Notes regarding submitting comments on this Draft Work Product:

Comments are Due June 20, 2018.

Comments shall be no longer than 5 pages.

Comments should be submitted to LDBPcomments@ebce.org

Opportunities for Natural Gas Fuel Switching

for

East Bay Community Energy

Prepared by:
The Offset Project
126 Bonifacio Place, Suite F
Monterey, CA 93940

April 2018

Table of Contents

Table of Figures

Introduction

Community Choice Aggregation (CCA) programs in California have been leaders in the State's aggressive climate protection campaign, and they have consistently exceeded greenhouse gas (GHG) and Renewable Portfolio Standard (RPS) targets and outpaced the investor-owned utilities (IOU's) when it comes to carbon-free content in their respective energy portfolios. However, as the State continues to ratchet up those targets and begins to contemplate setting 100% renewable/carbon-free goal for all load-serving entities (LSE's), the ability to maintain this competitive edge will become more and more challenging. The new frontier for GHG reductions in the CCA space will be innovative fuel switching programs, which essentially provide an incentive for customers to move away from fossil fuels in favor of clean, low-carbon electricity.

This process is often referred to as "electrification," and it can apply equally to the electrification of the built environment (i.e., switching natural gas-fired appliances, HVAC and/or hot water systems for smart and efficient electric equipment), as well as the transportation system (i.e., swapping vehicles with gasoline and diesel fed internal combustion engines for clean and green electric vehicles). One of the key benefits of fuel switching programs is the potential for CCA's like East Bay Community Energy (EBCE) to address multiple sources of GHG emissions that can be challenging to reach, including point source emissions from the transportation and natural gas sectors. CCA's are uniquely positioned to leverage their influence over these sectors through the land-use authority of their jurisdictional members, as well as their ability to engage directly with customers and stakeholders in the communities they serve to promote the value and virtue of transitioning away from fossil fuel as a primary source of energy.

This can be a boon for retail electricity providers like CCA's, since it not only represents the potential for substantial GHG reductions, but it can also generate new revenues through increased sale of kilowatt hours, presenting a potentially golden opportunity for EBCE to consider and take advantage of. In the CCA context, this strategy pays multiple dividends and benefits the CCA, its customers, and California ratepayers at large by reducing emissions and strain on the grid, while mitigating risk exposure and lowering operating costs for the CCA. These strategies also provide a valuable co-benefit for CCA's that are working to reduce loads through demand-side management (DSM) programs like Energy Efficiency, because the new electricity load that fuel switching yields for the CCA essentially backfills the reduced loads delivered by DSM, allowing the CCA to maintain a stable revenue base.

For these reasons, CCA's throughout the State are evaluating and implementing various fuel switching opportunities. Sonoma Clean Power, for example, has made fuel switching a top priority by developing innovative programs to incentivize customers to reduce their fossil fuel consumption by switching to electric vehicles and electric heat pump hot water heaters, which yields new dispatchable load that the CCA can aggregate and control remotely in times of need (i.e., heat wave events, high grid congestion, etc.).

"Fuel Switching is actually Sonoma Clean Powers number one goal, and in fact we identified it as the biggest potential for cutting emissions and saving costs for customers."
–Geof Syphers, CEO- Sonoma Clean Power (CPUC CCA En Banc Hearing, February 1, 2017[1])

This segment of the EBCE Local Development Business Plan (LDBP) seeks to shed light on the opportunities presented by natural gas fuel switching strategies, and to provide innovative, feasible, and cost-effective recommendations for how EBCE can incorporate natural gas fuel switching (aka-building electrification) strategies into its portfolio through implementation of the LDBP.

Natural Gas Fuel Switching Opportunities

This section of the report focuses on the natural gas side of the fuel switching equation, and provides background and context relating to the challenges and opportunities presented by building electrification strategies that can benefit EBCE, the customers and communities it serves, and California in general.

Benefits of Natural Gas Fuel Switching

Supporting California ratepayers' transition away from natural gas as a primary energy resource to clean and reliable electricity will deliver a breadth of benefits to EBCE, the customers and communities it was established to serve, ratepayers outside of the EBCE service territory, the State of California, and even the communities that are environmentally affected by natural gas storage and the drilling and fracking of the natural gas wells. As energy providers throughout California work towards meeting or exceeding the aggressive Renewable Portfolio Standard[2] (RPS) mandates and greenhouse gas (GHG) emission reduction targets[3] established by the State legislature and regulatory agencies, the value and importance of natural gas fuel switching (aka-building electrification, or beneficial electrification) will increase exponentially.

The ability for CCA's to tap the value of aggressive building electrification strategies will provide the means for them to continue to be leaders in the State's efforts to achieve those imperatives, while simultaneously stabilizing their revenue base and supporting their ongoing efforts to maintain low and stable rate structures and deliver meaningful local benefits. This section of the report seeks to outline some of the primary benefits that can be achieved through natural gas fuel switching programs from a CCA perspective. Fuel switching provides a myriad of benefits from the natural gas wellhead to the burner tip (i.e. natural gas combustion by the end user).

[1] Access video recording of the CPUC En Banc Hearing on CCA here:
http://www.adminmonitor.com/ca/cpuc/en_banc/20170201/2/ (Note- the SCP statement referenced is at approximately - 3:28:00)
[2] http://www.energy.ca.gov/portfolio/
[3] https://www.arb.ca.gov/cc/ab32/ab32.htm

The following is a short bulleted list of some of the benefits that deployment of an effective EBCE natural gas fuel switching program could yield.

Benefits for the Community

- Local jobs created by the demand for equipment replacement.
- Local reductions GHG emissions and criteria pollutants, which can support community climate protection goals, improve air quality by reducing pollutants, and reduce negative health impacts for local residents and workers.
- The technologies promoted by well-crafted fuel switching programs are ultra-efficient, and thus can lead to long-term customer cost savings.

Benefits for EBCE

- Fuel switching increases electricity consumption which results in increased revenue for EBCE.
- Fuel switching can enhance EBCE customer retention, and provide incentives for program participants to remain in the program over a certain period of time.
- The recommended OFF Gas program is an innovation that would further distinguish EBCE from PG&E and other CCA's, and it would allow EBCE to extract new revenue streams from the retail natural gas market.
- The new equipment for water and space heating are Smart technologies that can provide dispatchable energy storage and load control options, flatten EBCE's load curve, and support a Virtual Power Plant strategy that delivers a breadth of risk management and portfolio optimization benefits for EBCE.

Benefits at the State Level

- Natural gas demand destruction will reduce GHG emissions and support California's aggressive clean energy and climate protection goals.
- With all the news about the Alison Canyon natural gas leak, it is evident that steps need to be taken and significant investments made to ensure natural gas storage facilities are properly maintained. By reducing demand, expensive new storage facility upgrades can be avoided, and older facilities can be shut down.
- Reduced natural gas transportation and distribution upgrade and maintenance costs in the U.S. (including California) and Canada.

Benefits at the National Level

- Reduced emissions from pipeline compressor stations in the US and Canada.
- Reduced environmental impacts at the wellhead in other states as well as Canada.
- Reduced environmental impacts of hydraulic fracturing ("fracking").

Deep Decarbonization Benefits

California's electricity supply already has a lower carbon intensity that most states and nations, and State policies and regulations are pushing towards 100% carbon free electricity in the near future. This means that it will become increasingly difficult to achieve further GHG reductions within the electricity sector alone. The potential for EBCE to diversify its portfolio of programs to include innovative natural gas programs that support beneficial building electrification can dramatically accelerate the reduction of local GHG emissions and support EBCE and its member jurisdictions' climate protection goals.

While it is true that compared to other fossil fuels such as coal or fuel oil, burning natural gas releases less carbon dioxide (CO2) into the atmosphere, the main element of natural gas is methane, which is a powerful greenhouse gas that is 84 times more powerful than CO2 in terms of its short-term heat trapping impacts. Methane emissions are a major factor in the global warming phenomenon, however, the lack of stringent state or federal regulations about tracking methane leaks has long obscured the full measure of its contribution to climate change.[4] There are many points along the natural gas supply chain that are prone to methane leakage that result in largely uncounted fugitive emissions from the original fracking wells, temporary storage tanks, the interstate and local transmission piping, the large in-ground storage that the utilities own and operate (i.e. Aliso Canyon), all the way to the point of combustion in our homes and businesses.

The California Air Resources Board (CARB) estimates that a 4-month-long leak at the Aliso Canyon natural gas storage facility in Southern California resulted in an estimated 109,000 metric tons[5] of methane being released into the atmosphere, representing more than 9.15 million metric tons of CO2 equivalent GHG emissions from a single event. This substantial setback on the State's GHG reduction goals, along with the shockwaves that the Aliso Canyon leak had on the natural gas market and related commodity costs has drawn much needed attention to California's overdependence on natural gas as a resource.

Carbon emissions from the built environment (buildings) are produced primarily from space and water heating activity, and in California (including the Bay Area) the primary fuel for those activities is still natural gas. Alameda County is responsible for about 3.5 percent of statewide natural gas sales, totaling 355 million therms annually.[6] This equals emissions close to 1.9 million metric tons CO2e per year or around 15 percent of the county's total emissions. 54 percent of this is from the residential sector. Over 80 percent of the natural gas used in buildings is for space and water heating. The California Commercial End Use Survey (CEUS)[7] completed by Itron several years ago, shows that for the climate zone in which Alameda County is based, natural gas use for heating is highest between 7 and 11AM. Water heating gas use is highest between 7AM and 7PM. Converting Alameda County's residential and non-residential building space heating and water heating equipment from natural gas to high-efficiency, low-emission heat pump electric technologies would bring significant greenhouse gas reduction benefits, and these benefits will increase as the carbon intensity of electricity generation decreases.

While high-efficiency electric appliance and HVAC options have been available for many years, the higher upfront costs and higher relative cost of electricity have been a barrier for widespread adoption. Of all the high efficiency options in the market today, heat pump technology has been found to be the most efficient (often 2-4 times as efficient as an equivalent natural gas unit), and

[4] http://menlospark.org/wp-content/uploads/2016/09/fossil-free-homes-factsheet.pdf
[5] Source: https://www.arb.ca.gov/research/aliso_canyon_natural_gas_leak.htm
[6] Source: CEC Energy Almanac, see: http://www.energy.ca.gov/almanac/naturalgas_data/
[7] See: http://www.energy.ca.gov/ceus/

they have the significant added value of delivering the best GHG reductions as well. Recent advances in the heat pump water heater segment have reduced the cost of equipment and installation, and improved the cost-benefit ratio.[8] However, the upfront cost of purchasing, installing, and operating these advanced heat pump options is still higher than a standard natural gas equivalent, which continues to be a barrier despite the benefits and overall lifecycle cost savings. Many of California's load-serving entities (LSE's)—including municipal utilities and CCA's—who are focused on providing clean, low-carbon electricity products are beginning to promote heat pump technology adoption through enhanced rebates and incentives, meant to overcome the upfront cost barrier for their customers.

Economic Benefits

The economic benefits presented by natural gas fuel switching through building electrification to CCA's like EBCE are significant, and include the potential for reduced costs through risk mitigation and load-shifting capabilities, as well as responsible electricity load growth that can be a source of new revenues that offset any reductions to EBCE's revenues resulting from load reduction strategies such as energy efficiency programming.

EBCE Cost-savings and Market Price Risk Management through Demand Response

Many of the high efficiency appliances and equipment that EBCE may consider including in a comprehensive natural gas fuel switching strategy can enable dispatchable load control through Demand Response (DR) technologies. The most intuitive example is probably the smart thermostat, which can control water heaters in addition to HVAC equipment and other devices and respond to Demand Response signals sent out by the utility or LSE. Smart thermostats have therefore been a go-to technology in terms of DR-enabled load control, and they can deliver high value to ratepayers and electricity providers at a low price point, making them an ideal place to start. However, many would overlook the innate energy storage functionality that is intrinsic to all water heaters that have water storage tanks, which are essentially thermal energy storage devices[9]. The water in these insulated tanks can store thermal energy for relatively long periods of time, which makes them a highly valuable distributed energy resource if harnessed through DR programs and technologies. This means that the water heaters to be controlled remotely in near real-time, typically through a smart thermostat, though some models are grid-enabled and have on board, Wi-Fi connected, programmable and automatable smart controls.

In either case, this can allow either the owner or the LSE (EBCE in this case) to program the water heater to shift electricity consumption to off-peak hours (i.e., during peak solar production hours) when the energy on the grid tends to be cleaner and cheaper. This provides a significant risk mitigation measure in the CCA context, as it can provide a mechanism to reduce demand during

[8] For more information about the benefits of heat pump water and space heating technologies see: http://carbonfreepaloalto.org/wp-content/uploads/2016/05/Heat-Pump-Furnaces-and-Water-Heaters-A-Clean-Energy-Solution-to-Decarbonize-Bay-Area-Homes-350SV-April-27-2016.pdf

[9] http://www.electric.coop/wp-content/uploads/2016/07/The-Hidden-Battery-01-25-2016.pdf

the high price periods. The LDBP Demand Response Assessment section highlighted several types of Demand Response services that are directly applicable here[10], including:

1. "Shed" is load curtailment to reduce peak demand, peak capacity and support the system in emergency or contingency events to reduce market price risk exposure and lower overall system costs.
2. "Shift" is nudging customer load from high demand periods toward times of high renewable generation, when demand (and prices) are typically much lower.
3. "Shape" is the re-shaping of customer load profiles, often through price signals intended to encourage customers to modify energy consumption behavior to lower costs for themselves and the electricity provider.
4. "Shimmy" is harnessing loads to dynamically mitigate short-run ramps and disturbances. This typically requires fast response that most heat pump equipment is not well suited for, though other technologies such as electric resistance hot water heaters are a good option for this due to their ability to heat water efficiently through short bursts of electricity.

Each of these options can deliver value to EBCE and its customers by lowering costs, while also supporting grid balancing and decarbonization goals.

Increased EBCE Retail Sales Revenue

By supporting EBCE customer transition from natural gas appliances to highly efficient electric models, EBCE will benefit from increased retail sales of kWh's. This can be an important element of EBCE's LDBP, as it can counterbalance the "lost" revenues associated with other beneficial strategies for local development such as NEM and energy efficiency programs.

