Clean O2 Technology Focused Pilot Market Study

Project Number ET23SWG0020

GAS EMERGING TECHOLOGIES PROGRAM (GET)

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Acknowledgements

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Disclaimer

Abbreviations and Acronyms

Abbreviation and Acronym	Term
CCU	Carbon Capture Unit
CO_2	Carbon Dioxide
DAAS	Decarbonization as a Service
EE	Energy Efficiency
LCA	Life Cycle Analysis
MCCU	Micro-Scale Carbon Capture Unit
PM	Program Manager
ROI	Return on Investment

Executive Summary

The Gas Emerging Technologies (GET) Program conducted a market study to investigate waste heat recovery technologies that include carbon capture solutions, which ultimately reduce building heating and hot water energy needs.

The first step of this market study was to conduct a literature review. The literature search found that the Clean O2 CarbinX™ unit exists as the only unit that can capture CO_2 from the customer side equipment while saving natural gas. The unit requires a supply of potassium hydroxide which reacts with carbon dioxide to create potassium carbonate. Life cycle analysis on the CarbinX™ unit shows that the unit decreases the building overall net emissions by 21–27%. Studies have found that a CarbinX™ unit offers a 5- to 6-year payback period through energy savings and rebates from the sale of the potassium carbonate product.

A series of surveys were developed for this market study to identify potential opportunities for the CarbinX™ unit that do not currently exist, including opportunities for utilizing the potassium carbonate product. Surveys were developed for SoCalGas EE program managers to understand the feasibility of including this technology in the measure portfolio. A total of 3,317 surveys were also sent to SoCalGas customers to better understand drivers and barriers at the customer level when it comes to implementing a new technology such as CarbinX™.

The study found that Clean O2 has faced challenges marketing their technology to trade groups, EE programs, and customers due to the novel technology that is relatively unknown to the average customer. The study found that Clean O2 is interested in expanding their customer base to include single detached homes, light industrial, and heavy commercial industries. The company has also expressed interest in the agriculture sector and is interested in leveraging the potassium carbonate to develop fertilizers.

SoCalGas PMs who were surveyed, expressed interest in the CarbinX™ technology. PM's expressed the need for further demonstration studies at various locations and industries to evaluate the units energy efficiency and gas savings prior to offering this technology as a measure for an EE program.

A total of 53 customers chose to participate in the voluntary survey, which provided information on customer behaviors towards the CarbinX™ unit, including drivers and barriers. Cost and lack of awareness of the technology was cited as a major barrier for most customers. Nearly half (43%) of customers expressed interest in reducing their buildings natural gas usage and 45% would participate in an EE program that offered such savings

from the unit. The study found that laundry facilities, schools, and other nonresidential buildings were the most interested in the technology.

The market study recommended a roadmap with a 5-year timeline for the California IOU's who seek to include the CarbinX™ technology in their EE Program Portfolio as a potential measure offering.

Introduction

Space heating and water heating is a significant driver contributor to global energy demand in both residential and commercial buildings. In 2022, roughly half of building energy demand was used for heating purposes, which resulted in 2,400 megatons of CO_2 emissions and 1,700 megatons of indirect CO_2 emissions [1]. Natural gas accounts for over 60% of the heating mix in the United States, 60.3% in California, and 42% for space and water heating globally [1]. There is a growing need for efficient and low-carbon technologies. This need is growing to address climate change and reduce greenhouse gas emissions.

In the past, carbon capture technologies have been developed to offer industrial scale solutions. CarbinX™ is an innovative carbon capture technology that differentiates itself from traditional large-scale industrial applications by combining waste heat recovery to permanently sequester carbon and transform it into a useful product, such as soaps and detergents. Technologies such as waste heat recovery, which can offer high-efficiency heating solutions combined with low-carbon improvements, can help decarbonize residential buildings and commercial industries to help meet California's statewide carbon neutrality goals.

Assessment Objectives

The main objectives of this market study are to conduct a literature review on waste heat recovery technologies with a carbon capture element, followed by a series of surveys to identify potential opportunities for the technology including ways to utilize the potassium carbonate product. Another objective was to identify potential energy efficiency programs that could include this technology in their measure portfolio. The last objective was to identify potential customers that would benefit from this technology.

Literature Review

A literature review was conducted to gather information on heat recovery technologies that can capture CO2 from the customer side equipment while saving natural gas. Technologies like the Clean O2 CarbinX™ technology will be researched. Additional research on carbon capture credits and potential opportunities for the Clean O2 sequestered potassium carbonate product was also explored.

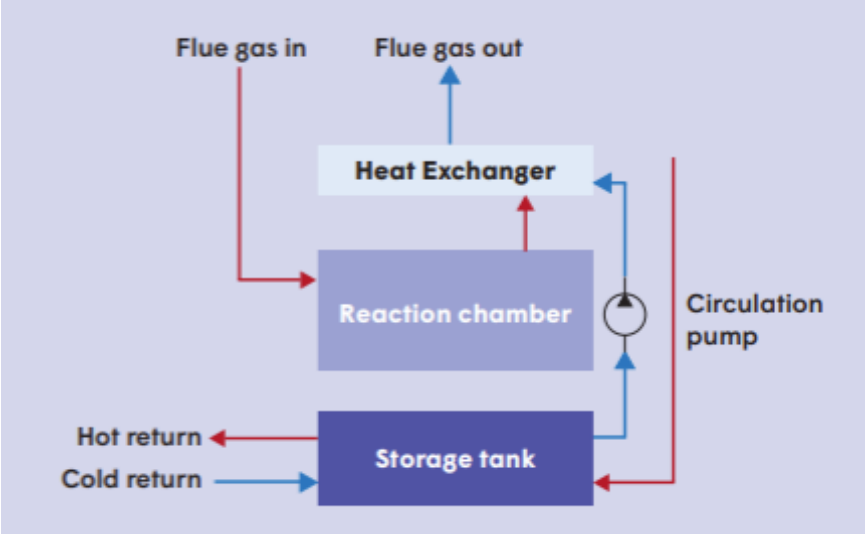
Technology Overview

The CarbinX™ unit, shown in Figure 1, is defined as a micro-scale carbon capture unit (MCCU). The unit operates by diverting a portion of waste carbon emissions from natural gas heating appliances flue gas emissions.

Figure 1. CarbinX™ Unit [6]

The CarbinX™ technology takes the waste heat from the flue and combines it with the heat generated from the exothermic carbon capture process to reduce the amount of gas needed for the building's energy use. The CarbinX™ unit, which is charged with potassium hydroxide (KOH), reacts with carbon dioxide to create potassium carbonate (K_2CO_3) that is permanently sequestered. Potassium carbonate, also known as Pearl Ash, is a valuable product that can be sold to multiple industries for use and serves as an ongoing revenue stream [6]. Figure 2 provides a flowchart of the waste heat recovery process.

Figure 2. CarbinX™ heat recovery process [6]



Life Cycle Analysis

An independent Life Cycle Analysis (LCA) was conducted by Brightspot Climate on the CarbinX ™ unit [4]. The study analyzed the impact of adding a CarbinX™ v4.0 system to a preexisting natural gas boiler in Calgary, Canada. The LCA compared the emissions from a baseline scenario consisting of the natural gas boiler to a project scenario that captures all of the processes related to the Potassium carbonate product, the production of the CarbinX™ unit, and the CarbinX™ including transportation, construction, energy use, and decommissioning. The study assesses the impact of the CarbinX™ unit's carbon footprint using a cradle-to-grave approach over its 20-year lifespan.

For the baseline natural gas-fired boiler, the average boiler in Calgary building, depending on the size, produces 436 to 1,675 GJ of heat depending on the size and application. The carbon dioxide emissions between the baseline scenario and the project scenario with the CarbinX™ unit are summarized below in Table 1 [4].

Table 1. LCA Project Scenario and Baseline Comparison [4]

CO_2 Emissions	Baseline Scenario (Kg)	Project Scenario (Kg)	Difference Between Scenarios (Kg)
Kg of CO_2e/kg K_2CO_3 produced	10.44 ± 2.51	5.95 ± 2.51	4.49 ± 3.55
Kg of CO_2e/ GJ heat produced	172.79 ± 23.04	74.93 ± 11.40	97.86 ± 25.71

The LCA also concluded that the electricity consumption of the CarbinX™ unit minimally impacts the emissions associated with its construction, use, and decommissioning. Depending on the boiler size, the LCA concluded that the project scenario emits 30-73% less CO_2 than the baseline.

The LCA calculated emissions based on various boiler heat-exchanger efficiencies of 79% and 65%, which is based on in-situ measurements on an operational CarbinX™ unit. Lowering efficiencies of the heat exchanger resulted in a greater amount of natural gas and carbon emissions which are summarized below in Table 2.

Table 2. LCA Sensitivity Analysis results of the CarbinX™ on boiler heat exchanger efficiencies [5]

	Boiler Heat Exchanger Efficiency	
Parameter	79%	65%
Heat Recovery	266 GJ/year	219 GJ/year
Natural Gas Volume Used	323-2,173 GJ/year	393-2,243 GJ/year
GHG emissions	5.95 ± 2.51 kg CO_2e/kg K_2CO_3 (average)	6.31 ± 2.52 kg CO_2e/kg K_2CO_3 (average)

The LCA also addresses the potential release CO_2 in the potassium carbonate product in an alternate project scenario in which the potassium carbonate thermally decomposes into potassium oxide and CO_2 as opposed to being mineralized and permanently stored. This thermal decomposition would occur when the potassium carbonate product is used in high temperature processes like glass making. The LCA found that this process would increase the carbon intensity of the CarbinX™ unit by 5% on average.

