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California Statewide Multifamily Boiler Market Assessment

FINAL REPORT

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1 Executive Summary

1.1 Background

Cadmus partnered with Benningfield Group Inc. (BGI) to conduct a multifamily boiler market assessment study for the Southern California Gas Company (SoCalGas), San Diego Gas & Electric Company (SDG&E), Pacific Gas and Electric Company (PG&E), and the California Public Utilities Commission (CPUC)—together comprising the Study Team. The Study Team was led by SoCalGas, with a SoCalGas study manager.

The impetus for the study was lack of market data, in addition to anecdotal evidence suggesting that a significant portion of the multifamily boiler installed base in the three gas Investor Owned Utilities' (IOU) service territories is old and beyond its effective useful life. The objective of this Multifamily Boiler Market Assessment Study was to provide a characterization of the multifamily market segment's installed base of the gas boilers for space heating and/or water heating in the IOU service territories. To improve the efficiency of gas boilers in the installed base, a targeted approach coupled with incentives is required.

The Multifamily Boiler Market Assessment Study focused on large multifamily buildings (those with 40 units or larger) built prior to 2001 to answer the following research questions:

1. What is the current stock and vintage of boilers in multifamily buildings in SoCalGas, SDG&E, and PG&E territories?
2. Do these boilers provide heating for hot water, space heat, or both?
3. Are the results in line with previous market studies in California?
4. What are the proportions of under-code, to-code, and above-code boilers in multifamily buildings?
5. What is the expected technical potential for energy efficient boilers in multifamily buildings? [1]
6. What insights can the study provide on the repair market?[2]

This study included central gas boilers and small commercial water heaters that are used in multifamily buildings. Cadmus did not limit the types of boilers examined through this research. The study was intended to achieve a ±10% precision at a 90% confidence level statewide with data collected during 140

[1] This study uses terms for technical, economic, and market potential consistent with their definition in the latest potential and goals study: Navigant Consulting. *Energy Efficiency Potential and Goals Study for 2018 and Beyond*. Final Report. Prepared for California Public Utilities Commission. Reference No.: 174655. September 25, 2017.

[2] The repair market is the portion of the multifamily gas boiler market with potential for activities that restore equipment performance to its nominal (or rated) efficiency but do not enhance the nominal efficiency.

site visits. The final research plan included a limited technical potential calculation task focused on gas boiler efficiency upgrades and add-on retrofits.

1.2 Summary of Methods

This market assessment study collected data through secondary and primary research. Through site visits, Cadmus collected primary data about gas boiler systems in large multifamily buildings (with a master or common area gas meter serving 40 or more units) built prior to 2001. Cadmus' approach in completing the study involved the following tasks:

- Literature Review
- Customer Data Screening and Sampling
- Customer Outreach and Recruitment
- On-site Data Collection
- Site Visit Data Analysis
- Population Estimation
- Technical Potential Analysis

1.3 Summary of Market Assessment Results

The results of the Multifamily Boiler Market Assessment Study responding to the research questions are provided here. The market assessments results achieved 10% precision at 90% confidence for key population characteristics statewide.

1.3.1 Multifamily Boiler Population Stock and End-Uses Served

Table 1 shows the population of study-eligible meters and boilers across all IOUs and building-age categories. Dedicated DHW boilers comprised the majority of the equipment, and domestic water heating was the end-use served most often. Pool heating boilers were the next most prevalent end-use.

Table 1. Multifamily Boiler Population Stock in California Gas IOU Territories[1]

IOU	Number of Meters[2]	Quantity of Boilers				
		Dedicated DHW Boilers	Dedicated Space Heating Boilers	Combined Space Heating and DHW Boilers	Pool Heating Boilers	All End Uses
PG&E	1,592***	4,957***	257**	218*	167**	5,599***
SoCalGas	4,361***	9,413***	545*	291*	872**	11,121***
SDG&E	914**	5,105	376	54	376	5,911
Total	**6,867*****	**19,475****	**1,178****	**563****	**1,415****	**22,631****

[1] Cadmus indicated the precision of each estimate at a 90% confidence level using the following asterisks: *** for ±5% precision or better, ** for ±5.1-10% precision, * for ±10.1-15% precision, and no label when precision was over ±15%.
[2] The population of meters included here are based on the data provided by the IOUs, which Cadmus screened for master and common area meters serving 40 or more dwelling units built before 2001.

1.3.2 Multifamily Boiler Population Vintage

Table 2 shows the average boiler age by IOU. Boiler ages vary within IOU territory and between end uses served by boilers. Cadmus observed the oldest boilers in PG&E and SoCalGas territories and the newest in SDG&E territory. Average boiler age ranged from brand new up to 19 years old.

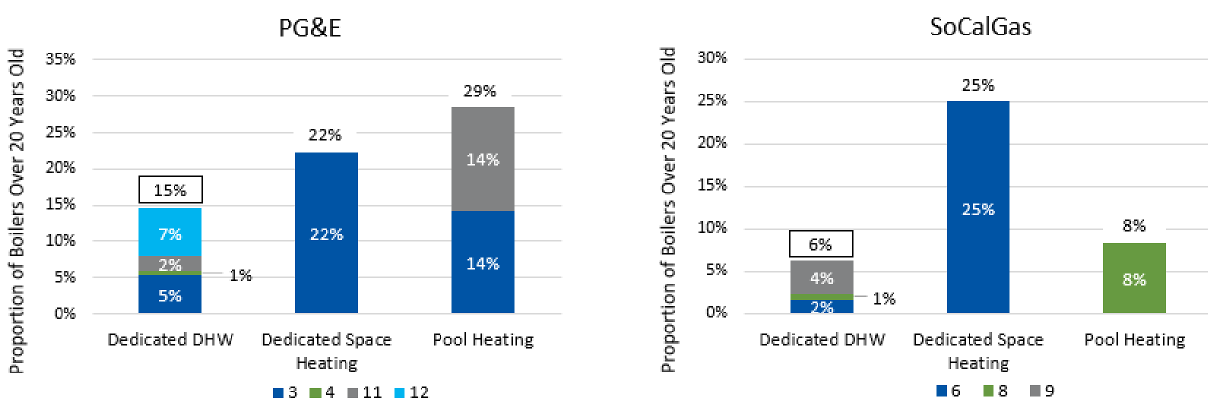
Table 2. Multifamily Boiler Population Vintage in California Gas IOU Territories(1)

IOU (2)	Average Age of Boilers - Years				
	Dedicated DHW Boilers	Dedicated Space Heating Boilers	Combined Space Heating and DHW Boilers	Pool Heating Boilers	All End Uses
PG&E	10.2 ***	14.3	-	17.0	10.6***
SoCalGas	9.5***	18.7	9.0*	6.3	9.7***
SDG&E	3.2***	0.0 (3)	-	-	3.0***
Overall	**8.9*****	**13.6**	**9.0***	**9.6**	**9.2*****

(1) Cadmus indicated the precision of each estimate at a 90% confidence level using the following asterisks: *** for ±5% precision or better, ** for ±5.1-10% precision, * for ±10.1-15% precision, and no label when precision was over ±15%.
(2) The population of meters included here are based on the data provided by the IOUs, which Cadmus screened for master and common area meters serving 40 or more dwelling units built before 2001.(2) The population of meters included here are based on the data provided by the IOUs, which Cadmus screened for master and common area meters serving 40 or more dwelling units built before 2001.(3) One boiler was manufactured in 2019.

The effective useful life (EUL) of a boiler is 20 years based on the Database for Energy-Efficient Resources (DEER). Figure 1 shows the proportion of boilers in operation that were 20 or more years old. Close to 30%, 22%, and 15% of pool heating, dedicated space heating, and dedicated DHW boilers, respectively, were operating at or beyond their EUL in PG&E territory. In SoCalGas territory, the percentages were 8%, 25%, and 6% of pool heating, dedicated space heating, and dedicated DHW boilers, respectively. Cadmus did not find any boilers operating at or beyond their EUL in SDG&E territory.

Figure 1. Proportion of Boilers Operating At or Beyond EUL of 20 Years



A box indicates that estimates achieved 15% precision with 90% confidence.
Results are color-coded for distinct climate zones.

Overall, 7% of boilers (regardless of end-use served) were operating at or beyond the EUL of 20 years. This proportion was 15%, 7%, and 0% in PG&E, SoCalGas, and SDG&E territories (the results at the IOU level are imprecisely estimated with greater than 15% precision with 90% confidence).

1.3.3 Multifamily Boiler Population Efficiency

Table 3 shows the relative efficiencies for boilers observed during site visits. Pool heating boilers tended to be of lower relative efficiency than those serving other end uses, on average achieving a relative efficiency of 81% across all IOUs. Boilers serving other end uses were more similar to each other, with higher efficiencies ranging from 82% to 88% across all IOUs. Across all end uses, each IOU comprised boilers of similar efficiencies.

Table 3. Multifamily Boiler Population Efficiency in California Gas IOU Territories(1)

IOU (2)	Rated Efficiency (3)				
	Dedicated DHW Boilers	Dedicated Space Heating Boilers	Combined Space Heating and DHW Boilers	Pool Heating Boilers	All End Uses
PG&E	86%**	85%	85%	81%	86%***
SoCalGas	85%**	83%	85%	81%	84%**
SDG&E	88%**	83%	82%	84%	87%**
Overall	**86%****	**84%**	**85%**	**81%**	**85%****

(1) Cadmus indicated the precision of each estimate at a 90% confidence level using the following asterisks: *** for ±5% precision or better, ** for ±5.1-10% precision, * for ±10.1-15% precision, and no label when precision was over ±15%.
(2) The population of meters included here are based on the data provided by the IOUs, which Cadmus screened for master and common area meters serving 40 or more dwelling units built before 2001.
(3) Cadmus did not differentiate between thermal efficiency and other efficiency metrics. Results across all efficiencies are compiled in this table.

1.3.4 Multifamily Boiler Population To-code and Under-code Proportions

Cadmus assessed the proportion of boilers that met mandatory requirements of California's current 2019 Title 20 and Title 24 efficiency standards for appliances and buildings, respectively. Table 4 shows the proportion of boilers to code in the market. Cadmus calculated a precision more than ±15% at a 90% confidence level for the results in this table.

For all end uses in this table, code compliance is defined by whether, for input capacities of more than 300 kBtu/h, relative efficiency exceeds 82%, or for lower input capacities, whether relative efficiency exceeds 80%. Cadmus assessed compliance against current code, which may be more stringent than the code that was current at the time of boiler installation.

The results indicated that a large proportion of boilers in all IOUs are to code or above code in both input capacity bins. Fewer boilers with input capacities larger than 300 kBtu/h were below code than boilers with lower input capacities—on average, 18% of boilers with lower input capacities were below code across all IOUs, compared to just 2% of boilers with larger input capacities.

Table 4. Multifamily Boiler Population Proportion of Above Code, To Code, and Under Code Boilers(1)(3)

IOU (2)	Input Capacity ≤300 kBtu/h			Input Capacity> 300 kBtu/h		
	Above Code	To Code	Below Code	Above Code	To Code	Below Code
PG&E	34%	10%	18%	30%	7%	2%
SoCalGas	20%	18%	14%	46%	2%	1%
SDG&E	43%	0%	23%	27%	4%	2%
Overall	**33%**	**15%**	**18%**	**37%**	**6%**	**2%**

(1) Cadmus indicated the precision of each estimate at a 90% confidence level using the following asterisks: *** for ±5% precision or better, ** for ±5.1-10% precision, * for ±10.1-15% precision, and no label when precision was over ±15%.
(2) The population of meters included here are based on the data provided by the IOUs, which Cadmus screened for master and common area meters serving 40 or more dwelling units built before 2001.
(3) Cadmus did not differentiate between thermal and other efficiency metrics, and results across all efficiencies are compiled in this table.

1.3.5 Multifamily Boiler Population Technical Potential for Select Efficiency Measures

Cadmus calculated the technical potential for a limited list of measures focused on gas boiler efficiency upgrades and add-on retrofits. Table 5 shows the 20-year cumulative technical potential for boiler equipment measures by both measure and IOU. Cadmus estimated the highest total potential for boiler equipment measures in SoCalGas territory, followed by PG&E and then SDG&E. This is due to the following:

- SoCalGas had nearly four times as many multifamily meters in the population eligible for this study as PG&E (4,361 vs. 1,592) and nearly five times as many as SDG&E (4,361 vs. 914).
- SDG&E had more boilers per meter than PG&E (4.67 vs. 2.53 for sites with one or more boilers with input capacity of ≤300 kBtu/h, 2.6 vs. 1.62 for sites with one or more boilers with input capacity of >300 kBtu/h)
- PG&E boilers tended to be higher efficiency than either SoCalGas or SDG&E (27.1% under code vs. 31% and 33.9% for SoCalGas and SDG&E regardless of input capacity, respectively).

Table 5. Summary of Cumulative 20-Year Technical Potential for Boiler Equipment Measures (therms)(1)

Input Capacity Range	PG&E		SoCalGas		SDG&E		Total
Measure	≤ 300 kBtu/h	>300-2500 kBtu/h	≤ 300 kBtu/h	>300-2500 kBtu/h	≤ 300 kBtu/h	>300-2500 kBtu/h	
Title 24 Code Efficiency Hot Water Boiler, 82% AFUE ≤300 kBtu/h, 80% Et >300-2500 kBtu/h	21,959	4,077	55,478	9,497	22,655	47,304	160,970
High Efficiency Boiler, AFUE 90%	60,995	107,070	198,750	63,315	3,166	52,560	485,857
Premium Efficiency Boiler, AFUE 94%	52,560	86,112	171,264	50,921	35,573	42,272	438,702
Advanced Efficiency Boiler, AFUE 95+%	37,560	60,861	122,388	35,990	25,421	29,876	312,097
Total	***431,194***		***707,604***		***258,827***		***1,397,625***

(1) The population of meters included here are based on the data provided by the IOUs, which Cadmus screened for master and common area meters serving 40 or more dwelling units built before 2001.

Table 6 shows the 10-year cumulative technical potential for boiler retrofit measures by measure and IOU. The technical potential for boiler retrofit measures is approximately 3.5 times the energy savings for boiler equipment measures. The largest energy savings measures are on-demand boiler circulation pump control, insulating currently uninsulated piping, and installing automated flue dampers. These three measures are currently required by code in new construction, but there are many boiler systems in the existing building stock that do not have these measures installed.

Unlike equipment measures, which Cadmus assumed would be installed as the equipment turns over, the retrofit measures can be installed at any time. Therefore, Cadmus calculated the technical potential for retrofit measures over a 10-year period.

Table 6. Summary of Cumulative 10-Year Technical Potential for Boiler Retrofit Measures (therms)[(1)]

Input Capacity Range	PG&E		SoCalGas		SDG&E		Total
Measure	≤300 kBtu/h	>300-2500 kBtu/h	≤300 kBtu/h	>300-2500 kBtu/h	≤300 kBtu/h	>300-2500 kBtu/h	
On-demand Boiler Circulation Pump Control	600,782		976,667		761,160		2,338,609
Boiler Pipe Insulation - to Code (Uninsulated Pipe) [(2)]	133,769		363,938		133,856		631,562
Boiler Pipe Insulation - to Code (Low Thickness Insulation Pipe) [(2)]	16,662		8,107		11,597		36,365
Boiler Pipe Insulation - Above Code (1.5" Thickness) [(2)]	8,751		12,605		4,211		25,568
Boiler Pipe Insulation - Above Code (2" Thickness) [(2)]	8,373		12,060		4,029		24,462
Boiler Pipe Insulation - Above Code (2.5" Thickness) [(2)]	6,970		10,039		3,354		20,362
Automated Flue Damper	79,299	219,299	122,098	932,704	50,694	150,809	1,554,904
Boiler Improvements – Economizer	56,029	21,255	84,762	0	2,599	34,784	199,427
Boiler Improvements - Tune-up	35,646		46,989		41,078		123,713
Total	***1,186,835***		***2,569,968***		***1,198,172***		***4,954,974***

[(1)] The population of meters included here are based on the data provided by the IOUs, which Cadmus screened for master and common area meters serving 40 or more dwelling units built before 2001.
[(2)] The potential calculated is for insulating the exposed pipe length between the boiler and the building (or the exit point from the boiler equipment room).

1.3.6 Multifamily Boiler Repair Market Insights

The vast majority of boilers with irregular maintenance or maintenance less than annually (more than 90% in each IOU territory) served dedicated DHW end uses.

Table 7 shows the maintenance schedules for boilers in the market across all end-uses. The majority of boilers in each IOU territory received regular maintenance at least annually—55% of boilers across all IOUs received maintenance more than once per year, and an additional 19% received maintenance once per year. Few boilers received maintenance less than once per year, but 27% of boilers were only maintained irregularly. Results were generally consistent across IOUs. The vast majority of boilers with irregular maintenance or maintenance less than annually (more than 90% in each IOU territory) served dedicated DHW end uses.

Table 7. Boiler Population Frequency of Maintenance(1)

IOU (2)	Maintenance Schedule			
	More Than Once Per Year	Once Per Year	Less Than Once Per Year	Irregular
PG&E	50%*	22%	1%	27%
SoCalGas	46%	19%	6%	30%
SDG&E	70%*	7%	-	23%
Overall	**55%***	**19%**	**5%**	**27%**

(1) Cadmus indicated the precision of each estimate at a 90% confidence level using the following asterisks: *** for ±5% precision or better, ** for ±5.1-10% precision, * for ±10.1-15% precision, and no label when precision was over ±15%.
(2) The population of meters included here are based on the data provided by the IOUs, which Cadmus screened for master and common area meters serving 40 or more dwelling units built before 2001.

1.3.7 Comparison of Technical Potential for On-demand Boiler Circulation Pump Control

The technical potential calculated in this study is not directly comparable with the potential calculated in the 2019 Energy Efficiency Potential and Goals Study (Navigant 2019), referred to as the 2019 P&G study, because this study had a smaller scope. The 2019 P&G study assessed potential for the multifamily sector as a whole, whereas Cadmus calculated the potential for multifamily residential complexes that have at least one meter serving 40 or more dwelling units built before 2001 with a central boiler serving the dwelling units.

Cadmus estimated 2.3 MMtherms of cumulative technical potential savings for the on-demand boiler recirculation pump control measure over the next 10-year period. The 2019 P&G study estimated over 271 MMtherms of cumulative technical potential saving over the next 10-year period for this measure in the residential multifamily sector (with additional potential for the low-income sector), which differs from Cadmus' estimate by two orders of magnitude.

