energy Program) (together, the research team) to develop assumptions for future costs and efficiencies of different biofuel conversion processes. APEP also conducted a technoeconomic assessment of power-to-gas pathways to produce renewable natural gas. That analysis examines a variety of different processes to produce hydrogen and synthetic natural gas. The result of that analysis is a conservative case and an optimistic case for the cost of electrolytic fuels ("power to gas").

The research team used these gas technology cost assumptions as inputs to the E3 California PATHWAYS Model. The authors' PATHWAYS model is used to develop economywide mitigation strategies that meet the state's climate policy targets using different combinations of mitigation measures. PATHWAYS is an energy infrastructure, energy and emissions counting model. A key source of variation in the PATHWAYS scenarios evaluated in this study is the blend of pipeline gas and the quantity of gas that is decarbonized.

Using the energy demand outputs from the PATHWAYS model, E3 evaluated how changes in natural gas demand by sector could affect natural gas utility revenues, gas rates, and customer energy bills. To perform this analysis, E3 developed the Natural Gas Revenue Requirement Tool (RR Tool). The RR Tool tracks utility capital expenditures, depreciation, and operational costs given user-defined scenario inputs, including changes in natural gas consumption by sector (from PATHWAYS scenarios), gas equipment reinvestment and depreciation schedules, cost allocation assumptions and the utility cost of capital, among other financial criteria. The tool is benchmarked to general rate case (GRC) filings from Southern California Gas Company (SoCalGas) and Pacific Gas and Electric Company (PG&E),[3] the state's two largest gas distribution utilities. The tool returns gas rates by customer class through 2050. It also includes the ability to model potential gas transition scenarios to reduce the customer bill impacts, as an illustration of some of the strategies that might be considered in more detail going forward.

Figure 1: Study Methods



Source: E3

E3 also developed a bill impacts calculator. The residential customer utility bill calculations in this analysis combine estimates of future electricity rates and gas commodity costs from the

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[3] The research team relied on the following regulatory filings to build and benchmark the revenue requirement models: PG&E GCAP 2018, PG&E GRC 2020, PG&E GTS 2019, SCG TCAP 2020, SCG GRC 2019, SCG 2017 PSEP Forecast Application, SCG PSEP Forecast application.

PATHWAYS model with gas delivery rates from the RR Tool. The result is a comparison of future utility bills for an "all-electric" and "mixed-fuel" customer in each scenario.

Finally, the UCI APEP team used the PATHWAYS scenario results to inform a detailed air quality and health impacts analysis. The energy demands from the PATHWAYS scenarios were geographically distributed using a tool called Sparse Matrix Operator Kerner Emissions (SMOKE). Then, the air quality impacts of these scenarios were simulated using the Community Multiscale Air Quality Modeling System (CMAQ) tool, accounting for atmospheric chemistry and transport effects to establish distributions of ground-level ozone and $PM_{2.5}$ at a local level. The air quality results were then translated into human health and health benefits metrics using the Environmental Benefits Mapping and Analysis Program (BenMAP) tool. The air quality analysis is discussed in Appendix F.

Building Electrification in California Versus Other Regions

This study finds that electrification in buildings is likely to be the lowest-cost means of dramatically reducing GHG emissions from California's buildings. However, this finding is influenced, in part, by California's relatively mild winter climate.

Electric heat pumps are an efficient means to deliver heating and cooling, but the associated efficiency decreases as the outdoor air temperature drops. Electric resistance heating is commonly used as a supplemental heat source in cold climates, but this use can also lead to substantial new electric-peak demands and the needs for new electric infrastructure in colder climates. Cold climate heat pumps are making important technology strides, but "peak-heat" challenges have been identified as legitimate concerns in colder climates, including parts of northern Europe (Strbac, 2018) and the northern United States (Aas, 2018). Peak heat needs occur during the coldest periods of the year when demand for heating in buildings in highest. These cold periods become particularly challenging when they correspond to periods of low renewable electricity availability. Research in those colder jurisdictions tends to find a plausible ongoing role for low-carbon gas as a "peak-heat" capacity resource.