The expected increase load for an electric heat pump water heater is 1,134 kWh[11] per year. This would equate to approximately $299 per year of increased retail electricity sales for EBCE for each residential customer that participates in the program (vs. an estimated ~$290 per year of natural gas costs for a comparable natural gas unit). The expected increase load for an electric heat pump space heater unit is 1,110 kWh[12] per year. This would equate to approximately $293 per year of increased retail electricity sales for EBCE for each residential customer that participates in the program (vs ~$232 per year of natural gas costs for a comparable natural gas unit).

At sufficient scale, these measures can produce substantial benefits for EBCE and the community it was created to serve, while supporting California's aggressive clean energy and climate protection goals. It is estimated that with every $1 million of investment, EBCE can incentivize approximately 3,000 customers to participate in an innovative fuel switching program that

---

[10] From LBNL's 2025 California Demand Response Potential Study, page 5-17, accessed here: http://www.cpuc.ca.gov/General.aspx?id=10622

[11] Based on performance specifications for A.O. Smith Voltex FPTU-50 electric heat pump water heater: https://www.hotwater.com/water-heaters/residential/electric/proline/xe/voltex-hybrid-electric/voltex-hybrid-electric-heat-pump-water-heater-fptu-50/

[12] Based on the performance specifications of a Carrier Infinity model 1200 CFM electric heat pump furnace

achieves significant environmental and economic benefits through the replacement of natural gas-powered water heaters and space heaters with ultra-high efficiency electric heat pump models. The LDBP Consultants estimate that if properly designed and implemented, an innovative natural gas fuel switching program can achieve a Net Present Value (NPV) of ~$500,000, and Return on Investment (ROI) of ~17% for every million dollars invested by EBCE. This is a substantial financial benefit for a CCA like EBCE to weigh against other investment opportunities.[13]

Local Workforce Benefits

The potential for EBCE to use natural gas fuel switching programs to drive customer participation in proactive building electrification activity that spurs local job creation is also significant. Such programs would provide incentives for customers to install these beneficial appliances prior to the failure of their existing appliances, creating increased demand for skilled labor contractors in Alameda County. Furthermore, the potential for EBCE to include workforce training and labor standards to the program design parameters can also support local workforce development goals. These workforce benefits (and other economic impacts) are further explored and quantified in the *Jobs, Labor Income, and Financial Impacts of EBCE* section of the LDBP.

Customer Cost-savings Opportunities

As stated above, the cost differential between natural gas and electricity has provided an artificial advantage for natural gas due to the externalization of the full costs of natural gas extraction and embedded GHG emissions that do not show up in the price of natural gas. However, customers who switch from inefficient natural gas appliances to ultra-high efficiency electric models can in fact see cost savings over the long-term. These customer benefits can be further enhanced through careful program design, since rebates and rate-based incentives offered by EBCE can reduce the costs for customers who participate in those programs.

Lifecycle Cost Comparison

A basic customer lifecycle cost comparison[14] of the most impactful appliances (water heaters and space heaters) puts the natural gas vs. electric cost equation described above into perspective, and shows the competitive disadvantage for electrification that must be overcome through careful program design parameters.

For example, the complete customer lifecycle costs for a standard natural gas water heater in EBCE's service territory is estimated to be approximately $4,400.00 (~$1,200.00 for equipment and installation + ~$3,200.00 for lifecycle fuel costs). That compares to an estimated lifecycle cost of approximately $6,400.00 for an equivalent hybrid electric heat pump model[15] (~$2,900.00 for equipment and installation + ~$3,500.00 for lifecycle electricity costs). This would suggest an

[13] See Appendix A for a detailed listing of model assumptions
[14] Note- Lifecycle cost estimates provided here were generated using Lifecycle Fuel Switching Analysis models published by Carbon Free Palo Alto, adjusted for weather and retail energy costs in EBCE's service territory. See: http://carbonfreepaloalto.org and https://www.dropbox.com/sh/yint62e96ns1l2u/D0sy8fX9QY
[15] Using the specifications for the A.O. Smith Voltex FPTU-50 model electric heat pump water heater

increased cost to customers (without any rebates or other incentives that EBCE could offer) of approximately $2,000.00 for the electric heat pump water heater.

The complete customer lifecycle costs for a standard natural gas furnace is estimated to be approximately $13,350.00 (~$4,600.00 for equipment and installation + ~$2,750.00 lifecycle maintenance costs + ~$6,000.00 lifecycle fuel costs). That compares to an estimated lifecycle cost of approximately $19,400.00 for an equivalent electric heat pump model[16] ($8,500.00 for equipment and installation + $2,750.00 lifecycle maintenance costs + $8,100.00 for lifecycle electricity costs). This would suggest an increased cost to customers (without any rebates or other incentives that EBCE could offer) of $6,050.00 for the electric heat pump furnace.

As discussed in greater detail below, these additional costs for the heat pump electric models do not reflect the value of the GHG reductions, or externalized costs associated with natural gas delivery and combustion, which are significant. These cost differentials also do not include the incentives and/or rebates that a carefully constructed EBCE fuel switching program would offer to customers to offset the additional costs.[17]

Through careful program design that leverages new revenue potential from retail natural gas sales to provide an array of customer incentives, including substantial rebates for building electrification, EBCE can provide a program that overcomes these issues and provides an opportunity for customers to switch natural gas appliances out for ultra-high efficiency electric heat pump models at a much lower cost. This approach can allow customers to achieve cost savings through natural gas fuel switching activity, as detailed further below.

Customer Rebates

Most EBCE customers will be familiar with utility rebate structures for high-efficiency appliances, as they have been offered by PG&E and energy efficiency program administrators (i.e., East Bay Energy Watch, BayREN, StopWaste, etc.) for many years. In most cases, EBCE customers will still be eligible to receive those rebates for the type of appliances considered here, which provides an interesting advantage for EBCE to consider in its design and implementation of any natural gas fuel switching program. The potential for EBCE to offer additional rebates to further incentivize customers to move away from natural gas to cleaner and more efficient appliances, and further reduce the customer lifecycle costs. For example, SMUD is offering a $1500.00 rebate[18] to customers who switch out their natural gas water heaters for heat pump water heaters, and Alameda Municipal Power (AMP) is offering a $500.00 rebate[19] to its customers for that same switch. SMUD and AMP both also offer a $75.00 rebate for smart thermostats.[20]

This indicates that the value to the utility of offering such enhanced rebates for relevant natural gas fuel switching appliances is widely accepted, which explains why other CCA's (including

[16] Using the specifications for the Carrier Infinity 1200 CFM model electric heat pump furnace

[17] It should also be noted here, that the typical warranty period for the equivalent electric heat pump models is 10 years vs only 6 years for the typical natural gas models. This value has not been captured in this simple cost model.

[18] https://www.smud.org/-/media/Documents/Rebates-and-Savings-Tips/Rebates/2018/Feb/SMUD-QPL_HPWH_Feb2018.ashx?la=en&hash=3F161C3A990F331D5A34228ABA5AA1AFB34BC7FE

[19] https://alameda.dsmtracker.com/shop/residential-rebates/heat-pump-water-heaters.html

[20] https://www.smud.org/-/media/Documents/Rebates-and-Savings-Tips/Rebates/2018/Feb/SMUD-QPL_Smart-Thermostat_Feb2018updated.ashx?la=en&hash=37A0959587697563990AB5FF176FFC2A29C9F140

Sonoma Clean Power and MCE Clean Energy) are offering similar rebates. This represents a win-win scenario for the CCA and its customers, as it can lower the customer's lifecycle costs and help them make the decision to dump their natural gas appliances in favor of cleaner and more efficient heat pump models that ultimately increase and stabilize retail sales for the CCA.

Demand Response Benefits

As detailed earlier in this report, smart thermostats can provide the additional benefits of load control, and heat pump electric water heaters provide the potential for behind-the-meter energy storage and related Demand Response (DR) benefits. This means that EBCE can further incentivize customers to participate in fuel switching programs by offering Demand Response benefits for those who also sign up to participate in EBCE DR programs. While heat pump water heaters are not quit as effective as their electric resistance water heater cousins in terms of their ability to mitigate short-run grid impacts (so-called "Shimmy" effect), they are highly effective at providing beneficial load shaping service (the so-called "Shape" effect).

The smart thermostats also contribute greatly to the potential DER benefits, as they provide the capacity for direct load control of both hot water heaters and HVAC equipment, and therefore are effective at load shaping on a day-to-day basis and load curtailment in particular times of need (e.g., extreme and unexpected load spikes associated with heat waves). For these reasons, it is important to factor the potential financial incentives that customers who deploy these technologies can receive through participation in EBCE DR programs into the cost differential equation.

Time of Use Rate Benefits

The appliances that are a focus of this report can all be controlled by a programmable smart thermostat, which means that customers who are on Time of Use (TOU) rate structures can extract additional benefits from the fuel switching measures discussed herein. The ability for customers to program their smart thermostats to reduce energy consumption during more expensive peak TOU pricing periods, provides the ability for them to reduce their monthly electricity bills substantially. This benefit is expected to increase over time, as the state makes new TOU rate structures mandatory and EBCE offers updated TOU rates to its customers.

Barriers to Natural Gas Fuel Switching

While all of these benefits are significant and the value of natural gas fuel switching through building electrification strategies and heat pump technologies clearly outweighs the upfront costs of implementation, a number of barriers have hindered successful deployment. The following are some of the issues that must be overcome in order to enable widespread adoption.

- **Up-front Costs**- Higher unit costs and installation costs can create a sticker shock effect that leads to the selection of a lower cost, standard efficiency natural gas model. In addition, the cost of necessary electrical upgrades can also be intimidating and/or unaffordable, as many homes only have a 100 Amp panel that would need to be upgraded to 200 Amps, and new 240V lines will need to be run to power the new equipment. Tiered electricity rate structures that charge higher rates at higher consumption levels can also discourage customers. These higher costs can make beneficial electric solutions cost prohibitive for many, especially low-income customers.

- **Hidden Costs of Carbon**- The social costs of carbon and environmental costs of hydraulic fracturing (fracking) for natural gas extraction are treated as externalities and not included in natural gas rates, which creates an artificial advantage for natural gas over electricity (natural gas tends to be a fraction of the cost of electricity on a per MMBtu basis). This has hampered building electrification efforts for many years, as end-use customers tend to make investment decisions based primarily on cost metrics, meaning that the higher cost of electricity drives most customers to natural gas options.
- **Building Codes**- California's Title 24 Building Codes still tend to favor natural gas in several ways because they are geared more towards lower costs, and do not factor in metrics such as GHG emissions. Despite the State's aggressive policies about decarbonization, renewable energy, and net zero energy buildings, the Building Codes still allow for new buildings to be plumbed for gas service. Also, very few local governments have exercised their control over land-use policies to implement codes and standards that level the playing field for all-electric building designs.
- **Increased Complexity**- Customers often find the process of selecting a high-efficiency model more technical and complex, and finding a qualified contractor who is familiar with the installation of these technologies can also be more difficult.
- **Multi-tenant Buildings**- This applies to both commercial buildings and multi-family residential structures, where multiple tenants rent or lease space from building owners. Most renters are reticent to invest in upgrades on a property they do not own, and likewise multi-tenant building owners do not tend to want to invest in energy upgrades if they don't pay the tenant's energy bills (and thus do not reap a return on that investment).

Example: Sacramento Municipal Utility District Building Electrification Programs

The Sacramento Municipal Utility District (SMUD) has assumed a strong leadership position regarding the value and importance of fuel switching through building electrification. SMUD has championed this concept to the CPUC, and has been developing and implementing a suite of programs and incentives designed to overcome the barriers that have slowed beneficial electrification efforts.

> *"SMUD feels strongly that there needs to be additional attention dedicated to the framework for counting of savings from fuel substitution in the near-term. Building electrification could represent one of the largest untapped sources of energy efficiency, carbon reduction, and renewable integration for the state. … Electrified heating and cooling appliances and equipment can in time provide a built-in renewable integration solution, significantly reducing the need for additional battery storage or other integration*

solutions. For example, a heat pump water heater can be equivalent to a 500 Watt, 2 kWh efficient thermal "battery" that actually saves energy rather than losing it in losses."[21]

SMUD is taking a multi-pronged approach to this challenge, and offering incentives to local builders to construct efficient, all-electric buildings (foregoing gas connections altogether) in the new construction sector, while also offering significant rebates for customers who switch out gas appliances for highly efficient electric heat pump models[22]. SMUD began piloting both of these programs in 2017, and has plans to scale them up in the near-term.

Example: MCE Low-income Families and Tenants Pilot

MCE Clean Energy has been demonstrating leadership in energy efficiency and electrification programming since their inception, and is currently piloting a program to serve hard to reach customer segments called the Low-income Families and Tenants (LIFT) pilot. While the LIFT program is not strictly a fuel switching or building electrification strategy, as it includes incentives for more common energy efficiency measures (i.e., lighting, insulation, high efficiency refrigerators, etc.), it does include enhanced rebates for participating customers who switch out gas appliances for highly efficient electric heat pump models.

"Additional rebates for purchasing and installing heat pumps will be available for 215 units, to support the transition from gas heating to high-efficiency electric heating and cooling equipment for cleaner, safer homes, and fewer greenhouse gas emissions. Participants who receive heat pumps will be trained to operate and troubleshoot their new equipment. The heat pump component of the pilot program will gather data to inform one side of the larger policy question on the relative costs and benefits of the electrification, as compared to investing in natural gas infrastructure."[23]

Notes on Natural Gas Deregulation

The ability for non-profit and for-profit organizations to provide retail natural gas service to residential and small commercial customers (aka- "core gas customers") throughout California has been established for more than 20 years. In 1991, the CPUC adopted a pilot program that allowed core natural gas customers to opt to purchase natural gas from third-party, non-utility suppliers known as Core Transport Agents (CTA's), and in 1995 the State made this a permanent feature of California's natural gas market. While no California CCA has yet taken advantage of the opportunity to become a certified CTA (retail natural gas provider), it is an option that can support the achievement of EBCE's goals and aspirations for the LDBP.