Because the two studies used different population sizes, Cadmus reviewed the per-unit saving assumptions in the 2019 P&G study for this measure. The 2019 P&G study calculated the potential for this measure by extrapolating per-dwelling unit estimates to the population. Cadmus calculated the potential not by using a per-dwelling unit estimate but rather by determining the baseline usage from input capacity and efficiency data (from this study), multiplying by the equivalent full load hours, applying savings factors to the baseline usage from various literature sources, and extrapolating to the population of meters estimated in this study. We used the equivalent full load hours from the DEER database by climate zone, estimated to be between 500 and 700 hours depending on the utility.

Cadmus' review of the savings assumption in the 2019 P&G study suggests that the per-dwelling unit savings (4.38 here vs. 22.64 used in the 2019 P&G study) and the initial technology saturations for pump controls (14% here vs. 2% used in the 2019 P&G study) should be reevaluated in the next P&G study.

1.4 Conclusions and Recommendations

This section presents Cadmus' high-level conclusions and recommendations for future direction, research, and analysis in this area for the Study Team. The results apply to boilers in multifamily complexes with at least one meter serving 40 or more dwelling units and built before 2001 in the IOU territories.

Conclusion 1. In this market study, a majority of boilers behind multifamily meters (86%) solely served DHW end-uses. Pool-heating and dedicated space-heating boilers constituted 6% and 5% of the population, respectively. Only 2.5% of boilers served both DHW and space-heating end-uses. *(See Section 5.1 Multifamily Boiler Population Stock and End-Uses Served)*

Conclusion 2. While Cadmus did not find evidence suggesting that a majority of boilers are old and operating beyond their EULs, boiler-age data suggested that 22% and 25% of dedicated space-heating boilers in PG&E and SoCalGas territories, respectively, operated at or beyond their EULs. Additionally, data suggest that 30% of pool-heating boilers in PG&E's territory operate at or beyond their EULs. Overall, 7% of boilers were at least 20 years old and operated at or beyond their EULs. Cadmus did not visit any boilers operating at or beyond their EULs within SDG&E's territory. Dedicated space-heating boilers had higher average input capacities, suggesting that they are larger and more expensive to replace. *(See Sections 5.2 Multifamily Boiler Population Vintage* and *5.4 Multifamily Boiler Population Input Capacity)*

> **Recommendation 1:** In their efforts to replace older, less-efficient boilers, PG&E and SoCalGas should consider focusing on dedicated space-heating boilers, and PG&E should consider focusing on pool-heating boilers. PG&E and SoCalGas may consider increasing program marketing or incentive amounts for high-efficiency replacements in these boiler categories.

Conclusion 3. Cadmus did not find older boilers in older buildings. Data collected through site visits showed boilers of all ages and efficiency levels among buildings in each 20-year age strata. The data did not show a correlation between building age and boiler age. Given limited program participation data from the IOUs, and limited indication of previous program participation from site-visit contacts, Cadmus could not establish the program's influence on replacements of old boilers. *(See Section 5.2 Multifamily Boiler Population Vintage)*

Conclusion 4. Cadmus calculated technical potential as 3.5 times higher for boiler retrofits (add-on or maintenance measures) than for boiler equipment replacements. Cadmus conducted a limited technical potential analysis for gas boiler equipment replacements (resulting in efficiency improvements) and retrofit measures (such as circulation pump demand-control, boiler pipe insulation, automated flue damper, economizer, and tune-ups). Cadmus calculated 1.4 and 4.9 MMtherms of technical potential for boiler equipment and retrofit measures, respectively, and Cadmus calculated the highest total potential for equipment and retrofit measures in SoCalGas territory (3.27 MMtherms), followed by PG&E (1.62 MMtherms) and SDG&E (1.46 MMtherms). *(See Section 5.6 Multifamily Boiler Population Technical Potential for Select Efficiency Measures)*

Conclusion 5. A comparison of technical potential savings calculated in this study and in the 2019 Energy Efficiency Potential and Goals Study (2019 P&G study) for the on-demand circulation pump control measure suggests that per-dwelling unit savings and initial saturation assumptions for this measure should be reevaluated in the next P&G study. The technical potential calculated in this study cannot be directly compared with the potential calculated in the 2019 P&G study due to this study's smaller scope. A comparison of per-dwelling unit savings (22.86 therms used in the 2019 P&G study versus 4.38 therms calculated in this study) and the initial technology saturation (2% in the 2019 P&G study versus 14% in this study) for the on-demand recirculation pump control measure suggests that these assumptions should be re-evaluated in the next P&G study. *(See Section 5.9 Comparison of Results with Previous Market Studies in California)*

> **Recommendation 2:** To increase the accuracy of its potential estimates in the multifamily water heating sector, the CPUC should consider re-evaluating estimates of per-dwelling unit savings and initial saturation for the on-demand pump control measure in the next P&G study.

Conclusion 6. Multifamily building decision-makers remain hard to reach. A coordinated phone outreach campaign, coupled with high incentives ($200 per site visit completed), proved key in reaching this group of IOU customers and in achieving the targeted sample size for site visits. Mailed postcards and emails were very helpful in getting the word out about the study, but the most productive outreach mode in recruiting participants was by phone. Cadmus found that IOU customer databases often did not contain accurate phone or email contact information for decision-makers of multifamily buildings, hence relying heavily on internet searches to find accurate contact information. It is difficult and costly for the IOUs to obtain and maintain current contact information for multifamily buildings. *(See Appendix F. Phone and Email Outreach Dispositions)*

> **Recommendation 3:** Given the difficulty in reaching multifamily building decision-makers and the high cost of data collection, Cadmus recommends future researchers and the IOUs consider a coordinated phone outreach approach, coupled with incentives, that allows for data collection about multiple research topics, or about the building and equipment as a whole, as opposed to data collection focused on a specific technology.

Conclusion 7. Cadmus' literature review confirmed a gap in previously available data about boilers in California residential, multifamily buildings, including numbers installed, end-uses served, input capacity, age, and efficiency. This study fills the gap in previously available data for boilers in the PG&E, SDG&E, and SoCalGas territories. This market assessment answers critical questions about the quantity, age, type, code compliance, and efficiency of boilers in large residential, multifamily building complexes with at least one meter serving 40 or more dwelling units built before 2001. *(See Appendix A. Literature Review Methods and Results)*

Conclusion 8. Additional research is needed to understand multifamily building owner/operator decision-making processes to assist in targeted program planning and utility intervention to encourage replacements of older boilers and installations of retrofit measures. The original RFP contained additional research questions for Phase 2 of this study, focused on understanding multifamily building owner/operator decision-making processes. Though Cadmus did not find a significant proportion of boilers operating beyond their EULs, Cadmus did estimate a large potential for boiler retrofit measures. Cadmus' literature review indicated that structural barriers remain regarding high IOU program uptake in the multifamily market, particularly for whole-building upgrades. Understanding how multifamily building owners and operators make decisions would help the IOUs target programs, not just for boiler replacements and retrofits but also for other whole-building energy efficiency improvements in the multifamily residential building sector. *(See Section 5.6 Multifamily Boiler Population Technical Potential for Select Efficiency Measures* and *Appendix A. Literature Review Methods and Results)*

> **Recommendation 4:** The IOUs and the CPUC should consider additional research to assist in targeting programs for multifamily customers in response to current state decarbonization priorities in the building sector. This additional research should build upon data collected through previous IOU multifamily customer segmentation and needs assessment studies, in addition to insights gathered from previous California multifamily program process evaluations.

2 Background

The boiler market study was approved in the December 2016 update to the 2013-2017 Energy Efficiency Evaluation, Measurement and Verification (EM&V) Roadmap.[3] At the time, investor-owned utilities (IOUs) posited that a significant portion of boilers installed at multifamily buildings are old and operating beyond their effective useful life.[4] These boilers are operational but do not meet the current code (2016 Title 20 and Title 24 at the time of the approval of the study, and 2019 Title 20 and Title 24 now). This indicates that the residential multifamily sector has high gas savings potential resulting from replacing the existing boilers with code-compliant or above code boilers.

There was also anecdotal evidence that these savings are often stranded. Available energy efficiency program incentives are not high enough to encourage multifamily building owners and operators to upgrade their existing equipment. Therefore, they are more likely to repair the boilers (and use it beyond its effective useful life) than to replace it with code or above code boilers. Targeted programs and utility interventions would be required to encourage the replacement of multifamily boilers that do not meet the code but are functional (i.e., meet load requirements).[5]

Southern California Gas Company (SoCalGas), San Diego Gas & Electric Company (SDG&E), Pacific Gas and Electric Company (PG&E), and the California Public Utilities Commission (CPUC)—together comprised the Study Team. The Study Team was led by SoCalGas. The Study Team issued an RFP for a Multifamily Boiler Market Assessment Study in March 2017, which envisioned two phases for the study.

Phase 1, the current study, focused on characterizing the installed base with a brief calculation of technical potential for boiler retrofits and add-ons. A future Phase 2, if approved, would focus on profiling the purchase decision process, assessing the role of market actors (i.e., market actors characterization), conducting customer decision study, performing latent class segmentation (i.e., perhaps a latent class discrete choice analysis to look at purchase decision trade-offs as well as customer segmentation), and diffusion analysis (i.e., to analyze various scenarios of boiler inventories to achieve energy efficiency goals).

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3 California Public Utilities Commission. 2013-2017 Energy Division & Program Administrator Energy Efficiency Evaluation, Measurement and Verification Plan Version 7 (Final). December 31, 2016.

4 The effective useful life of a boiler is 20 years based on the Database for Energy-Efficient Resources (DEER).

5 Based on Resolution E-4818 issued by the CPUC in December 2015, energy efficiency program administrators must apply a normal baseline to calculate savings for the replacement of equipment that is broken, poorly performing or not able to meet its load requirement. In its resolution E-4939 issued in October 2018, the CPUC further clarified that functioning equipment, those that still provide their intended service, are eligible for incentives with an accelerated replacement (i.e., existing) baseline treatment, provided they meet the preponderance of evidence requirements for equipment viability and provided that the program administrators can show that the equipment would have continued in service in the absence of the program.

In October 2017, the Study Team selected Cadmus, which partnered with Benningfield Group Inc. (BGI), to perform Phase 1 of the multifamily boiler study, heretofore referred to as the Multifamily Boiler Market Assessment Study. Cadmus submitted a draft research plan for public review in January 2018. The final study research plan was approved in March 2018. This report details the methods and results of this market assessment.

2.1 Multifamily Boiler Market Assessment Research Questions

The objective of the Multifamily Boiler Market Assessment Study is to provide a characterization of the multifamily market segment's installed base of the gas boilers for space heating and/or water heating in the IOU service territories. Specifically, the study aimed to answer the following research questions:

1. What is the current stock and vintage of boilers in multifamily buildings in SoCalGas, SDG&E, and PG&E territories?
2. Do these boilers provide heating for hot water, space heat, or both?
3. Are the results in line with previous market studies in California?
4. What are the proportions of under-code, to-code, and above-code boilers in multifamily buildings?
5. What is the expected technical potential for energy efficient boilers in multifamily buildings? [6]
6. What insights can the study provide on the repair market?[7]

As mentioned above, the Study Team envisioned a second phase for this study in the future, pending CPUC approval, to answer additional market study questions. As the Phase 2 study was not approved or assigned to Cadmus, the research questions identified for Phase 2 in the March 2017 RFP for Multifamily Boiler Market Study were not addressed within the scope of this study. These Phase 2 research questions are included here for future reference only:

1. Who are the decision-makers and how long does the decision-making process take regarding boiler replacements?
2. Who are the market actors? What role/influence do trade allies and market actors have in encouraging boiler replacements?
3. What role/influence do contractors have in driving the selection of boilers and boiler add-ons?
4. Where is the best point of intervention for incentives (upstream, midstream, downstream)?
5. What are the barriers to replace existing boilers with above-code boilers?

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[6] Cadmus used technical, economic, and market potential terms consistent with their definition in the latest potential and goals study at the time: Navigant Consulting. *Energy Efficiency Potential and Goals Study for 2018 and Beyond*. Final Report. Prepared for California Public Utilities Commission. Reference No.: 174655. September 25, 2017.

[7] The repair market is the portion of the multifamily gas boiler market with potential for activities that restore equipment performance to its nominal (or rated) efficiency but do not enhance the nominal efficiency.

6. Since MF property owners/managers are known to utilize boilers beyond effective useful life, what does it take to motivate early replacement actions?
7. How do on-bill financing (OBF) options affect the decision-making process?

2.2 Boilers and Water Heaters

Boilers create steam primarily for space heating, while water heaters generate hot water that can be used for domestic hot water, space heating, or pool heating end-uses. This market assessment addresses both types of equipment. Throughout this report, Cadmus uses the term “boiler” to refer to central gas hot water and steam boilers and small commercial water heaters that serve space heating, pool heating, or domestic hot water end uses. In presenting the data collection and market assessment results, Cadmus distinguishes between “boilers” based on the end-use they serve. Given the lack of existing information about boilers serving existing multifamily buildings, Cadmus considered any equipment serving more than one dwelling unit as central, for the purposes of this study. Since little was previously known about the diversity of equipment serving multifamily buildings, Cadmus did not set a minimum size or capacity requirement for the central equipment.

2.3 Preliminary Sampling Plan

Originally, the study research plan presented for public review targeted ±15% precision at 90% confidence for key population estimates statewide. Cadmus planned to conduct a total of 80 site visits statewide to achieve this level of confidence and precision. However, during the study research plan public review period, stakeholders voiced concerns about the number of site visits planned, recommending more site visits and better precision.

In its final project research plan, based on approved IOU budget for additional site visits, Cadmus presented a draft sampling plan targeting ±10% precision at 90% confidence for key population estimates statewide. Using an approximate coefficient of variation (CV) of 0.75, Cadmus estimated that 140 site visits would be required to reach the targeted ±10% precision at 90% confidence level for key population estimates statewide.[8]

Cadmus anticipated that multifamily buildings in different age categories would be heterogeneous with respect to boiler age and efficiency. Further, the Study Team required that the total sample size of 140 buildings be allocated proportional to the project cost allocation by IOU. Therefore, Cadmus used a stratified sample design defined by IOU and 20-year building age categories, where the total sample size was allocated proportionally to the population sizes in each stratum. California climate zones were not a stratification factor in the study.

However, Cadmus committed to distributing the 140 sample of site visits to include the climate zones across IOU territories. To achieve the targeted levels of confidence and precision, the Study Team agreed to limit the study to focus on large multifamily buildings (with 50 units or more) built prior to

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[8] Cadmus. *California Statewide Multifamily Boiler Market Assessment Final Project Research Plan*. March 22, 2018.

2001, assuming that boilers in newer buildings would have lower potential for efficiency upgrades. The study eligibility criteria were further refined through the course of the study. The final research plan included a limited technical potential calculation task focused on gas boiler efficiency upgrades and add-on retrofits.

2.4 Limitations of the Study

This market assessment is limited to residential multifamily complexes built before 2001. Buildings must have at least one gas IOU meter serving 40 or more dwelling units and a central boiler. In the IOU territories, there are some large multifamily complexes with 40 or more dwelling units, but at which none of the meters serve 40 or more dwelling units. These complexes are not counted as part of the population and are not represented by the site visit sample in this research. Instead, the literature review appendix of this report includes a detailed assessment of the number of large multifamily buildings and the number of multifamily dwelling units in large buildings across the three IOU territories.

To plan for future decarbonization in California, it is important to understand the installed gas boiler stock and its characteristics in the multifamily building sector. This study provided a detailed market assessment by examining the installed base of central boilers and water heaters in multifamily buildings built before 2001, with at least one gas IOU meter serving 40 or more dwelling units. The technical potential study approved in the final research plan was limited to a specific set of measures focused on gas boiler efficiency upgrades, add-on retrofits, and maintenance. Studying the potential for replacing existing gas boilers with electric water heaters or adding solar water heating was outside of the scope of this study.

3 Market Assessment Methods

This market assessment study is based on site visits to collect primary data about gas boiler systems in large multifamily buildings (with 40 or more units) built prior to 2001. Cadmus' approach in completing the study involved the following tasks:

- **Literature Review:** The literature review examined information about the multifamily gas boiler market available in prior studies and reports. Cadmus planned to uncover any information already available about the multifamily boiler market and use secondary data collected in the literature review to inform the research, including site visit sample design, on-site data collection, and technical potential estimates.
- **Customer Data Screening and Sampling:** Cadmus requested gas IOU multifamily customer data with monthly gas usage to compile the population of master or common area meters in IOU territories. Cadmus used one meter as a proxy for one building. Using the customer lists provided by the IOUs, Cadmus pre-screened the customer data to focus on master or common area meters that served 50 or more dwelling units (and later reduced this limit to 40 or more units) and served a building built prior to 2001. Cadmus used this pre-screened list of meters in the population to develop a site visit sampling plan and to develop study sample frames for conducting outreach to IOU customers for further screening and recruitment activities.
- **Customer Outreach and Recruitment:** Cadmus conducted outreach to IOU customers via postcard, email, and phone. Using an online recruitment and screening survey, Cadmus obtained contact information for scheduling site visits, and further screened meters for a central boiler serving the dwelling units. To effectively recruit for the site visits, Cadmus offered a $5 incentive for taking the short survey and a $200 incentive for completing a site visit.
- **On-site Data Collection:** Cadmus and BGI staff conducted site visits in all three IOU territories to collect boiler characteristics, including boiler condition (e.g., boiler age, input capacity, efficiency), operation (e.g., temperature setpoint, schedule, maintenance frequency), end-use service (e.g., space heating, water heating, pool heating), and any boiler add-ons. Cadmus kept tracking workbooks to track participation of IOU customers across multiple modes of outreach and meet targeted quotas according to the sampling plan.
- **Site Visit Data Analysis and Population Estimation:** Cadmus compiled data in a master database and conducted analyses using stratified mean and proportion estimators to produce population estimates of multifamily complex and boiler system characteristics (e.g., boiler vintage and efficiency, end uses, frequency of maintenance, and possibility for upgrades).
- **Technical Potential Analysis:** Cadmus used available primary and secondary data to estimate technical potential for energy savings from boiler equipment replacement and retrofits. We compared the primary data with secondary data to determine whether results were consistent.

The sections that follow describe market assessment methods in detail. Literature review methods and results are included in *Appendix A. Literature Review Methods and Results.*

3.1 Customer Data Screening and Sampling Methods

In its final project research plan, Cadmus identified each IOU multifamily master or common area gas meter as a unit in the study's population of interest. Cadmus chose this approach as it allowed for greater accuracy in quantifying the study's total population. Though Cadmus' literature review indicated uncertainty around the number of large multifamily buildings, the number of IOU multifamily meters could be quantified. In fact, quantifying the total population of interest was important because Cadmus planned to extrapolate the study sample's data collection results to the population.