A separate LCA was conducted by the University of British Columbia (UBC). The UBC LCA assessment accounted for a 20-year lifetime GHG emissions including material extraction, manufacturing, and lifetime operations of the CarbinX™ unit. This LCA was conducted based on a CarbinX™ system in operation at a 30,000 sq-ft building in Calgary. The study found that the unit decreases the building overall net emissions by 21 –27% [5]. The LCA breaks down the carbon emissions further in Table 3.

Table 3. LCA CO_2 Analysis of CarbinX™ Unit [5]

Source of CO_2	Δ CO_2 (kg/year)	Increase or Decrease in CO_2 emissions
Annual natural gas consumption	2,905	decrease
Electricity consumed by device	185	increase
Production of Potassium Hydroxide	5,516	increase
Production of Potassium Carbonate	8,403	decrease
Transportation of Chemicals	155	increase
Manufacture of the CarbinX™ Unit	52	increase
NET Annual Change in CO_2	5,400	decrease

Prior Carbin X Installations

The CarbinX™ unit has been installed in markets across Canada and the U.S. Some of its installations include partnering with CenterPoint Energy, Enbridge Gas, ATCO, and Fortis BC.

RDH Buildings conducted a carbon capture pilot project using a total of four CarbinX™ units across various installation sites. The project captured the units carbon sequestration reduction measurements in addition to the heat recovery energy savings. Tables 4 and 5 summarize the carbon sequestered by the CarbinX™ unit as well as the heat recovery efficiencies from each unit [7].

Table 4. Carbon Sequestered by CarbinX™ [7]

Carbon Sequestration Summary				
Site	Gas Equipment	Avg. Inlet CO_2 (%)	Avg. Outlet CO_2 (%)	Average Carbon Reduction/Sequestration
1	Soap Storage Room	0.37	0.32	14% reduction
2	Domestic Hot Water System	0.43	0.29	33% reduction
3	Space Heating System	0.05	0.08	No measurable change
4	Domestic Hot Water System	0.70	0.50	31% reduction

Table 5. Heat Recovery Efficiencies from each CarbinX™ unit. [7]

Heat Recovery Summary			
Site	**Off-Gas Equipment**	**Daily Average Heat Recovery**	**Anticipated Annual Energy Savings**
1	Soap Storage Room	12 MJ (3 kWh)	4.3 GJ (1,200 kWh)
2	Domestic Hot Water System	26 MJ (7.2 kWh)	9.4 GJ (2,600 kWh)
3	Space Heating System	No measurable recovery	No measurable recovery
4	Domestic Hot Water System	18 MJ (5kWh)	6.6 GJ (1,850 kWh)

The results from this pilot also provided several recommendations for future installations. The project team has recommended pre-approval for CarbinX™ units from local technical and safety personnel to comply with regional standards. The project also found that not all sites are ideal for the CarbinX™ unit even after a system reconfiguration. For example, sites with minimal boiler runtime are not ideal for the unit, resulting in minimal carbon reduction and heat recovery as shown in Site #3 in Tables 4 and 5. According to Clean O2, the CarbinX™ unit works best with boiler inputs between 200,000 BTU/hr and 1,500,000 BTU/hr. Ultimately, the CarbinX™ unit was able to lower the appliances CO_2 emissions because the outlet CO_2 concentration was lower than the inlet CO_2 concentration. The pilot study also found that the heat recovery was measurable for instances where the runtime of the boiler and the CarbinX™ unit was applicable. The study recommends measuring the energy required for operating the CarbinX™ unit and the total energy used by the boiler to have a clearer picture of the energy savings of the unit.

Cost and Raw Materials for the CarbinX™ Unit

The CarbinX™ unit requires KOH as a raw material and consumes roughly 12,264 kg annually while producing 15,085 kg of potassium carbonate. Transportation services are needed to refill the unit with KOH and collect the product.

The unit is also composed of primarily steel and weighs 480 kg or 1,058 lbs and roughly 52 units are produced every year. The energy and natural gas required to construct and decommission each of the 52 units is 930 kWh and 190 GJ over the unit's lifespan or 0.89 kWh and 0.18 GJ per year.

The CarbinX™ unit offers a 5-6 year payback period through energy savings and rebates from the sale of the potassium carbonate product.

Additional Waste Heat Recovery Technologies

This literature review made the effort to identify similar waste heat recovery technologies that can save natural gas and capture carbon from the customer's side. Modern Hydrogen offers a solution that removes carbon from natural gas technologies at the point of use, while generating clean hydrogen. Modern Hydrogen uses a concurrent combustion and pyrolysis process that separates methane (CH_4) into carbon and hydrogen. The purpose of this technology is to decarbonize natural gas and offer on-site generation of hydrogen while sequestering carbon, however the process is not meant for heat recovery since it uses more energy than it produces. Since hydrogen generation is not within the scope of the GET program, the findings of the literature review conclude that the Clean O2 CarbinX™ unit is the only unique technology that can offer this solution for customer end-use gas equipment.

Opportunities for Potassium Carbonate Product

Potassium Carbonate has many uses in the manufacturing of multiple products. The compound is typically produced commercially by reacting potassium hydroxide with carbon dioxide, followed by crystallization, and if desired, dehydration to obtain anhydrous potassium carbonate. The market opportunity for potassium carbonate is huge, and the U.S. potassium carbonate market is expected to reach a market value of $500 million by 2023 [3]. European companies such as Vynova which supply potassium carbonate in a liquid supply, have recently launched a variety of low-carbon potassium (K) derivatives to meet sustainability needs across various industries [3]. The low carbon potassium carbonate product created from the CarbinX™ units could potentially supply this product to the North American marketplace.

Potassium carbonate is commonly used to produce cleaning products and has experienced popularity in the food industry as a flavor enhancer. Another industry that uses potassium carbonate in abundance is the glass manufacturing industry. The compound is used to make super strong glass used in smart phone screens and airplane windows [2]. Potassium carbonate is also used for making special glass such as potash glass, borosilicate glass, and optical glass for telescopes and microscopes [2]. However, as previously noted, potassium carbonate will release CO_2 in high temperature processes such as glass manufacturing.

Common end uses for potassium carbonate are listed below:

- Soaps, Detergents & Cleaning Products
- Agrochemicals
- Food & Beverage Processing
- Personal Care Products

- Glass
- Paper
- Dyes & Inks
- Fire Suppression Products
- Water Treatment

Carbon Capture Credits

The Section 45Q Tax Credit for Carbon Sequestration is computed per metric ton of qualified carbon oxide captured and sequestered. To claim a tax credit, the carbon oxide emissions must be measured at the point of capture as well as at the point of disposal, injection, or other use. The Inflation Reduction Act (IRA) of 2022 has recently modified and extended Section 45Q to allow a larger credit for qualified facilities or carbon capture equipment that meet certain wage and apprenticeship requirements. The IRA has also extended eligibility to claim credit to certain nonprofits and entities without ownership interests. However, this market study found that tax credits or incentives for MCCU's do not yet exist. Figure 3.0 summarizes the equipment eligibility.

Figure 3. Section 45Q Tax Credit [8]

Equipment Placed in Service after 2/8/2018 and before 1/1/2023	Equipment Placed in Service after 12/31/2022 and Construction Beginning Prior to 1/1/2033
Credit Amount (per Metric Ton of CO_2)	
Geologically Sequestered CO_2	
$40.89 per Metric Ton of CO_2 in 2023. Increasing ratably to $50 by 2026, then inflation-adjusted.	Base credit of $17 per Metric Ton of CO_2 ($36 for DAC), increased to $85 ($180 for DAC) for facilities that pay prevailing wages during the construction phase and during the first 12 years of operation and meet registered apprenticeship requirements. Amounts adjusted for inflation after 2026.
Geologically Sequestered CO_2 with EOR	
$27.61 in 2023. Increasing ratably to $35 by 2026, then inflation-adjusted.	Base credit of $12 ($26 for DAC), increased to $60 ($130) for facilities that pay prevailing wages during the construction phase and during the first 12 years of operation and meet registered apprenticeship requirements. Amounts adjusted for inflation after 2026.
Other Qualified Use of CO_2	
$27.61in 2023. Increasing ratably to $35 by 2026, then inflation-adjusted.	Base credit of $12 ($26 for DAC), increased to $60 ($130) for facilities that pay prevailing wages during the construction phase and during the first 12 years of operation and meet registered apprenticeship requirements. Amounts adjusted for inflation after 2026.
Claim Period	
12-year period once facility is placed in service.	12-year period once facility is placed in service, reduced to 5-year period if transferred.
Annual Capture Requirements	
Power plants: Capture at least 500,000 metric tons. *Facilities that emit no more than 500,000 metric tons per year:* Capture at least 25,000 metric tons. *DAC and other capture facilities:* Capture at least 100,000 metric tons.	*Power plants:* Capture at least 18,750 metric tons and a capture design capacity not less than 75% of baseline emissions. *DAC facilities:* capture at least 1,000 metric tons. *Other capture facilities:* capture at least 12,500 metric tons.
Eligibility to Claim Credit	
Entity who owns the capture equipment and physically or contractually ensures the disposal, utilization, or use as a tertiary injectant of the CO_2.	Entity who owns the capture equipment and physically or contractually ensures the disposal, utilization, or use as a tertiary injectant of the CO_2. Certain tax-exempt entities can claim the tax credit through "direct pay" and other entities are allowed a one-time transfer to another entity.

Source: CRS analysis of IRC Section 45Q, 26 U.S.C. §45Q.

Notes: After 2017, the credit can be claimed for all carbon oxides, not just CO_2. Equipment placed in service prior to February 8, 2018, is no longer eligible for the 45Q tax credit.