CTA's are non-utility retail natural gas suppliers, who procure natural gas on behalf of core natural gas customers who elect to receive gas service from them (i.e., "opt-in"). CTA customers can choose to receive their gas bill from the incumbent utility, directly from the CTA, or a combination of both. CTA's are not regulated by the CPUC, and are free to set rates and provide

[21] http://docketpublic.energy.ca.gov/PublicDocuments/17-IEPR-06/TN219995_20170630T145154_William_Westerfield_III_Comments_Comments_of_the_Sacramento_Mun.pdf
[22] https://www.smud.org/-/media/Documents/Rebates-and-Savings-Tips/Rebates/2018/Feb/SMUD-QPL_HPWH_Feb2018.ashx?la=en&hash=3F161C3A990F331D5A34228ABA5AA1AFB34BC7FE
[23] https://www.mcecleanenergy.org/news/press-releases/lift/

programs to meet their customers' needs. However, Senate Bill 656[24] (signed into law on October 5, 2013) established a registration process with the CPUC and provides consumer protections that allow the CPUC to suspend or revoke the registration of any CTA under specific circumstances. Under SB 656, organizations who wish to provide retail gas service to core gas customers must 1) register with the CPUC following the rules established under Public Utilities Code Chapter 4.7,[25] and 2) go through the steps required by the incumbent investor-owned utility (IOU) to become a certified CTA in their service territories. PG&E has provided the CPUC mandated process for CTA's to follow[26] since that time, and dozens of organizations have been providing retail gas service to core gas customers in PG&E's territory for many years.[27]

Under the direction of the CPUC, PG&E implements rules and tariffs to enable CTA's to provide competitive natural gas supply. Under the PG&E existing tariffs, customers must stay with a CTA for a minimum of 12 months, but the CTA has the option to send the customer back to PG&E at any point. A significant difference between electricity and natural gas supply is the timing and process involved with supply, distribution and balancing (settlement). PG&E is the system operator and provides the distribution and balancing services for CTAs. Natural gas is settled on a monthly basis, under normal operating conditions. Natural gas supply is traded at the main California delivery points, making it straightforward to contract for competitive supply delivered to the PG&E Citygate (the point of connection into the PG&E distribution system).[28]

Similar to CCAs, CTAs register with the CPUC, execute the necessary agreements with PG&E, and provide the necessary credit required to supply and transport natural gas. Also, since CTA's are not regulated by the CPUC, they can develop programs and customized pricing offers to meet needs of customers, in ways that PG&E cannot. It is also important to note that unlike California's electricity market, there is no independent system operator (i.e., CAISO) for the natural gas market, and the incumbent utility (PG&E) provides all distribution and balancing services. Retail gas suppliers have a range of options to contract for transportation and storage to get natural gas supply to the PG&E Citygate. PG&E allocates a proportionate amount of its contracted storage and transportation to CTA's, somewhat similar to the PCIA in the CCA industry.

Overall, registering as a CTA and launching a retail natural gas program is not nearly as complicated as setting up and launching a Community Choice Aggregation electricity program. This is due in part to the fact that the commodity is cheaper and natural gas is normally balanced (settled) on a monthly basis, as compared to the significantly more complex 5-minute settlement required in the California electricity market. The billing is handled by PG&E in the same way it is done for electricity in the CCA setting. Overall, there is less risk because of how the natural gas market operates on a delayed basis, the liquidity of market pricing, and the ability to store natural

---

[24] http://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201320140SB656

[25] http://leginfo.legislature.ca.gov/faces/codes_displayText.xhtml?lawCode=PUC&division=1.&title=&part=1.&chapter=4.7.&article

[26] https://www.pge.com/en_US/for-our-business-partners/retail-energy-suppliers/incore-transport-agent-resource-center/core-transport-agent-documents/core-transport-agent-documents.page

[27] https://www.pge.com/en_US/business/services/alternatives-to-pge/gas-services/core-gas-aggregation/core-gas-aggregation-transport-agents.page

[28] *"The Citygate is any point at which the backbone transmission system connects to the local transmission and distribution system. The Citygate is not one specific, physical location. It is a virtual trading point on CGT's system."* For more details, see: https://www.pge.com/pipeline/library/doing_business/citygate_diagram/index.page

gas cost-effectively for relatively long periods of time. The lower volume of supply per customer and the lower commodity cost also requires less credit and less capital. Furthermore, the volume of customers would also naturally be far lower as compared to the CCA electricity service, since the gas program would be offered on a voluntary, opt-in basis and customer enrollment would be almost wholly dependent on effective marketing and outreach strategies.

Example: ABAG POWER

The Association of Bay Area Governments (ABAG) has been an active CTA since the start of retail natural gas competition in the PG&E territory. ABAG Publicly Owned Energy Resources (ABAG POWER) is a Joint Powers Agency (JPA) formed to serve local governments and special districts with energy procurement and management services, which it has been providing to its members for more than a decade.[29] As a CTA, ABAG provides economies of scale for purchasing and managing natural gas supply for its members. It's core objective is to *"conduct pooled purchasing of natural gas on behalf of local governments and special districts who voluntarily join the Pool."*

As the monopoly utility, PG&E is regulated and is limited to the natural gas pricing options it can offer. However, as a registered CTA ABAG POWER is not regulated and has the ability to purchase natural gas, gas transportation and gas storage in a way that meets the specific needs of its members. The program has focused on providing two important benefits to participants: 1) Price Stability through fixed pricing for set periods of time, and 2) Cost Savings through collaborative ("pooled") procurement of natural gas supplies.

The program is currently focused on serving interested public agency natural gas loads, including local governments (cities and counties) and special districts (i.e., libraries, waste districts, etc.) in the PG&E service territory, though the potential exists for the program to be extended to include the residential sector (residential natural gas accounts are classified as "core," and can be served by registered CTA's). There is no commitment to purchase natural gas required to join, and those agencies who decide to purchase natural gas through the program can do so at any time by simply signing the ABAG POWER Natural Gas Aggregation Agreement.[30]

ABAG POWER members have input into the natural gas buying strategy that is implemented, as well as administrative costs, billing procedures, and other related policies. Natural Gas prices have been very volatile and the ability to stabilize pricing and limit volatility and price risk can be a tremendous advantage for local governments and special districts. Additionally, members benefit from ABAG POWER's ongoing regulatory and legislative monitoring and engagement activities.

---

[29] For more information on the ABAG POWER program see: https://abag.ca.gov/services/power/

[30] See the ABAG POWER service agreement here: https://abag.ca.gov/services/power/downlfiles/Agreement.pdf

Example: SPURR

The School Project for Utility Rate Reduction (SPURR) is the Utilities Joint Powers Authority (JPA) of California public schools, which includes more than 250 school districts, county offices of education, and community college districts throughout the State. SPURR is a registered CTA, and it provides retail gas service to core gas customers, as well as to larger ("non-core") customers that exceed the 20,800 therms per month threshold for core gas customers.

SPURR has been providing innovative natural gas procurement, management, data, and conservation services for over 20 years in California. SPURR's natural gas program provides participants with deep expertise in public utility procurement and provides services that PG&E and other natural gas suppliers cannot provide. SPURR has implemented a transparent natural gas purchasing strategy that balances a fixed rate portfolio with a transparent market-based rate. SPURR utilizes a competitive bidding process to achieve the most competitive rates along with the most reliable supply option. Figure 1 below provides a list of representative natural gas program benefits that SPURR provides.

Natural Gas Programs	PG&E	SPURR	Private Marketer
Fixed rate supply options		✓	✓
No high-pressure sales tactics	✓	✓	
No incentive to charge high rates	✓	✓	
Core and Noncore supply		✓	?
Overhead costs set by program participants		✓	
Unbiased market advice		✓	?
Competitive procurement for best practices	?	✓	?
Screen and investigates unusual meter readings		✓	?
Advocates for participants and regulatory/legislative process		✓	
Specializes in schools and public agencies		✓	
Equal participant access to CPUC incentive programs	✓	✓	✓

Figure 1: Overview of benefits of SPURR's natural gas program for California public schools.[31]

[31] For more information about SPURR's natural gas offerings, see: https://spurr.org/Services/Gas-Services

Recommendations for Natural Gas Fuel Switching: OFF Gas Program

As noted above, the natural gas sector will likely represent the final frontier for innovative decarbonization strategies, and building electrification will surely become a top priority for most CCA's in the near term. Tapping into this potential will not only extend this important competitive advantage for CCA's, but it can also yield new revenues and further strengthen CCA balance sheets and long-term fiscal performance. This section of the report provides recommendations for how EBCE can extract significant value from the natural gas sector that yields local economic, environmental, and social benefits for the greater EBCE community, while further supporting California's long-term goals through an innovative, 2-step approach to natural gas fuel switching program design that we refer to herein as the *Offset Fossil Fuel Gas* (or "OFF Gas") program.

Step 1: Offer an Opt-in Natural Gas Program

Pacific Gas & Electric (PG&E) has been in an advantageous position because it supplies both electricity and natural gas to its "bundled" retail customers. This means that PG&E has the ability to create, capture, and leverage value from both electricity and natural gas markets, which has been a strategic benefit for PG&E. As a Community Choice Aggregation program, EBCE has an opportunity to put itself in a similar position by taking advantage of the customer choice that exists on the natural gas supply side of the California retail energy market. As detailed earlier in the report, the state legislature and the CPUC restructured California's natural gas market segment in the early 1990's to provide retail choice to all customers. This means that the ability for residential and small commercial customers in California to choose their natural gas supplier exists today, and it provides a significant opportunity for EBCE to provide enhanced value and service to the customers it was created to serve.

Taking advantage of the opportunity to become a registered Core Transport Agent (and/or to partner with an existing CTA) to offer retail natural gas service would allow EBCE to provide a broader set of valuable services to its customers. For example, the ability to offer customers a choice regarding their natural gas supplier means that EBCE could offer low and/or no carbon retail natural gas products that bundles the retail natural gas supplies with certified carbon offsets to balance (or "offset") overall GHG emissions relating to natural gas consumption. EBCE could also consider offering a retail natural gas product that includes a percentage of biogas and/or natural gas obtained without hydraulic fracturing ("frack-free gas"), both of which are available at a premium on the wholesale market.

Similar to Palo Alto Municipal Utility's Green Gas Program,[32] it is recommended that EBCE's natural gas offering would be a premium-priced natural gas service, with participating OFF Gas customers paying a monthly service fee,[33] as well as a nominally higher rate per therm of natural gas they consume to cover the cost of the bundled carbon offsets (and/or premium gas content

---

[32] A low or now carbon retail gas product would involve bundling the gas supply with certified carbon offsets (i.e., sourced from dairy methane offset projects) as piloted by Palo Alto Municipal Utilities. For more information see the Palo Alto Green Gas Program Example below or the following web source: https://www.cityofpaloalto.org/news/displaynews.asp?NewsID=2970

[33] Note- it is recommended that EBCE split that monthly service fee equally between the natural gas and electricity portions of the customer bills, which our modeling demonstrates would provide enhanced financial value to the long-term program performance

like biogas or frack-free gas). This would provide natural gas customers in the EBCE service territory with a climate and environmentally conscious alternative to their existing natural gas service, providing an opportunity for participating customers to reduce their carbon footprint and support state and local climate action goals. The cost of administering the program would be included in the retail rate, and the proceeds collected by EBCE from the monthly fee could be returned to the participating customers in the form of substantial rebates and incentives for switching out their natural gas appliances for beneficial, high-efficiency electric heat pump models, which would ultimately drive additional long-term load growth and increased retail sales of electricity (kWh) in support of the core business model for the CCA. Customers would see a nominal increase in their total energy bills initially, but would recoup that initial expense through enhanced rebates designed to support their transition away from natural gas.

This would provide a cost-effective transitional pathway for customers to reduce their carbon footprint, support certified carbon offset projects (such as methane capture at dairy farms and landfills), and ultimately get “off gas” over a reasonably accelerated timeframe. If properly structured and executed, this innovative programmatic approach will allow EBCE to move customers off of natural gas in an efficient, scalable, and sustainable way that yields immediate GHG reductions to support state and local climate protection goals, long-term customer savings, as well as valuable new revenues streams for EBCE.

It is therefore recommended that EBCE offer an opt-in (optional) low or no carbon, premium natural gas service to its customers to offset local natural gas-related emissions, and create new revenue streams to support robust natural gas fuel switching (aka- “building electrification”) incentives. Partnering with an existing CTA to be the implementer of EBCE’s retail gas service would reduce the administrative burden for EBCE, and may yield lower costs due to increased economies of scale through combined market buying power. The monthly OFF Gas customer invoice would be handled through PG&E utility consolidated billing, just like for EBCE’s retail electricity sales. This means that EBCE’s OFF Gas customers would see no change in reliability or customer service from PG&E.

Example: Palo Alto Green Gas program

The City of Palo Alto pioneered this concept in the municipal utility setting (i.e., not as a Core Transport Agent), and offered a comparable program called PaloAltoGreen Gas (PAGG),[34] which provides a recent and useful Bay Area case study for consideration. The City of Palo Alto Utilities (CPAU) is known as a progressive municipal utility that has been at the forefront of innovation in California since the utility’s inception. Since California opened up its natural gas market in the early 1990’s, CPAU has been a leader in providing economic and reliable natural gas supply to its customers. More recently, CPAU has demonstrated leadership in regard to innovation and environmental programs, and in 2014 implemented a voluntary 100% carbon neutral natural gas supply for all customers.

[34] See Appendix B for more details about CPAU’s PaloAltoGreen Gas (PAGG) program.