For two additional reasons, Cadmus chose to target IOU meters (rather than physical buildings) as units in the population:

- First, the limited budget precluded screening large multifamily buildings, based on the number of units in a building or complex and relying on geographic or real estate data.
- Second, screening large multifamily buildings, without concern for gas usage by a master or common area meter, would include many residential complexes with small usage meters (tied to individual units with individual water heaters) in the sample frame. This would steer Cadmus away from the study's focus (boilers), making it more difficult to recruit eligible buildings for the study.

Therefore, Cadmus used meters as a proxy for buildings and defined large multifamily buildings as master or common area meters serving 50 or more dwelling units (and later reduced the size criteria to 40 or more dwelling units, as described under *Study Sample* Frame).[9]

3.1.1 Data Request

After project kick-off, Cadmus requested customer account information and one year of monthly gas usage data for master-metered and common area multifamily customers in the three gas IOU territories. With these data, Cadmus could update the draft sampling plan and prepare the sample frame for its data collection activities. By October 2018, Cadmus received the requested data from PG&E, SDG&E, and SoCalGas.

SoCalGas provided all multifamily residential gas accounts, including individually metered accounts.

PG&E provided residential and commercial gas accounts with annual usage of more than 2,000 therms per year, which was based on Cadmus' conservative minimum annual usage estimate for multifamily buildings with 50 or more units. PG&E also limited the data to those accounts with account-on-premise-start-dates prior to December 31, 2001.

SDG&E provided all multifamily residential gas accounts.

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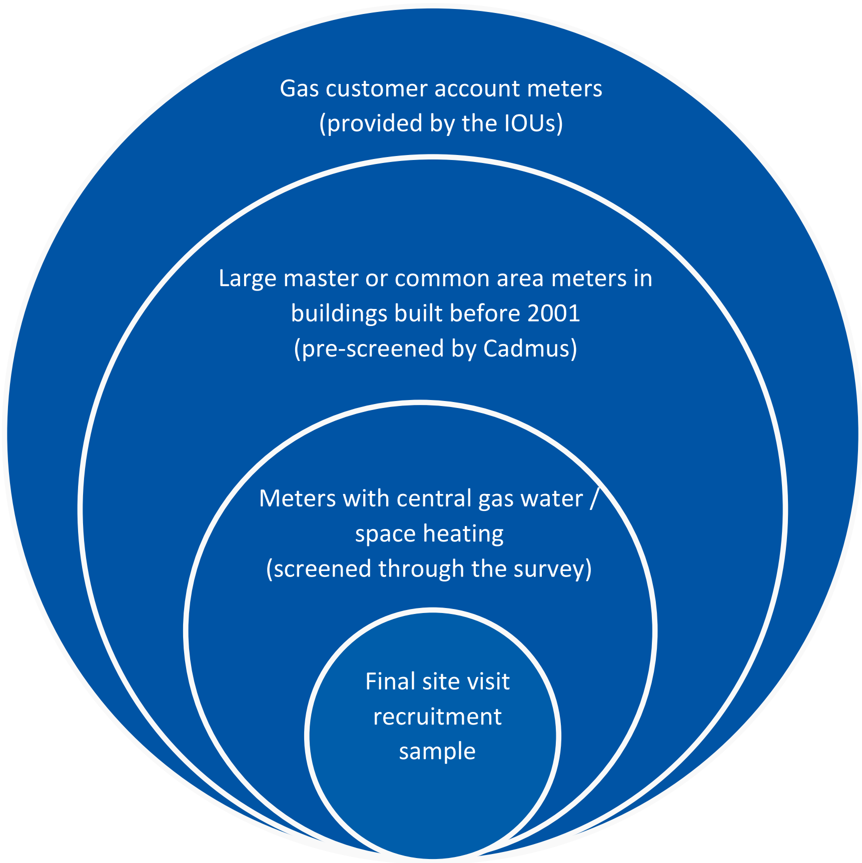
[9] A meter may serve multiple boilers and a building may have multiple meters. Cadmus' approach to site visit data collection addressed these scenarios as described in *On-Site Data Collection Methods.*

Each account is equivalent to a meter in the study population.

As illustrated in Figure 2, Cadmus started with the IOU gas customer data and pre-screened the data for master and common area meters serving large multifamily buildings built before 2001. This dataset with contact information, supplemented from other data sources, was the basis for developing the screening and recruitment survey sample frame. A description of the three main steps completed to screen the IOU customer data and develop the sample frame, representing the study population, follows.

Figure 2. Pre-Screening, Screening, and Recruitment of Market Study Population of Meters



3.1.2 Step 1. Identify multifamily master or common area meters

Cadmus filtered out all individually metered residential unit meters based on rate code. A central boiler in a multifamily building is billed under either a master or a common area meter (not under an individual dwelling unit meter).

Cadmus sorted meters by decreasing usage. Cadmus then reviewed common area and master meters by detailed service address, service description, service name, or NAICS code, as available. Cadmus filtered out meters that did not serve multifamily tenant units (i.e., solely served a commercial business, office, laundry, club-house, or pool).

3.1.3 Step 2. Identify large master or common area meters serving buildings built before 2001

If the account descriptions indicated that the meter was tied to a boiler or central water heater or if it had the requisite number of tenant units, Cadmus used that information. SoCalGas data included information about the number of units served by each meter. Cadmus spot-checked this information for accuracy by searching for the address on real estate sites online and, given its accuracy, used this information to screen out multifamily meters serving fewer than 40 units.

Initially, Cadmus planned to rely on the SoCalGas data to estimate the number of units per building for the other IOUs, by using average annual gas usage per multifamily dwelling unit. However, Cadmus found significant variation in annual gas usage per dwelling unit in both the SoCalGas and PG&E territories, which made it impossible for Cadmus to identify large buildings solely through gas usage. Therefore, Cadmus relied primarily on online building look-ups to determine the number of units for PG&E and SDG&E. Cadmus searched for the premise address on websites such as *www.apartments.com* or *www.redfin.com.*

The earliest account start date (used as a proxy for the year during which the building was built) in SoCalGas and PG&E customer data was 1960. Through online building look-ups, Cadmus found that this value represented premise start dates before 1960 but also after 1960. Additional look-ups were used to derive the most accurate year built for each SoCalGas, PG&E, and SDG&E meter.

3.1.4 Step 3. Identify meters with central boilers or water heaters

Using the available data, Cadmus could not screen for the presence of central boilers or water heaters behind the meter. Consequently, further screening via surveys was necessary to identify the study population and to recruit for site visits. Cadmus flagged the meters in the IOU gas master-metered and common area multifamily meter list that were estimated to meet the study eligibility criteria. These pre-screened meters constituted the screening and recruitment sample frame.

3.1.5 Change in Study Eligibility Criteria

As noted previously, Cadmus identified large multifamily buildings as those (with meters) serving 50 or more units. Cadmus limited the building size to 50+ units based on prior experience with what constituted a "large" residential complex. The recruitment and screening survey asked for the number of dwelling units at the premise address because we believed that most people would know this, whereas, they would not know the number of units served by the meter at the premise address and would drop out of the survey.

At the halfway point in our recruitment efforts, we found that the process was screening out otherwise eligible meters in large multifamily complexes. This was because Cadmus' pre-screening prior to outreach was not 100% accurate, particularly for meters that served 45 to 55 units. Asking about the number of units at the premise address during outreach screened out large multifamily complexes that had fewer than 50 units in one building at the premise address but had 50 or more dwelling units served by the meter at the premise address distributed in multiple buildings. This was the case in large residential complexes with central meter(s) and boilers, serving multiple small buildings.

In June 2019, Cadmus requested, and the IOUs approved, a change to the study eligibility criteria to include meters serving 40 or more units. The IOUs requested that the proportion of completed site visits for meters serving 40 to 49 units and 50 or more units be equal among the three IOUs, to the extent possible.

Since the study recruitment postcards had been mailed by that time, the primary mode of outreach to meters serving 40 to 49 dwelling units was phone and email. Cadmus completed its pre-screening for building size and age in the summer of 2018. At that time, Cadmus identified the number of dwelling units served by each meter in the IOU data and conducted research to confirm building age for the meters that served 50+ units. Therefore, to prepare the sample of meters serving 40 to 49 dwelling units, Cadmus referred to its original pre-screened IOU database and identified additional meters to include in our sample frame.

When Cadmus completed pre-screening in summer 2018, it had conducted research only on the age of meters in the 50+ category. Because this pre-screening had not included confirmation of building age for meters with 40 to 49 units in PG&E and SoCalGas customer data, Cadmus relied on building age in the IOU customer data.[10] This did not pose an issue for recruitment or following the sampling plan, because Cadmus tracked its progress against the sampling plan using the building age obtained from the survey.

3.1.6 Customer Data Pre-screening Attrition

Each step described above resulted in some attrition of meters from the original lists Cadmus received from the IOUs. Table 8 presents the PG&E gas customer meter data attrition as Cadmus developed the study screening and recruitment sample frame. Table 9 presents the SoCalGas customer meter data attrition as Cadmus developed the study screening and recruitment sample frame. Table 10 presents the SDG&E customer meter attrition.

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10 Cadmus had confirmed that building age in SDG&E customer data was accurate.

Table 8. PG&E Gas Customer Data Attrition in Developing the Study Population of Meters

Groups of Meters	Number of Meters	Number of Meters Dropped	Percentage of Meters Dropped (%)	Note
Initial data from IOU	26,762			All commercial and residential meters with account-on-premise-start-dates before December 31, 2001, and with annual gas usages over 2000 therms
Kept meters before 2001	25,337	1,425	5.32%	Removed meters with account-on-premise start date after December 31, 2000
Removed single-family and individually metered	23,192	2,145	8.02%	Removed single-family and individually metered
Removed non-unit serving common area meters(1)	8,036	15,156	56.63%	Removed meters that did not serve residential units (such as pools, laundry, recreation rooms, club houses, other commercial buildings, etc.)
Removed small multifamily meters (<40 dwelling units)	1,801	6,235	23.30%	Removed meters with less than 40 units (based on web search)
Large Multifamily Master / Common Area Meters Built Before 2001	**1,801**	**24,961**	**93.27%**	

(1) Given the limited number of sample points in the study, Cadmus focused on identifying multifamily meters serving residential heating/water heating end-uses. PG&E provided billing data for all commercial meters with usage over 2,000 therms, which contributed to the attrition. Of the 15,156 dropped, 87% (13,220) were commercial sites such as restaurants, offices, and retail. An additional 1,936 meters served pools, laundry, and common areas and not dwelling units in multifamily buildings. Cadmus identified these meters by reviewing their service account name/description, billing data usage pattern, and annual gas usage. The average annual gas usage of the meters dropped in this step was 4,360 therms, while the average annual usage of confirmed large multifamily meters was 14,963 therms, over three times higher. Cadmus reviewed all meters in this category that used over 6,000 therms annually to make sure they did not serve dwelling units.

Table 9. SoCalGas Customer Data Attrition in Developing the Study Population of Meters

Groups of Meters	Number of Meters	Number of Meters Dropped	Percentage of Meters Dropped (%)	Note
Initial data from IOU	1,923,947			All multifamily meters including individually metered
Kept meters before 2001	1,688,258	235,689	12.3%	Removed meters with account-on-premise start date after December 31, 2000
Removed individually metered	112,301	1,575,957	81.9%	Removed meters that were individually metered, unless they are flagged as boilers or central water heaters by SoCalGas
Removed meters with small total usage	22,451	89,850	4.7%	Removed meters that have annual usage less than 2500 therms
Removed meters with less than 40 units	7,642	14,809	0.8%	Removed meters with less than 40 units even if known boilers + central water heaters (based on web search)
Removed meters with no address	7,438	204	Less than 0.1%	Removed meters with missing addresses + non-apartment use meters
Removed non-unit common area meters*	4,864	2,574	0.1%	Removed common area meters serving pools, recreation buildings, laundry, etc.
Removed low usage per unit meters	4,678	186	Less than 0.1%	Removed meters with low annual usage <50 therms per unit
Large Multifamily Master / Common Area Meters Before 2001	**4,678**	**1,919,269**	**99.8%**	

[1] Given the limited number of sample points in the study, Cadmus focused on identifying multifamily meters serving residential heating/water heating end-uses. The 2,574 meters dropped in this step were under the multifamily rate class but served only pool, laundry, or other common area end-uses. Cadmus identified these meters by reviewing their service account name/description, billing data usage pattern, and annual gas usage. The average annual usage for the dropped multifamily common area meters was 5,249 therms, while the average annual usage for the large multifamily meter subset was 17,936 therms – over three times higher than the dropped meters. Cadmus reviewed all meters in this category that used over 6,000 therms annually to make sure they did not serve dwelling units.

Table 10. SDG&E Customer Data Attrition in Developing the Study Population of Meters

Groups of Meters	Number of Meters	Number of Meters Dropped	Percentage of Meters Dropped (%)	Note
Initial data from IOU	209,816			All multifamily meters
Removed meters with small total usage	3,090	206,726	98.5%	Removed meters that have annual usage less than 3,000 therms - based on SoCalGas + PG&E only 1-2% boilers in this category - boilers extremely unlikely
Kept meters before 2001	2,894	196	0.1%	Removed meters with year built after December 31, 2000
Removed low per unit usage after obtaining correct number of units	2,883	11	Less than 0.1%	Removed meters with low annual usage per unit (<50 therms/unit)
Removed non-unit common area meters	2,497	386	0.2%	Removed common area meters serving pools, recreation buildings, laundry, etc.
Removed meters with less than 40 units	1,022	1,475	0.7%	Removed meters with less than 40 units (based on web search)
Large Multifamily Master / Common Area Meters Before 2001	**1,022**	**208,794**	**99.5%**	

3.1.7 Site Visit Sampling Plan

After Cadmus pre-screened the IOU customer meters, Cadmus revised the preliminary site visit sampling plan (reflected in the final research plan for the study) to reflect the number of meters in each IOU territory and age stratum. Table 11 shows the meter population in each stratum for each IOU based on the pre-screening steps outlined above.

Table 11. Final Population of Multifamily Common Area and Master Meters Serving 50 or More Dwelling Units in IOU Territories

Utility	Year Built	Final Population Size	Percentage of IOU Population
PG&E	1960 and before	153	11%
	1961 - 1980	746	52%
	1981 - 2000	527	37%
SoCalGas	1960 and before	245	8%
	1961 - 1980	1,767	58%
	1981 - 2000	1,052	34%
SDG&E	1960 and before	12	1%
	1961 - 1980	488	61%
	1981 - 2000	304	38%
Total by Year Built	**1960 and before**	**410**	**8%**
	1961 - 1980	**3,001**	**57%**
	1981 - 2000	**1,883**	**36%**
Total by IOU	**PG&E**	**1,426**	**27%**
	SoCalGas	**3,064**	**58%**
	SDG&E	**804**	**15%**
Total		**5,294**	**100%**

Table 12 shows the target final site visit sampling plan for the California statewide Multifamily Boiler Market Assessment Study. Cadmus used the distribution of meters in the population (in Table 11) and an estimated coefficient of variation (CV) of 0.75, based on its professional judgment, to determine the sample sizes that would be required to estimate boiler characteristics with 90% confidence and 10% precision. Note that this sampling plan was developed for the population of meters serving 50 or more dwelling notes. Cadmus and the Study Team later revised the study eligibility criteria to include meters serving 40 or more dwelling units. Cadmus did not revise its sampling plan to reflect this change. However, Cadmus' final analysis is based on the total population of accounts serving 40 or more dwelling units.

Table 12. California Statewide Multifamily Boiler Market Assessment Site Visit Sampling Plan

IOU	Sample Allocation	Year Built	Site Visit Sample Size Target
PG&E	45% (63 site visits)	1960 and before	7
		1961 - 1980	33
		1981 - 2000	23
SoCalGas	43% (60 site visits)	1960 and before	5
		1961 - 1980	34
		1981 - 2000	21
SDG&E[(1)]	12% (17 site visits)	1960 and before	11
		1961 - 1980	
		1981 - 2000	6
Total	**100%**		**140**

[(1)] Because of the small number of units in the 1960-and-before age stratum, Cadmus combined this stratum with the 1961-1980 stratum.

3.2 Customer Outreach and Recruitment Methods

Ultimately, Cadmus sought to refine the study population estimate and complete 140 site visits of boilers behind study-eligible meters across IOU territories, consistent with the project sampling plan. Cadmus prepared a sample frame of pre-screened study-eligible meters and their account-owning customers (as discussed in the next section) then needed to inform these customers about the study, confirm the eligibility of their meters, and recruit their premises for site visits.

Based on Cadmus' experience in conducting previous multifamily building market assessments in California and with recent evaluation studies published, Cadmus and the IOUs agreed that recruiting multifamily building owners and operators posed difficulties for the following reasons:

- Multifamily building owners and operators are very busy, often spending their days attending to multiple properties.
- IOU databases have accurate mailing addresses for their customers, but the phone numbers or email addresses included can be spotty and inaccurate, primarily due to building ownership or operation turnover.
- IOU databases contain contact information for entities paying utility bills, which often differs from the person managing a building on a day-to-day basis and the person Cadmus sought to reach.

To meet these challenges, Cadmus designed an outreach plan with two key components:

- Multimode outreach with careful tracking across modes
- Incentives

The next section explains each of these components, followed by descriptions of the outreach tracking, outreach plan flowchart, and schedule.

3.2.1 Multi-Mode Customer Outreach

Using three modes, Cadmus reached out to the IOU customer contacts in the study sample frame:

- **Mailed postcards.** Cadmus mailed postcards to customer addresses listed in the IOU database. For postcards to be effective, they had to be received by a person sufficiently familiar with the premise listed on the postcard. Cadmus organized the sample frame by customer mailing address. Addresses with a larger number of meters assigned were run by large property management companies (typically with variable points of contact who may not have enough familiarity with the premise). Therefore, Cadmus sent postcards to customer mailing addresses with five or fewer premises associated with them. The template used for outreach postcards is provided in *Appendix B. Outreach Postcard, Email, and Reminder Email.*

- **Emails**. Cadmus sent outreach emails to customer email addresses listed in the IOU database, organizing the sample frame by customer email addresses. If a customer email address had more than 10 premises associated, Cadmus picked 10 random premises for inclusion in the email. (Cadmus only included up to 10 premises in customer emails to keep the emails short.) *Appendix B. Outreach Postcard, Email, and Reminder Email* provides the template used for outreach emails and reminder emails.

- **Phone calls.** For each property in the sample frame, Cadmus called phone numbers listed in the IOU customer database or found through research on the internet for each property in the sample frame. Cadmus referred to the residential complex name (if available) and/or the premise address and asked for the building owner, operator, or maintenance staff. *Appendix D. Outreach Phone Call Script* provides the script used for outreach phone calls.