In studies from colder regions of the world, electrification is also identified as an important strategy to decarbonize buildings, however with a greater reliance on supplemental heat sources. For example, a recent report commissioned by a coalition of European gas utilities finds that widespread electrification of buildings is necessary to achieve the continent's climate goals, and it can be achieved at reasonable cost (Navigant 2019). In that study, gas is used in buildings solely as a capacity resource to avoid large electric sector upgrades. In contrast, in California, with its relatively mild winters and warm summers, electrification of buildings is not expected to cause the state's electricity system to shift from summer peaking to winter peaking (Mahone, 2019). However, more research into local distribution upgrades associated with electrification, as well as changes in electricity demand under future weather conditions influenced by climate change, are both warranted.

This research also did not consider scenarios with greater than 7 percent (by energy) hydrogen blended into the gas pipeline, due to the projected costs of upgrading the gas distribution system and end-use appliances to handle higher blends of hydrogen gas. In European studies, hydrogen in the gas pipeline has been suggested as an option for back-up heating needs in cold climates but, to the author's knowledge, has not been suggested as a cost-effective alternative to building electrification for meeting the majority of annual energy demands in buildings.

CHAPTER 3:
California Economywide Decarbonization Scenarios

Methods

PATHWAYS Model

The California PATHWAYS model uses user-defined scenarios to test how mitigation measures interact across sectors and add up to meet deep economywide emissions targets. The California PATHWAYS model has been used in several California studies, including research that informed setting the state's 2030 GHG goal (E3, 2015), studies to model the California Air Resources Board (CARB) Scoping Plan Update (CARB, 2017), and CEC research exploring a range of scenarios to achieve an 80 x 50 goal for 2050 (Mahone et al, 2018). Because the model represents the stocks and turnover of building appliances and on-road vehicles, it represents the infrastructure inertia of the energy system. Modeling a deep decarbonization scenario requires making tradeoffs about how to allocate scarce fossil and bioenergy budgets across sectors to meet an economywide GHG constraint. For example, different scenarios may leave more fossil emissions in the transportation sector versus the industrial or buildings sector.

The model used in this study includes minor updates to that used in Mahone et al (2018) beyond the improved representation of RNG and biofuels discussed in Chapter 2 and described in Appendix E. Costs of renewable electricity generation and battery storage resources have been updated, resulting in lower cost renewable electricity post-2030.

In addition, retrofit costs for installing heat pumps in existing buildings were added, with a range of \$0 to \$8,000 of incremental capital cost assumed upon first fuel-switching to heat pump space heating for homes, depending on vintage and the presence of existing air conditioning (AC).[12] Retrofit costs were added in commercial buildings upon first fuel-switching, with a range of 0% to 100% of the capital cost of heat pump HVAC. Together, these retrofit costs add nearly \$3 billion of annualized capital costs to high electrification scenarios in 2050 based on building retrofits over the preceding decades. This cost increment peaks in 2048 and would decline over time if the scenario were continued beyond 2050, as a smaller share of buildings incur retrofit costs over time. While incremental building electrification retrofit costs are uncertain, they were not found to significantly impact the study results.

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[12] See (Mahone et al., 2019) for a more detailed analysis of costs to retrofit existing buildings for electric appliances. The range here is based loosely on TRC (2016) and accounts for electrical panel upgrade costs, as well as first-time costs in the absence of existing air conditioning like compressor siting. See Appendix E for more details.

Scenario Design

In (Mahone et al., 2018), researchers developed 10 scenarios that met the climate goal of 80 percent GHG reductions below 1990 levels by 2050 ("80 x 50"). These scenarios tested the impact of greater or lesser reliance on key decarbonization strategies, like building electrification, biofuels, and hydrogen trucks. That study found that building electrification resulted in substantially lower economywide mitigation costs, relative to a scenario that excluded building electrification but had comparable other assumptions, such as biofuel availability.

In this study, the research team adapts several of the scenarios presented in 2018 to incorporate the biofuels and P2G analysis in Chapter 2, as well as other minor updates to cost and scenario assumptions. These scenarios (Table 2) were designed to investigate whether updated RNG cost information changes any of the previous findings, as well as to explore the distributional and air quality impacts of building decarbonization strategies (subsequent chapters). This report highlights two bookend scenarios, a "high building electrification" scenario (HBE) and a "no building electrification" scenario (NBE). Those scenarios are compared against a common baseline, the "current policy reference scenario" (shortened to Reference). Full scenario assumptions, such as key input measures by sector, are in Appendix E. Several additional scenarios were developed with intermediate levels of building electrification, but these were found to show predictable intermediate results on key scenario metrics, so they are included only in the appendix.