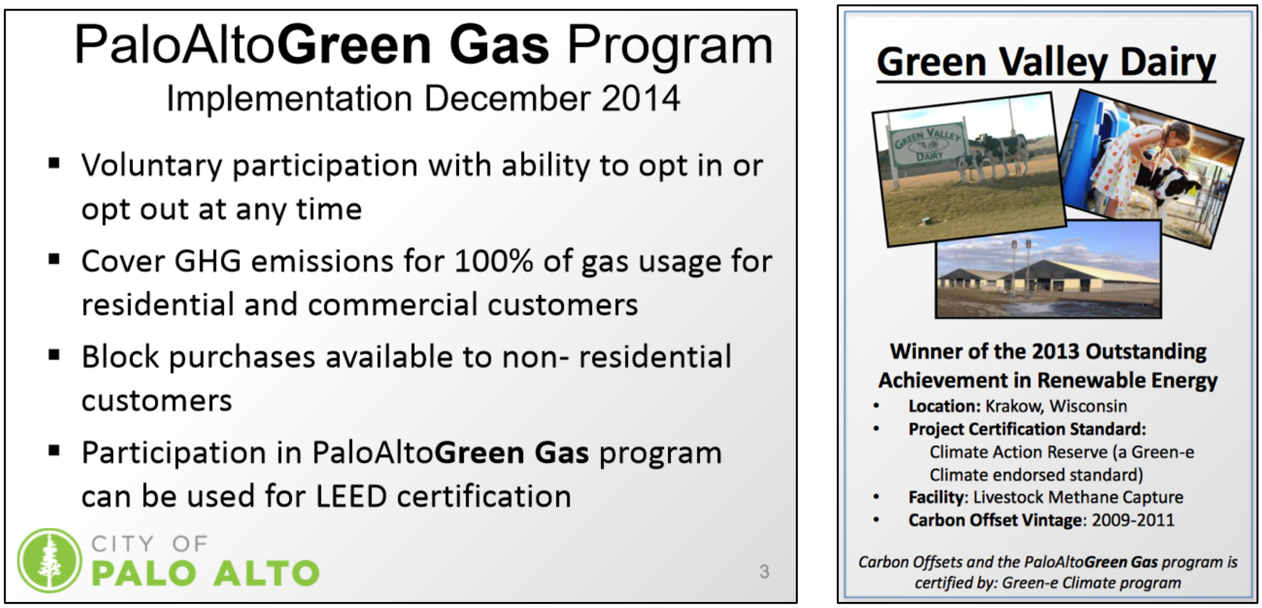


Figure 2: Overview of Palo Alto's Green Gas Program- a Green-e Certified program that bundled Climate Action Reserve Certified Carbon Offsets from livestock methane capture with retail natural gas sales to offset local GHG emissions from natural gas.[35]

CPAU customers who opt in to the program pay a nominal monthly service fee (~$10.00 per month) and a $0.12/therm surcharge to cover the cost of implementation of the program (including the cost of certified carbon offsets).[36] The program is marketed directly to customers through bill inserts, direct mailers, etc., (see Figure 3 below) participation in the program is simple (interested customers need only fill out a simple online enrollment form[37]), and participating customers can cancel the service at any time.

[35] See PaloAltoGreen Gas presentation to the Center for Resource Solutions here: http://resource-solutions.org/images/events/rem/presentations/2014/Dailey_Karla.pdf

[36] See the PaloAltoGreen Gas tariff with itemized charges here: https://www.cityofpaloalto.org/civicax/filebank/documents/42872

[37] See the PaloAltoGreen Gas program enrollment form here: https://justgreen.secure.force.com/CheckoutCPAU?product=a0HE000000fthJZ

Figure 3: Sample Marketing Collateral for the PaloAltoGreen Gas Program.

CPAU decided that offering customers a simple, voluntary way to offset their natural gas-related GHG emissions with certified carbon offsets was a "good first step" towards implementing sustainable changes that support state and local climate protection goals. However, CPAU has a stated long-term goal of reducing natural gas usage by promoting the switching to high-efficiency electric appliances (see Figure 4 below), and this voluntary measure is meant to provide an accessible interim solution that achieves immediate GHG reductions. The City reports that annual natural gas-related GHG emissions in the City declined by 35% in 2017, due largely to the implementation of the PAGG program. [38]

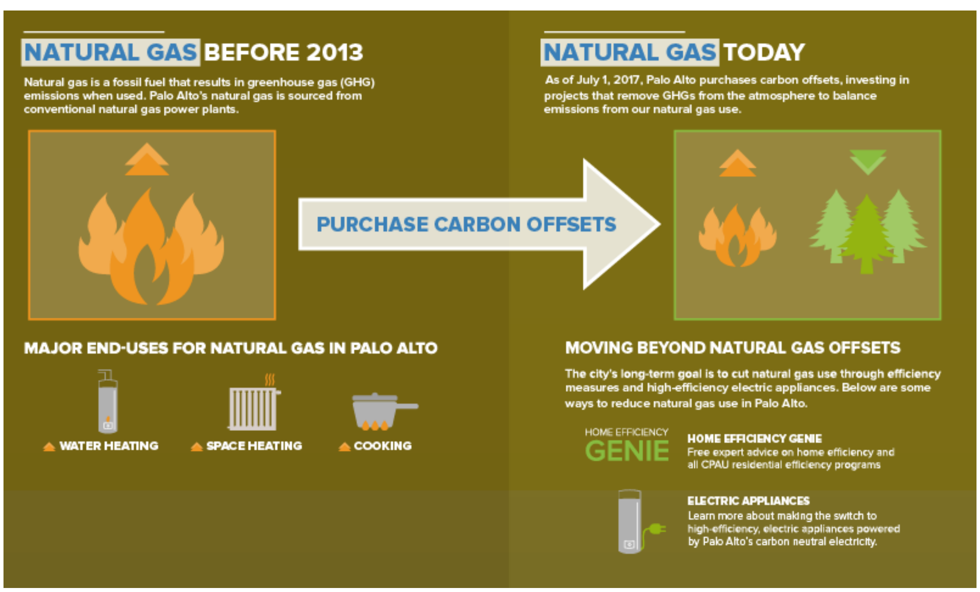


Figure 4: The City of Palo Alto's Green Gas Program as an initial step in a long-term fuel switching strategy.[39]

[38] See City Council Staff Report here: https://www.cityofpaloalto.org/civicax/filebank/documents/64462
[39] https://www.cityofpaloalto.org/gov/depts/utl/residents/sustainablehome/carbon_neutral/default.asp

Step 2: Offer Enhanced Rebates and Incentives for Fuel Switching

Investor-owned utilities (IOU's), municipal utilities (MUNI's), energy efficiency program administrators, and some CCA's are currently offering a wide range of rebates and incentives for various energy efficiency upgrades, and there has been a recent uptick in incentives offered for fuel switching. There has been an increasing focus on incentivizing ultra-high efficient heat pump technologies for hot water heating and (to a lesser extent) space heating applications, with strong interest from municipal utilities and CCA's and early leadership from MCE Clean Energy (MCE) and Sonoma Clean Power (SCP) due to the multifaceted benefits that these technologies can yield for CCA's and their customers. For example, SMUD[40] and CPAU[41] municipal utilities are currently piloting $1,500.00 rebates to customers who switch out their natural gas water heaters for heat pump electric models, as compared to PG&E's current rebate of $300.00 for the same technology.

However, it is important to note that because the MUNI's receive revenue from both Transmission and Distribution (T&D) and Generation they can recoup such investments faster than CCA's (who only receive Generation revenue). This is why Step 1 of the 2-step approach recommended here is an important innovation for CCA's to consider, because it provides the ability for the CCA to tap a new revenue stream to reduce the "out-of-pocket" cost required to subsidize the substantial rebates and incentives necessary to justify the cost of fuel switching from the customer perspective. This approach essentially levels the playing field for CCA's, and it can allow EBCE to achieve a solid return on investment from enhanced fuel switching rebates and incentives, which is the essence of Step 2 of the recommended OFF Gas program.

Another important thing to note here is that, as long as EBCE uses its own revenues from retail natural gas and/or electricity sales, participating customers would be eligible to receive rebates from EBCE as well as PG&E. This means that, unlike its municipal utility colleagues, EBCE can leverage existing rebates offered by PG&E[42] to further reduce out-of-pocket costs and maximize the value to participating customers.

In Step 2, it is recommended that EBCE provide enhanced incentives to customers participating in the OFF Gas program (leveraging the proceeds raised through the CTA natural gas service in Step 1). Our recommendation is that EBCE set up a logical loading order, which requires customers to follow a prescriptive pathway that moves them steadily towards complete electrification over time. This will allow EBCE to optimize program performance and community benefits, while constraining cost and risk. It is recommended that EBCE offer rebates for the following technologies due to their significant value to EBCE operations: 1) Smart Thermostats, 2) Heat Pump Water Heaters, and 3) Heat Pump Space Heaters.

---

[40] https://www.smud.org/-/media/Documents/Rebates-and-Savings-Tips/Rebates/2018/Feb/SMUD-QPL_HPWH_Feb2018.ashx?la=en&hash=3F161C3A990F331D5A34228ABA5AA1AFB34BC7FE

[41] https://www.cityofpaloalto.org/gov/depts/utl/residents/resrebate/smartenergy/heat_pump_water_heaters/heat_pump_water_heater_pilot_program.asp

[42] PG&E currently offers a $50 rebate for Smart Thermostats, and a $300 rebate for Heat Pump Water Heaters. For current information about PG&E rebates see: https://www.pge.com/en_US/residential/save-energy-money/savings-solutions-and-rebates/rebates-by-product/rebates-by-product.page

The following is a recommended loading order, which the LDBP Consultant deem will provide the optimal balance of benefits to EBCE and participating OFF Gas customers based on extensive probabilistic scenario modeling and sensitivity analysis. We recommend that OFF Gas customers be eligible to receive the rebate for smart thermostats immediately upon joining the program, due to their lower relative cost and the fact that these devices establish valuable load control over existing appliances (including air conditioners, as well as natural gas water heaters and space heaters), which can reduce costs for both the customer and EBCE through dynamic load shifting and peak shaving. After one full year in the program, we recommend that EBCE allow OFF Gas customers to receive a substantial rebate for switching out natural gas water heaters for heat pump electric models, which provide the most significant value to EBCE due to the intrinsic energy storage capabilities outlined earlier in this report. After two full years of participation in the OFF Gas program, it is recommended that customers be eligible to receive an enhanced rebate for switching out natural gas-powered space heaters for high-efficiency heat pump models. We suggest that the heat pump space heater rebate be offered only to customers who have electric water heaters, or who are switching out their natural gas water heaters for high-efficiency electric models. Customers should have the option of waiting until their third year in the OFF Gas program to implement all three upgrades in a single pass, when they become eligible for each of the rebates.

Adhering to this recommended loading order will minimize financial risks and maximize financial performance of the program, because it ensures that customers remain in the program long enough for EBCE to build up adequate funding to support the enhanced rebate amounts. This is concept is demonstrated in the illustrative example detailed below, which follows the prescribed loading order and models the financial benefits to EBCE and participating OFF Gas customers.

Recommended OFF Gas Program Rebate Structure

The following enhanced rebate structure is recommended for consideration by EBCE in support of its efforts to promote beneficial fuel switching to customers participating in the OFF Gas program. This is meant to provide a solid starting point, and should be updated by EBCE staff prior to launching the OFF Gas program based on current market conditions and available data regarding participation rates for other CCA, MUNI, and/or IOU fuel switching programs.

EBCE may also wish to consider offering standard rebates (i.e., at lower dollar amounts) to customers who do not enroll in the OFF Gas program, such as low-income CARE customers. EBCE may also consider adding rebates for customers who switch out natural gas-powered stoves and clothes dryers, however these appliances contribute far less to gas-related emissions and present a lesser value proposition to EBCE.

It is worth repeating here that as long as EBCE uses its own revenue to fund these rebates, EBCE customers will also be eligible to receive any applicable rebates offered by its IOU partner (PG&E).

The following is the recommended starting rebate structure for the OFF Gas program:

1. Smart Thermostat Rebate* = $100

*(*Note- It is recommended that EBCE OFF Gas customers would be eligible for the enhanced Smart Thermostat Rebate immediately upon enrollment in the OFF Gas program.)*

2. Heat Pump Electric Water Heater Rebate* = $700

*(*Note- It is recommended that EBCE OFF Gas customers would be eligible for the enhanced Heat Pump Electric Water Heater Rebate after a minimum of 1 full year of enrollment in the OFF Gas program.)*

3. Heat Pump Space Heater (Furnace)* = $1000

*(*Note- It is recommended that EBCE OFF Gas customers would be eligible for the enhanced Heat Pump Electric Space Heater Rebate after a minimum of 2 full years of enrollment in the OFF Gas program.)*

Applying the Market Responsive Pricing Mechanism to Fuel Switching Rebates

An effective and easy to implement mechanism to reduce financial risks and constrain costs of various distributed energy resource (DER) and demand-side management (DSM) programs in EBCE's local development portfolio of programs that has been recommended throughout the LDBP is referred to as Market Responsive Pricing (MRP). This is a tool that can help EBCE ensure that it is getting the desired response to a particular program with lower financial risk, as it provides a structure for lowering (or in some cases increasing) the price for a given incentive or rebate based on the market response to the program. This can be applied effectively to rebate structures, such as those recommended here in the Fuel Switching Assessment section of the LDBP, and is also applied to the baseline and adder pricing for programs like Feed-in Tariff and Net Energy Metering.

In the context of any Fuel Switching programs that EBCE may implement, MRP could be applied to the rebate incentive dollar amounts to ensure maximum participation in these valuable programs, while effectively managing the financial risks to the CCA's budget. This is a common approach with many well-known rebate incentive structures in California, including the California Solar Initiative[43] (CSI) and the Self-Generation Incentive Program[44] (SGIP), which both have structured MRP mechanisms built in that step down the rebate amounts when specified deployment thresholds are reached. This strategy is an efficient and cost-effective way of incentivizing early adoption of emerging technologies, as it encourages customers to move quickly before the rebate levels drop. It also extends the impact of the limited pool of funding available for the incentives, and allows more customers to receive some benefit from the program overall.

It is therefore recommended that EBCE apply the recurring LDBP mechanism of Market Responsive Pricing to the fuel switching rebate amounts offered. Gradual step down in the

[43] http://www.gosolarcalifornia.ca.gov/csi/index.php
[44] https://www.selfgenca.com/home/about/

individual rebate amount based either on market response (i.e., number of rebates issued), or at clearly communicated time-based intervals (i.e., specific dates or periods of time) can drive early adoption, minimize risks, and maximize the impact of EBCE's investment.

Financing as an Incentive

Access to capital and out-of-pocket costs can be a barrier to participation in cost-saving programs for may customers. Providing an array of financing options that address this market barrier can provide further incentives that increase customer participation and enhance programmatic outcomes for EBCE's OFF Gas program.