Before beginning the outreach, Cadmus obtained approvals from the IOUs and their marketing and branding departments regarding the outreach materials. In the outreach material, Cadmus explained the study and asked customers to take a short recruitment and screening survey (programmed in Qualtrics online). The short survey was designed to give Cadmus accurate contact information for each building (hence to schedule subsequent site visits, if eligible) and to screen for study eligibility criteria. *Appendix E. Recruitment and Screening Survey Instrument* provides the questions asked during the recruitment and screening survey.

3.2.2 Incentives

To encourage participation, Cadmus offered two incentives in the outreach plan:

- Cadmus offered a $5 electronic gift card for coffee, intended to encourage customers to take the recruitment and screening survey. The study made the incentive available whether customers completed the online survey independently or with the recruiter on the phone. Cadmus disbursed the $5 gift card in biweekly batches to all customers who completed the recruitment and screening survey, regardless of eligibility for the site visits (determined after this short screening survey).
- Cadmus offered a $200 VISA gift card to each site visit participants, disbursed by field technicians at the conclusion of the site visit.

3.2.3 Outreach Tracking

To track the survey and gift cards across multiple outreach modes for each meter in the sample frame, Cadmus assigned a Survey ID to each meter. Respondents accessed the online survey through a generic survey link, entering a Survey ID to start the survey. The outreach postcards and emails included the generic survey link and up to five (postcard) or 10 (email) Survey ID numbers. We removed meters with the same premise address (and in the same residential complex, if possible). After validating the Survey ID, the survey confirmed the premise address assigned to that Survey ID and the survey continued with references to the premise address. Each Survey ID was valid one time only so that, once the survey was completed, another survey could not be completed for the same Survey ID and premise address.

In scheduling site visits for eligible meters, Cadmus followed the study sampling plan closely. This sampling plan provided site visit targets by IOU and by building age strata. Cadmus recruiters targeted their scheduling and recruitment phone outreach, prioritizing gaps remaining in sample targets and age strata in the sample frame. During pre-screening of building ages in the IOU customer databases, Cadmus refined the age strata in the sample frame. However, Cadmus again confirmed the building age during the survey and used this to track progress against the study sampling plan.

The online recruitment and screening survey referred to the premise address (instead of the utility account number or meter ID). As noted, it asked about the building's age but also if the building had a central boiler or water heater serving dwelling units as well as the number of units at the premise address. Cadmus marked meters with survey data as follows:

- Meters with 50 or more units (and—later—40 or more units, as explained later in this section) at premise address were possibly eligible, to be confirmed during scheduling calls.
- Meters not meeting this criterion could be ineligible, to be confirmed during scheduling calls.
- Meters with buildings built after 2000 and/or individual unit water heaters were ineligible.

Cadmus tracked customer participation by maintaining tracking workbooks for recruiters, updating these daily with results from online surveys completed the previous day:

- Cadmus followed up by phone with customers completing surveys through postcard or email outreach, confirmed the number of dwelling units served by the meter(s) at the premise address, and scheduled eligible buildings for a site visit.
- Cadmus phoned customers who had not completed the survey online. After introductions and confirming they had the right person on the phone, recruiters completed the survey online with responses provided by the contact. If the meter proved eligible, the recruiters scheduled the site visit.

Cadmus consolidated all pre-screened IOU meters and prepared the study sample frame by cleaning and standardizing the addresses and phone numbers and removing records that the IOUs flagged as "do not contact." Cadmus added available additional contact information from the BGI database of multifamily owner and operator contacts. Cadmus prepared three lists for postcard outreach, email outreach, and phone outreach.

Cadmus consolidated the outreach lists as follows:

- First, Cadmus identified all meters with the same premise address (and within the same residential complex, to the extent possible) and kept only one meter with the same premise address and/or from the same residential complex. This was because only one survey was needed from each residential complex to confirm eligibility of at least one meter to recruit for the study.
- Second, Cadmus identified all meters associated with the same customer account mailing address or email address. These meters are referred to as siblings. Cadmus conducted outreach to customer contacts about all the siblings together in one postcard or email.

3.2.4 Sample Frame Preparation Attrition

Cadmus attempted to contact every meter by phone, except those marked as “do not call” by the IOUs. For meters with missing phone contacts in the IOU data, Cadmus recruiters referred to BGI contact data and conducted online searches for phone numbers. Attrition for outreach by phone to meters serving 50 or more dwelling units is presented in Table 13.

Table 13. Phone List Attrition for Meters serving 50 or more Dwelling Units by Utility and Age Strata

Attrition Reason	50+ Units								
	PG&E			SDG&E			SoCalGas		
	pre 1960	1960-1980	1980-1999	pre 1960	1960-1980	1980-1999	pre 1960	1960-1980	1980-1999
Original Population of Meters	153	746	527	12	488	304	245	1,767	1052
Removed Duplicates	153	746	527	12	478	294	245	1,767	1,052
Removed “Do not contact”	151	727	522	12	476	294	238	1,713	1,026
Removed Multiple Meters in a Complex	144	631	452	12	470	292	232	1,582	918
Totals	**1,227**			**774**			**2732**		

Table 14 and Table 15 show the attrition of the Cadmus pre-screened IOU lists in preparing the email and postcard sample frames. Attrition for meters serving 50+ dwelling units are shown separately, broken out by age strata.

Table 14. Email List Attrition for Meters Serving 50 or More Dwelling Units by Utility and Age Strata

Attrition Reason	50+ Units								
	PG&E			SDG&E			SoCalGas		
	pre 1960	1960-1980	1980-1999	pre 1960	1960-1980	1980-1999	pre 1960	1960-1980	1980-1999
Original Population of Meters	153	746	527	12	488	304	245	1,767	1,052
Removed Duplicates	153	746	527	12	478	294	245	1,767	1,052
Removed “Do Not Contact”	151	727	522	12	476	294	238	1,713	1,026
Removed Multiple Meters in a Complex	144	631	452	12	470	292	232	1,582	918
Removed Meters with No Email	45	245	187	11	322	229	167	1,001	616
Sampled meters with >10 Siblings in Email List	**40**	**181**	**134**	**11**	**307**	**214**	**155**	**850**	**513**
Totals	**355**			**532**			**1518**		

Table 15. Postcard List Attrition for Meters Serving 50 or More Dwelling Units by Utility and Age Strata

Attrition Reason	50+ Units								
	PG&E			SDG&E			SoCalGas		
	pre 1960	1960-1980	1980-1999	pre 1960	1960-1980	1980-1999	pre 1960	1960-1980	1980-1999
Original Population of Meters	153	746	527	12	488	304	245	1767	1,052
Removed Duplicates	153	746	527	12	478	294	245	1,767	1,052
Removed “Do not Contact”	151	727	522	12	476	294	238	1,713	1,026
Removed Multiple Meters in a Complex	144	631	452	12	470	292	232	1,582	918
Removed Meters with No Mailing Address	143	628	450	12	470	292	218	1,462	837
Removed Meters With >5 Siblings in Mailing List	**121**	**532**	**359**	**11**	**284**	**129**	**141**	**823**	**481**
Totals	**1,012**			**424**			**1,445**		

Cadmus later added customer meters serving 40 to 49 dwelling units to the study population but did not confirm building age for PG&E and SoCalGas as it had originally done for the meters serving 50+ dwelling units. Table 16 shows the attrition for the list of meters serving 40 to 49 dwelling units; this list was used to conduct email outreach to this group.

Table 16. Email Attrition for Meters Serving 40 to 49 Dwelling Units by Utility and Age Strata[1]

Disposition Reason	40 to 49 Units				
	PG&E	SDG&E			SoCalGas
	All Years	pre 1960	1960-1980	1980-1999	All Years
Original Population of Meters	375	10	124	68	1,611
Removed Duplicates	375	10	124	68	1,611
Removed "Do not Contact"	375	10	123	67	1,599
Removed Meters with No Email	130	10	123	67	805
Sampled Meters with >10 Siblings in Email List	**120**	**9**	**83**	**55**	**800**
Totals	**120**	**147**			**800**

[1] Data presented by age strata when available.

3.3 On-Site Data Collection Methods

Cadmus and BGI planned to observe—that is, collect—detailed boiler characteristics for the equipment behind 140 sampled meters. We used two frames of reference. Building(s) that the sampled meters served were referred to as sampled buildings. The residential complexes housing such buildings were referred to as sampled complexes.

If multiple boilers were behind a sampled meter, Cadmus observed all of the boilers. If the sampled building was served by multiple meters, Cadmus observed all boilers that served the sampled building. If other boilers were accessible during the same site visits—for example, other boilers in the same boiler room serving other unsampled buildings, Cadmus observed those boilers as well. Cadmus counted all other boilers at the complex and, if possible, obtained the age of the boilers. Cadmus did not consistently count pool heating boilers at each sampled residential complex, when they were not served by the sampled meter. Table 17 shows Cadmus' data collection approach for sampled and unsampled boilers.

Table 17. Cadmus Data Collection Approach for Sampled and Unsampled Boilers

	Residential Complex		
	Sampled Meter	Unsampled Meter(s)	
	Sampled Boiler(s)	Unsampled Boiler(s)	Unsampled Boiler(s)
	All	Accessible	Not Accessible
Observed	✓	✓	-
Counted	✓	✓	✓

The Study Team had expressed interest in collecting multifamily building characteristics during the site visits. Multifamily residential complexes often have multiple buildings of the same type. Therefore, Cadmus expanded its terminology to account for various building types. Buildings of the same age and construction type were considered to be the same building type.[11]

Cadmus and BGI collected detailed building characteristics for the sampled building types. Cadmus counted the other buildings in the sampled complex and obtained the age and number of dwelling units in each building from the site contact.

Table 18. Cadmus Data Collection Approach for Sampled Buildings or Building Types

	Residential Complex	
	Sampled Building or Building Types	Unsampled Building or Building Types
Observed	✓	-
Counted	✓	✓

The site visit data collection form used during site visits is provided in *Appendix G. On-Site Data Collection Form.*

3.4 Site Visit Data Analysis Methods

Cadmus organized the data collection into the following categories:

- **Site data.** Cadmus collected information on the site address and contact information.
- **Sampled building information.** Cadmus counted sampled and unsampled buildings and distinguished by type. For each sampled building type, Cadmus collected year of building construction, number of inhabitable floors, conditioned square footage, number of dwelling units, and the type of HVAC heating equipment if boilers were not used for space heating.
- **Unsampled building information.** For each unsampled building type, Cadmus collected the number of buildings, number of dwelling units, number of space heating/domestic hot water/combination boilers, year of construction, and year of manufacture of the boilers.
- **Boiler nameplate information.** Cadmus collected make and model information, the input and output capacity, date of manufacture, and efficiency information for boilers behind sampled meters, serving the sampled building, or those that were otherwise in the same location.
- **Boiler burner information.** Cadmus collected make and model information on the burners, where available. Cadmus also recorded the presence of combustion controls, including type of combustion control, if there was an oxygen trim system, and if the system uses flue gas recirculation. Lastly, Cadmus collected information on physical efficiency improvements, such as boiler economizers, if the blowers are controlled by VFDs, if the exhaust stack has automated flue dampers, and if the boiler has a premixing chamber.

[11] Cadmus considered construction type to be closely related to the number of stories. For example, buildings built around the same year and comprising five five-story buildings and five three-story buildings were documented as two building types. Cadmus treated physically separate structures as individual buildings. Buildings wrapped around or connected to a shared podium parking were counted as one.

- **Hot water/steam distribution.** Cadmus collected information on the total length of piping, the length of piping that was insulated, the type of insulation, and the thickness of the insulation. Cadmus also collected information on the number of pumps, the pump control method, the hot water temperature setpoint, and if there were automatic means of adjusting the temperature setpoint.
- **Boiler maintenance practices.** Cadmus collected information on the date of the last major repair, what the repair involved, and the schedule for regular maintenance.

Cadmus organized the boilers by these input capacities—units 300 kBtu/h or less, units between 300 kBtu/h and 2500 kBtu/h, or greater than 2500 kBtu/h. These units have different mandatory efficiency requirements according to 2019 Title 20 and Title 24 efficiency standard. Cadmus evaluated each boiler to be above code, at code, or below code on an individual basis based on efficiency level and mandatory code requirements, such as the presence of an automated flue damper or having automatic temperature controls. Cadmus evaluated other mandatory code requirements, such as piping insulation or distribution loop pump controls, on a site-level basis.

A list of mandatory Title 24 and Title 20 codes requirements that Cadmus evaluated is provided in *Appendix H. Water Heater Code* Requirements.

3.5 Population Estimation Methods

This section describes how Cadmus developed population estimates of multifamily complex and boiler system characteristics based on the data collected throughout the study.

3.5.1 Data

Cadmus used data collected during survey and site visits to calculate population estimates for the market assessment of boilers in IOU territories. As described in the *Customer Data Screening and Sampling Methods* section, the study population included IOU gas customer account meters that served 40 or more dwelling units in buildings built before 2001 with a central boiler.

In total, Cadmus used site visit data for 139 sampled meters and survey data for 282 meters to estimate the population characteristics for the market assessment.

3.5.2 Weighting and Estimation

Cadmus applied stratified sampling weights and estimation methods to observed complex, building, and boiler characteristics within IOU. Sampling weights were based on meter population and sample sizes and were applied to ensure the aggregate results across IOU and building age strata provided accurate and precise population level-boiler market characteristic estimates. The population estimates are presented in the *Summary of Market Assessment Results* and *Market Assessment Results* sections below.

Cadmus first estimated meter population sizes with each IOU and building-age strata by first approximating building ages based on meter/account activation dates. Cadmus confirmed building ages provided in the population data through the initial surveys (for meters identified as serving 50 or more dwelling units but did not continue this research for meters serving 40 to 49 dwelling units after the study criteria were updated). Cadmus also collected building age data from building owners and operators during site visits. We compared building ages in the survey and site visit data to our previous estimates based on meter data and found that the population data aligned with the survey and site visit data for majority of meters but differed for still differed for a subset of buildings included in the site visits, adding uncertainty to distribution of meters in the population across building-age strata and resulting in imprecise estimates of meters within these strata. Therefore, Cadmus did not consider building-age strata when estimating the population of boilers in the IOU territories.

In the surveys, Cadmus screened complexes by whether they were served by central gas-fired boilers serving more than one dwelling unit. Cadmus assumed the proportion of meters screened out of the survey represented the proportion of meters in the population data that were not part of complexes served by central gas-boilers serving multifamily units. We adjusted the meter population sizes accordingly, resulting in more accurate population counts in each IOU territory. We used these meter population sizes to estimate the population of boilers in the IOU territories.

3.6 Technical Potential Analysis Methods

Cadmus conducted a limited technical potential analysis focused on gas boiler efficiency upgrades, add-on retrofits, and maintenance. Cadmus used the site visit data to calculate the portion of multifamily buildings with under-code, to-code, and above-code boilers in the sample of multifamily meters then used population weighting factors to estimate the proportions in IOU territories. Cadmus used the statewide population results to calculate estimates of technical potential.

Table 19 shows boiler efficiency upgrade measures for which Cadmus estimated technical potential.

Table 19. Multifamily Energy Efficiency Measures

Measure Type	Measure
Boiler Equipment	T24 Code Efficiency Hot Water Boiler, 82% AFUE
	High Efficiency Boiler, AFUE 90%
	Premium Efficiency Boiler, AFUE 94%
	Advanced Efficiency Boiler, AFUE 95+%
Boiler Retrofit	Circulation Pump Demand-Control
	Boiler Pipe Insulation - to Code (Uninsulated Pipe)
	Boiler Pipe Insulation - to Code (Low Thickness Insulation Pipe)
	Boiler Pipe Insulation - Above Code
	Automated Flue Damper
	Boiler Improvements – Economizer
	Boiler Improvements - Tune-up

3.6.1 Technical Potential Approach

Technical potential represents the amount of energy savings that would be possible for all technically applicable opportunities regardless of economic or market constraints. Cadmus developed a 20-year savings projection (2020 through 2039) of the number of units that could feasibly be installed for each permutation of each energy efficiency measure researched. As noted in Table 19, two types of measures were evaluated—boiler equipment and boiler retrofit measures.

- ***Equipment measures*** would be installed when the equipment it replaces has failed or otherwise reached the end of its effective useful life (EUL).[12]
- ***Retrofit measures*** are installed to improve the performance of existing equipment (e.g., boiler controls) and can theoretically be completed any time. Unlike equipment measures, the timing of retrofit savings is not determined by equipment EUL. For the proposes of this study, we assumed all retrofit measures would be installed over a 10-year period.

To determine measure-specific technical potential, five factors were considered:

- ***Multifamily unit forecasts*** are estimates of the number of multifamily master or common area meters with a central boiler or water heater in IOU territories. Cadmus estimated the market population (described in the *Population Estimation* section) based on the IOU gas customer data provided to Cadmus.
- ***Measure saturations (units per building)*** are estimates of the number of central boiler or water heater units per multifamily meter in IOU territories. Cadmus calculated this saturation by extrapolating the site visit data to the population of meters in IOU territories.
- ***Applicability factors (technical feasibility percentage and measure competition share)*** are the percentage of meters that can feasibly receive the measure and the percentage of eligible installations, after accounting for competition with similar measures. Cadmus calculated this factor by extrapolating its observations during site visits to the population of meters in the IOU territories.
- ***Turnover rates (for equipment measures)*** are used to determine the percentage of units that can be installed in each year for equipment measures. The turnover rate equals 1 divided by the measure EUL. We assumed a 20-year EUL for boilers based on the California Database of Energy Efficiency Resources (DEER). As a result, a turnover rate of 5% (one-twentieth) of all boilers will be replaced each year.[13]
- ***Turnover rates (for retrofit measures)*** are used to determine the percentage of units that can be installed in each year for retrofit measures. For this study, we assume all retrofit measures can be installed in the first 10 years of the 20-year time horizon.
- ***Unit energy savings*** are a conservation measure's annual per-unit therm savings. Cadmus relied on UES values from DEER, U.S. Department of Energy reports, California utility workpapers and tools, and Cadmus research.

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12 The technical potential analysis treated boiler all equipment as replacement (e.g., this study does not calculate early replacement impacts since older boilers can be maintained longer than the EUL).

13 Though older boilers can be maintained longer than the EUL, the technical potential analysis estimated the potential savings over a 20-year period if all inefficient equipment would be replaced.

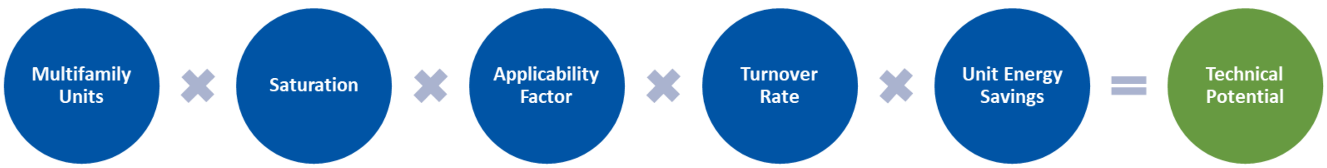
Table 20 shows the sources used to develop the factors listed above.