- Current Policy Reference: This scenario does not meet California's 2030 and 2050 GHG goals. It reflects the energy efficiency goals of Senate Bill (SB) 350, the CARB Short-Lived Climate Pollutant Strategy (SLCP—De León, Chapter 547, Statutes of 2015), the CARB Mobile Source Strategy, and other known policy commitments included in the 2017 Scoping Plan Update (CARB, 2017),[13] as well as a "zero-carbon retail sales" interpretation of SB 100.[14] Besides SB 100, additional updates since the 2018 published "Current Policy Scenario," based on recent trends and legal challenges, include assuming reduced progress in fuel economy standards of new vehicles and higher vehicle miles traveled (VMT). Only very high efficiency natural gas furnaces and water heaters are installed by 2025, and no building electrification is assumed.
- High Building Electrification: This scenario (based on the 2018 "no hydrogen" scenario) achieves a 40 percent reduction of GHGs below 1990 levels by 2030 and 80 percent by 2050. It includes high electrification of buildings. The scenario also includes high electrification of light-duty vehicles and moderate electrification of medium- and heavy-duty vehicles, with fuel-switching of most non-electrified diesel trucks to compressed natural gas (CNG) for air quality. The limited biofuel and fossil energy emissions

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[13] As in previous PATHWAYS studies, the CARB Cap-and-Trade Program is not explicitly modeled, but it would be expected to contribute to further emission reductions beyond those associated with these known policy commitments.

[14] Interpretation of SB 100, a 2018 law to decarbonize electricity, is still ongoing. This study assumes that it requires utilities to procure zero-carbon generation equal to their retail sales by 2045, with a small amount of remaining in-state or imported natural gas generation commensurate with losses, exports, and other exemptions. In 2030, SB 100 is represented as a 60 percent RPS.

budgets are allocated largely to transportation (particularly heavy-duty and off-road) and industry, including pipeline biomethane. Buildings are nearly completely decarbonized by 2050. Most but not all the available biomass is used for advanced biofuels, as the maximum portfolio is not needed to meet the economywide GHG target.

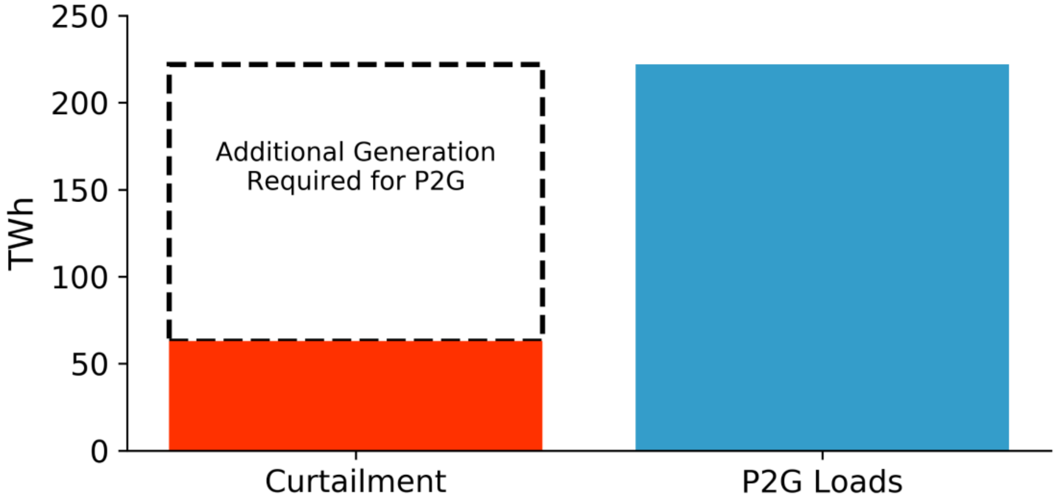
Table 2: PATHWAYS Scenario Summary of Key Metrics for 2050