Survey Tools

Three separate survey tools were developed to target potential customers, Clean O2 executives, and EE program managers. Survey Tool #1 can be found in Appendix 1.0. This survey consisted of a series of questions that was used to gather information on barriers and opportunities on the CarbinX™ unit from Clean O2's perspective. The survey also had questions designed to gather input on market ideas, identify lessons learned from previous installations, and potential opportunities for the selling and utilization of the potassium carbonate product.

Similarly, Survey Tool #2 was designed to identify EE programs in California that can offer this technology as a measure. The questions were posed to EE program managers in an interview format. A brief description of the CarbinX™ unit was provided to the two EE

program managers who were interviewed for this study. The tool can be found in Appendix 2.0.

The final survey tool was developed to ask potential customers questions on drivers and barriers as it pertains to installing a CarbinX™ unit. Clean O2 provided feedback on this survey tool, and their suggestions were incorporated into the survey. The survey was sent out to potential customers via email using Microsoft Forms, and customers were offered a $50 Amazon Gift Card incentive for completing the survey. The survey questions can be found in Appendix 3.0.

Survey Results

This section summarizes the results of all of the surveys for the three targeted groups: Clean O2, Program Managers, and SoCalGas customers. Data was collected through virtual meetings, emails, and Microsoft forms.

Clean O2 Interview Summary

A Clean O2 executive was interviewed to gather information on opportunities and barriers to the CarbinX™ technology from the company's perspective. The main goal of this interview was to understand where the company sees itself in the future and gather input on market ideas and potential lessons learned from previous installations.

Clean O2 had expressed market opportunities for the CarbinX™ unit such as single detached homes, heavy commercial and light industrial applications for industries bigger than a hotel. The goal for the company in the future is to eventually move away from being an optional auxiliary device to becoming a primary device and manufacturing items such as boilers and furnaces with the imbedded carbon capture technology. Clean O2 hopes to remain a necessary component in the heating industry in the future. They also hope to move from being an optional add on device to a mandatory device for natural gas heating appliances.

Several key lessons that the company has learned from prior CarbinX™ installations include how to technically solve the issue of moisture build up in the reaction chamber. Since the CarbinX™ unit is the first time a carbon capture device is using anhydrous hydroxide, they have had to overcome the moisture build up hurdle that other carbon capture devices don't typically encounter since other CCU technologies don't use anhydrous hydroxide, but rather liquid solutions to capture CO_2. When using a hydrate, the water contributes to the final volume and concentration, but by contrast an anhydrous compound needs additional water to achieve the desired concentration that takes place within the chemical reaction of the unit. The company has solved this issue using proprietary technology and has also learned how to optimize flue gas handling over the years. From a business perspective, they

have realized there is somewhat of a sensitivity towards capital expenditure versus operating expenditures since larger organizations are more flexible towards operational expenditures, whereas smaller often franchised businesses are more sensitive to capital expenditure. To decrease the expense, Clean O2 hopes to move into the direction of offering Decarbonization as a Service (DAAS), where the CarbinX™ unit is offered as an operating expense where the unit is provided at low to zero cost, but there is an ongoing fee that the customer is charged.

Clean O2 believes that DAAS will be helpful in overcoming installation and logistical challenges to ensure widescale adoption in the future. As the company moves to version 4.0 of the unit, they anticipate a curbside service for the potassium hydroxide cartridges will help with the biweekly replacement by simplifying the collection of the product and replacing the cartridge with potassium hydroxide. Another logistical challenge that Clean O2 faces is that they are limited to operating within major urban centers since that is where their service providers are located, so a CarbinX™ installation in a remote area isn't always feasible.

When asked about other opportunities for the potassium carbonate product, Clean O2 hopes to focus more on the agriculture sector and is interested in leveraging the potassium carbonate to develop fertilizers. Other opportunities noted include textiles, pharmaceuticals, food preparation, and production of rubber materials.

Clean O2 also faces challenges in marketing the CarbinX™ unit to potential customers and energy efficiency (EE) programs. From their perspective, the industry is slow to adopt, especially with a technology that is completely different from what has been used in the past. The hardest part is changing the mindset of customers and trade people. Educating trade groups on the technology and encouraging them to support its deployment and maintenance has been challenging.

Finally, Clean O2 has a list of screening criteria that can be provided to California Programs to establish "good" and "bad" sites for install. The CarbinX™ unit is compatible with UL category 1, 2, and 3 vented natural-gas heating appliances and works best with boiler inputs between 200,000 BTU/hr and 1,500,000 BTU/hr. The footprint of a CarbinX™ unit is roughly 30" x 78" x 74" and would need a building or mechanical room that could provide access to an appliance of that size and could still be connected to the boiler flue.

SoCalGas Program Manager Interviews

Individuals from both the SCG Multifamily and Business Programs for Energy Efficiency Rebates were interviewed to learn more about how feasible it is for these programs to offer the CarbinXTM unit as a measure. The PMs had limited answers to some of our survey

questions but were able to answer some a few questions regarding program implementation.

When determining what measure to implement into a program, they evaluate both the cost effectiveness and incentive level pricing for the program to consider it. One of the PMs noted that since CarbinX™ is being handled through the statewide emerging technologies program, it is possible for SCG to find a place for the CarbinX™ unit offering in either their research side or equity side.

Given that the current plan is to evaluate the CarbinX™ unit in a hospitality setting, the multifamily PM has called for further tests to be conducted at a multifamily site in order to bring this technology into multifamily programs. The programs would also need to see a measure package (aka workpaper) developed to offer this technology at a downstream level.

When asked about if any EE program would be able to able to claim credit for carbon capture savings associated with the CarbinX™ unit, the PMs were not sure if carbon capture credits could be claimed through the program. They stated they can only incentivize on the energy efficiency component of the technology.

Ultimately, both PMs agreed that there needs to be a unit installed and tested in each sector in order to offer the CarbinX™ unit at the program level.

SoCalGas Customer Survey Findings

Customers across multifamily and commercial businesses that have boiler heating needs were identified. Based on this list, a survey was sent out to potential customers who may potentially benefit from a CarbinX™ unit. A $50 gift card incentive was offered to those who participated in this survey. Table 6.0 summarizes the list of customer types for each business facility type, the number of boiler equipment at each facility, and the boiler load.

Table 6. SoCalGas Survey Customer List

Type of Facility	Count of Customers	Sum of Boilers	Sum of Boiler Equipment Load (MBTUH)	Sum of Boiler Equipment Load (Therms)	Potential Energy Savings with CarbinX (Therms)	Potential CO_2 removal (lbs)
Assisted Living Facilities for the Elderly	74	163	86,709	867,090	173,418	2,028,991
Beauty Salons	16	30	16,507	165,070	33,014	386,264
Casino Hotels	2	10	26,929	269,290	53,858	630,139

Type of Facility	Count of Customers	Sum of Boilers	Sum of Boiler Equipment Load (MBTUH)	Sum of Boiler Equipment Load (Therms)	Potential Energy Savings with CarbinX (Therms)	Potential CO_2 removal (lbs)
Coin-Operated Laundries and Drycleaners	380	991	524,598	5,245,980	1,049,196	12,275,593
Colleges, Universities, and Professional Schools	201	370	1,336,434	13,364,340	2,672,868	31,272,556
Consumer Electronics and Appliances Rental	4	5	2,572	25,720	5,144	60,185
Continuing Care Retirement Communities	58	125	81,070	810,700	162,140	1,897,038
Correctional Institutions	11	57	232,300	2,323,000	464,600	5,435,820
Cosmetology and Barber Schools	4	4	3,439	34,390	6,878	80,473
Courts	11	49	74,547	745,470	149,094	1,744,400
Drycleaning and Laundry Services (except Coin-Operated)	314	647	525,555	5,255,550	1,051,110	12,297,987
Elementary and Secondary Schools	540	934	888,472	8,884,720	1,776,944	20,790,245
Fire Protection	22	29	16,171	161,710	32,342	378,401
General Medical and Surgical Hospitals	164	316	1,363,139	13,631,390	2,726,278	31,897,453
Hotels (except Casino Hotels) and Motels	541	1,238	834410	8,344,100	1,668,820	19,525,194
Industrial Launderers	12	26	110,130	1,101,300	220,260	2,577,042
Junior Colleges	52	88	123,024	1,230,240	246,048	2,878,762

Type of Facility	Count of Customers	Sum of Boilers	Sum of Boiler Equipment Load (MBTUH)	Sum of Boiler Equipment Load (Therms)	Potential Energy Savings with CarbinX (Therms)	Potential CO_2 removal (lbs)
Lessors of Nonresidential Buildings (except Miniwarehouses)	500	1,091	2,607,427	26,074,270	5,214,854	61,013,792
Lessors of Real Estate	36	62	100,869	1,008,690	201,738	2,360,335
Lessors of Residential Buildings and Dwellings	58	136	76,442	764,420	152,884	1,788,743
Linen Supply	8	16	96,821	968,210	193,642	2,265,611
Nail Salons	10	22	9,867	98,670	19,734	230,888
Nonresidential Property Managers	60	182	738,919	7,389,190	1,477,838	17,290,705
Nursing Care Facilities (Skilled Nursing Facilities)	24	63	30,080	300,800	60,160	703,872
Offices of Real Estate Agents and Brokers	80	151	151,590	1,515,900	303,180	3,547,206
Other Activities Related to Real Estate	41	67	96,874	968,740	193,748	2,266,852
Other Commercial and Industrial Machinery and Equipment Rental and Leasing	3	4	3,950	39,500	7,900	92,430
Other Personal Care Services	10	25	8,758	87,580	17,516	204,937
Other Technical and Trade Schools	3	5	2,329	23,290	4,658	54,499
Parking Lots and Garages		1	440	4,400	880	10,296
Pet Care (except Veterinary) Services	7	11	5,285	52,850	10,570	123,669