Table 20. Technical Potential Components and Data Sources

Component	Data Source
Population of Study-eligible Meters	PG&E, SoCalGas, and SDG&E multifamily gas customer data as screened by Cadmus
Saturation of Equipment	Site visit data extrapolated to the population
Applicability Factor	Site visit data extrapolated to the population
Turnover Rate	Informed by EULs (DEER or T24 Stakeholder documents)
Unit Energy Savings	DEER, California workpapers and tools, U.S. Department of Energy, Lawrence Berkeley National Laboratory (LBNL), and Cadmus research

Figure 3 illustrates the general equation we used to estimate the number of units for each measure and the technical potential over the study horizon.

Figure 3. Technical Potential Equation



Appendix I. Technical Potential Calculation Inputs includes further details on the inputs used for technical potential calculations.

3.6.2 Economic and Market Potential

Estimates of economic and market potential are not included because this study included funding only for the technical study. A future phase of this research may include activities to calculate the expected market potential--with and without barriers--for energy-efficient boilers in multifamily buildings.

A market potential study conducted in the future will benefit from additional in-depth interviews and choice-based surveys with building owners and operators about their decision-making process and challenges faced upgrading boilers.

4 Data Collection Results

Cadmus and BGI completed 143 site visits and collected data for 139 residential complexes with eligible meters. Four site visits did not include any eligible meters and were therefore excluded from the analysis and results presented in this report.

The project research plan did not contain a target number of recruitment and screening surveys. Cadmus anticipated 700 surveys, using three modes of outreach, would be needed to complete 140 site visits. However, as shown in Table 21, Cadmus was able to complete 139 eligible site visits with 282 surveys. The most successful mode of outreach and recruitment was by phone. *Appendix F. Phone and Email Outreach* Dispositions provides disposition from phone and email outreach efforts.

Table 21. Targeted and Completed Site Visit Sample Size

Utility	Sample Allocation (%)	Sample Allocation	Building Age	Target Site Visit Sample Size	Completed Phone and Online Surveys	Completed Site Visits
PG&E	45%	63	1960 and before	7	23	8
			1961 - 1980	33	73	35
			1981 - 2000	23	49	19
SoCalGas	43%	60	1960 and before	5	8	4
			1961 - 1980	34	64	35
			1981 - 2000	21	32	21
SDG&E	12%	17	Before 1981	11	21	13
			1981 - 2000	6	12	4
Total	**100%**	**140**		**140**	**282**	**139**

Cadmus and BGI visited 23 sites with 40 to 49 dwelling units associated with the sampled meter, and 116 sites with 50+ units associated with the sampled meter (Table 22).

Table 22. Number of Site Visits Completed for Meters Serving 50+ and 40-49 Dwelling Units

Utility	Meter Serving 40-49 Units	Meter Serving 50+ Units
PG&E	8	54
SoCalGas	14	46
SDG&E	1	16
Total	**23**	**116**

Cadmus and BGI completed site visits in 12 climate zones in California (Table 23).

Table 23. Number of Unique Climate Zones Visited in Each IOU Territory

Utility	Number of Unique Climate Zones Visited	Climate Zones Visited
PG&E	6	2, 3, 4, 11, 12, 13
SoCalGas	4	6, 8, 9, 10
SDG&E	2	7, 10
Total	**12**	

4.1 Sampled Meter Data Collection Results

This section describes Cadmus' findings for sampled meters and the boilers served by sampled meters. The next section, Unsampled Meter Data Collection Results, describes our findings for meters that were not sampled but were at the same site as sampled meters. Cadmus counted and/or observed boilers and buildings served by unsampled meters during its site visits. We combined data from sampled and unsampled meters to estimate population characteristics for the market assessment in the Market Assessment Results section, which is where we provide population estimates and associated confidence and precision.

4.1.1 Boiler Counts

Cadmus collected information on a total of 311 dedicated domestic hot water (DHW) boilers, 24 space heating only, eight combined space heating and DHW boilers, and 24 pool heaters behind 139 sampled meters. Table 24 shows the total number of boilers behind the sampled meters, by equipment type. Cadmus observed 367 boilers behind the 139 sampled meters, or 2.6 boilers per sampled meter. We observed over five times as many dedicated DHW boilers than the other types of boilers combined.

Table 24. Boiler Counts Behind Sampled Meters (n=139)

IOU	Building Age	Sampled Meters	Total Boiler Quantities (Equipment Behind Sampled Meters)			
			Dedicated DHW	Space Heating Only	Combined Heating & DHW	Pool Heating
PG&E	1960 and before	8	14	2	-	-
	1961 - 1980	35	58	7	1	4
	1981 - 2000	19	57	-	2	1
SoCalGas	1960 and before	4	6	1	-	-
	1961 - 1980	35	65	3	4	10
	1981 - 2000	21	40	4	-	2
SDG&E	1980 and before	13	61	7	1	7
	1981 - 2000	4	10	-	-	-
Totals(1)		**139**	**311**	**24**	**8**	**24**

(1) The sum of boilers is greater than the number of meters because some meters served multiple boilers.

Table 25 separates the dedicated DHW boiler totals into three categories: stand-alone tank, sidearm, and tankless boilers. These counts exclude the other types of boilers and thus are based on 131 meters rather than the total 139 in the sample. Cadmus observed more stand-alone tank boilers than either sidearm or tankless boilers. However, the number of sampled meters serving sidearm (n=66) and stand-alone tanks (n=61) were similar. Very few sampled meters served tankless DHW boilers. The counts of sampled meters serving each type of equipment are shown below in Table 27.

Table 25. Dedicated DHW Boiler Counts Behind Sampled Meters (n=131)

IOU	Building Age	Sampled Meters Serving Dedicated DHW Heaters	Total Dedicated DHW Boiler Quantities (Equipment Behind Sampled Meters)		
			Stand-Alone Tank	Sidearm	Tankless
PG&E	1960 and before	8	8	6	0
	1961 - 1980	34	31	25	2
	1981 - 2000	18	31	6	20
SoCalGas	1960 and before	3	6	0	0
	1961 - 1980	32	33	32	0
	1981 - 2000	20	2	28	10
SDG&E	1980 and before	12	55	2	4
	1981 - 2000	4	10	0	0
Totals(1)		**131**	**176**	**99**	**36**

(1) The sum of boilers is greater than the number of meters because some meters served multiple boilers.

4.1.2 Sampled Meter Counts

Table 26 shows the total number of sampled meters serving boilers of each type. Almost all of the sampled meters served dedicated DHW boilers (131 of 139). Only 18 of 139 meters served either central space heating only or combined space heating and DHW boilers—one meter served a space heating only boiler and combined space heating and DHW boiler and so appears in both columns. Only 15 of 139 sampled meters served pool heating boilers.

Eight of 139 sampled meters did not serve any dedicated DHW boilers. Six of these served combined space heating and DHW boilers. One served a space heating boiler only (with the DHW boilers on a separate meter at the same site), and the other meter was at a site that utilized gas-fired space heating boilers for space heating and small individual electric water heaters (one per unit).

Table 26. Sampled Meters Serving Each Boiler Type (n=139)

IOU	Building Age	Sampled Meters	Meter Count			
			Dedicated DHW	Space Heating Only	Combined Heating & DHW	Pool Heating
PG&E	1960 and before	8	8	2	-	-
	1961 - 1980	35	34	3	1	4
	1981 - 2000	19	18	-	1	1
SoCalGas	1960 and before	4	3	1	-	-
	1961 - 1980	35	32	2	3	6
	1981 - 2000	21	20	2	-	1
SDG&E	1980 and before	13	12	3	1	3
	1981 - 2000	4	4	-	-	-
Totals(1)		**139**	**131**	**13**	**6**	**15**

(1) The sum of meter counts can exceed the total number of meters because some meters served multiple types of equipment.

Table 27 shows the sampled meters serving each type of dedicated DHW boiler described above.

Table 27. Sampled Meters Serving Dedicated DHW Boiler Configurations (n=131)

IOU	Building Age	Meter Count		
		Stand-Alone Tank	Sidearm	Tankless
PG&E	1960 and before	3	5	-
	1961 - 1980	14	19	1
	1981 - 2000	11	5	2
SoCalGas	1960 and before	3	-	-
	1961 - 1980	15	18	-
	1981 - 2000	1	18	1
SDG&E	1980 and before	10	1	2
	1981 - 2000	4	-	-
Totals		**61**	**66**	**6**

(1) The sum of meter counts can exceed the total number of meters because some meters served multiple types of equipment.

4.1.3 Average Boiler Counts Per Sampled Meter

Table 28 shows the average number of boilers behind sampled meters, calculated by dividing boiler counts in Table 24 by the number of sampled meters in each IOU and building age stratum in the same table. These results indicate that in future research, each sampled meter can be expected to serve 2.2 dedicated DHW boilers, 0.2 space heating only boilers, 0.1 combined space heating and DHW boilers, and 0.2 pool heating boilers, on average.

Table 28. Average Boiler Counts Behind Sampled Meters (n=139)

IOU	Building Age	Average Number of Boilers Per Sampled Meter			
		Dedicated DHW	Space Heating Only	Combined Space Heating & DHW	Pool Heating
PG&E	1960 and before	1.8	0.3	-	-
	1961 - 1980	1.7*	0.2	0.0	0.1
	1981 - 2000	3.0	-	0.1	0.1
SoCalGas	1960 and before	1.5	0.3	-	-
	1961 - 1980	1.9	0.1	0.1	0.3
	1981 - 2000	1.9	0.2	-	0.1
SDG&E	1980 and before	4.7	0.5	0.1	0.5
	1981 - 2000	2.5	-	-	-
Overall Average		**2.2***	**0.2**	**0.1**	**0.2**

(1) Cadmus indicated the precision of each estimate at a 90% confidence level using the following asterisks: *** for ±5% precision or better, ** for ±5.1-10% precision, * for ±10.1-15% precision, and no label when precision was over ±15%.
(2) Cadmus was unable to determine an estimate's precision because there was no variability between units (including when only one unit was observed).

In Table 29, Cadmus calculated the average number of boilers behind each meter by dividing boiler counts (Table 24) by the number of meters serving each equipment type (in Table 26). These results indicate that in PG&E territory, for example, there was typically one pool heater behind each sampled meter when pool heaters were present, whereas in SoCalGas and SDG&E territories, 1.7 to 2.3 pool heaters were served by each sampled meter. While the preceding result provides insight into the equipment served by the average meter, this result provides additional detail in the event that sites with each equipment type (e.g., pool heaters) can be identified in advance of sampling meters.

Table 29. Average Boiler Counts Behind Sampled Meters (Equipment Served) (n=139)

IOU	Building Age	Average Boiler Quantities			
		Dedicated DHW	Space Heating Only	Combined Space Heating & DHW	Pool Heating
PG&E	1960 and before	1.8	1.0(2)	-	-
	1961 - 1980	1.7*	2.3	1.0(2)	1.0(2)
	1981 - 2000	3.2	-	2.0(2)	1.0(2)
SoCalGas	1960 and before	2.0(1)	1.0(2)	-	-
	1961 - 1980	2.0*	1.5	1.3	1.7
	1981 - 2000	2.0	2.0(2)	-	2.0(2)
SDG&E	1980 and before	5.1	2.3	1.0(2)	2.3
	1981 - 2000	2.5	-	-	-
Overall Average		**2.4***	**1.8***	**1.3**	**1.6**

(1) Cadmus indicated the precision of each estimate at a 90% confidence level using the following asterisks: *** for ±5% precision or better, ** for ±5.1-10% precision, * for ±10.1-15% precision, and no label when precision was over ±15%.
(2) Cadmus was unable to determine an estimate's precision because there was no variability between units (including when only one unit was observed).

Table 30 shows the average number of dedicated DHW boilers across all sampled meters by dividing the number of each dedicated DHW boiler configuration (Table 25) by the number of meters serving any dedicated DHW configuration in the same table.

Table 30. Average Dedicated DHW Boilers Behind Sampled Meters (n=131)

IOU	Building Age	Average Dedicated DHW Boiler Quantities		
		Stand-Alone Tank	Sidearm	Tankless
PG&E	1960 and before	1.0	0.8	0.0(2)
	1961 - 1980	0.9	0.7	0.1
	1981 - 2000	1.7	0.3	1.1
SoCalGas	1960 and before	2.0(2)	0.0(2)	0.0(2)
	1961 - 1980	1.0	1.0	0.0(2)
	1981 - 2000	0.1	1.4	0.5
SDG&E	1980 and before	4.6	0.2	0.3
	1981 - 2000	2.5	0.0(2)	0.0(2)
Totals		**1.3**	**0.8**	**0.3**

(1) Cadmus indicated the precision of each estimate at a 90% confidence level using the following asterisks: *** for ±5% precision or better, ** for ±5.1-10% precision, * for ±10.1-15% precision, and no label when precision was over ±15%.
(2) Cadmus was unable to determine an estimate's precision because there was no variability between units (including when only one unit was observed).

Table 31 shows the average number of boilers for each site, given the number of meters serving each configuration.

Table 31. Average Dedicated DHW Boilers Behind Sampled Meters (Equipment Served) (n=131)

IOU	Building Age	Average Dedicated DHW Boiler Quantities		
		Stand-Alone Tank	Sidearm	Tankless
PG&E	1960 and before	2.7	1.2	-
	1961 - 1980	2.2	1.3	2.0(2)
	1981 - 2000	2.8	1.2	10.0
SoCalGas	1960 and before	2.0(2)	-	-
	1961 - 1980	2.2*	1.8	-
	1981 - 2000	2.0(2)	1.6	10.0(2)
SDG&E	1980 and before	5.5	2.0(2)	2.0
	1981 - 2000	2.5	-	-
Totals		**2.9**	**1.5****	**6.0**

(1) Cadmus indicated the precision of each estimate at a 90% confidence level using the following asterisks: *** for ±5% precision or better, ** for ±5.1-10% precision, * for ±10.1-15% precision, and no label when precision was over ±15%.
(2) Cadmus was unable to determine an estimate's precision because there was no variability between units (including when only one unit was observed).

4.1.4 Boiler Age

Table 32 shows the average boiler age within IOU and building age strata. Cadmus calculated boiler ages based on the year they were manufactured. On average, space heating boilers and sidearm DHW boilers were older than other boilers–possibly because these types of equipment are larger and thus more expensive to replace. Tankless boilers had the lowest average age, likely because they have only recently become more widely used.

Cadmus expected to find older boilers in older buildings. However, Cadmus did not find significant differences between boiler ages in buildings of different ages. For example, in PG&E territory, average boiler ages in older buildings were lower than boiler ages in younger buildings. We hypothesized that this could be because older equipment had previously been replaced due to age, burn-out, and/or accelerated replacement through program participation. However, based on the data collected on site, only 14 of multifamily building contacts responded that they had previously participated in a program.[14]

[14] During early conversations, the Study Team suspected most boilers in large multifamily buildings have already been touched by IOU program efforts and therefore would have limited potential for upgrade and retrofit. In its response to our data request, SoCalGas provided three years of Multifamily Energy Efficiency Rebate (MFEER) Program and Multifamily Upgrade Program (MUP) participation data with measure names for during 2015, 2016, 2017. In its review, Cadmus found a very small cohort of past program participants (2%) among the Cadmus-screened large multifamily master or common area accounts.

Within this subsample, there was no correlation between program participation and boiler age— on average, it was the same among previous program participants and nonparticipants. In older buildings (built 1980 or before), the average age of boilers was lower for sites that previously participated. One of these sites indicated that they received a rebate for replacing their boilers.

Table 32. Average Boiler Age of Boilers Behind Sampled Meters (n=139)(1)

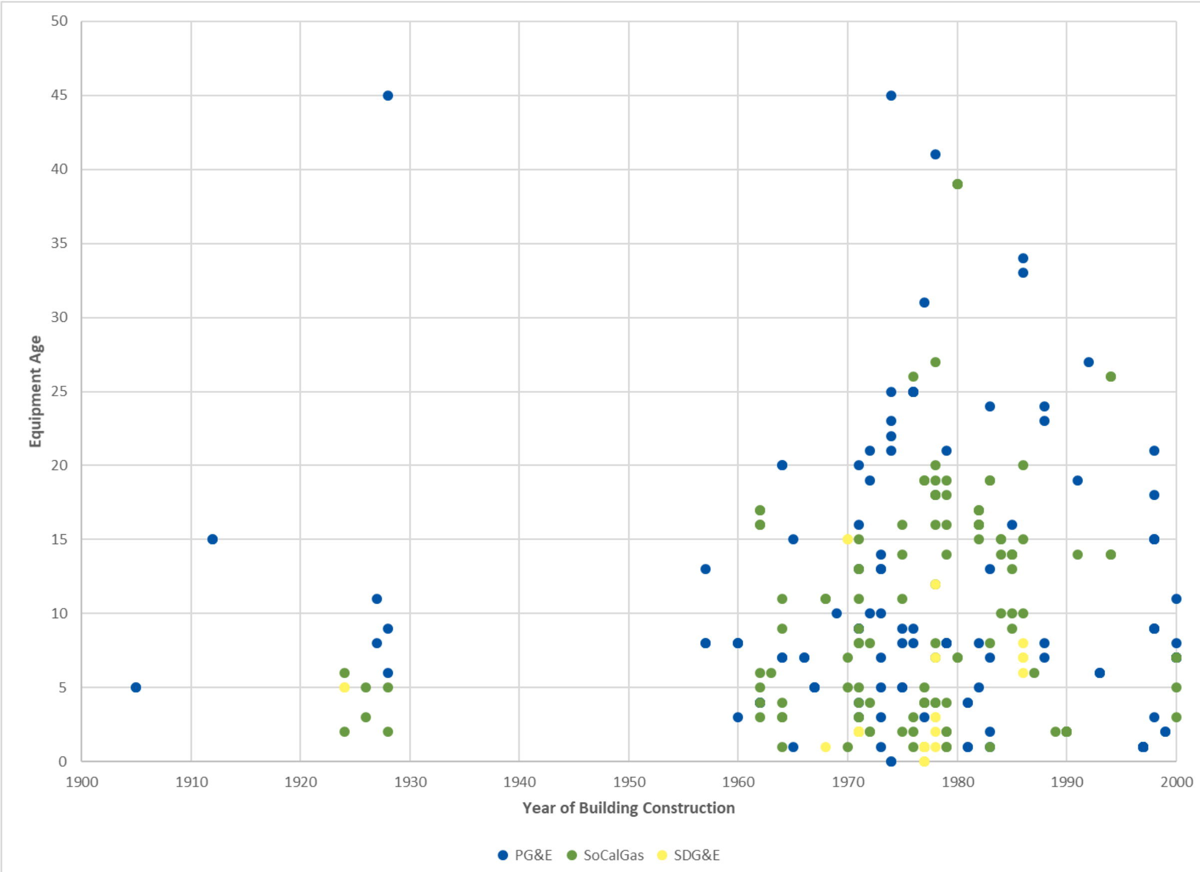
IOU	Building Age	Average Boiler Age (Years)						
		Heating Boilers			Dedicated DHW Boilers			All End Uses
		Space Heating Only	Combined Space Heating & DHW	Pool Heating	Stand-Alone Tank	Sidearm	Tankless	
PG&E	1960 and before	10.0*	-	-	6.6**	17.0	-	10.9**
	1961 - 1980	16.5	-	11.0	7.9***	18.8***	8.0(2)	12.3***
	1981 - 2000	-	-	-	10.0***	19.0	3.4**	8.6***
SoCalGas	1960 and before	-	-	-	3.8*	-	-	3.8*
	1961 - 1980	27.7	9.0*	6.8	6.1***	14.4***	-	10.4***
	1981 - 2000	12.0	-	4.0	4.5	14.6***	2.0(2)	10.7***
SDG&E	1980 and before	0.0(3)	-	-	2.2***	15.0(2)	-	2.6***
	1981 - 2000	-	-	-	7.0***	-	-	7.0***
Overall Average		**10.4**			**9.1**			**9.2*** **
Average by Boiler Type		**13.6**	**9.0***	**7.3**	**6.2*** *	**15.9*** *	**3.3*** **	

(1) Cadmus indicated the precision of each estimate at a 90% confidence level using the following asterisks: *** for ±5% precision or better, ** for ±5.1-10% precision, * for ±10.1-15% precision, and no label when precision was over ±15%.
(2) Cadmus was unable to determine an estimate's precision because there was no variability between units (including when only one unit was observed).
(3) Cadmus observed one boiler manufactured in 2019.