PACE Financing

As recommended in the LDBP *Energy Efficiency Assessment*, there is a robust network of established providers of Property Assessed Clean Energy (PACE) financing that is already actively serving the EBCE territory. These financiers have extensive experience and expertise in providing financing for energy upgrades such as the ones contemplated in this report, and it is recommended that EBCE pursue collaborations with existing PACE providers and work to connect interested customers with these valuable financial tools to support adoption of fuel swtiching activities. This financing option can work particularly well for customers who own the properties where the fuel switching activity will take place, but are not as applicable to tenant customers who lease or rent the buildings in question.

On-bill Financing and On-bill Repayment

As detailed in the *On-bill Financing and On-bill Repayment* section of the LDBP, these financing mechanisms can support adoption of energy upgrades for customers who do not qualify for other financing options (i.e., PACE, or standard bank loan products). As noted in that section of the LDBP, OBF and OBR have not yet been implemented effectively by CCA's, and there are some regulatory and financial hurdles that must be cleared for this to work well for EBCE. However, these obstacles are not insurmountable, and the value proposition presented by these financing mechanisms are substantial and would support broader customer participation in EBCE's fuel switching programs. Therefore, it is recommended that EBCE pursue OBF/OBR—including possibly tariffed OBF solutions such as Pay As You Save (PAYS)[45] or Inclusive Financing[46] structures, which may require some regulatory engagement and/or agreement with the IOU to fully enable for CCA's—financing options as part of its fuel switching program offerings.

[45] See "Pay As You Save harnesses a proven utility investment model to offer virtually all consumers cost-effective energy building upgrades" here: https://tinyurl.com/yc6zytc9
[46] See "Inclusive Financing for Efficiency and Renewable Energy" here: https://ilsr.org/report-inclusive-energy-financing/

Demand Response as an Incentive

Due to the embedded potential for smart thermostats and heat pump water heaters[47] to be dispatchable assets that can provide load shaping benefits to EBCE, it is also recommended that participating OFF Gas customers be eligible for any applicable Demand Response (DR) programs that EBCE offers. This can provide an additional incentive for customers to participate, since typically participation in a DR program would yield cost savings through bill credits (i.e., monthly and/or during peak demand events). Off Gas customer participation in EBCE's DR programs will also further enhance the outcomes of the OFF Gas program from EBCE's perspective, due to the market risk mitigation and cost savings benefits that can be realized through Demand Response.

Illustrative Example of OFF Gas Program Design and Implementation

The recommended OFF Gas program provides an innovative and effective way for EBCE to promote fuel switching to its customer base. While this program has added complexity in design and implementation as compared to other programs recommended in the LDBP, it also has the potential to yield substantial benefits to EBCE, its customers, and the State of California as a while, and is therefore deemed to be worth the additional effort.

The final OFF Gas program design and rates will need to be further refined by EBCE utilizing the appropriate staff and risk management and operating policies. However, the LDBP team has prepared a probabilistic analysis to provide conceptual cash flow potentials for the program under the modeled scenario.[48] A thorough sensitivity analysis was also performed to test all model assumptions, and the results of that analysis are also provided here to assist EBCE staff in making any final adjustments to model assumptions prior to launching the OFF Gas program.

It is anticipated that EBCE would need to provide an initial program investment to subsidize the costs of enhanced rebates, which is recouped through increased electricity sales over time. This section of the report provides an example that illustrates a feasible scenario for OFF Gas program design and implementation, including rate design, rebate levels, and resulting theoretical range of cash flows based on a $1 million investment by EBCE. The modeled scenario yields a Net Present Value (NPV) of ~$500,000, a Return on Investment (ROI) of 17%, and a Simple Payback of 12 years, as indicated in the Projected Cashflow Analysis table below.

[47] Note- A number of widely available smart thermostats are equipped to control hot water heaters in addition to HVAC equipment, which provides a powerful load management opportunity for CCA's. For example, see: https://nest.com/uk/support/article/Learn-more-about-the-3rd-generation-Nest-Thermostat-s-domestic-hot-water-control

[48] This analysis was performed using the Solvryn Enterprise software package provided by GPT (http://greenplanet.tech)

OFF Gas Program Scenario Analysis Findings

The following is an overview of research and findings from the probabilistic modeling of one feasible scenario for implementation of the recommended OFF Gas program for consideration by EBCE staff and administrators.[49] While this reflects one possible scenario, the program design parameters reflected here were carefully crafted to optimize program performance and balance benefits to EBCE, participating OFF Gas customers, and the EBCE community at-large.

The following is the estimated annual total consumption of natural gas by city, and the resulting metric tons of carbon dioxide produced by each community.[50]

	Annual MMBTUs Consumed	Metric tons of CO2 Produced
Albany	228,430	12,107
Berkeley	2,404,371	127,432
Dublin	1,202,897	63,754
Emeryville	692,940	36,726
Fremont	3,238,574	171,644
Hayward	2,631,799	139,485
Livermore	1,801,507	95,480
Oakland	6,143,935	325,629
San Leandro	2,806,349	148,737
Union City	1,034,567	54,832

Figure 5: 2017 natural gas consumption and related GHG emission estimates by city.[51]

According to data provided by PG&E through their Energy Data Request program,[52] in 2017 there were approximately 426,000 natural gas accounts in the residential sector of EBCE's service territory alone. The annual natural gas consumption for those accounts in 2017 was approximately 17 million MMBtu.

[49] See Appendix A for a detailed accounting of model assumptions
[50] Note- Data is provided by zip code, and these estimates were aggregated by zip code. Due to overlapping zip codes, data is not provided for Piedmont or the County of Alameda
[51] The U.S. Environmental Protection Agency GHG Coefficient for natural gas is 0.053 Metric Tons of CO2 per MMBtu
[52] For information about PG&E's Energy Data Request program see: https://www.pge-energydatarequest.com/

Estimated Annual Gas Revenues *(In Year 1)*		
Number of Participating Accounts		2,980
Annual MMBtus*		119,122
Commodity Surplus Revenue (Profit Margin)	$	25,552
Program Fees (Gas)	$	268,184
Operation, Carbon Offsets & Program Cost	$	(110,215)
Communication (Mailers)	$	(9,833)
Available Funds	**$**	**173,687**

Figure 6: Estimated EBCE OFF Gas program revenues from Year 1 natural gas commodity sales and program fees.

Estimated Increased Annual Electric Revenues *(In Year 7)*		
Number of Participating Accounts		2,980
Annual Water Heater Increased kWh's		3,379,115
Annual Space Heater Increased kWh's		3,307,600
Program Fees (Electric)	$	268,184
Water Heater Surplus Revenue (Profit Margin at 100% participation)	$	52,038
Space Heater Surplus Revenue (Profit Margin at 50% participation)	$	25,469
Available Surplus Revenue (Profit Margin)	**$**	**345,691**

Figure 7: Estimated EBCE OFF Gas program revenues from increased electricity sales and program fees in Year 7.

OFF Gas Program Projected Cash Flow							
	Cash Flow	Participation Level	Number of Rebates	Cumulative Total Rebates Given	Rebate Level	Rebate Level	Rebate Level
First Year TH Rebates	$ (104,294)	35%	1,043	1,043	$ 100	$ -	$ -
First Year WH Rebates	$ -	0%	-	-	$ -	$ -	$ -
First Year SH Rebates	$ -	0%	-	-	$ -	$ -	$ -
First Year OFF Gas Revenue	$ 173,687	100%	-		$ -	$ -	$ -
First Year Electric Revenue (Program Fee)	$ 268,184	100%					
First Year Electric Revenue (Water Heaters)	$ -	0%	-	-	$ -	$ -	$ -
First Year Electric Revenue (Space Heaters)	$ -	0%	-		$ -	$ -	$ -
Available Balance	**$ 337,578**						
Second Year TH Rebates	$ (74,495)	25%	745	1,788	$ 100	$ -	$ -
Second Year WH Rebates	$ (730,056)	35%	1,043	1,043	$ 700	$ -	$ -
Second Year SH Rebates	$ -	0%	-	-	$ -	$ -	$ -
Second Year OFF Gas Revenue	$ 165,003	95%			$ -	$ -	$ -
Second Year Electric Revenue (Program Fee)	$ 268,184	100%					
Second Year Electric Revenue (Water Heaters)	$ 18,213	35%			$ -	$ -	$ -
Second Year Electric Revenue (Space Heaters)	$ -	0%			$ -	$ -	$ -
Available Balance	**$ (15,573)**						
Third Year TH Rebates	$ (44,697)	20%	596	2,384	$ -	$ 75	$ -
Third Year WH Rebates	$ (521,468)	25%	745	1,788	$ 700	$ -	$ -
Third Year SH Rebates	$ (297,982)	10%	298	298	$ 1,000	$ -	$ -
Third Year OFF Gas Revenue	$ 138,950	80%	2,384		$ -	$ -	$ -
Third Year Electric Revenue (Program Fee)	$ 241,365.38	90%					
Third Year Electric Revenue (Water Heaters)	$ 31,223	60%			$ -	$ -	$ -
Third Year Electric Revenue (Space Heaters)	$ 5,094	10%			$ -	$ -	$ -
Available Balance	**$ (463,089)**						
Fourth Year TH Rebates	$ (22,349)	10%	298	2,682	$ -	$ 75	$ -
Fourth Year WH Rebates	$ (297,982)	20%	596	2,384	$ -	$ 500	$ -
Fourth Year SH Rebates	$ (446,973)	15%	447	745	$ 1,000	$ -	$ -
Fourth Year OFF Gas Revenue	$ 104,212	60%	1,788		$ -	$ -	$ -
Fourth Year Electric Revenue (Program Fee)	$ 201,138	75%					
Fourth Year Electric Revenue (Water Heaters)	$ 41,631	80%					
Fourth Year Electric Revenue (Space Heaters)	$ 12,734	25%			$ -	$ -	$ -
Available Balance	**$ (870,677)**						
Fifth Year TH Rebates	$ (7,450)	5%	149	2,831	$ -	$ -	$ 50
Fifth Year WH Rebates	$ (223,486)	15%	447	2,831	$ -	$ 500	$ -
Fifth Year SH Rebates	$ (223,486)	10%	298	1,043	$ -	$ 750	$ -
Fifth Year OFF Gas Revenue	$ 78,159	45%	1,341		$ -	$ -	$ -
Fifth Year Electric Revenue (Program Fee)	$ 174,319	65%					
Fifth Year Electric Revenue (Water Heaters)	$ 49,436	95%					
Fifth Year Electric Revenue (Space Heaters)	$ 17,828	35%			$ -	$ -	$ -
Available Balance	**$ (1,005,356)**						
Sixth Year TH Rebates	$ (7,450)	5%	149	2,980	$ -	$ -	$ 50
Sixth Year WH Rebates	$ (52,147)	5%	149	2,980	$ -	$ -	$ 350
Sixth Year SH Rebates	$ (223,486)	10%	298	1,341	$ -	$ 750	$ -
Sixth Year OFF Gas Revenue	$ 60,791	35%	1,043		$ -	$ -	$ -
Fourth Year Electric Revenue (Program Fee)	$ 147,501	55%	1,639				
Fourth Year Electric Revenue (Water Heaters)	$ 52,038	100%					
Fourth Year Electric Revenue (Space Heaters)	$ 22,922	45%			$ -	$ -	$ -
Available Balance	**$ (1,005,188)**						
Seventh Year TH Rebates	$ -	0%	-	2,980	$ -	$ -	$ 50
Seventh Year WH Rebates	$ -	0%	-	2,980	$ -	$ -	$ 350
Seventh Year SH Rebates	$ (59,596)	5%	149	1,490	$ -	$ -	$ 400
Seventh Year OFF Gas Revenue	$ 26,053	15%	447		$ -	$ -	$ -
Seventh Year Electric Revenue (Program Fee)	$ 134,092	50%	1,490				
Seventh Year Electric Revenue (Water Heaters)	$ 52,038	100%					
Seventh Year Electric Revenue (Space Heaters)	$ 25,469	50%			$ -	$ -	$ -
Available Balance	$ (827,132)						
Net Present Value (NPV)	**$492,489**						
Return on Investment (ROI, %)	**17%**						
Simple Payback (Years)	**12**						

Figure 8: Annual Cashflow Projection for EBCE OFF Gas Program. Note the total EBCE revenue investment required for the modeled scenario is $1,005,356, which is realized in Year 5 of program implementation, as indicated by the red oval.

# of Years Enrolled in OFF Gas Program	Total OFF Gas Bills *(Fees + Commodity)*	Utility User Tax (UUT)	Increased Electricity Bills *(incl- T&D)*	OFF Gas Program Rebates	PG&E Rebates	Demand Response Incentive	Net Total Customer Bills	PG&E Gas Bill *(what it would have been if customer made no change)*	Total Bill Change Compared to PG&E	Total % Change
Year 1* *(Thermostat)*	$ 666	$ 40	$ 90	$ (100)	$ (50)	$ -	$ 646	$ 585	$ 61	10%
Year 2* *(Water Heater)*	$ 385	$ 20	$ 369	$ (700)	$ (300)	$ -	$ (226)	$ 485	$ (711)	-147%
Year 3	$ 385	$ 20	$ 369	$ -	$ -	$ (66)	$ 708	$ 518	$ 190	37%
Year 4* *(Space heater)*	$ 161	$ 4	$ 641	$ (1,000)	$ -	$ (66)	$ (260)	$ 538	$ (798)	-148%
Year 5	$ 161	$ 4	$ 551	$ -	$ -	$ (66)	$ 650	$ 555	$ 95	17%
Year 6	$ 161	$ 4	$ 551	$ -	$ -	$ (66)	$ 650	$ 585	$ 65	11%
Year 7	$ 161	$ 4	$ 551	$ -	$ -	$ (66)	$ 650	$ 603	$ 47	8%
*(*Appliance Upgrade Indicated)*	**$ 2,079**	**$ 97**	**$ 3,122**	**$ (1,800)**	**$ (350)**	**$ (330)**	**$ 2,817**	**$ 3,868**	**$ (1,051)**	**-27%**

Figure 9: Estimated Cost Comparison for Individual EBCE OFF Gas Customer (who completes the prescribed fuel switching process) vs. Individual PG&E Customer (who makes no changes).