Type of Facility	Count of Customers	Sum of Boilers	Sum of Boiler Equipment Load (MBTUH)	Sum of Boiler Equipment Load (Therms)	Potential Energy Savings with CarbinX (Therms)	Potential CO_2 removal (lbs)
Police Protection	24	40	33,027	330,270	66,054	772,832
Psychiatric and Substance Abuse Hospitals	10	20	128,982	1,289,820	257,964	3,018,179
Rooming and Boarding Houses, Dormitories, and Workers' Camps	14	19	21,115	211,150	42,230	494,091
RV (Recreational Vehicle) Parks and Campgrounds	12	20	5,432	54,320	10,864	127,109
Specialty (except Psychiatric and Substance Abuse) Hospitals	6	15	16,014	160,140	32,028	374,728
Traveler Accommodation	5	8	6,396	63,960	12,792	149,666
Grand Total	3,317	7,040	10,386,623	103,866,230	20,773,246	243,046,978

A considerable amount of time was spent reaching out to customers. Surveys were sent out to a total of 3,317 customer emails. The total boiler load from these facilities was 10,386,623 MBTU or 103,866,230 therms. Assuming an average 20%, savings from a CarbinX unit, a total of 20,773,246 therms could be saved if CarbinX units were installed at all eligible facilities. Note that boiler heat exchanger efficiencies and the total load will vary based on application, so this number is a general approximation of the potential savings. Furthermore, a 20,773,256-therm savings correspond to an estimated total of 243,046,978 lb CO_2 captured.

A total of 53 customers chose to participate in the voluntary survey, leading to a 1.5% response rate. Table 7.0 summarizes the types of customers who voluntarily participated in the survey.

Table 7. Types of Survey Participants

Sector	Number of Survey Participants
Coin-Operated Laundries and Drycleaners	22
Lessors of Nonresidential Buildings (except Miniwarehouses)	9
Elementary and Secondary Schools	8
Other	6
Hotels (except Casino Hotels) and Motels	2
Offices of Real Estate Agents and Brokers	2
Colleges, Universities, and Professional Schools	2
Homeless Shelter	1
Continuing Care Retirement Communities	1
Total	53

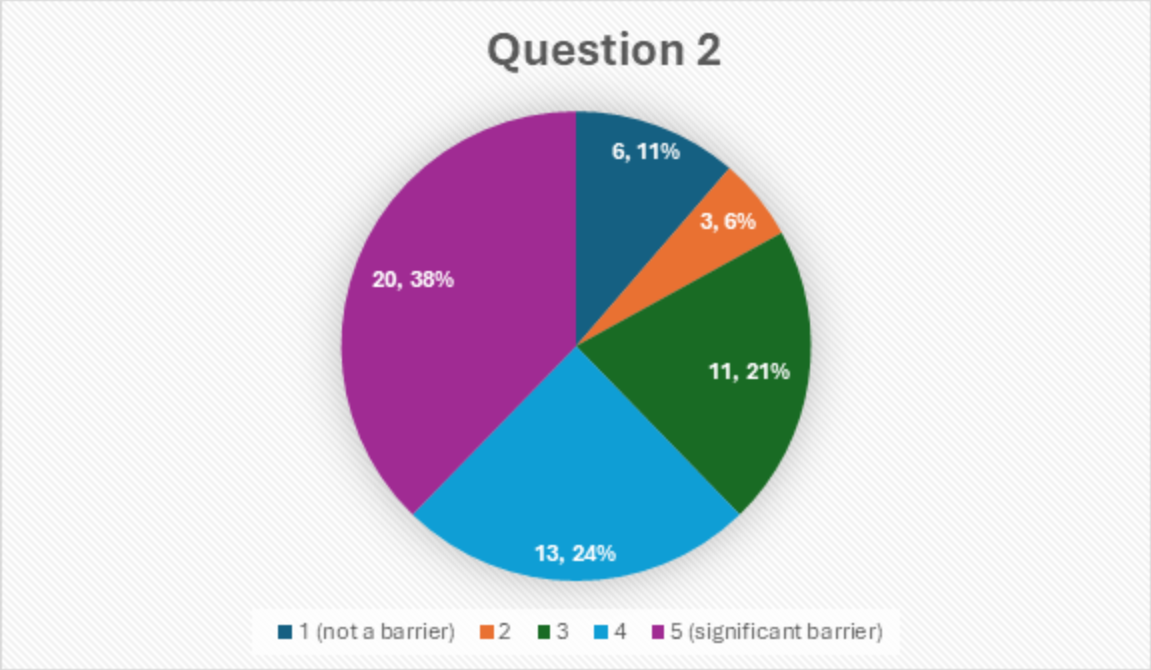
Laundry Facilities, Schools, and other nonresidential buildings have a considerable amount of boiler equipment with larger loads than other facilities. These facilities would be of interest for Clean O2 and potential SCG EE programs to target going forward. Most of the customer responses to the survey came from schools, laundry/dry cleaning facilities, hotels/motels, or business. The key responses for each survey question are summarized and graphed below:

1. Are there any barriers preventing you from installing a CarbinX™ unit at your facility?

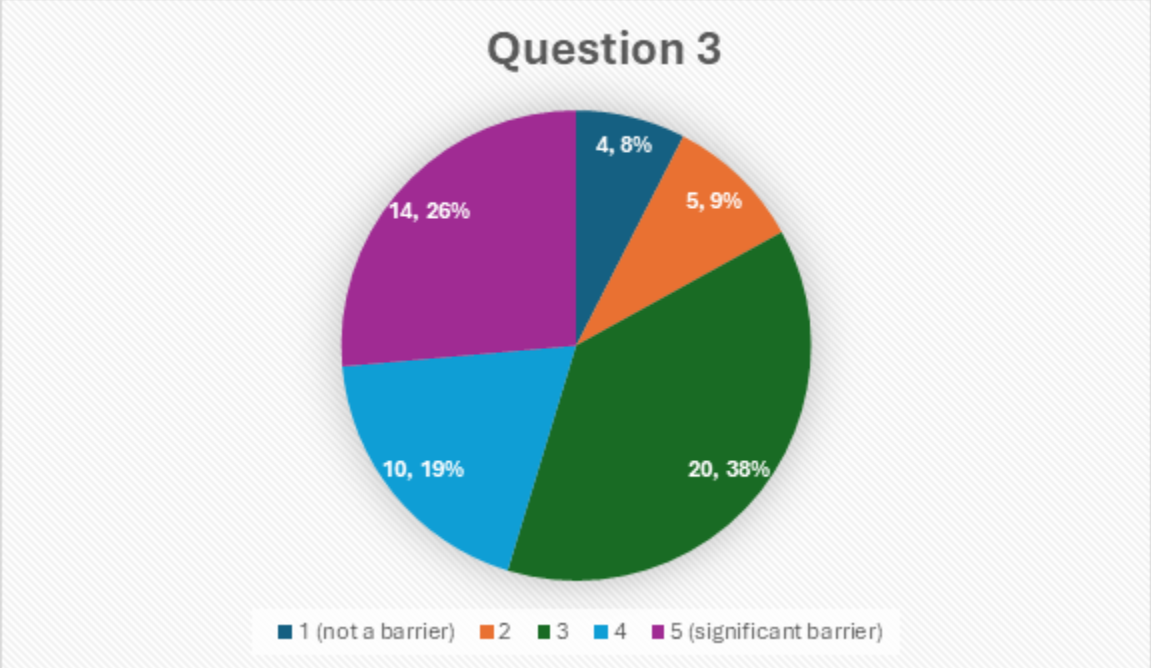
This was an open-ended question, and the key responses include the following:

- 22% of customers answered “cost”
- 30% said no barriers.
- Some stated that the space and size of the unit would be a barrier
- Some claimed that the return on investment was a barrier
- Some have never heard of the product or don’t know anyone
- who has used it. Thus, the lack of awareness.
- Some stated that corporate approval was a barrier.

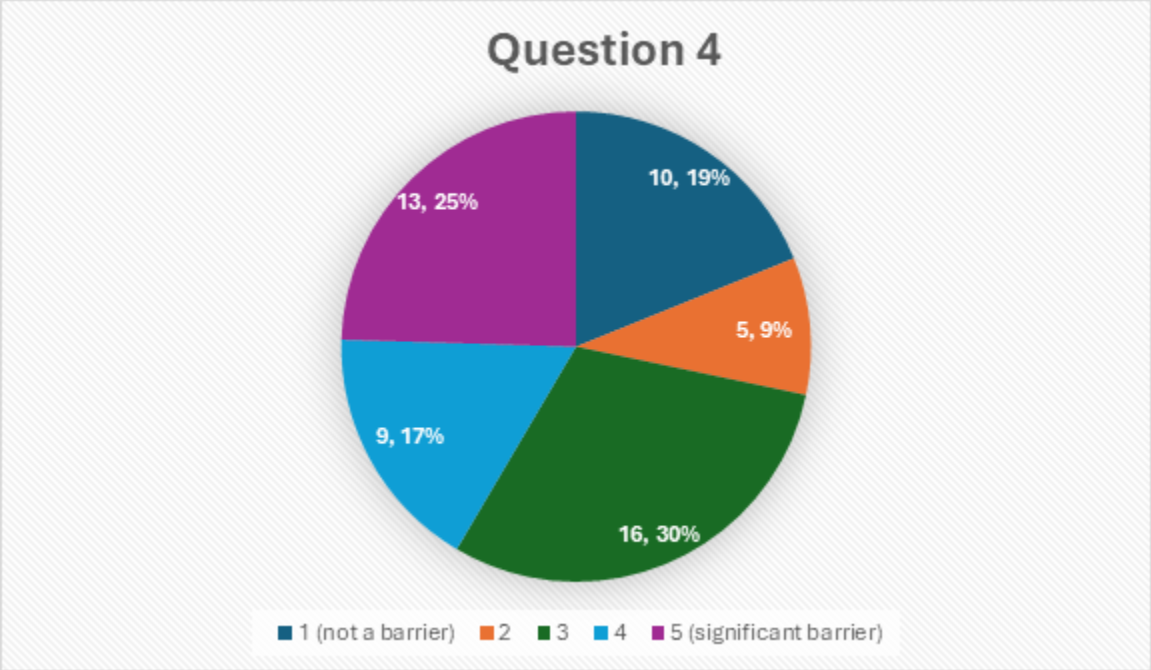
2. On a scale of 1-5, how much of a barrier is the initial investment of the CarbinX™ unit?