Figure 4 shows the boiler age distribution based on the year of the building's construction. While there was no apparent correlation between building age and boiler age, a few buildings constructed between 1970 and 1990 had the oldest boilers. The majority of the buildings constructed before 1970 have already replaced their original boiler.

PG&E's response to Cadmus' request for the MFEER program and MUP participation data lacked measure names. Therefore, Cadmus could not determine how many large multifamily common area or master meters have installed a boiler measure in the past three years (PG&E later stated it did not have measure names to provide).

Figure 4. Boiler Age by Year of Building Construction for Equipment Behind Sampled Meters



4.1.5 Input Capacity

Table 33 shows the average input capacity for boiler behind sampled meters. As shown here, the boilers which provide space heating are larger on average than the pool heating and dedicated DHW boilers.

The average total input capacity per sampled meter is shown in Table 34. Average total input capacity of space heating only and combined space heating and DHW boilers were clearly larger than the other boiler types. While the average input capacity of the pool heating boilers was about 73% of the dedicated DHW boiler capacity in the previous table, each meter included more than one DHW boiler on average (shown in Table 28). Therefore, the total DHW capacity per meter was more than twice the average total capacity of the pool heating boiler.

Table 33. Average Input Capacity (kBtu/h) for Equipment Behind the Sampled Meters (n=139)(1)

IOU	Building Age	Average Boiler Capacity (kBtu/h)					
		Heating Boilers			Dedicated DHW Boilers		
		Space Heating Only	Combined Space Heating & DHW	Pool Heating	Stand-Alone Tank	Sidearm	Tankless
PG&E	1960 and before	1,077	-	-	217***	732*	-
	1961 - 1980	1,600**	-	314**	291***	694***	800(2)
	1981 - 2000	-	1,000(2)	-	239***	764*	199(2)
SoCalGas	1960 and before	1,500	-	-	268***	-	-
	1961 - 1980	904	1,275	269**	251***	640***	-
	1981 - 2000	1,900***	-	299	260***	820***	200(2)
SDG&E	1980 and before	843	926	335	223**	300(2)	1,049
	1981 - 2000	-	-	-	328***	-	-
Overall Average		**893**			**405**		
Average by Boiler Type		**1,294***	**1,147**	**292***	**250*****	**711****	**327****

(1) Cadmus indicated the precision of each estimate at a 90% confidence level using the following asterisks: *** for ±5% precision or better, ** for ±5.1-10% precision, * for ±10.1-15% precision, and no label when precision was over ±15%.
(2) Cadmus was unable to determine an estimate's precision because there was no variability between units (including when only one unit was observed).

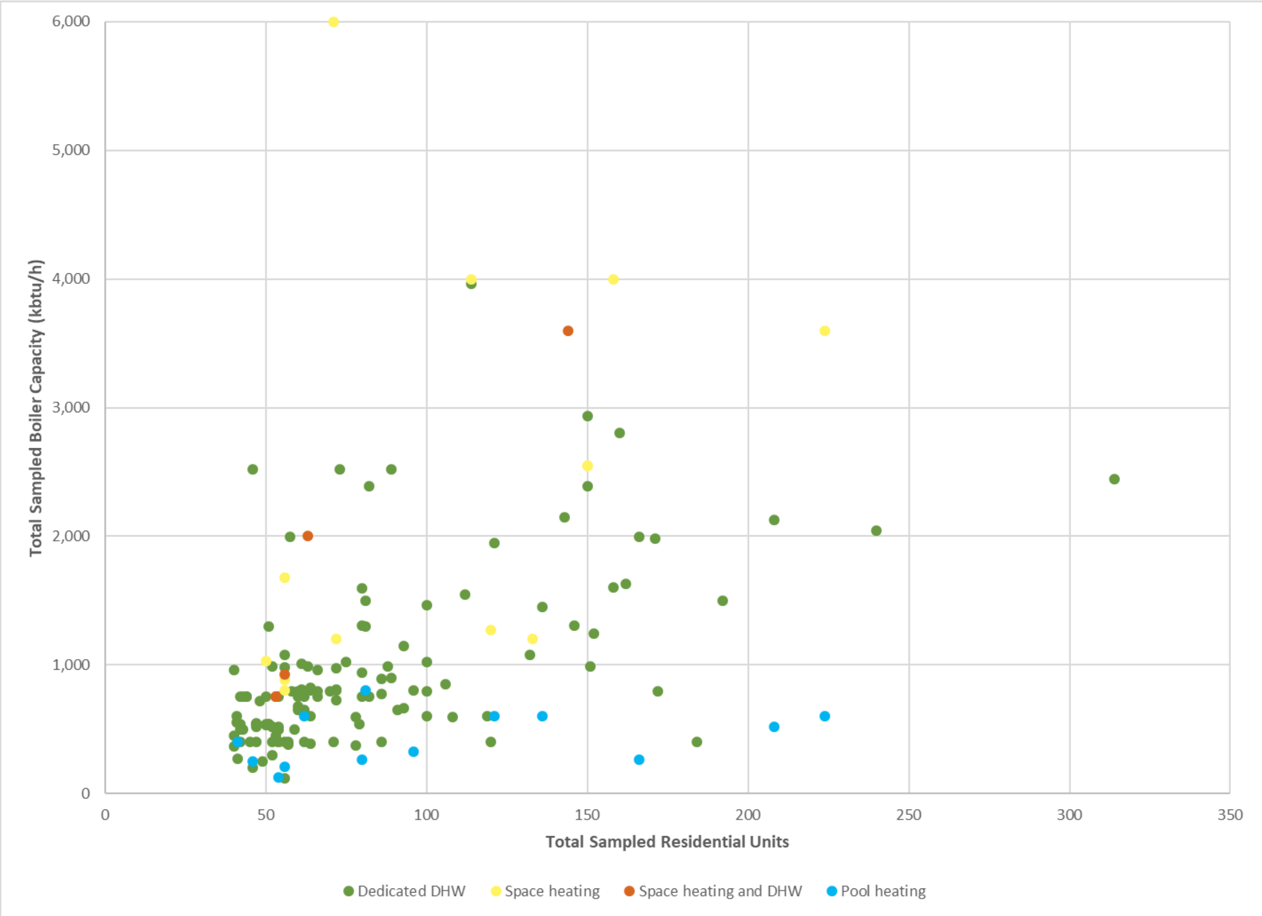
Table 34. Average Total Input Capacity (kBtu/h) per Sampled Meter (n=138)(1)(2)

IOU	Building Age	Average Total Input Capacity (kBtu/h)			
		Dedicated DHW	Space Heating Only	Combined Space Heating & DHW	Pool Heating
PG&E	1960 and before	766	1,077	-	-
	1961 - 1980	827**	3,733	-	314
	1981 - 2000	887	-	2,000(3)	-
SoCalGas	1960 and before	535***	1,500(3)	-	-
	1961 - 1980	871	1,356	1,700	448
	1981 - 2000	1,275	3,799**	-	599
SDG&E	1980 and before	1,420	1,967	926(3)	503
	1981 - 2000	820	-	-	-
Overall Average		**962****	**2,389**	**1,605**	**427**

(1) This excludes one meter that included both a combined space heating & DHW and a space heating only boiler, because the total capacity for space heating would be different had there not been a combined boiler. Including that meter would skew the space heating boiler total capacity averages.
(2) Cadmus indicated the precision of each estimate at a 90% confidence level using the following asterisks: *** for ±5% precision or better, ** for ±5.1-10% precision, * for ±10.1-15% precision, and no label when precision was over ±15%.
(3) Cadmus was unable to determine an estimate's precision because there was no variability between units (including when only one unit was observed).

Figure 5 shows total input capacity of boilers per dwelling unit served. As expected, pool heating capacity does not increase with the number of dwelling units served. However, the increase in capacity by the increase in the number of dwelling units served is clear for the dedicated DHW and the space heating boilers. Most boilers surveyed served 40 to 100 units (the meter eligibility criteria was 40 or more served by a meter) with less than 2000 kBtu/h input capacity.

Figure 5. Total Input Capacity of Boilers per Dwelling Unit Served



4.1.6 Boiler Average Rated Efficiency

The average rated thermal efficiency of boilers is provided in Table 35. Overall, pool heating boilers had the lowest rated average efficiency. Dedicated DHW boilers were more efficient on average than space heating boilers. This is due, at least in part, to the average age of the boilers. As shown previously in Table 32, heating boilers were on average older than dedicated DHW boilers. The space heating boilers are generally of higher input capacity, therefore larger and more expensive to replace.

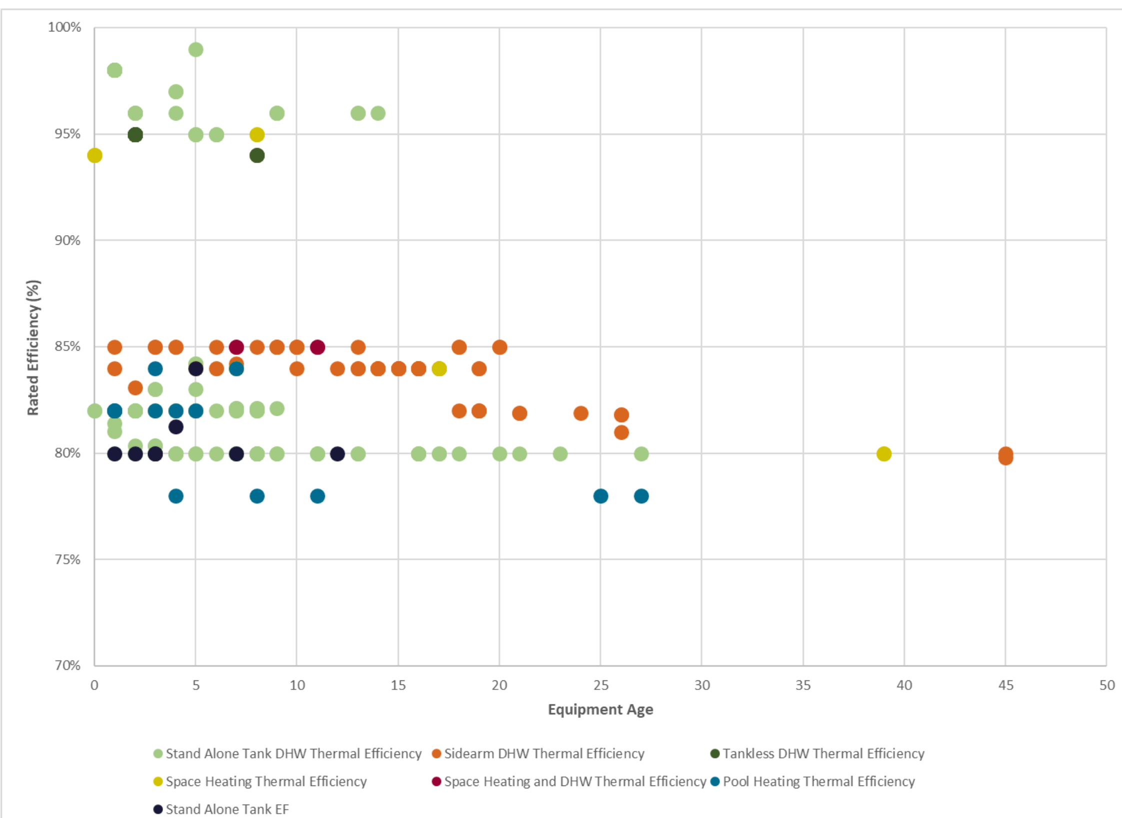
Table 35. Average Rated Thermal Efficiency for Equipment Behind Sampled Meters (n=110) [(1)(2)]

IOU	Building Age	Average Thermal Efficiency				
		Dedicated DHW	Space Heating Only	Combined Space Heating & DHW	Pool Heating	All End Uses
PG&E	1960 and before	86%	81%	-	-	86%
	1961 - 1980	86%*	89%	-	81%	86%**
	1981 - 2000	84%*	-	-	-	84%*
SoCalGas	1960 and before	81%	-	-	-	81%
	1961 - 1980	83%**	81%	85%	81%	82%**
	1981 - 2000	87%*	84%	-	82%	86%**
SDG&E	1980 and before	93%**	83%	82%	84%	91%**
	1981 - 2000	80%	-	-	-	80%
Overall Average		**86%****	**84%**	**84%**	**81%**	**86%***

(1) Cadmus indicated the precision of each estimate at a 90% confidence level using the following asterisks: *** for ±5% precision or better, ** for ±5.1-10% precision, * for ±10.1-15% precision, and no label when precision was over ±15%.
(2) The total number of meters included is less than 139 because Cadmus could not determine the thermal efficiency of boilers in some sites or found the efficiency expressed in a metric other than thermal efficiency.

Figure 6 shows the rated efficiency distribution based on the boiler age and type. Cadmus found ten stand-alone tank DHW, one tankless DHW, and one space heating boilers that were highly efficient (with thermal efficiency of 95% or more).

Figure 6. Boiler Efficiency and Age for Equipment Behind Sampled Meters



In several cases, the boiler nameplates did not include rated efficiency data but provided rated input and output capacities. In these cases, we calculated the efficiency as the rated output capacity divided by the rated input capacity. Additionally, there were boiler nameplates included the rated Energy Factor (EF), Uniform Energy Factor (UEF), or Annual Fuel Utilization Efficiency (AFUE) metrics instead of rated Thermal Efficiency. Table 36 below provides the overall average efficiencies based on all rated or calculated efficiency information.

Table 36. Average Rated or Calculated Efficiency for Equipment Behind Sampled Meters (n=130)(1)(3)

IOU	Building Age	Average Efficiency (Combined Metrics)				
		Dedicated DHW	Space Heating Only	Combined Space Heating & DHW	Pool Heating	All End Uses
PG&E	1960 and before	86%	81%	-	-	85%
	1961 - 1980	85%**	87%	-	81%	85%**
	1981 - 2000	87%**	-	85%	-	87%**
SoCalGas	1960 and before	81%	80%	-	-	81%
	1961 - 1980	83%**	81%	85%	81%	82%**
	1981 - 2000	87%*	84%	-	82%	86%**
SDG&E	1980 and before	89%**	83%	82%	84%	88%**
	1981 - 2000	81%	-	-	-	81%
Overall Average		**86%***	**84%**	**85%**	**81%**	**85%***

(1) Cadmus indicated the precision of each estimate at a 90% confidence level using the following asterisks: *** for ±5% precision or better, ** for ±5.1-10% precision, * for ±10.1-15% precision, and no label when precision was over ±15%.
(2) Total number of meters included is less than 139 because Cadmus could not determine the efficiency of boilers in nine sites.
(3) Cadmus did not differentiate between thermal and other efficiency metrics, and results across all efficiencies are compiled in this table.

4.1.7 Above, Below, and To-Code Boilers

Table 37 shows the number of above-code, to-code, and below-code boilers on sampled meters by utility. Figure 7 shows the number of above-code, to-code, and below-code boilers on sampled meters by utility for boilers with an input capacity less than or equal to 300 kBtu/h. Figure 8 shows the number of to-code, above-code, and below-code boilers on sampled meters by utility for boilers with an input capacity of more than 300 to 2500 kBtu/h. Cadmus did not find boilers greater than 2500 kBtu/h. As stated previously, Cadmus assessed code compliance based on mandatory requirements in 2019 Title 20 and Title 24. Therefore, below-code boilers may have been to- or above-code when originally installed.

These tables and figures show that for every territory there were more boilers above-code and to-code than below-code. Boilers above 300 kBtu/h had a higher rate of being above-code than boilers below 300 kBtu/h. Some boilers have values listed as could not determine (CND); for these boilers, generally the nameplate was either not present, illegible, or did not list relevant information.