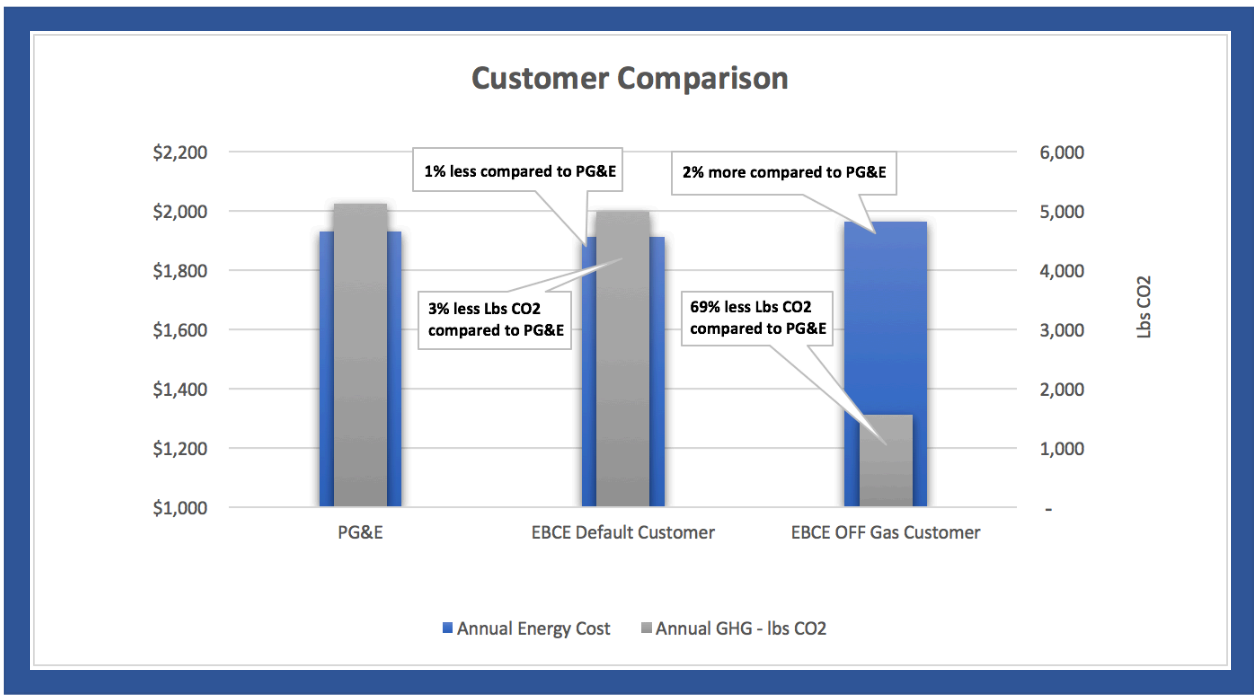


Figure 10: PG&E, EBCE Bright Choice, and EBCE OFF Gas Customer Cost and GHG Intensity Comparison.[53]

[53] Notes- This comparison is based on a single residence using 4,774 kWh/yr. This comparison is based on a single residence using 400 Therms/yr. The totals include annual estimated electricity usage and natural gas usage. The EBCE Off Gas program is based on water and space heating natural gas appliances fuel switching to electric models.

# of Years Enrolled in OFF Gas Program	Net Bill for EBCE OFF Gas Customers	Total Bill for PG&E Customers	Annual Costs for OFF Gas Customers Compared to PG&E	Total % Change
Year 1	$ 2,043,852	$ 1,743,566	$ 300,287	17%
Year 2	$ 1,262,280	$ 1,445,584	$ (183,304)	-13%
Year 3	$ 1,198,317	$ 1,542,428	$ (344,111)	-22%
Year 4	$ 1,275,507	$ 1,602,024	$ (326,517)	-20%
Year 5	$ 1,526,399	$ 1,654,171	$ (127,772)	-8%
Year 6	$ 1,684,294	$ 1,743,566	$ (59,272)	-3%
Year 7	$ 1,601,862	$ 1,795,712	$ (193,850)	-11%
	$ 10,592,511	**$ 11,527,050**	**$ (934,539)**	**-8%**

Figure 11: Annual comparison of total OFF Gas customer costs vs total PG&E customer costs.[54]

OFF Gas Program Implementation Year	Therms Reduced by Water Heater Fuel Switching	Therms Reduced by Space Heater Fuel Switching *(at 50% Participation)*
Year 1	0	0
Year 2	20,859	0
Year 3	14,899	4,768
Year 4	11,919	7,152
Year 5	8,939	4,768
Year 6	2,980	4,768
Year 7	0	2,384
TOTAL	**59,596**	**23,839**

Figure 12: Natural Gas Demand Destruction Resulting from the modeled scenario for the EBCE OFF Gas Program.[55]

[54] Includes all participating customers, and takes into consideration fuel switching impacts and customer attrition.

[55] The OFF Gas program design includes Certified Carbon Offsets matched with all Natural Gas commodity sales, and therefore the program yields immediate GHG reductions that effectively offset 100% of all participating customer natural gas consumption from Year 1. In this example, that would be 119,122 MMBtu of Gas*,* equaling ~6,313 MTCO2e of GHG reductions

Conclusion

As the carbon intensity of California electricity generation decreases due to the shift away from fossil fuel-based power plants to wind and solar, shifting more energy use to electricity can reduce overall greenhouse gas emissions. In addition to the societal greenhouse gas benefits, targeted electrification of Alameda County's buildings through programatic fuel switching initiatives can increase and stabilize retail electricity sales for EBCE, while reducing greenhouse gases in the county. The LDBP Consultants recommend that natural gas fuel switching strategies be pursued in concert with other programs to optimize investments where they are most valuable in meeting EBCE's goals.

Specifically, high efficiency heat pumps should be widely deployed for water and space heating. A heat pump water heater may reduce kWh by 50% compared to a resistance water heater, but a heat pump water heater controlled (i.e., by a smart thermostat) so as to have its load met during the middle hours of the day when solar PV production is highest and grid carbon intensity is lowest may reduce emissions 75% or more.[56]

Unfortunately, electrification of buildings is not always as simple as swapping out old equipment for new equipment. It often requires running new conduit, upgrading electricity panels, and capping or removing gas lines. This work should be completed in coordination with energy efficiency retrofits and solar installation, which will create increased demand for skilled labor (i.e., electricians). However, beneficial building electrification costs money, and there are other market barriers including the artificallly low retail rates for natural gas as compared to the higher cost of cleaner electricity. Accelerating the electrification of buildings will require broad based efforts including making building electrification a policy priority, effective marketing strategies and consumer education, updating building codes, designing an effective incentive structure, and workforce education and training.

EBCE has an opportunity to demonstrate leadership in this arena through implementation of LDBP natural gas fuel switching program recommendations. This opportunity includes the potential for achieving deep decarbonization that stretches well beyond what is possible in the electricity sector alone, and extending the CCA value proposition to California's legislature and regulatory institutions who are already asking how CCA's can support the State's aggressive climate protection goals beyond procurement of clean electricity portfolios. As RPS goals continue to ramp up towards 100% renewable, all electricity portfolios in the state will eventually become carbon free, making it increasingly difficult for CCA's to distinguish themselves from their IOU competitors based on renewable and/or carbon free content in their electricity portfolios.

The innovative approach to stimulating local building electrification proposed by the EBCE Local Development Business plan (referred to as the OFF Gas program) provides a sustainable framework for a programmatic approach to natural gas fuel switching that can yield significant benefits for EBCE (and its member jurisdictions), the customers it was created to serve, and the State of California as a whole. The recommended program design was developed to deliver immediate GHG emission reductions, create new demand for local skilled labor, build new and

[56] See: http://www.sciencedirect.com/science/article/pii/S1040619016301075

stable revenue streams for EBCE, and overcome barriers to customer adoption of ultra-high efficiency and low emission heat pump technologies. The OFF Gas program is self-sustaining, and can lead to permanent natural gas demand destruction in support of California's aggressive clean energy and climate protection goals, while simultaneously supporting the goals and aspirations codified in EBCE's Joint Powers Agreement.[57]

The EBCE community of stakeholders has been an active participant in the development of the LDBP, and is excited by the potential of the LDBP to help EBCE exceed the CCA status quo in terms of innovative approaches to local DER deployment in ways that enhance and maximize benefits to the greater EBCE community. The recommended OFF Gas program provides a potentially powerful value added differentiator that distinguishes EBCE from the incumbent investor-owned utility, and sets a new standard for decarbonization through natural gas demand destruction that can become a best practice for all California CCA's.

Offering an opt-in natural gas service that offsets natural gas emissions using certified carbon offsets, as recommended here, can provide a beneficial transitionary means to effectively phasing out natural gas appliances and moving away from fossil fuel gas altogether. This approach taps into the existing retail natural gas market to create new revenue streams that can support EBCE's delivery of substantial rebates and incentives to customers, which helps overcome barriers and drive increased participation in natural gas fuel switching through beneficial building electrification. Given that no California CCA has to-date offered retail natural gas service to its customers, this provides an excellent opportunity to further distinguish EBCE from its peers and establish thought leadership within the CCA industry on this important issue. There is no other comparable entity to CCA's that is motivated in the same way to create a natural gas program that seeks to reduce, and ultimately eliminate demand for natural gas. EBCE has an opportunity to put into effect an innovative natural gas fuel switching program that provides the necessary incentives to accelerate adoption and penetration into a large pool of EBCE customers that are supportive of decarbonization and environmental protection.

While the recommended OFF Gas program has more complexity than other LDBP recommended programs, the substantial value presented by the program outweighs that added complexity. It is recommended that EBCE staff and administrators devote focused effort to further evaluating and refining this innovative program design in 2019, with the goal of launching the OFF Gas program in 2020. It is also recommended that EBCE initially work in tandem with a registered Core Transport Agent (i.e., ABAG POWER) as a partner and implementer to reduce cost, risk, staffing requirements, and overall complexity to ensure successful delivery of the program in its early stages. Over time, as the program becomes established and begins to grow, it is recommended that EBCE seek to become a registered CTA and build the internal capacity necessary to facilitate the continued growth and expansion of the OFF Gas program.

[57] EBCE's Joint Powers Agreement can be found here: https://ebce.org/wp-content/uploads/EBCE_JPA_Agreement_12_1_16.pdf

Appendix A: Modeled OFF Gas Program Scenario Assumptions

The following are the assumptions for the included modeled scenario:

- Approximately $1 million of total investment of EBCE revenue* *(*Note- this is a scalable investment amount, and all indicators will scale proportionally to the actual investment amount determined by EBCE Board and Staff)*
    - A $1 million investment indicates ~0.7% participation of residential natural gas accounts in the EBCE service territory (approximately 3,000 natural gas accounts)
- The end goal of the OFF Gas program is to achieve significant natural gas demand destruction, ultimately losing natural gas commodity margins from customers participating the OFF Gas program as they fuel switch. This goal is counter to that of most, if not all, retail natural gas suppliers in California and reflects EBCE's core values of reducing GHG emissions in ways that benefit the local community
- Average annual natural gas consumption per customer was assumed to be 40 MMBtu/year, based on data provided by PG&E under the Energy Data Request program
- Annual natural gas consumption for base model water heaters was assumed to be 20 MMBtu/yr, and for base model space heaters the assumption is 16 MMBtu/yr[58]
- Retail cost of natural gas was assumed to be $13.47/MMBtu ($4.29/MMBtu for commodity + $9.18/MMBtu for Distribution), plus 7.5% Utility User Tax (UUT). Retail cost of electricity was assumed to be $0.264/kWh ($0.0734/kWh Generation + $0.1383 T&D + $0.0339 PCIA)[59]
- Wholesale cost of natural gas was assumed to be $4.29/MMBtu. Wholesale cost of electricity was assumed to be $0.058/kWh
- The assumed natural gas commodity profit margins is 5%
- The cost of Certified Carbon Offsets was assumed to be $0.55/MMBtu
- The assumed cost of program operations is $1.25/account per month, and the assumed cost of customer communications (i.e., direct mail notifications) is $1.65/account per year
- Annual electricity consumption for heat pump water heater (based on the AO Smith FPTU-50 Voltex model) was assumed to be 1,134 kWh/yr, and for the heat pump space heater (based on the Carrier Infinity model) the assumption is 1,110 kWh/yr[60]
- A fixed monthly service charge of $15/month was assumed for all OFF Gas customers until customers complete the fuel switching process and terminate natural gas service

---

[58] Sources: https://www.physics.uci.edu/~silverma/actions/HouseholdEnergy.html; http://www.energy.ca.gov/2010publications/CEC-200-2010-004/CEC-200-2010-004-PG+E.PDF

[59] These retail rate assumptions are estimated based on expected costs in 2020

[60] Heat Pump Water Heater and Heat Pump Space Heater performance was modeled using Life Cycle Fuel Switching Analysis tools published by Carbon Free Palo Alto (adjusted for EBCE climate zone and expected retail rates in 2020), see: http://carbonfreepaloalto.org ; https://www.dropbox.com/sh/yint62e96ns1l2u/D0sy8fX9QY

- It is assumed that all of the proceeds raised by the program will be distributed back to participating OFF Gas customers by the seventh year in the form of enhanced rebates
- There are three rebate opportunities available (Smart thermostat, HP water heater, HP space heater)
- All customers would be eligible to obtain a smart thermostat rebates immediately upon enrollment in the program
- Appliance rebates would not start until the second year, and customers must follow the prescribed loading order
- Rebate levels adjust downward at set time periods (at 2-year intervals)
- It was assumed that OFF Gas customers would be eligible to receive rebates currently available from PG&E for Smart Thermostats ($50) and Heat Pump Water Heaters ($300). It was assumed that no PG&E rebate would be available for Heat Pump Space Heaters, based on information available on PG&E's rebate website
- Demand Response incentive was assumed to be $66/yr, and it was assumed that 50% of OFF Gas customers would participate in the DR program.
- It was assumed that 100% of OFF Gas customers would receive the rebates for the Smart Thermostat and Heat Pump Water Heater, and 50% of OFF Gas customers would receive the rebate for the Heat Pump Space Heater during the analysis period.