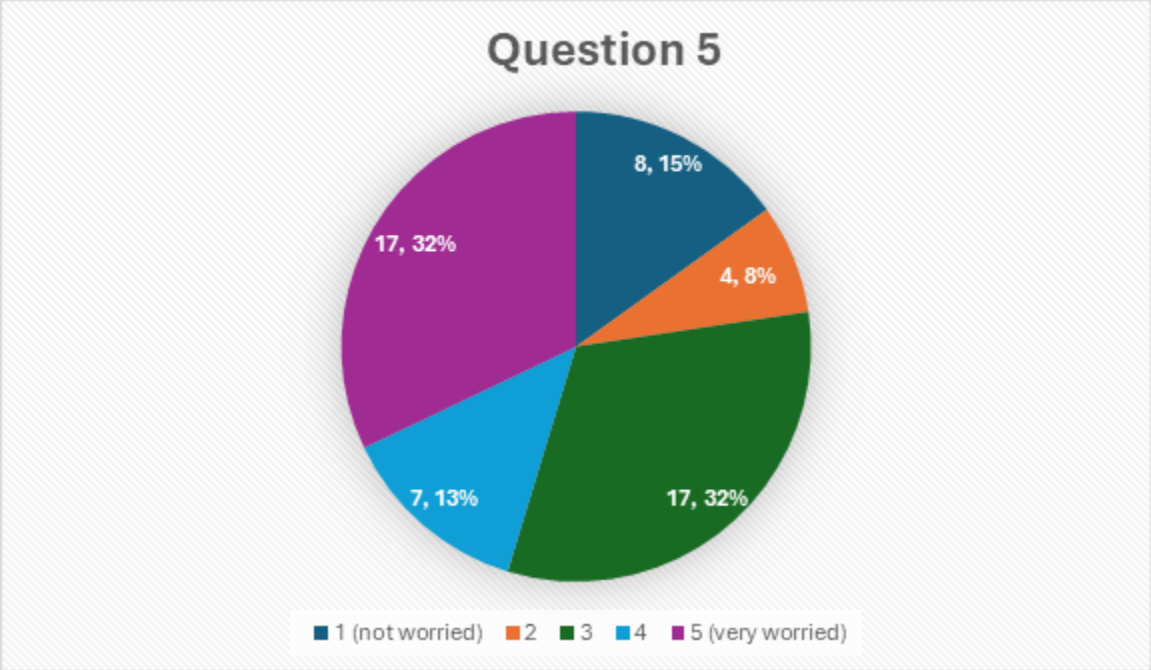
3. On a scale of 1-5, how much of a barrier is the uncertainty of the CarbinX™ unit's performance?



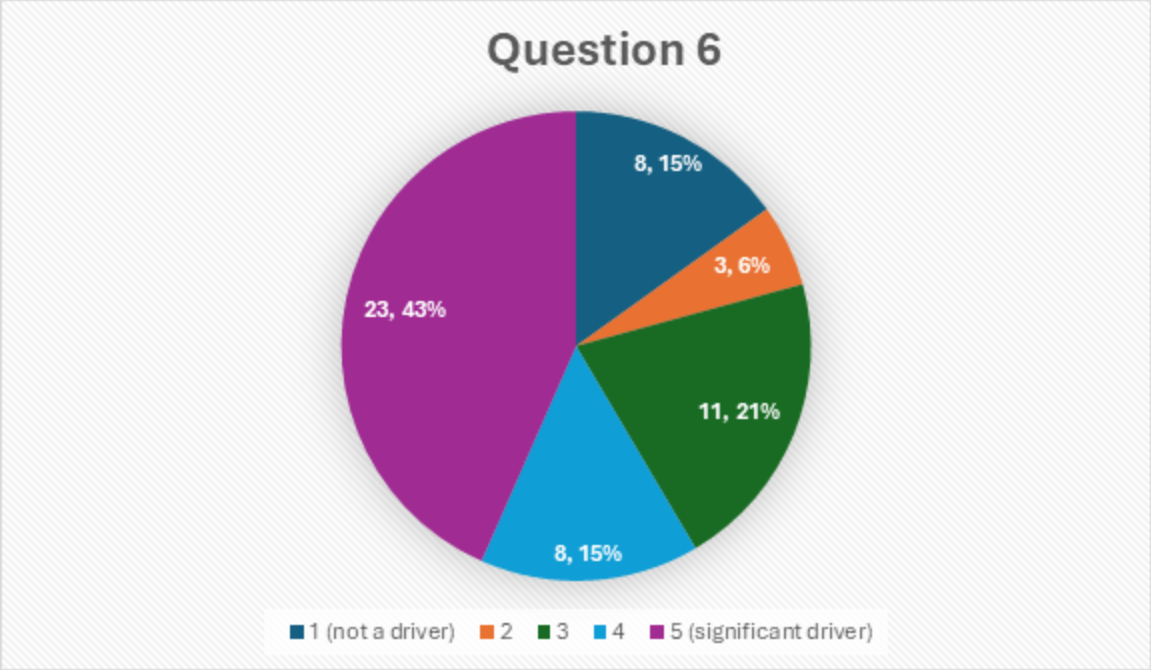
4. How much of a barrier is dealing with maintenance personnel removing the Pearl Ash product?



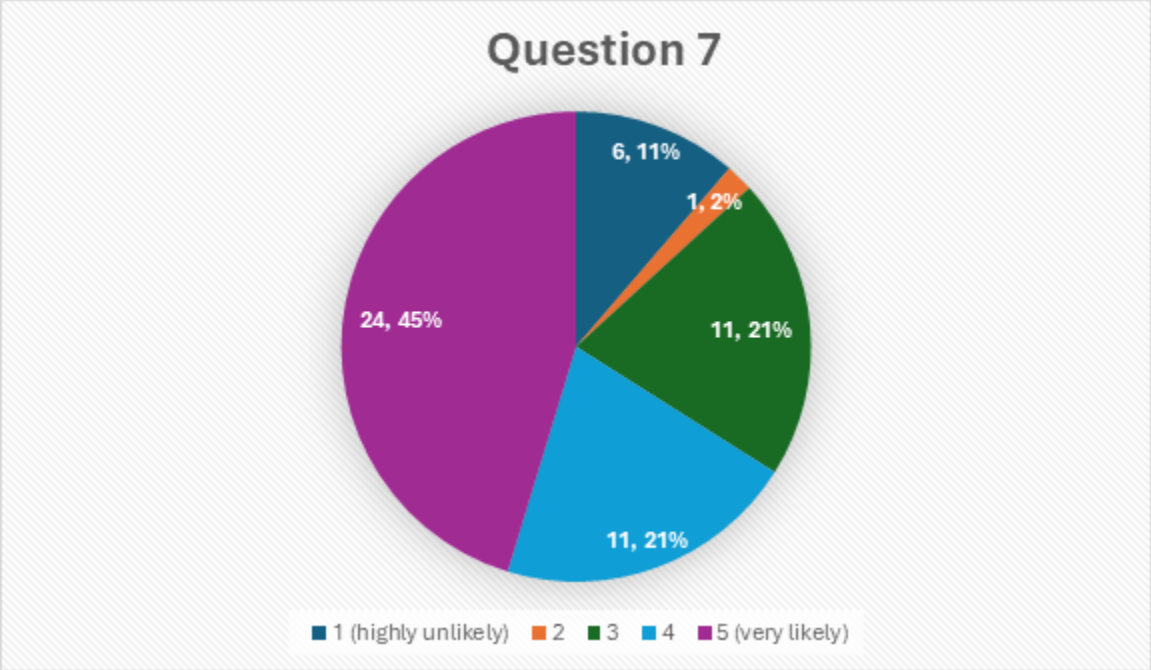
5. On a scale of 1-5, how worried are you about your natural gas bill?