Category	Reference	High Building Electrification	No Building Electrification
GHG Emissions	Does not meet state climate goals	Meets 40 x 30 and 80 x 50 goals	Meets 40 x 30 and 80 x 50 goals
Building Electrification	None	100% equipment sales by 2040	None
Industrial Electrification	None	None	None
Pipeline Biomethane (% energy)	0%	25%	16%
Pipeline H_2 (% energy)	0%	0%	7%
Pipeline SNG (% energy)	0%	0%	21%
Electric and Fuel Cell Trucks	Low	Medium	High
Advanced Biofuels	71 TBTU	478 TBTU	533 TBTU
Energy Efficiency	Meets SB 350	Exceeds SB 350	Exceeds SB 350
Light-Duty Vehicle Electrification	Medium	High: 100% Sales by 2035	High: 100% Sales by 2035
Short-Lived Climate Pollutants	Meets CARB SLCP Strategy	Exceeds CARB SLCP Strategy	Exceeds CARB SLCP Strategy
CNG Trucks	Displace some diesel trucks	Displace most non-electrified diesel trucks	Displace most non-electrified diesel trucks
% Zero-Carbon Generation	89%	95%	95%

Notes: The “40 x 30” goal is a 40% reduction of GHG emissions below 1990 levels by 2030, and the “80 x 50” goal is an 80% reduction of GHG emissions below 1990 levels by 2050. Although the blend proportion of biomethane is smaller in the no building electrification scenario, the total quantity is similar due to the greater pipeline throughput. Advanced biofuels exclude corn ethanol. SB 100 compliance is based on a zero-carbon retail sales interpretation, meaning that less than 100% of total generation is served by zero-carbon resources. The reference and no building electrification scenarios do not include any fuel substitution of natural gas end uses in buildings for electricity, instead maintaining a constant market share of natural gas end uses; however, some propane and fuel oil end uses are electrified. A more detailed listing of scenario measures is in Appendix E.

Source: E3

Figure 10: 2050 Curtailment Compared to Power to Gas Loads in the No Building Electrification Scenario



Source: E3

Natural Gas Throughput and Commodity Composition

Natural gas throughput declines in all scenarios. In the reference scenario, natural gas electricity generation declines markedly as renewables displace natural gas because of modeled implementation of SB 100 (Figure 11). In the no building electrification scenario, high energy efficiency and reduced petroleum industry energy demand (included in both mitigation scenarios) further reduce natural gas demand. However, natural gas demand in buildings remains relatively flat in this scenario (and in the reference), with efficiency offsetting population and economic growth. In the high building electrification scenario, in contrast, natural gas demand in buildings falls precipitously post-2030, reaching an 89 percent reduction by 2050, and is on pace to decline further beyond 2050.

The throughput declines in each scenario follow from the respective decarbonization strategies. In the high building electrification scenario, decrease in gas throughput is a key source of emissions reduction as electricity is used to displace gas use in buildings. A blend of 25 percent biomethane plays an important role in reducing the GHG emissions intensity of remaining pipeline gas demands. In the no building electrification scenario, hydrogen and SNG are blended in addition to biomethane to reduce GHGs from natural gas consumption. These RNG blends increase the aggregate, or combined, pipeline blend commodity cost, especially in the no building electrification scenario, where the commodity cost reaches $1.8/therm in the optimistic P2G cost scenario and $2.9/therm in the conservative P2G cost scenario.[22] The authors emphasize that this blended commodity cost assumes that 56 percent of the pipeline gas is natural gas. The commodity cost in a completely decarbonized gas pipeline would be between $5.5 per therm and $9.0 per therm if SNG were used to displace all remaining fossil fuel.