Appendix B: OFF Gas Program Model Sensitivity Analysis

The LDBP consultants performed rigorous sensitivity analysis on all model inputs to help EBCE staff and administrators identify program parameters that have the highest impact on program performance. While there are many ways to model the input variables, forecasts and probabilities, the analysis included here pinpoints the elasticity of each variable and identifies the most impactful variables.

The complete spreadsheet model developed by the LDBP Consultants will be provided to EBCE to allow EBCE staff to make any necessary adjustments to program parameters and/or assumptions. Further modeling and fine tuning can be conducted by EBCE to refine inputs and narrow in on the sensitivities that matter most to EBCE, allowing EBCE staff to focus on the inputs that actually make a difference in likely program outcomes. In this first round of modeling indicates that it is important to focus on the Heat Pump Water Heater efficiency (kWh/yr), which has the greatest impact on overall program performance (esp. Customer Savings). Once that variable is dialed in then EBCE would focus on the space heater, monthly OFF Gas program fees, etc.

The figures below provide a detailed overview of the sensitivity analysis outcomes.

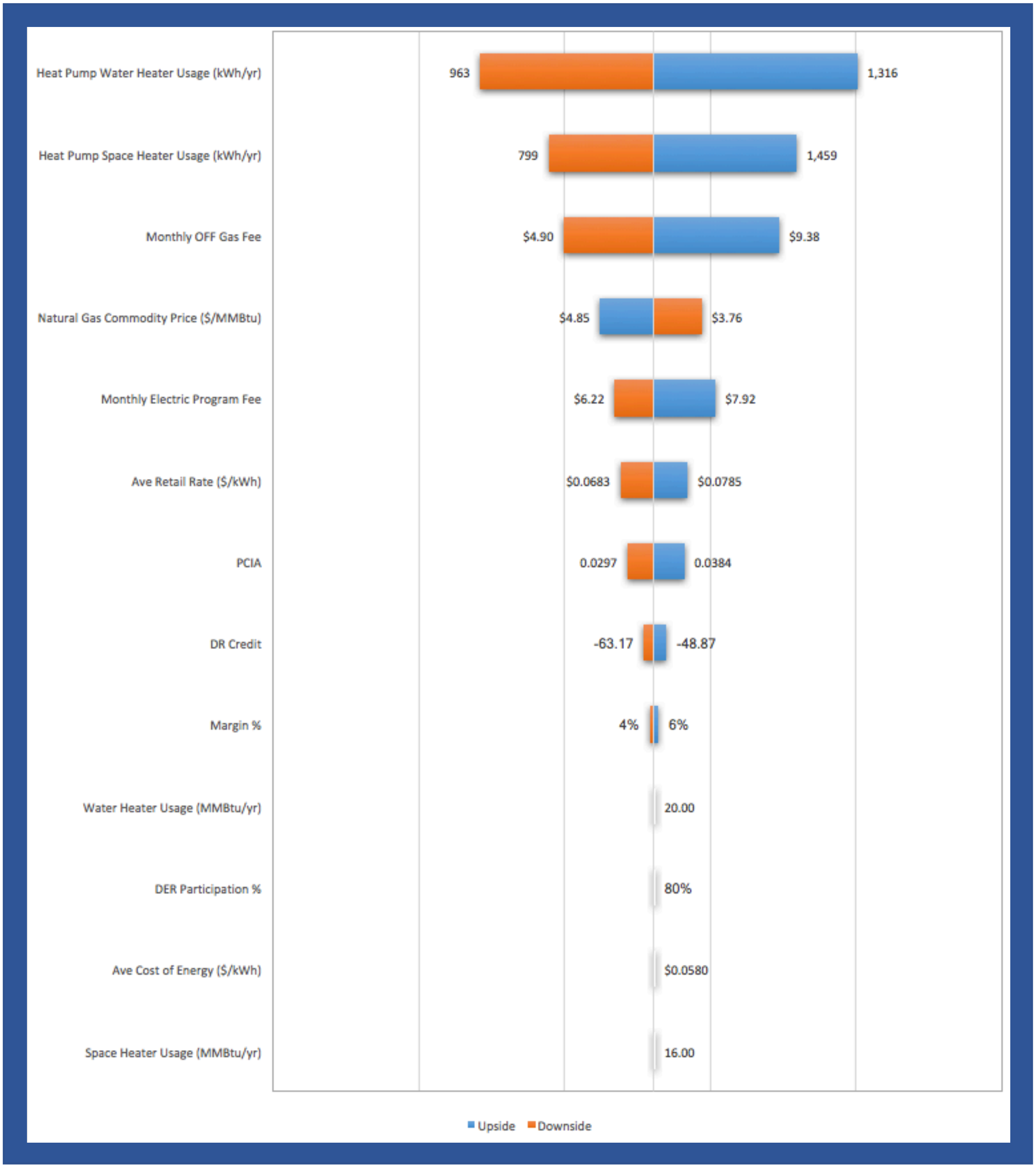
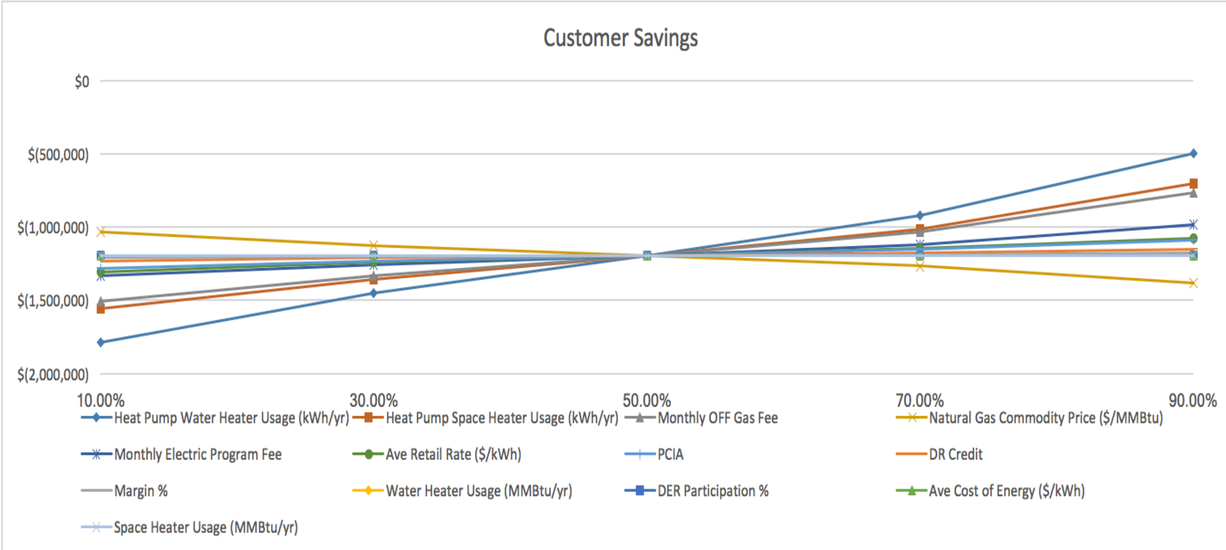


Figure 13:Sensitivity Analysis Tornado Chart for modeled scenario variable assumptions.[61]

[61] Note- Bar labels in the Tornado Chart indicate the tested range for each model input variable



		Customer Savings				
Input Variable	Elasticity[1]	10.00%	30.00%	50.00%	70.00%	90.00%
Heat Pump Water Heater Usage (kWh/yr)	3.96	$(1,789,875)	$(1,448,611)	$(1,193,076)	$(920,654)	$(495,250)
Heat Pump Space Heater Usage (kWh/yr)	1.29	$(1,555,266)	$(1,354,538)	$(1,193,076)	$(1,010,480)	$(703,869)
Monthly OFF Gas Fee	1.03	$(1,503,424)	$(1,332,326)	$(1,193,076)	$(1,034,066)	$(763,854)
Natural Gas Commodity Price ($/MMBtu)	-1.14	$(1,030,065)	$(1,123,846)	$(1,193,076)	$(1,266,024)	$(1,378,316)
Monthly Electric Program Fee	1.21	$(1,328,567)	$(1,255,719)	$(1,193,076)	$(1,118,209)	$(983,613)
Ave Retail Rate ($/kWh)	1.39	$(1,308,308)	$(1,240,228)	$(1,193,076)	$(1,145,924)	$(1,077,845)
PCIA	0.64	$(1,284,122)	$(1,231,743)	$(1,193,076)	$(1,152,332)	$(1,089,614)
DR Credit	0.26	$(1,229,278)	$(1,208,611)	$(1,193,076)	$(1,176,462)	$(1,150,418)
Margin %	0.10	$(1,208,138)	$(1,199,239)	$(1,193,076)	$(1,186,913)	$(1,178,014)
Water Heater Usage (MMBtu/yr)	0.00	$(1,193,076)	$(1,193,076)	$(1,193,076)	$(1,193,076)	$(1,193,076)
DER Participation %	0.00	$(1,193,076)	$(1,193,076)	$(1,193,076)	$(1,193,076)	$(1,193,076)
Ave Cost of Energy ($/kWh)	0.00	$(1,193,076)	$(1,193,076)	$(1,193,076)	$(1,193,076)	$(1,193,076)
Space Heater Usage (MMBtu/yr)	0.00	$(1,193,076)	$(1,193,076)	$(1,193,076)	$(1,193,076)	$(1,193,076)

[1]Elasticity is averaged across the entire test range

Figure 14: Sensitivity Analysis Spider Chart indicating elasticity of all modeled variables and relative impact on Customer Savings.

Appendix C: OFF Gas Program Performance With $3 Million Investment

The following tables shows the modeling outcomes of how the OFF Gas program would perform with a $3 million total investment by EBCE. All other scenario assumptions were held constant with the scenario included in the body of the report, and only the total investment amount was altered. This is meant to provide additional context for EBCE staff, and demonstrates that the ROI and Simple Payback are consistent with the base scenario outlined above regardless of the investment amount.

However, this also demonstrates that at higher levels of investment the OFF Gas program produces increased benefits to EBCE, and because it would facilitate more customers to participate it also increases beneficial outcomes from the GHG perspective as well. These additional impacts scale proportionally to the amount of investment, meaning that with three times the total investment by EBCE (i.e., $3 million instead of the $1 million modeled in the base scenario in the body of the report) we would expect to see roughly three times the number of customers served (~9,000 customers vs. ~3,000 in the base scenario above). It should be noted here that this would also incur increased staff and administrative time proportionately as well, as the workload required to market and deliver the program to a larger pool of customers would also scale accordingly.

Estimated Annual Gas Revenues ***(In Year 1)***		
Number of Participating Accounts		8,897
Annual MMBtus*		355,666
Commodity Surplus Revenue (Profit Margin)	$	76,290
Program Fees (Gas)	$	800,720
Operation, Carbon Offsets & Program Cost	$	(329,069)
Communication (Mailers)	$	(29,360)
Available Funds	**$**	**518,581**

Estimated Increased Annual Electric Revenues ***(In Year 7)***		
Number of Participating Accounts		8,897
Annual Water Heater Increased kWh's		10,089,073
Annual Space Heater Increased kWh's		9,875,548
Program Fees (Electric)	$	800,720
Water Heater Surplus Revenue (Profit Margin)	$	155,372
Space Heater Surplus Revenue (Profit Margin)	$	152,083
Available Surplus Revenue (Profit Margin)	**$**	**1,108,175**

OFF Gas Program Projected Cash Flow

	Cash Flow	Participation Level	Number of Rebates	Cumulative Total Rebates Given	Rebate Level	Rebate Level	Rebate Level
First Year TH Rebates	$ (311,391)	35%	3,114	3,114	$ 100	$ -	$ -
First Year WH Rebates	$ -	0%	-	-	$ -	$ -	$ -
First Year SH Rebates	$ -	0%	-	-	$ -	$ -	$ -
First Year OFF Gas Revenue	$ 518,581	100%	-		$ -	$ -	$ -
First Year Electric Revenue (Program Fee)	$ 800,720	100%					
First Year Electric Revenue (Water Heaters)	$ -	0%	-	-	$ -	$ -	$ -
First Year Electric Revenue (Space Heaters)	$ -	0%	-		$ -	$ -	$ -
Available Balance	**$ 1,007,910**						
Second Year TH Rebates	$ (222,422)	25%	2,224	5,338	$ 100	$ -	$ -
Second Year WH Rebates	$ (2,179,738)	35%	3,114	3,114	$ 700	$ -	$ -
Second Year SH Rebates	$ -	0%	-	-	$ -	$ -	$ -
Second Year OFF Gas Revenue	$ 492,652	95%			$ -	$ -	$ -
Second Year Electric Revenue (Program Fee)	$ 800,720	100%					
Second Year Electric Revenue (Water Heaters)	$ 54,380	35%			$ -	$ -	$ -
Second Year Electric Revenue (Space Heaters)	$ -	0%			$ -	$ -	$ -
Available Balance	**$ (46,498)**						
Third Year TH Rebates	$ (133,453)	20%	1,779	7,118	$ -	$ 75	$ -
Third Year WH Rebates	$ (1,556,956)	25%	2,224	5,338	$ 700	$ -	$ -
Third Year SH Rebates	$ (889,689)	10%	890	890	$ 1,000	$ -	$ -
Third Year OFF Gas Revenue	$ 414,865	80%	7,118		$ -	$ -	$ -
Third Year Electric Revenue (Program Fee)	$ 720,648.06	90%					
Third Year Electric Revenue (Water Heaters)	$ 93,223	60%			$ -	$ -	$ -
Third Year Electric Revenue (Space Heaters)	$ 15,208	10%			$ -	$ -	$ -
Available Balance	**$ (1,382,651)**						
Fourth Year TH Rebates	$ (66,727)	10%	890	8,007	$ -	$ 75	$ -
Fourth Year WH Rebates	$ (889,689)	20%	1,779	7,118	$ -	$ 500	$ -
Fourth Year SH Rebates	$ (1,334,533)	15%	1,335	2,224	$ 1,000	$ -	$ -
Fourth Year OFF Gas Revenue	$ 311,149	60%	5,338		$ -	$ -	$ -
Fourth Year Electric Revenue (Program Fee)	$ 600,540	75%					
Fourth Year Electric Revenue (Water Heaters)	$ 124,297	80%					
Fourth Year Electric Revenue (Space Heaters)	$ 38,021	25%			$ -	$ -	$ -
Available Balance	**$ (2,599,593)**						
Fifth Year TH Rebates	$ (22,242)	5%	445	8,452	$ -	$ -	$ 50
Fifth Year WH Rebates	$ (667,267)	15%	1,335	8,452	$ -	$ 500	$ -
Fifth Year SH Rebates	$ (667,267)	10%	890	3,114	$ -	$ 750	$ -
Fifth Year OFF Gas Revenue	$ 233,362	45%	4,004		$ -	$ -	$ -
Fifth Year Electric Revenue (Program Fee)	$ 520,468	65%					
Fifth Year Electric Revenue (Water Heaters)	$ 147,603	95%					
Fifth Year Electric Revenue (Space Heaters)	$ 53,229	35%			$ -	$ -	$ -
Available Balance	**$ (3,001,707)**						
Sixth Year TH Rebates	$ (22,242)	5%	445	8,897	$ -	$ -	$ 50
Sixth Year WH Rebates	$ (155,696)	5%	445	8,897	$ -	$ -	$ 350
Sixth Year SH Rebates	$ (667,267)	10%	890	4,004	$ -	$ 750	$ -
Sixth Year OFF Gas Revenue	$ 181,503	35%	3,114		$ -	$ -	$ -
Fourth Year Electric Revenue (Program Fee)	$ 440,396	55%	4,893				
Fourth Year Electric Revenue (Water Heaters)	$ 155,372	100%					
Fourth Year Electric Revenue (Space Heaters)	$ 68,438	45%			$ -	$ -	$ -
Available Balance	**$ (3,001,203)**						
Seventh Year TH Rebates	$ -	0%	-	8,897	$ -	$ -	$ 50
Seventh Year WH Rebates	$ -	0%	-	8,897	$ -	$ -	$ 350
Seventh Year SH Rebates	$ (177,938)	5%	445	4,448	$ -	$ -	$ 400
Seventh Year OFF Gas Revenue	$ 77,787	15%	1,335		$ -	$ -	$ -
Seventh Year Electric Revenue (Program Fee)	$ 400,360	50%	4,448				
Seventh Year Electric Revenue (Water Heaters)	$ 155,372	100%					
Seventh Year Electric Revenue (Space Heaters)	$ 76,042	50%			$ -	$ -	$ -
Available Balance	$ (2,469,580)						
Net Present Value (NPV)	**$1,470,430**						
Return on Investment (ROI, %)	**17%**						
Simple Payback (Years)	**12**						