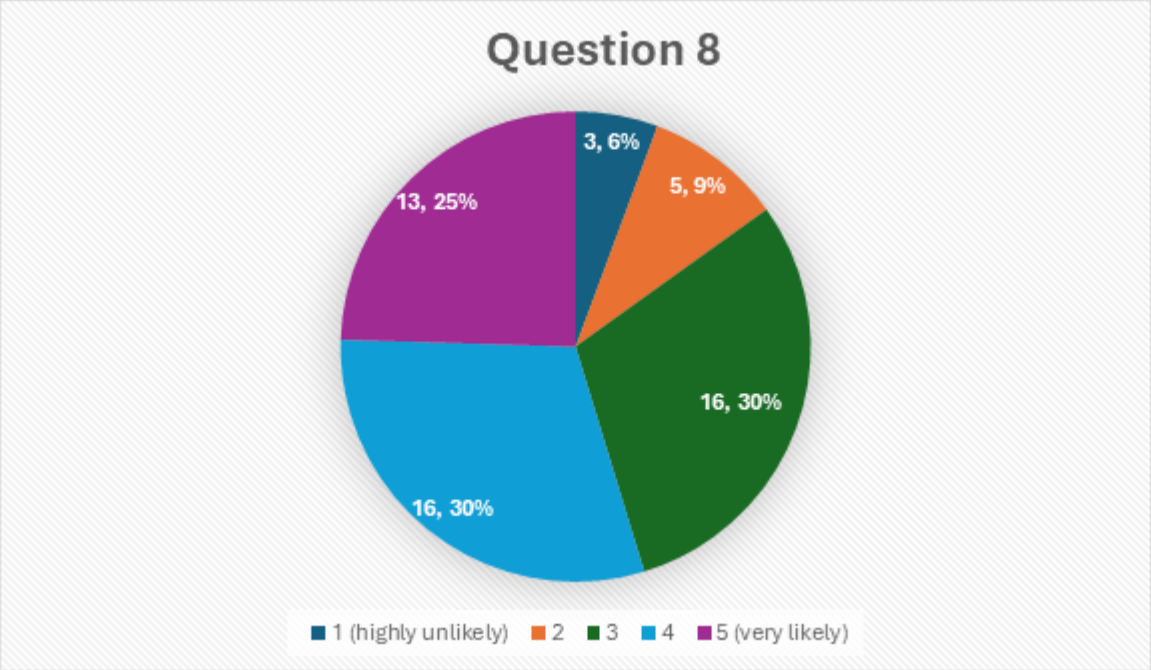
6. On a scale of 1-5, how much of a driver is reducing your natural gas bill?



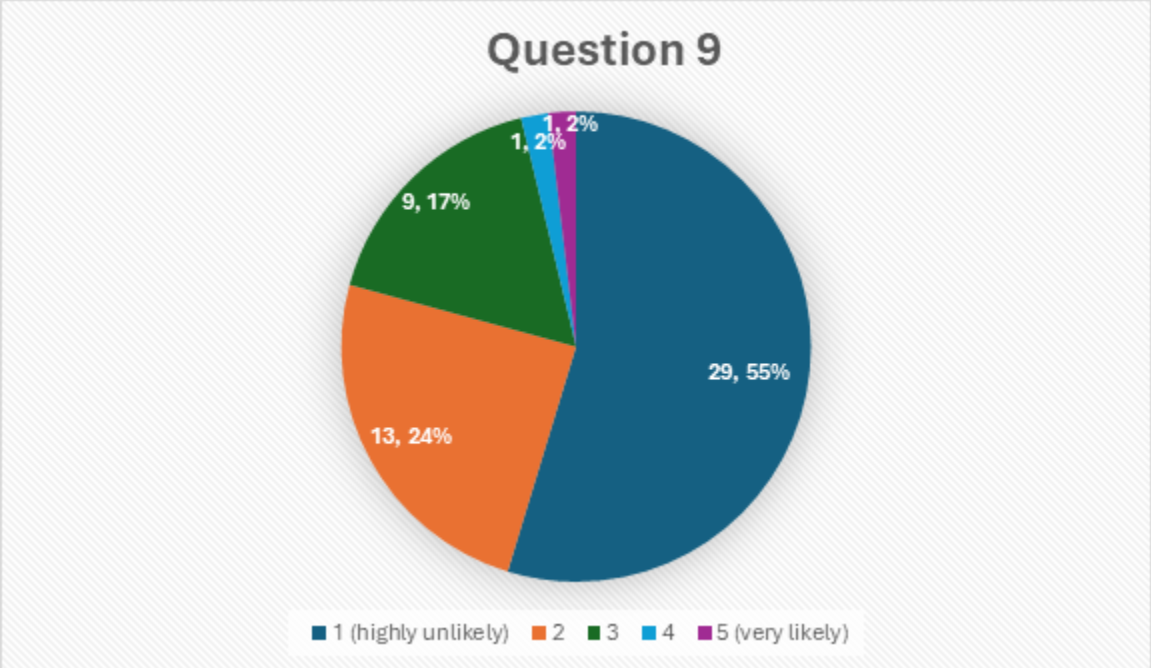
7. On a scale of 1-5, how likely are you to participate in an Energy Efficiency program that could help you lower your gas consumption?



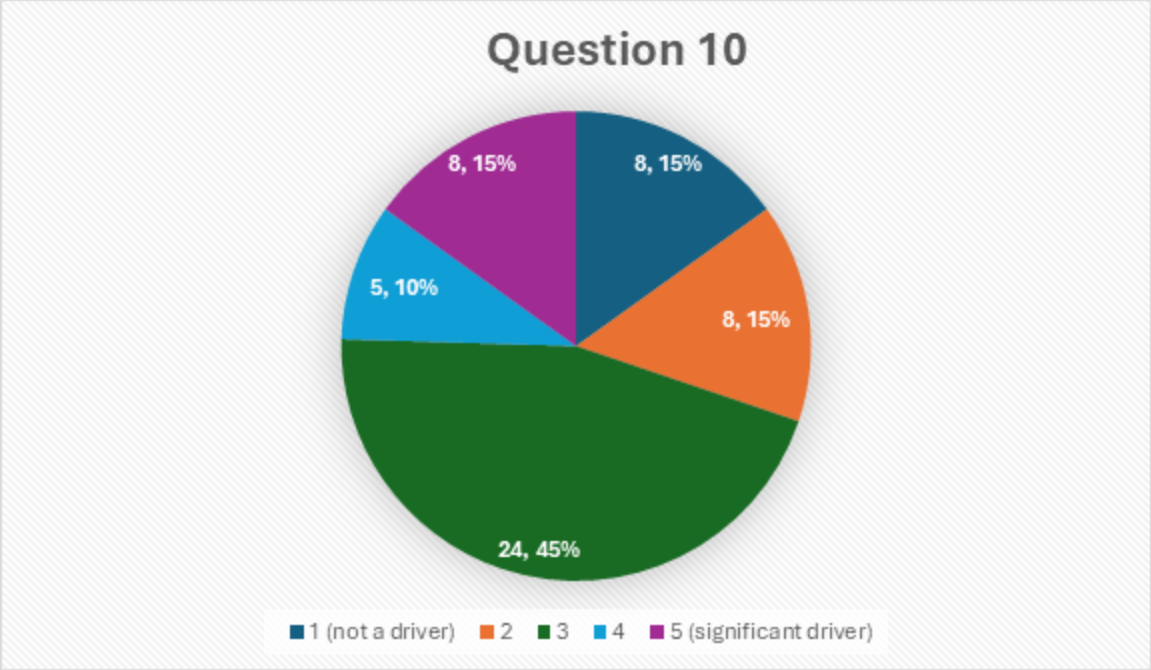
8. On a scale of 1-5, how likely are you to install a CarbinX™ unit if there was some kind of financial incentive (e.g. rebate) attached to it?



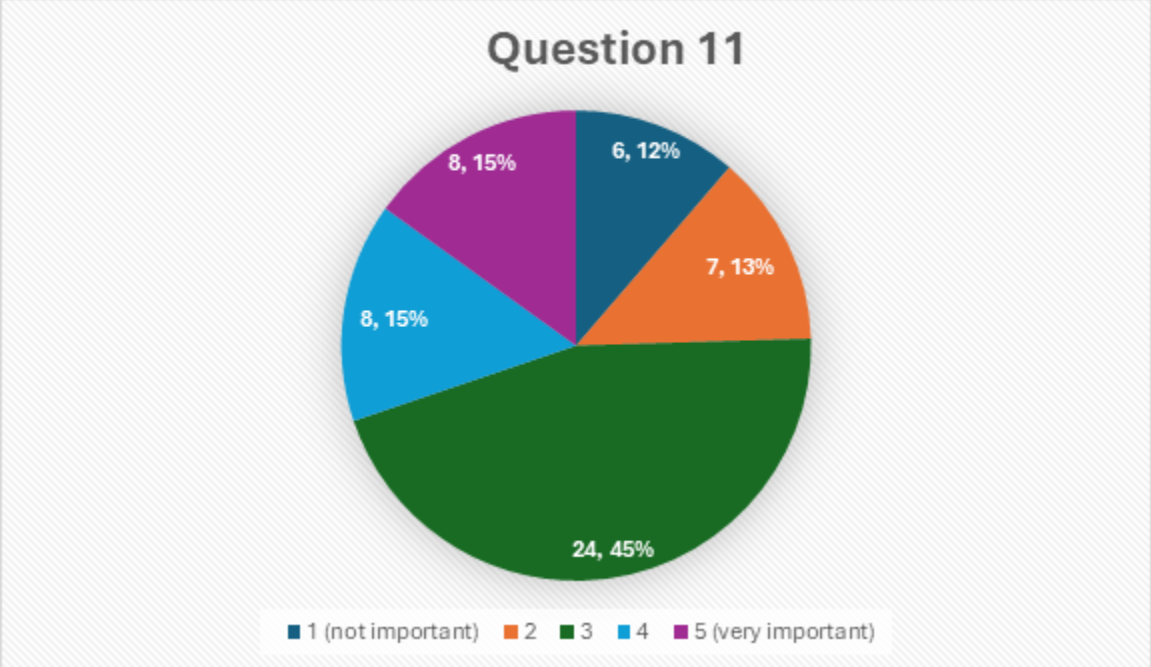
9. On a scale of 1-5, how likely are you to install a CarbinX™ unit without any financial incentive?