Table 37. Above-Code, To-Code, and Below-Code Boilers for Equipment Behind Sampled Meters (n=139)

Utility	Building Age	Input Capacity Range							
		≤300 kBtu/h				300 kBtu/h - 2500 kBtu/h			
		Above Code	At Code	Below Code	CND	Above Code	At Code	Below Code	CND
PG&E	1960 and before	4	4	-	-	5	-	1	-
	1961 - 1980	14	3	10	1	26	6	1	6
	1981 - 2000	29	4	13	3	4	5	-	1
SoCalGas	1960 and before	2	1	3	-	-	-	-	-
	1961 – 1980	5	18	14	2	33	2	1	5
	1981 - 2000	11	1	1	-	28	-	-	5
SDG&E	1980 and before	35	-	13	2	16	3	2	1
	1981 - 2000	-	-	6	-	4	-	-	-
Totals		**100**	**31**	**60**	**8**	**116**	**16**	**5**	**18**

Figure 7. Above-Code, To-Code, and Below-Code for Boilers with Less than 300 kBtu/h Input Capacity (n=139)

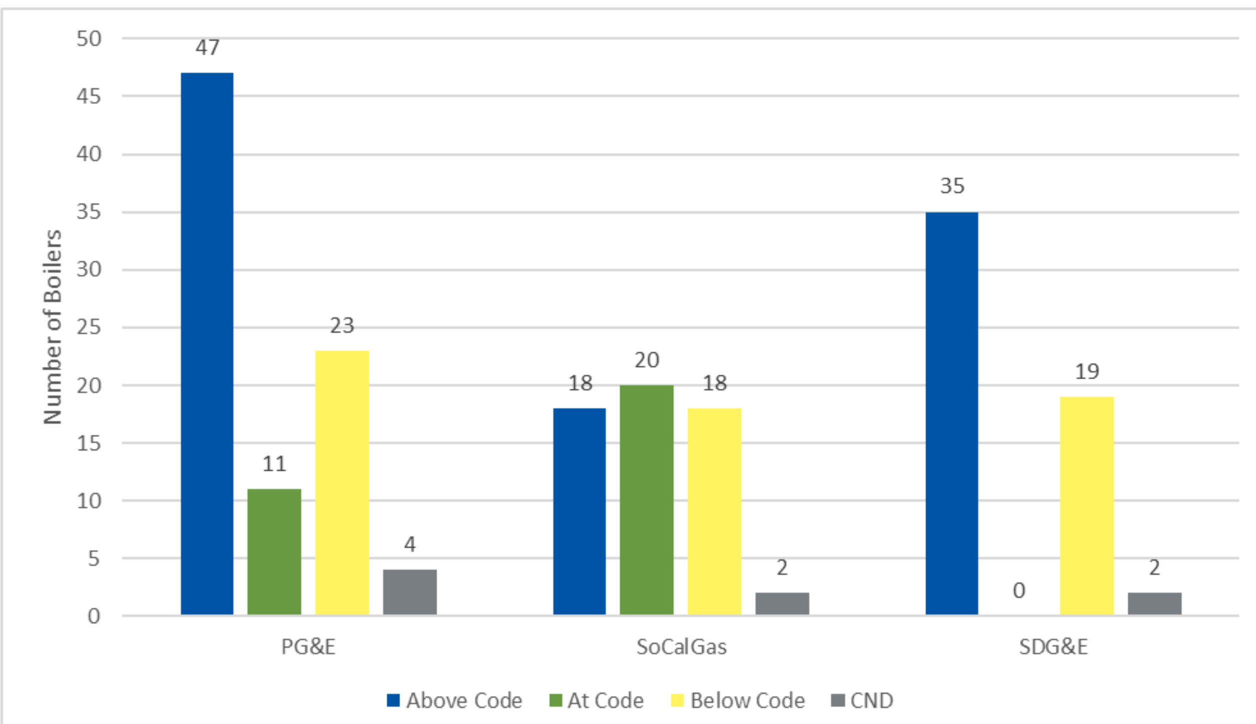
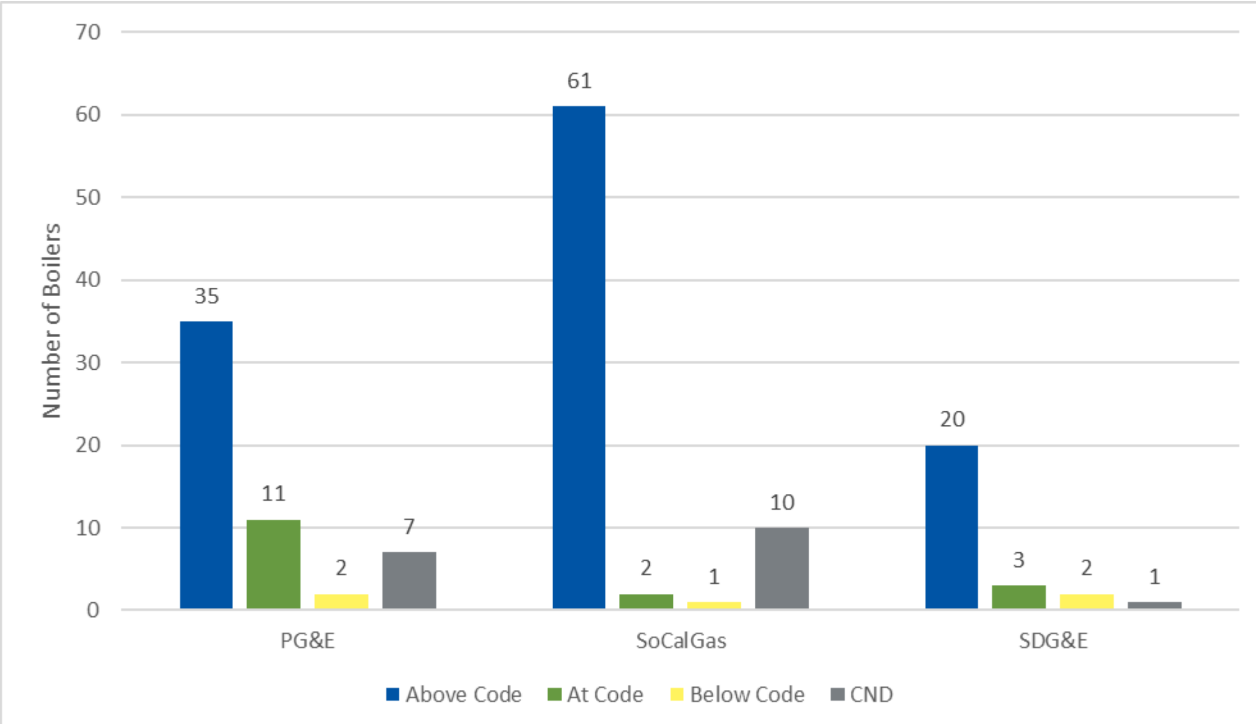


Figure 8. Above-Code, To-Code, and Below-Code for Boilers with >300-2500 kBtu/h Input Capacity (n=139)



4.1.8 Maintenance Frequency

Table 38 shows how frequently the boilers behind sampled meters undergo routine maintenance. Fifty-nine percent of sampled boilers received maintenance more frequently than once per year. Only five percent of boilers were maintained on less than once per year frequency, and 31% were maintained on an irregular scheduled.

In PG&E territory, a larger proportion of boilers in the 1961-1980 building age category were maintained less often than once a year or on an irregular schedule, than in the 1960 and before age category. On the other hand, 95% boilers in the 1981-2000 building age category were maintained once per year or more often.

In SoCalGas territory, a larger share of boilers in buildings built in 1960 and before were maintained less often than once a year or on an irregular schedule, compared with the other two age categories. The maintenance schedule of boilers in the 1961-1980 and 1981-2000 age categories were similar.

In SDG&E territory, 74% of boilers in buildings built in the 1980 and before age category were maintained more often than once per year. A larger share of boilers in the 1981-2000 building age category were maintained less often than once per year or on an irregular schedule, than those in the 1980 and before age category.

Table 38. Maintenance Frequency of Boilers Behind Sampled Meters (n=139)[(1)]

IOU	Building Age	Maintenance Frequency			
		More than Once per Year	Once per year	Less than Once per Year	Irregular
PG&E	1960 and before	31%	44%	0%	25%
	1961 - 1980	41%	20%	3%	36%
	1981 - 2000	75%*	20%	0%	5%
SoCalGas	1960 and before	29%	0%	14%	57%
	1961 - 1980	46%	21%	3%	30%
	1981 - 2000	44%	22%	0%	33%
SDG&E	1980 and before	74%*	5%	0%	21%
	1981 - 2000	40%	20%	0%	40%
Overall Average		**59%**	**22%**	**5%**	**31%**

[(1)] Cadmus indicated the precision of each estimate at a 90% confidence level using the following asterisks: *** for ±5% precision or better, ** for ±5.1-10% precision, * for ±10.1-15% precision, and no label when precision was over ±15%.

4.1.9 Existing Efficiency Measures

Table 39 shows existing installed efficiency measures observed by Cadmus for equipment behind sampled meters. Close to half of the stand-alone tank dedicated DHW boilers had automated flue dampers installed and a third had premixing. Half of space heating only boilers had premixing. A quarter of the combined space heating and DHW boilers had VFD fan controls. Flue gas recirculation has a low saturation rate; however, most often this measure is installed as a NOx emission reduction method and not solely for energy efficiency.

Table 39. Existing Installed Efficiency Measure by Boilers End-use and Type for Equipment Behind Sampled Meters (n=139)[(1)]

End Use	Boilers Type	Existing Installed Efficiency Measure				
		Automated Flue Damper	Economizer	Flue Gas Recirculation	Premixing	VFD Fan Control
Dedicated DHW	Stand-Alone Tank	49%*	7%	2%	33%	4%
	Sidearm	5%	-	0%	21%	0%
	Tankless	0%	-	0%	6%	0%
Pool and Space Heating Boilers	Space Heating	17%	13%	4%	50%	15%
	Space Heating & DHW	0%	0%	0%	0%	25%
	Pool Heating	-	-	0%	6%	0%

[(1)] Cadmus indicated the precision of each estimate at a 90% confidence level using the following asterisks: *** for ±5% precision or better, ** for ±5.1-10% precision, * for ±10.1-15% precision, and no label when precision was over ±15%.

Table 40 shows the combustion control types by boiler end-use (dedicated DHW, Space Heating, Combined Space Heating and DHW, and Pool heating). For Dedicated DHW boilers, Cadmus has presented the combustion control types by boiler type for stand-alone tank, sidearm, and tankless boilers. All pool heating boilers have on/off combustion controls. Dedicated space heating boilers are most commonly controlled by modulating controls. Combined space heating and DHW boilers often have high/low combustion controls.

Table 40. Boiler Combustion Control Types by Boilers End-use and Type for Equipment Behind Sampled Meters (n=139)(1)(2)

End Use	Boilers Type	Combustion Control		
		On/Off	High/Low	Modulating
Dedicated DHW	Stand-Alone Tank	68%**	2%	30%
	Sidearm	33%	54%	13%
	Tankless	30%	3%	67%
Pool and Space Heating Boilers	Space Heating	27%	23%	50%
	Space Heating & DHW	0%	71%	29%
	Pool Heating	100%(2)	0%(2)	0%(2)
Overall Average		**53%****	**17%**	**30%***

(1) Cadmus indicated the precision of each estimate at a 90% confidence level using the following asterisks: *** for ±5% precision or better, ** for ±5.1-10% precision, * for ±10.1-15% precision, and no label when precision was over ±15%.
(2) Cadmus was unable to determine an estimate's precision because there was no variability between units (including when only one unit was observed).

4.2 Sampled Residential Complex Data Collection Results

As described under *On-Site Data Collection Methods,* Cadmus collected data for residential complexes that Cadmus visited. Cadmus recorded the number of buildings and obtained the following information from the site contact for unsampled buildings in the same complex:

- Number of dwelling units in each building
- Number of boilers in each building
- Vintage of each building and if known, the vintage of boilers

Cadmus is not presenting complex-level boiler vintage data in this section since there were many gaps in the collected data about the vintage of counted boilers (those that were not accessible to Cadmus during its site visits).

Table 41 shows the average number of buildings and dwelling units both observed as being served by the sampled meters and counted (not being served by the sampled meters but within the sampled residential complex). Based on these data, in PG&E and SoCalGas territories (less so in SDG&E territory), it was more common to find multiple meters at the same complex.

Table 41. Average Building and Dwelling Units per Sampled Meter and Per Residential Complex Visited (n=139)

IOU	Building Age	Average Building Quantity		Average Residential Unit Quantity	
		Sampled Meter	Complex	Sampled Meter	Complex
PG&E	1960 and before	1.4	1.4	112	112
	1961 - 1980	3.5	5.9	81	167
	1981 - 2000	1.3	4.0	81	126
SoCalGas	1960 and before	1.0	1.0	70	70
	1961 - 1980	2.4	2.7	73	83
	1981 - 2000	1.5	1.7	79	91
SDG&E	1980 and before	3.2	3.9	107	119
	1981 - 2000	4.8	5.0	97	122
Overall Average		**2.4**	**3.6**	**83**	**117**

Table 42 shows the average number of boilers per sampled residential complex based on the total sampled meter quantities. Pool heating boilers are missing from this table, because Cadmus did not consistently count pool heating boilers at each sampled residential complex, when they were not served by the sampled meter.

Table 42. Overall Average Boilers per Sampled Residential Complex (n=139)

IOU	Building Age	Average Boiler Quantity		
		Dedicated DHW	Space Heating Only	Combined Space Heating & DHW
PG&E	1960 and before	1.8	0.3	-
	1961 - 1980	3.1	0.2	0.2
	1981 - 2000	4.3	0.1	0.1
SoCalGas	1960 and before	1.5	0.3	-
	1961 - 1980	2.1	0.1	0.1
	1981 - 2000	3.4	0.2	-
SDG&E	1980 and before	6.5	0.6	0.1
	1981 - 2000	3.0	-	-
Overall Average		**3.3**	**0.2**	**0.1**

Table 43 illustrates the average number of boilers per complex for the complexes that included boilers serving each end-use. This means that, for example, if a site did not include boilers for space heating, that site would not be included in the calculated space heating boiler quantity averages. Conversely, in Table 42 above, a site without space heating boilers would be included in the average quantities as having zero space heating boilers.

Table 43. Average Boilers per Sampled Residential Complex (if Equipment Present) (n=139)

IOU	Building Age	Average Boiler Quantity		
		Dedicated DHW	Space Heating Only	Combined Space Heating & DHW
PG&E	1960 and before	1.8	1.0	-
	1961 - 1980	3.1	2.3	4.0
	1981 - 2000	4.6	1.0	2.0
SoCalGas	1960 and before	2.0	1.0	-
	1961 - 1980	2.3	1.5	1.3
	1981 - 2000	3.6	2.0	-
SDG&E	1980 and before	7.0	2.3	1.0
	1981 - 2000	3.0	-	-
Overall Average		**3.4**	**1.8**	**2.1**

The average dedicated DHW boiler count is slightly greater in Table 43 than in Table 42 because a small number of the sampled complexes utilized combined space heating and DHW boilers to serve the facility's DHW load.

Table 44 shows ownership status for residential units in sampled residential complexes. While the table shows low levels of ownership in the complexes visited by Cadmus (12% overall cross all IOU territories), it should be noted that the population of this market study was screened by Cadmus for master or common area meters that had one or more central boilers serving residential dwelling units. Master meters, and common boiler is naturally less common in owned multifamily dwelling units. These results are not applicable to the overall statewide population of multifamily buildings. Among rented units in multifamily buildings, Cadmus observed a higher ratio of affordable units in PG&E territory.

Table 44. Ownership Status of Residential Units in Sampled Residential Complexes (n=139)

IOU	Building Age	Dwelling Unit Ownership Status		
		Rented - Market Rate	Rented - Affordable	Owned
PG&E	1960 and before	57%	43%	0%
	1961 - 1980	52%	25%	23%
	1981 - 2000	70%	30%	0%
SoCalGas	1960 and before	100%	0%	0%
	1961 - 1980	84%	8%	7%
	1981 - 2000	84%	12%	4%
SDG&E	1980 and before	57%	18%	25%
	1981 - 2000	62%	12%	26%
Overall Average		**68%**	**20%**	**12%**

4.3 Unsampled Meter Data Collection Results

As described under the *On-Site Data Collection Methods,* Cadmus observed boilers behind unsampled meters at the same site as a sampled meter (that were accessible to Cadmus). Cadmus noted which boilers and buildings observed during site visits were behind the each. Though Cadmus observed or counted unsampled boilers, it did not track which unsampled boiler was behind which unsampled meter. Cadmus did not observe significant differences between sampled and unsampled boilers and so combined boilers behind sampled and unsampled meters, as described in the Population Estimation section to produce the population level Market Assessment Results.

4.3.1 Unsampled Boiler Counts

Table 45 reflects the boilers counted during 33 site visits where Cadmus collected data on equipment behind unsampled meters. Dedicated DHW boilers comprised the majority of equipment behind unsampled meters; very few boilers of other types were observed.

Table 45. Unsampled Boiler Quantities by Strata and End-use (n=33)

IOU	Building Age	Total Boiler Quantities (Equipment Not Under Sampled Meters)			
		Dedicated DHW	Dedicated Space Heating	Combined Space Heating and DHWs	Pool Heating
PG&E	1960 and before	1	-	-	-
	1961 - 1980	51		7	2
	1981 - 2000	25	1	-	-
SoCalGas	1960 and before	4	-	-	-
	1961 - 1980	9	-	-	-
	1981 - 2000	31	-	-	-
SDG&E	1980 and before	22	-	-	-
	1981 - 2000	2	-	-	-
Totals		**145**	**1**	**7**	**2**

Table 46 shows dedicated DHW boiler counts for equipment behind unsampled meters. Cadmus found similar numbers of sidearm and tankless DHWs and about twice as many stand-alone tanks, similar to the distribution of equipment behind sampled meters. Note there are fewer boilers in Table 46 (n=43) compared to Table 45 (n=145) because, although we counted all boilers behind unsampled meters, we were able to collect only configuration data for a portion of those.

Table 46. Unsampled Dedicated DHW Boilers by Dedicated DHW Configuration (n=32)

IOU	Building Age	Sites with Sampled and Unsampled Meters	Total Dedicated DHW Boiler Quantities (Equipment Not Behind Sampled Meters)		
			Stand-Alone Tank	Sidearm	Tankless
PG&E	1960 and before	1	1	-	-
	1961 - 1980	17	13	6	-
	1981 - 2000	4	-	2	-
SoCalGas	1960 and before	1	4	-	-
	1961 - 1980	5	2	2	-
	1981 - 2000	2	-	1	10
SDG&E	1980 and before	1	-	-	-
	1981 - 2000	1	2	-	-
Totals		**32**	**22**	**11**	**10**

4.3.2 Unsampled Meter Counts

Table 47 shows the number of sites visited where Cadmus observed boilers behind unsampled meters. Thirty two of the 139 sites visited by Cadmus were served by dedicated DHWs found behind unsampled meters, whereas boilers at only one or two sites were served by space heating only, combined space heating and DHW, and/or pool heating boilers behind unsampled meters.