# of Years Enrolled in OFF Gas Program	Net Bill for EBCE OFF Gas Customers		Total Bill for PG&E Customers		Annual Costs for OFF Gas Customers Compared to PG&E		Total % Change
Year 1	$	6,102,359	$	5,205,789	$	896,570	17%
Year 2	$	3,768,807	$	4,316,100	$	(547,293)	-13%
Year 3	$	3,577,833	$	4,605,249	$	(1,027,416)	-22%
Year 4	$	3,808,301	$	4,783,187	$	(974,886)	-20%
Year 5	$	4,557,391	$	4,938,882	$	(381,491)	-8%
Year 6	$	5,028,820	$	5,205,789	$	(176,968)	-3%
Year 7	$	4,782,702	$	5,361,484	$	(578,782)	-11%
	$	**31,626,213**	**$**	**34,416,479**	**$**	**(2,790,267)**	**-8%**

OFF Gas Program Implementation Year	Therms Reduced by Water Heater Fuel Switching	Therms Reduced by Space Heater Fuel Switching *(at 50% Participation)*
Year 1	0	0
Year 2	62,278	0
Year 3	44,484	14,235
Year 4	35,588	21,353
Year 5	26,691	14,235
Year 6	8,897	14,235
Year 7	0	7,118
TOTAL	**177,938**	**71,175**

Appendix D: PaloAltoGreen Gas Program Case Study

City of Palo Alto Leads the Way in Sustainability

Palo Alto, CA (January 12, 2015)— The City of Palo Alto is once again taking a leadership role in its quest to make the city one of the most sustainable in the country.

The City's Utilities Department (CPAU) just launched a new program that allows its customers to reduce the carbon footprint of their natural gas energy consumption. In keeping with efforts to combat climate change, the new PaloAltoGreen Gas program helps further reduce greenhouse gas emissions generated by the community.

Since 2013, CPAU has purchased 100% of its electric supply from renewable energy sources including hydroelectric, wind and landfill-to-gas energy resources, drastically reducing the City’s greenhouse gas emissions.

The PaloAltoGreen Gas program now gives customers an opportunity to offset the carbon emissions associated with their natural gas usage to further lower their carbon footprint.

Through the voluntary PaloAltoGreen Gas, utility customers can pay a small premium on their utility bill each month to offset the carbon emissions associated with their natural gas use. The Green-e Climate Certified program bundles a customer’s regular natural gas purchases with carbon offsets that reduce the amount of greenhouse gases released into the atmosphere. Participation in PaloAltoGreen Gas supports carbon offset projects at dairy farms that capture methane from animal manure and then destroy the harmful greenhouse gas by burning it as fuel to produce electricity.

"In 2007, we adopted Palo Alto's Climate Protection Plan that clearly outlined our goals for reducing greenhouse gas emissions from all sources," said City Manager James Keene. “The PaloAltoGreen Gas program aligns with the plan’s vision, and is the first Green-e Climate certified gas offset program offered by a municipal utility, and the first to be offered to individual community members. This program helps move Palo Alto forward in our goal to become the greenest community in the country."

By participating in the new PaloAltoGreen Gas program, customers will support projects from rural communities throughout the United States that help make the best possible use of a waste product by turning it into a useful carbon offset and environmental good. The City of Palo Alto is choosing to support projects in areas where PaloAltoGreen Gas participants’ dollars make a big difference in building and running the projects.

Green Valley Dairy in Krakow, Wisconsin is an example of a project supported by PaloAltoGreen Gas. The dairy’s management team operates with sustainability in mind and won the 2013 Outstanding Achievement in Renewable Energy award for the Innovation Center for U.S. Dairy. The dairy uses an anaerobic digester to capture renewable biomethane as the manure breaks down. The biomethane is destroyed when it is burned as fuel to produce electricity.

“Since 2013, Palo Alto has purchased 100% of its electric supplies from renewable energy sources and matches any “brown” market purchases with Renewable Energy Certificates (RECs).” Keene said. “However, there is still a carbon footprint associated with the natural gas we use in Palo Alto and emissions reduction projects are an effective way to offset these emissions.”

Upon enrollment, residents and businesses pay a small additional fee each month to offset the carbon emissions associated with their natural gas use. Participation in PaloAltoGreen Gas costs 12 cents more per therm of natural gas used. That is only about $5 more per month for the average residential household to offset the greenhouse gas emissions associated with 100% of their natural gas use. Local businesses can choose to offset 100% of their emissions at 12 cents per therm or purchase monthly increments of 100-therm blocks for $12 per block.

“As a resident who is conscious about energy conservation and the environment, I wanted to express myself further by choosing a green option for gas,” said Palo Alto resident Earl Dworkin. “I am already an energy efficient customer. For a few dollars a month, why not go green?”

About the City of Palo Alto Utilities (CPAU): The City of Palo Alto is the only municipality in California operating a full suite of utility services. CPAU has been providing quality services to the citizens and businesses of Palo Alto since 1896. For more information about CPAU, visit cityofpaloalto.org/utilities

This article can be accessed in its entirety here:
https://www.cityofpaloalto.org/news/displaynews.asp?NewsID=2970

References

Alison Canyon leak sheds light on national problem (Environmental Defense Fund). Accessed here: https://www.edf.org/climate/methane-progress-california

California Greenhouse Gas Inventory. California Air Resources Board (CARB). Accessed here: https://www.arb.ca.gov/cc/inventory/inventory.htm

City of Palo Alto Heat Pump Water Heater Program. Accessed here: https://www.cityofpaloalto.org/gov/depts/utl/residents/resrebate/smartenergy/heat_pump_water_heaters/heat_pump_water_heater_pilot_program.asp

Commission Should Enable Switching to Clean Energy for Heat (NRDC- Merrian Borgeson). Accessed here: https://www.nrdc.org/experts/commission-should-enable-switching-clean-energy-heat

Data Driven Path to Economic and Ecological Sustainability: A Roadmap for Community Choice Innovation. January 2017, North Bay Clean Energy Forum. Accessed here: https://cleanpowerexchange.org/wp-content/uploads/2017/01/NBCEForumWhitePaper_CCA_2017-0124_FINAL.pdf

Environmentally beneficial electrification: The dawn of emissions efficiency. Accessed here: http://www.sciencedirect.com/science/article/pii/S1040619016301075

Fossil Fuel Free Homes: A Guide to the All Electric, Low Carbon, Clean Home, (Menlo Spark) Accessed here: http://menlospark.org/wp-content/uploads/2016/09/fossil-free-homes-factsheet.pdf

Fuels Switching- Essential Step Towards Decarbonized Future. CleanTechnica. Accessed here: https://cleantechnica.com/2016/05/23/fuel-switching-essential-step-towards-decarbonized-future/

Greenhouse gas emissions from domestic hot water: heat pumps compared to most commonly used systems. Accessed here: http://onlinelibrary.wiley.com/doi/10.1002/ese3.112/epdf

Health Problems Emerge Near Natural Gas Fields. Scientific American. Accessed here: https://www.scientificamerican.com/article/science-lags-as-health-problems/

Heat Pump Furnaces and Water Heaters - A Clean Energy Solution to Decarbonize Bay Area Homes (NRDC- Pierre Delforge). April 27, 2016. Accessed here: http://carbonfreepaloalto.org/wp-content/uploads/2016/05/Heat-Pump-Furnaces-and-Water-Heaters-A-Clean-Energy-Solution-to-Decarbonize-Bay-Area-Homes-350SV-April-27-2016.pdf

How electric utilities could revive their sagging fortunes and decarbonize the country. Accessed here: http://www.vox.com/science-and-health/2017/2/22/14681674/electric-utilities-electrification

Inclusive Financing for Efficiency and Renewable Energy. Accessed here: https://ilsr.org/report-inclusive-energy-financing/

Information about Heat Pump HVAC Technologies (GreenAndSave). Accessed here: http://www.greenandsave.com/heating/furnaces/heat_pumps_ac.html

Information about MCE Clean Energy Rebates and Programs:

https://www.mcecleanenergy.org/business-savings/

https://www.mcecleanenergy.org/multifamily-savings/

Information about Pacific Gas and Electric Rebates and Programs:

https://marketplace.pge.com

Information about the PaloAltoGreen Gas Program:

Rate Tariff: https://www.cityofpaloalto.org/civicax/filebank/documents/42872

Articles: https://www.prnewswire.com/news-releases/terrapass-launches-innovative-sustainability-program-with-the-city-of-palo-alto-300025734.html

Presentation: http://resource-solutions.org/images/events/rem/presentations/2014/Dailey_Karla.pdf

Information about SMUD Fuel Switching and Heat Pump Rebate Programs:

https://www.smud.org/-/media/Documents/Rebates-and-Savings-Tips/Rebates/2018/Feb/SMUD-QPL_HPWH_Feb2018.ashx?la=en&hash=3F161C3A990F331D5A34228ABA5AA1AFB34BC7FE

https://www.smud.org/-/media/Documents/Rebates-and-Savings-Tips/Rebates/2018/Feb/SMUD-QPL_Clothes-Dryer_Feb2018.ashx?la=en&hash=10DEF1D9FE266BF60B20AA4F1E6465E32566DC22

https://www.smud.org/-/media/Documents/Rebates-and-Savings-Tips/Rebates/2018/Feb/SMUD-QPL_Smart-Thermostat_Feb2018updated.ashx?la=en&hash=37A0959587697563990AB5FF176FFC2A29C9F140

https://www.smud.org/-/media/Documents/Rebates-and-Savings-Tips/Rebates/ductless-mini-split-heatpump-application-3558.ashx?la=en&hash=FD850FEAEF0950757278094DC65FC8A0D758305B

https://www.smud.org/-/media/Documents/Rebates-and-Savings-Tips/Rebates/2018/2486.ashx?la=en&hash=5F498C3416C2C31733E9393EC6DC62BE70451817

http://docketpublic.energy.ca.gov/PublicDocuments/17-IEPR-06/TN219995_20170630T145154_William_Westerfield_III_Comments_Comments_of_the_Sacramento_Mun.pdf

http://docketpublic.energy.ca.gov/PublicDocuments/17-BSTD-01/TN221572_20171020T154049_Steven_G_Lins_Comments_SMUD_Comments_on_Draft_2019_Building_Ene.pdf

Lifecycle costs of EV's and Heat Pump Appliances- portfolio of spreadsheets that perform life cycle analysis on fuel switching for EVs, hot water heaters, and furnaces. Carbon Free Palo Alto, http://carbonfreepaloalto.org, www.dropbox.com/sh/yint62e96ns1l2u/D0sy8fX9QY

Motion of the Natural Resources Defense Council (NRDC), Sierra Club, and the California Energy Efficiency Industry Council (The Council) Seeking Review and Modification of the Three-prong Fuel Substitution Test. Accessed here: https://drive.google.com/file/d/0B2t1mDNwWpVKQ0VJWnlxVGQ3YVU/view

Pay As You Save (PAYS) harnesses a proven utility investment model to offer virtually all consumers cost-effective energy building upgrades. Accessed here: https://tinyurl.com/yc6zytc9

Scenarios to decarbonize residential water heating in California. Accessed here: https://tinyurl.com/yd5suhn3

The Hidden Battery: Opportunities in Electric Water Heating (Brattle Group). Accessed here: http://www.electric.coop/wp-content/uploads/2016/07/The-Hidden-Battery-01-25-2016.pdf

U.S. Department of Energy (DOE) information about heat pump technologies. Accessed here: http://energy.gov/energysaver/articles/heat-pump-systems

U.S. Environmental Protection Agency (EPA) information about electric storage capabilities of water heaters. Accessed here: http://www.energystar.gov/products/certified-products/detail/high-efficiency-electric-storage-water-heaters

U.S. Environmental Protection Agency (EPA) information about heat pump technologies. Accessed here: https://www.energystar.gov/products/certified-products/detail/heat-pumps-air-source