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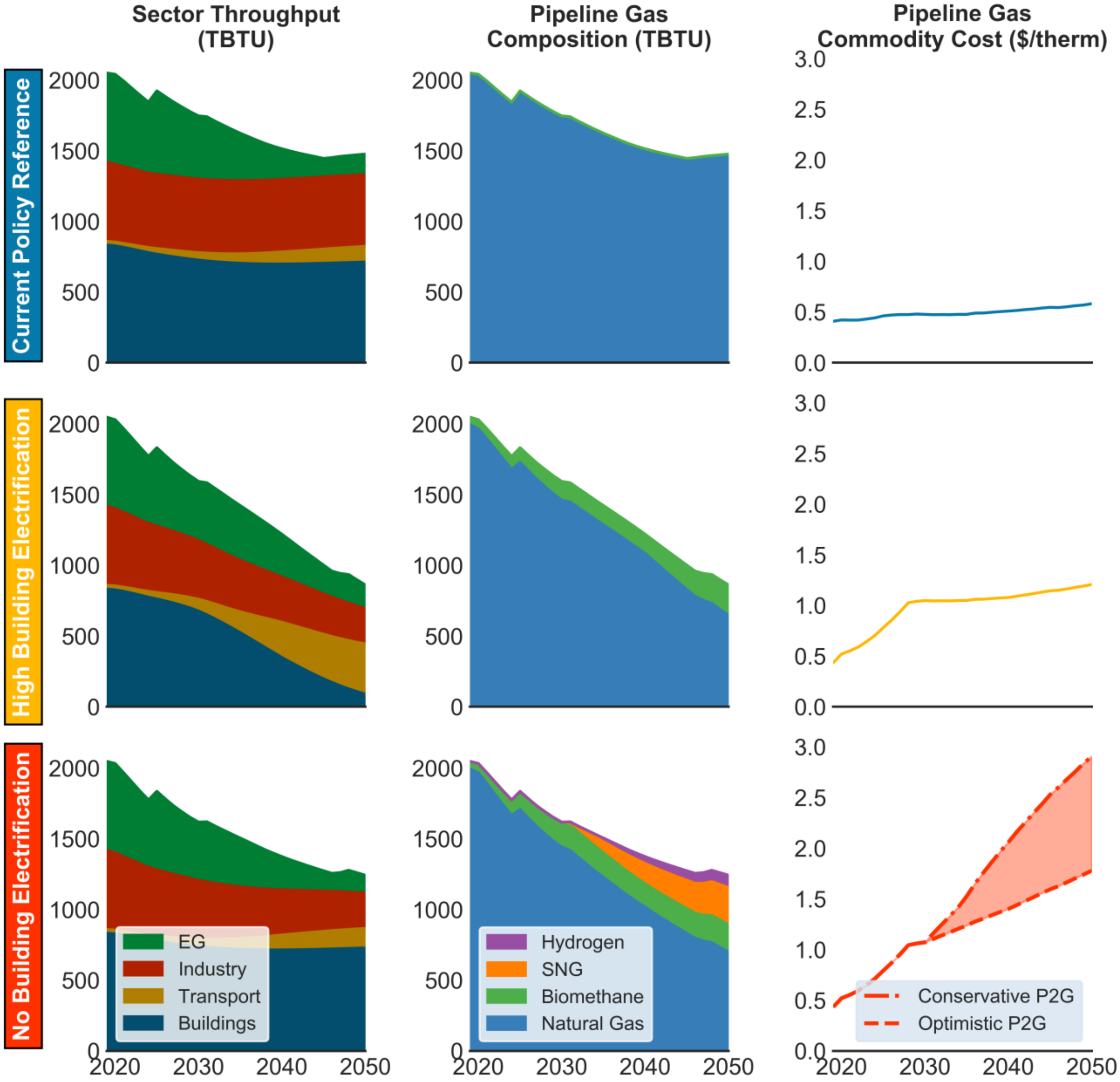
[22] In the reference scenario, commodity costs of fossil natural gas increase only modestly to $0.59/therm based on the Energy Information Agency (EIA) Annual Energy Outlook (AEO) forecast for the Pacific region.

Figure 11: Gas Throughput, Pipeline Gas Composition, and Pipeline Gas Blend Commodity Cost in PATHWAYS Scenarios



Pipeline commodity costs do not include gas transmission, storage, or distribution costs. Biomethane shown in the reference scenario corresponds to biogas used in CNG trucks. Throughput figures in these charts are based on gas utility loads and do not include use of nonutility gas for enhanced oil recovery steaming or cogeneration.

Source: E3

Economywide Costs

Similar to the results in Mahone et al. (2018), high reliance on building electrification is projected to lower economywide costs relative to a scenario in which building electrification is excluded (Figure 12). The costs of the high building electrification and no building electrification scenarios are similar through 2030 because both scenarios include a similar set of GHG mitigation measures through this time frame to meet the state's 2030 GHG reduction goal. The costs of the scenarios diverge after 2030 as increasing quantities of expensive hydrogen and SNG are blended into the pipeline in the no building electrification scenario. The