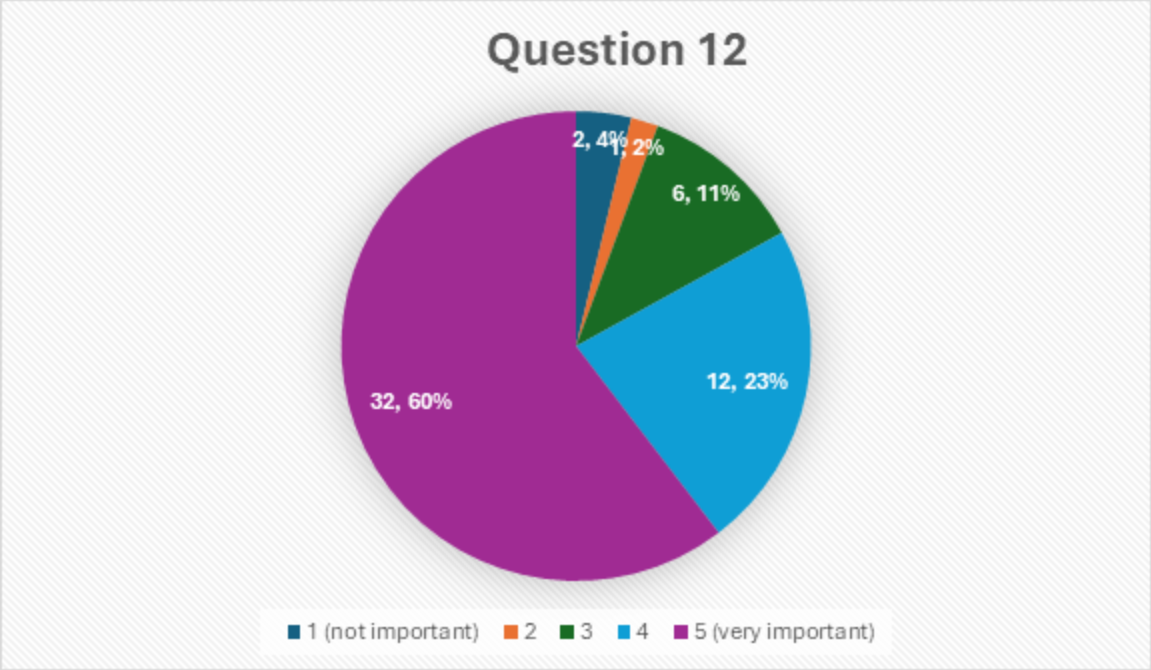
10. On a scale of 1-5, how much of a driver is lowering your buildings carbon footprint?



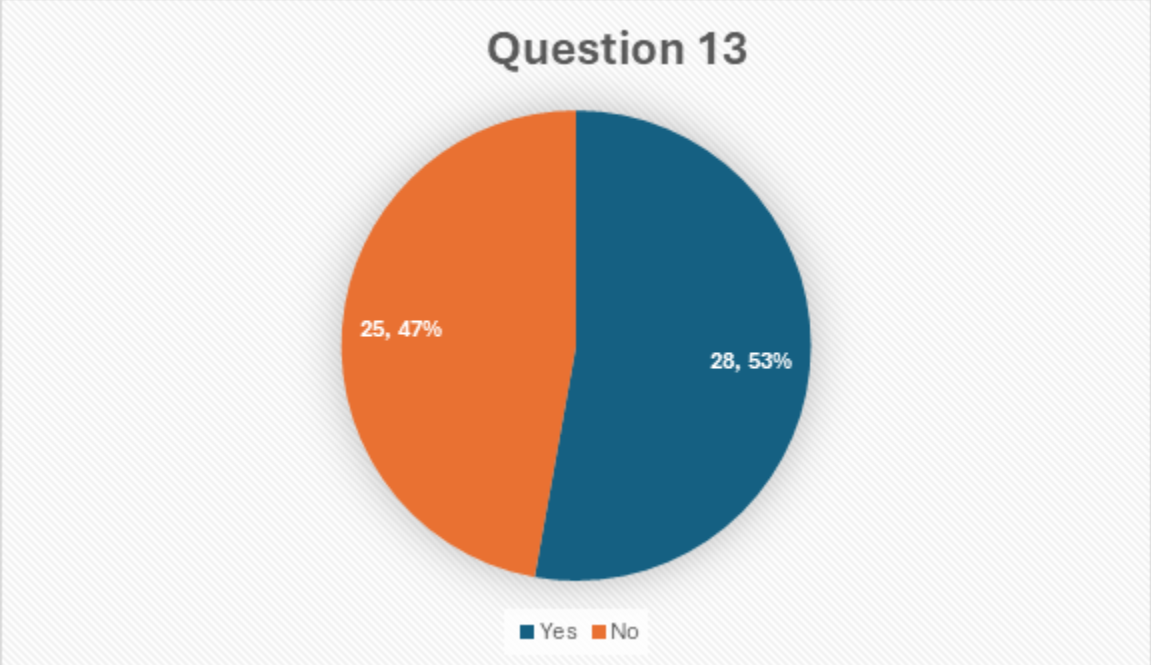
11. On a scale of 1-5, how important is the circular economy (minimizing waste and emissions by reusing and recycling products) to your building operations?



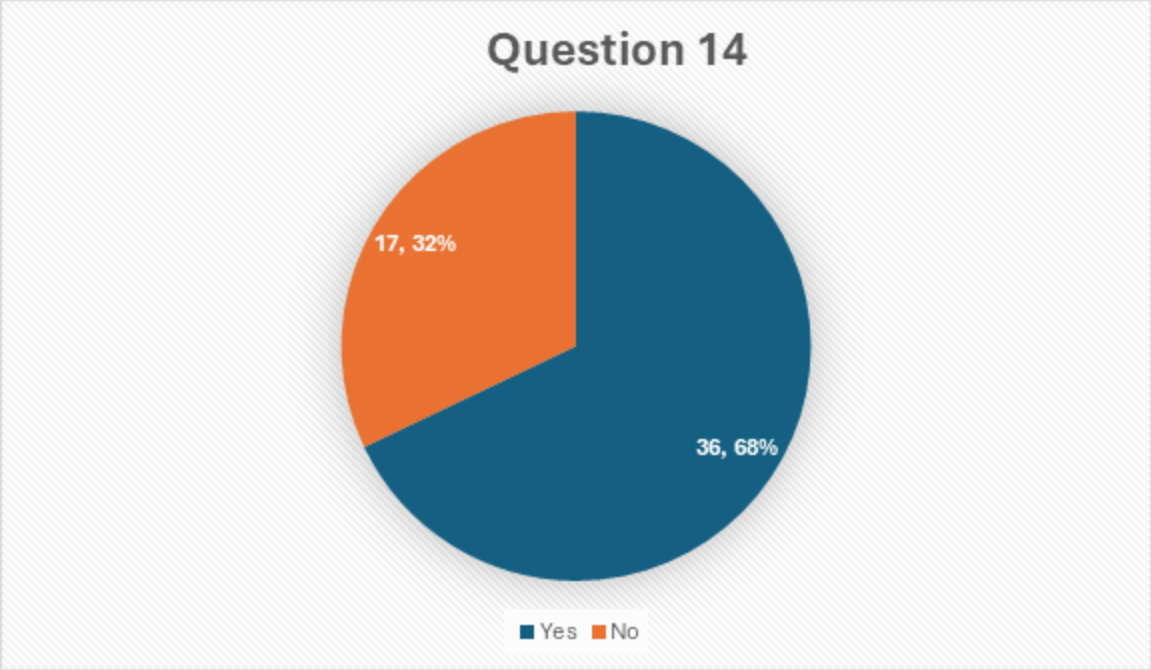
12. On a scale of 1-5, how important is free preventative maintenance to you?



13. Do products made with carbon such as soaps, detergents, and fertilizers add value to your building/business operations?



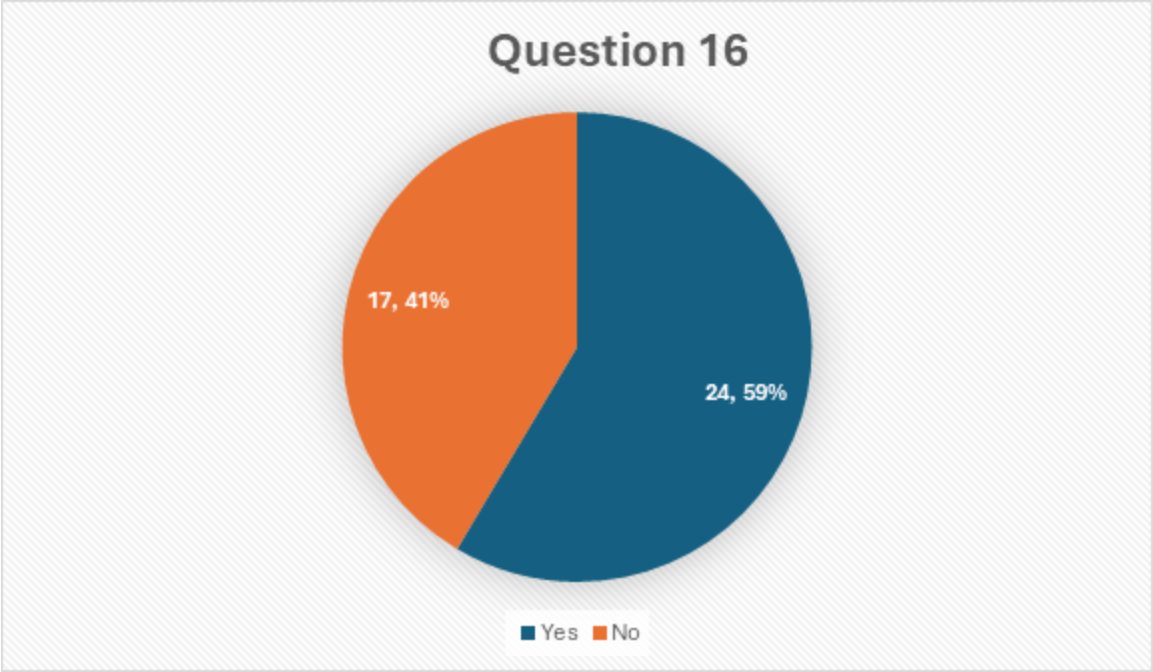
14. Would you support Decarbonization as a service (DAAS)?



15. What are your buildings' natural gas boiler/hot water loads? (BTU/hr)

- 54% were unsure about the loads, and some stated that it varied based on their facility.
- File "ET23SWG0020 (MS04e) Customer Survey Responses" has a list of the customer natural gas building loads if they were known upon completing the survey.

16. Do you want to be contacted with more information about how a CarbinX™ unit can provide energy savings to your facility?



Overall, the customer response from the survey was generally positive, with most taking an interest in the unit and its savings potential. The majority of customers who participated in this survey want to be contacted for more information to see if this technology is right for them. One negative customer response (unrelated to the CarbinX™ unit) to the email outreach effort was received via email.

Conclusions

The CarbinX™ unit has the potential to significantly reduce building heating needs while acting as a MCCU as well. The market study has found that there is significant interest at the SoCalGas program level to investigate this technology within the IOU's territory and evaluate its energy savings. Customer responses to this technology have been mostly positive, with a significant number of customers in the commercial sector, mostly laundromats and schools taking an interest to this MCCU. Clean O2 has also expressed interest in exploring various opportunities to demonstrate their CarbinX™ MCCU technology across different sectors; however, costs, ROI concerns, and unfamiliarity of the unit are some market barriers that the company will have to overcome when it comes to engaging customers. Ultimately, a series of demonstration projects within the California IOU territory that can verify energy savings and emissions reductions will be essential in determining how the technology gets adopted by EE programs.

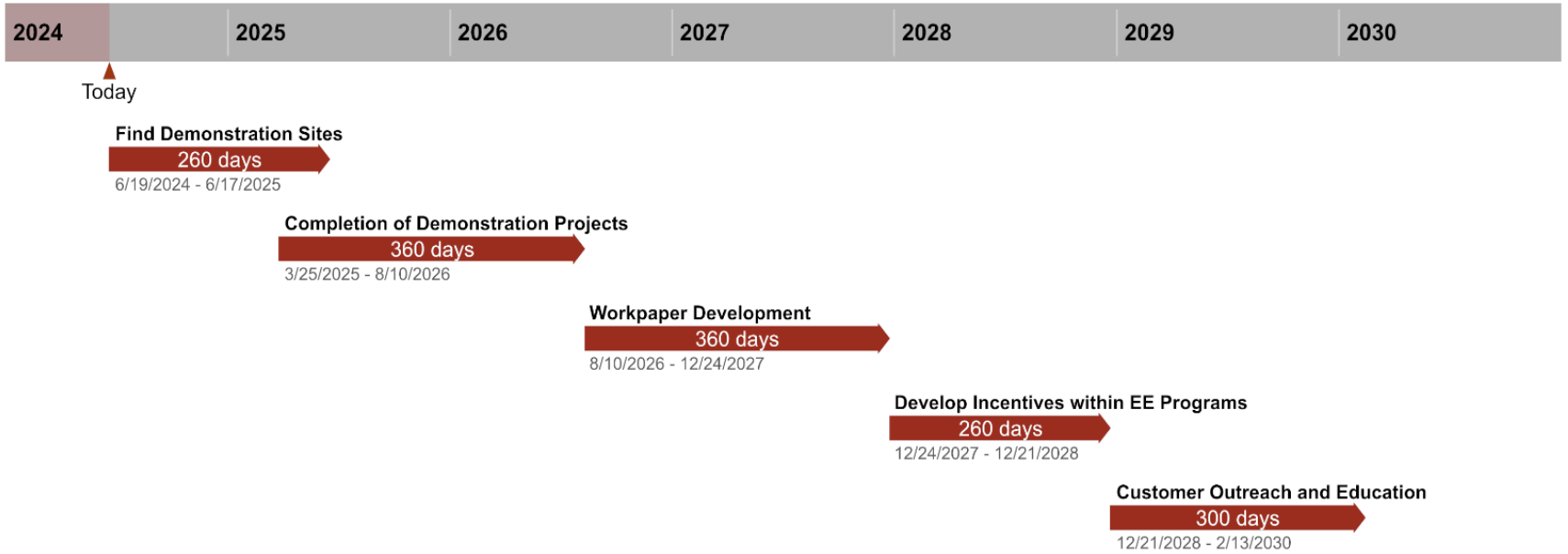
Recommendations

The study provides the following roadmap and recommendations to the California IOU's who seek to include the CarbinX™ technology in their EE Program Portfolio as a potential measure offering.

1. First, utilities need to engage implementors to find feasible sites to demonstrate the CarbinX™ unit in California. Examples include multifamily, agriculture, laundromats, schools/universities, hospitals, and even offices.
2. A series of demonstration projects need to be implemented and completed with sufficient data showing customer energy savings.
3. A measure package would need to be developed for the CarbinX™ technology, based on the data gathered from the demonstration projects.
4. Following the measure package and inclusion of the CarbinX™ unit into the California measure portfolio, EE programs such as the Multifamily, Agriculture, and Non-Residential Business Programs can develop an incentive and rebate structure for customers.
5. EE programs should engage in customer outreach and education to implement the CarbinX™ unit statewide.

A proposed roadmap with an example timeline is provided in Figure 4.0

Figure 4. CarbinX™ California EE Program Uptake Roadmap



Appendices

Appendix 1.0 Survey Tool #1 – Clean O2 Survey Questions

1. What are some market opportunities for CarbinX that don't currently exist?
2. Is Clean O2 interested in expanding to other industries, and if so which ones would be the most feasible in CA?
3. Where does Clean O2 see itself in the future?
4. Are there any key lessons learned from prior CarbinX unit installations?
5. Are there additional opportunities to sell/use the potassium carbonate product that haven't been explored?
6. What are some challenges in implementing these units in programs that need to be overcome?
7. What are some installation/logistical challenges that will need to be overcome?
8. What are the greatest challenges in marketing these units in EE programs?
9. Are there clear screening criteria that can be provided for program delivery to establish which sites are "good" vs "bad" candidates?
10. Can you provide some information about the range of CO_2 % that can be removed in a given building/process if you have enough space, enough load, and enough units?

Appendix 2.0 Survey Tool #2 – EE Program Survey Questions

1. How feasible is it to include the CarbinX unit in an EE program?
2. What is the potential that this technology could be a deemed or custom measure offering?
3. Would the EE program be able to claim any credit for carbon capture?
4. What is the timeframe for adopting the CarbinX unit into an EE program?
5. Engineering targeted question: Could Carbinx be treated as an existing deemed boiler economizer for savings claims or would a new one be required?
6. What types of additional support would be required for this offer vs a typical economizer?
7. What types of technical information, that could be provided by the GET program, would be helpful for a program launch for this offer?
8. Are there different program models that you think might work best for his product?

Appendix 3.0 Survey Tool #3 – Customer Survey Questions

Clean O2 CarbinX Unit Customer Survey Tool

A CarbinX unit can help you save up to 20% on your building's natural gas consumption while also lowering your building's carbon footprint. Whether you've got a residential complex, a recreation center, manufacturing plant, stadium or high-rise apartment, a CarbinX unit can help lower your emissions. The following survey questions are aimed at identifying barriers and drivers of property managers relating to the CarbinX technology. For more information visit: https://www.carbinx.com

* Required

1. Are there any barriers preventing you from installing a CarbinX unit at your facility? *

2. On a scale of 1-5, how much of a barrier is the initial investment of the CarbinX unit? *

- ◯ 1 (not a barrier)
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5 (significant barrier)

3. On a scale of 1-5, how much of a barrier is the uncertainty of the CarbinX units' performance? *

- ◯ 1 (not a barrier)
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5 (significant barrier)

4. How much of a barrier is dealing with maintenance personnel removing the Pearl Ash product *

- ◯ 1 (not a barrier)
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5 (significant barrier)

5. On a scale of 1-5, how worried are you about your natural gas bill? *

- ◯ 1 (Not Concerned)
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5 (Very Concerned)

6. On a scale of 1-5, how much of a driver is reducing your natural gas bill? *

- ◯ 1 (not a driver)
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5 (significant driver)

7. On a scale of 1-5, how likely are you to participate in an Energy Efficiency program that could help you lower your gas consumption? *

- ◯ 1 (highly unlikely)
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5 (very likely)

8. On a scale of 1-5, how likely are you to install a CarbinX unit if there was some kind of financial incentive (e.g. rebate) attached to it? *

- ◯ 1 (highly unlikely)
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5 (very likely)

9. On a scale of 1-5, how likely are you to install a CarbinX unit without any financial assistance? *

- ◯ 1 (highly unlikely)
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5 (very likely)

10. On a scale of 1-5, how much of a driver is lowering your buildings carbon footprint? *

- ◯ 1 (not a driver)
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5 (significant driver)

11. On a scale of 1-5, How important is the circular economy (minimizing waste and emissions by reusing and recycling products) to your building operations? *

- ◯ 1 (not important)
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5 (very important)

12. On a scale of 1-5, How important is free preventative maintenance to you? *

- ◯ 1 (not important)
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5 (very important)

13. Do products made with carbon like soaps, detergents and fertilizers add value to your building/business operations? *

- ◯ Yes
- ◯ No

14. Would you support Decarbonization as a service (DAAS)? *

- ◯ Yes
- ◯ No

15. What are your buildings natural gas boiler/hot water loads? (BTU/hr) *

16. Do you want to be contacted with more information about how a CarbinX unit can provide energy savings to your facility? *

- ◯ Yes
- ◯ No

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