Table 47. Number of Sites with Unsampled Boilers (n=33)

IOU	Building Age	Number of Sites with Unsampled Boilers			
		Dedicated DHW	Space Heating Only	Combined Space Heating & DHW	Pool Heating
PG&E	1960 and before	1	-	-	-
	1961 - 1980	17	-	2	2
	1981 - 2000	4	1	-	-
SoCalGas	1960 and before	1	-	-	-
	1961 – 1980	5	-	-	-
	1981 - 2000	2	-	-	-
SDG&E	1980 and before	1	-	-	-
	1981 - 2000	1	-	-	-
Overall Average		**32**	**1**	**2**	**2**

4.3.3 Unsampled Boiler Counts Per Sampled Meter

Table 48 for boilers behind unsampled meters is similar to Table 29 for boilers behind sampled meters. In these results, however, the averages were calculated by dividing counted boilers behind unsampled meters (in Table 45) by the number of sampled meters (i.e., sites) where the equipment was present (Table 47). This table indicates that, where dedicated unsampled DHW boilers were present, Cadmus found on average more than four dedicated DHW boilers behind unsampled meters.

Table 48. Average Unsampled Boilers per Sampled Meter (Equipment Present) (n=33)[(1)]

IOU	Building Age	Average Number of Boilers Per Sampled Meter (Boilers Not Behind Sampled Meter)			
		Dedicated DHW	Space Heating Only	Combined Space Heating & DHW	Pool Heating
PG&E	1960 and before	1.0[(2)]	-	-	-
	1961 - 1980	3.0	-	3.5	1.0[(2)]
	1981 - 2000	6.3	1.0[(2)]	-	-
SoCalGas	1960 and before	4.0[(2)]	-	-	-
	1961 – 1980	1.8	-	-	-
	1981 - 2000	15.5	-	-	-
SDG&E	1980 and before	22.0[(2)]	-	-	-
	1981 - 2000	2.0[(2)]	-	-	-
Overall Average		**4.5**	**1.0**[(2)]	**3.5**	**1.0**[(2)]

[(1)] Cadmus indicated the precision of each estimate at a 90% confidence level using the following asterisks: *** for ±5% precision or better, ** for ±5.1-10% precision, * for ±10.1-15% precision, and no label when precision was over ±15%.
[(2)] Cadmus was unable to determine an estimate's precision because there was no variability between units (including when only one unit was observed).

Table 49 shows the average number of unsampled boilers per sampled meter. On average, Cadmus found one dedicated DHW boiler behind unsampled meters at sites with sampled meters. Cadmus found fewer than 0.2 unsampled space heating only, combined space heating and DHW, and/or pool heating boilers per sampled meter.

Table 49. Average Unsampled Boilers Per Sampled Meter (n=139)[(1)]

IOU	Building Age	Average Number of Boilers Per Sampled Meter (Boilers Behind Unsampled Meter)			
		Dedicated DHW	Space Heating Only	Combined Space Heating & DHW	Pool Heating
PG&E	1960 and before	0.1	-	-	-
	1961 - 1980	1.5	-	0.2	0.1
	1981 - 2000	1.3	0.1	-	-
SoCalGas	1960 and before	1.0	-	-	-
	1961 – 1980	0.3	-	-	-
	1981 - 2000	1.5	-	-	-
SDG&E	1980 and before	1.7	-	-	-
	1981 - 2000	0.5	-	-	-
Overall Average		**1.0**	**0.0**	**0.1**	**0.0**

[(1)] Cadmus indicated the precision of each estimate at a 90% confidence level using the following asterisks: *** for ±5% precision or better, ** for ±5.1-10% precision, * for ±10.1-15% precision, and no label when precision was over ±15%.

4.3.4 Unsampled Boiler Age

Table 50 shows the average boiler age based on the year of manufacture for boilers behind unsampled meters. Vintages were similar to those observed for boilers behind sampled meters—across end uses, sampled boilers were 9.2 years old, while unsampled boilers have an average age of 8.5 years. The two unsampled pool heating boilers were significantly older on average than sampled pool heating boilers.

Table 50. Average Unsampled Boiler Age in Years Since Manufacture (n=42)[(1)]

IOU	Average Boiler Age (years)				All End Uses
	Heating Boilers	Dedicated DHW Boilers			
	Pool Heating	Stand-Alone Tank	Sidearm	Tankless	
PG&E	26.0	7.9 ***	12.3*	-	10.8
SoCalGas	-	5.8*	18.0***	2.0[(2)]	5.7
SDG&E	-	-	-	-	-
Overall Average	**26.0**	**7.3****	**14.0***	**2.0[(2)]**	**8.5**

[(1)] Cadmus indicated the precision of each estimate at a 90% confidence level using the following asterisks: *** for ±5% precision or better, ** for ±5.1-10% precision, * for ±10.1-15% precision, and no label when precision was over ±15%.
[(2)] Cadmus was unable to determine an estimate's precision because there was no variability between units (including when only one unit was observed).

4.3.5 Unsampled Boiler Input Capacity

Table 51 shows the average input capacity (in kBtu/h) for boilers behind unsampled meters. Average input capacities for unsampled boilers followed similar trends as sampled boilers—dedicated DHW boilers with sidearm configuration tended to have higher input capacities than dedicated DHWs of other configurations, and non-dedicated DHWs tended to have even higher input capacities. Cadmus did not observe any unsampled, non-dedicated DHW besides pool heating boilers, leading to an overall lower input capacity than among boilers behind sampled meters on average. Comparisons between end uses may not be appropriate.

Table 51. Average Unsampled Boiler Input Capacity (kBtu/h) (n=45)[(1)]

IOU	Average Boiler Capacity (kBtu/h)				
	Heating Boilers	Dedicated DHW Boilers			All End Uses
	Pool Heating	Stand-Alone Tank	Sidearm	Tankless	
PG&E	542	224***	605***	-	377***
SoCalGas	-	258***	683***	200[(1)]	295***
SDG&E	-	512[(2)]	-	-	512[(2)]
Overall Average	**542**	**259*****	**626*****	**200[(1)]**	**348*****

[(1)] Cadmus indicated the precision of each estimate at a 90% confidence level using the following asterisks: *** for ±5% precision or better, ** for ±5.1-10% precision, * for ±10.1-15% precision, and no label when precision was over ±15%.
[(2)] Cadmus was unable to determine an estimate's precision because there was no variability between units (including when only one unit was observed).

4.3.6 Unsampled Boiler Average Efficiency

Table 52 shows average rated efficiencies observed for boilers behind unsampled meters, based on rated or calculated efficiency metrics. These results are similar to those observed for boilers behind sampled meters—dedicated DHW boilers had the highest average efficiency while pool heating boilers were the least efficient.

Table 52. Average Rated Efficiency (n=45)(1)

IOU	Average Number of Boilers Per Sampled Meter (Boilers not Behind Sampled Meter)				
	Dedicated DHW	Space Heating Only	Combined Space Heating & DHW	Pool Heating	All End Uses
PG&E	85%*	-	-	81%	85%*
SoCalGas	89%*	-	-	-	89%*
SDG&E	82%	-	-	-	82%
Overall Average	**87%**	**-**	**-**	**81%**	**86%**

(1) Cadmus indicated the precision of each estimate at a 90% confidence level using the following asterisks: *** for ±5% precision or better, ** for ±5.1-10% precision, * for ±10.1-15% precision, and no label when precision was over ±15%.

4.3.7 Unsampled Boiler Above, Below, And To-code Boilers

Table 53 shows the proportion of boilers found on site visits (but that were not behind the sampled meter) that were above code, to code, and below code for boilers with input capacities less than or equal to 300 kBtu/h and those with higher input capacities. Across IOUs, the majority of boilers were found to be above code, regardless of input capacity. About the same number of boilers were to code as below code: Cadmus did not observe any boilers with input capacities greater than 300 kBtu/h that were below code in any IOU territory, but almost 20% of boilers with lower input capacities were found below code. As stated previously, Cadmus assessed code compliance based on mandatory requirements in 2019 Title 20 and Title 24. Therefore, below-code boilers may have been to- or above-code when originally installed.

Table 53. Proportion of To-Code for Boilers Not Behind Sampled Meters (n=139)(1)(3)

IOU	≤300 kBtu/h			> 300 kBtu/h		
	Above Code	To Code	Below Code	Above Code	To Code	Below Code
PG&E	21%	17%	21%	38%	4%	0%(2)
SoCalGas	53%	26%	5%	16%	0%(2)	0%(2)
SDG&E	-	-	-	100%(2)	0%(2)	0%(2)
Overall	**42%**	**22%**	**18%**	**42%**	**4%**	0%(2)

(1) Cadmus indicated the precision of each estimate at a 90% confidence level using the following asterisks: *** for ±5% precision or better, ** for ±5.1-10% precision, * for ±10.1-15% precision, and no label when precision was over ±15%.
(2) Cadmus was unable to determine an estimate's precision because there was no variability between units (including when only one unit was observed).
(3) Cadmus did not differentiate between thermal and other efficiency metrics, and results across all efficiencies are compiled in this table.

4.3.8 Unsampled Boiler Maintenance Frequency

Table 54 shows the proportion of boilers found on site visits (but that were not behind the sampled meter) that received maintenance more than once per year, annually, less than annually, and only irregularly. Results differ somewhat from the maintenance schedules provided for boilers behind sampled meters, though Cadmus unable to estimate the proportion of boilers with each maintenance schedule with precision better than 30% at the 90% confidence level.

Table 54. Maintenance Frequency of Boilers Not Behind Sampled Meters (n=139)(1)

IOU	Maintenance Frequency			
	More than once per year	Once per year	Less than Once per Year	Irregular
PG&E	27%	14%	-	59%
SoCalGas	56%	-	44%	-
SDG&E	100%(2)	-	-	-
Overall Average	**49%**	**14%**	**44%**	**59%**

(1) Cadmus indicated the precision of each estimate at a 90% confidence level using the following asterisks: *** for ±5% precision or better, ** for ±5.1-10% precision, * for ±10.1-15% precision, and no label when precision was over ±15%.
(2) Cadmus was unable to determine an estimate's precision because there was no variability between units (including when only one unit was observed).

4.3.9 Unsampled Boiler Existing Efficiency Measures

Table 55 shows the proportion of boilers behind unsampled meters with installed efficiency measures. None of the boilers behind unsampled meters were equipped with economizers, flue gas recirculation, or VFD fan control, and none of the observed tankless dedicated DHW boilers or pool heating boilers were equipped with any of the efficiency measures assessed in this study. Just over half of the observed unsampled dedicated DHWs configured with stand-along tanks had automatic flue dampers, which is similar to what Cadmus observed for boilers behind the sampled meters. A third of unsampled stand-alone tanks were installed with premixing equipment, as did over a third of unsampled DHW boilers with sidearm configurations. These are similar to the proportions observed for sampled DHW boilers with these configurations.

Table 55. Existing Installed Efficiency Measure by Boilers End-use and Type for Equipment Not Behind Sampled Meters (n=16)(1)

End Use	Boilers Type	Existing Installed Efficiency				
		Automated Flue Damper	Economizer	Flue Gas Recirculation	Premixing	VFD Fan Control
Dedicated DHW	Stand-Alone Tank	55%	0%(2)	0%(2)	36%	0%(2)
	Sidearm	0%(2)	0%(2)	0%(2)	36%	0%(2)
	Tankless	0%(2)	0%(2)	0%(2)	0%(2)	0%(2)
Pool and Space Heating Boilers	Space Heating	-	-	-	-	-
	Space Heating & DHW	-	-	-	-	-
	Pool Heating	0%(2)	0%(2)	0%(2)	0%(2)	0%(2)

(1) Cadmus indicated the precision of each estimate at a 90% confidence level using the following asterisks: *** for ±5% precision or better, ** for ±5.1-10% precision, * for ±10.1-15% precision, and no label when precision was over ±15%.
(2) Cadmus was unable to determine an estimate's precision because there was no variability between units (including when only one unit was observed).

Table 56 shows the proportion of boilers observed behind unsampled meters with one of the three types of combustion controls. Results are generally consistent with what Cadmus observed for boilers behind sampled meters.

Table 56. Boiler Combustion Control Types by Boilers End-use and Type for Equipment Not Behind Sampled Meters (n=16)[(1)]

End Use	Boilers Type	Combustion Control		
		On/Off	High/Low	Modulating
Dedicated DHW	Stand-Alone Tank	68%	5%	27%
	Sidearm	22%	22%	56%
	Tankless	100%	0%[(2)]	0%[(2)]
Pool and Space Heating Boilers	Space Heating	-	-	-
	Space Heating & DHW	-	-	-
	Pool Heating	50%	50%	0%
Overall Average		**65%**	**9%**	**26%**

[(1)] Cadmus indicated the precision of each estimate at a 90% confidence level using the following asterisks: *** for ±5% precision or better, ** for ±5.1-10% precision, * for ±10.1-15% precision, and no label when precision was over ±15%.
[(2)] Cadmus was unable to determine an estimate's precision because there was no variability between units (including when only one unit was observed).

4.4 Combined Sampled and Unsampled Meter Data Collection Results by Climate Zone

Cadmus investigated the distribution of boilers and differences in observed boiler characteristics by climate zone. Cadmus had not designed the site visit sampling plan to achieve 10% precision with 90% confidence for each climate zone, so the results are imprecise in some climate zones.

Cadmus did not complete any site visits in climate zones 14, 15, and 16 since those climate zones cover the most eastern and least populated areas in the state. Cadmus also did not complete any site visits in climate zone 5, which covers parts of Santa Barbara and San Luis Obispo counties.

Of 139 site visits, Cadmus completed 113 in climate zones 3, 7, 9, 10, and 12 covering the counties of San Francisco, San Mateo, Contra Cost, San Diego, Orange, Los Angeles, San Bernardino, Riverside, and Sacramento.

Table 57 shows the distribution of all boilers counted during 139 site visits in California climate zones 2 through 13 (with the exception of climate zone 5).

Table 57. Boiler Quantities by Climate Zone and End Use at Sampled Meters (n=139)

Climate Zone	Completed Eligible Site Visits	Total Boiler Quantities (All Observed Boilers)				All End Uses
		Dedicated DHW	Space Heating Only	Combined Space Heating & DHW	Pool Heating	
2	1	3	-	-	-	3
3	25	75	7	5	4	91
4	8	38	1	-	2	41
6	7	19	4	2	2	27
7	10	72	7	1	3	83
8	4	10	-	-	4	14
9	45	119	4	2	5	130
10	11	30	-	-	5	35
11	5	15	-	5	1	21
12	22	73	-	-	-	73
13	1	2	2	-	-	4
Totals	**139**	**456**	**25**	**15**	**26**	**522**

Table 58 shows average boiler age for all boilers observed during 139 site visits in California climate zones 2 through 13 (with the exception of climate zone 5). Across all end uses boilers in climate zones 6 and 11 had the highest average age, followed by climate zones 8 and 3.

Table 58. Average Boiler Age (Years Since Manufacture) by Climate Zone and End Use (n=139)(1)

Climate Zone	Average Thermal Efficiency				All End Uses
	Dedicated DHW	Space Heating Only	Combined Space Heating & DHW	Pool Heating	
2	10.0 (2)	-	-	-	10.0 (2)
3	11.0***	17.5	-	12.3	11.7**
4	7.1**	-	-	7.0	7.1**
6	15.3**	23.0	7.0 (2)	4.0	14.9**
7	2.5**	0.0	-	-	2.3**
8	13.5**	-	-	10.0	12.5**
9	8.2***	13.0	11.0	4.2	8.2***
10	7.4**	-	-	-	7.4**
11	14.5*	-	-	41.0	16.7*
12	10.0***	-	-	-	10.0***
13	8.0 (2)	8.0 (2)	-	-	8.0 (2)
Overall Average	**8.9*** **	**13.6**	**9.0(2)**	**9.6**	**9.2*** **

(1) Cadmus indicated the precision of each estimate at a 90% confidence level using the following asterisks: *** for ±5% precision or better, ** for ±5.1-10% precision, * for ±10.1-15% precision, and no label when precision was over ±15%.
(2) Cadmus was unable to determine an estimate's precision because there was no variability between units (including when only one unit was observed).

Table 59 shows the average thermal efficiency by climate zone. Climate zones 7 and 13 had the highest average efficiencies.

Table 59. Average Efficiency for All Observed Boilers (n=130)[1-4]

Climate Zone	Average Efficiency				All End Uses
	Dedicated DHW	Space Heating Only	Combined Space Heating & DHW	Pool Heating	
2	85%	-	-	-	85%
3	85%*	83%	85%	81%	84%**
4	86%*	-	-	84%	86%*
6	83%	82%	85%	82%	83%
7	91%**	83%	82%	84%	90%**
8	83%	-	-	79%	82%
9	85%**	83%	85%	82%	85%**
10	81%*	-	-	84%	81%*
11	81%	-	-	80%	81%
12	87%**	-	-	-	87%**
13	94%	95%	-	-	95%
Overall Average	**86%***	**84%**	**85%**	**81%**	**85%***

(1) The total number of meters included is less than 139 because Cadmus could not determine the efficiency of boilers in nine sites.
(2) Cadmus did not differentiate between thermal and other efficiency metrics, and results across all efficiencies are compiled in this table.
(3) Cadmus indicated the precision of each estimate at a 90% confidence level using the following asterisks: *** for ±5% precision or better, ** for ±5.1-10% precision, * for ±10.1-15% precision, and no label when precision was over ±15%.
(4) Cadmus was unable to determine an estimate's precision because there was no variability between units (including when only one unit was observed).

Table 60 shows the number of above-code, to-code, and below-code boilers and water heaters on sampled meters by climate zone. Figure 9 shows the number of to-code, above-code, and below-code boilers and water heaters on sampled meters by climate zone for boilers with an input capacity less than or equal to 300 kBtu/h. As stated previously, Cadmus assessed code compliance based on mandatory requirements in 2019 Title 20 and Title 24. Therefore, below-code boilers may have been to- or above-code when originally installed.

Figure 10 shows the number of to-code, above-code, and below-code boilers and water heaters on sampled meters by climate zone for boilers with an input capacity between >300-2500 kBtu/h.

Cadmus did not find boilers greater than 2500 kBtu/h not observe any boilers in omitted climate zones. Climate zones 9, 10, and 12 had the most boilers that were below code in efficiency.

Table 60. Above-Code, To-Code, and Below-Code Boilers by Climate Zone

Climate Zone	Input Capacity Range					
	≤300 kBtu/h			300 kBtu/h - 2500 kBtu/h		
	Above Code	At Code	Below Code	Above Code	At Code	Below Code
2	0	0	0	1	0	0
3	10	7	6	27	1	2
4	15	0	1	4	0	0
6	0	4	2	12	2	0
7	35	0	3	16	2	2
8	0	3	2	5	0	1
9	27	18	15	41	1	0
10	1	0	16	12	1	0
11	0	0	7	4	2	0
12	27	8	14	6	8	1
13	0	0	0	4	0	0
Totals	**115**	**40**	**66**	**132**	**17**	**6**

Figure 9. Above-Code, To-Code, and Below-Code Boiler Count by Climate Zone, ≤300 kBtu/h

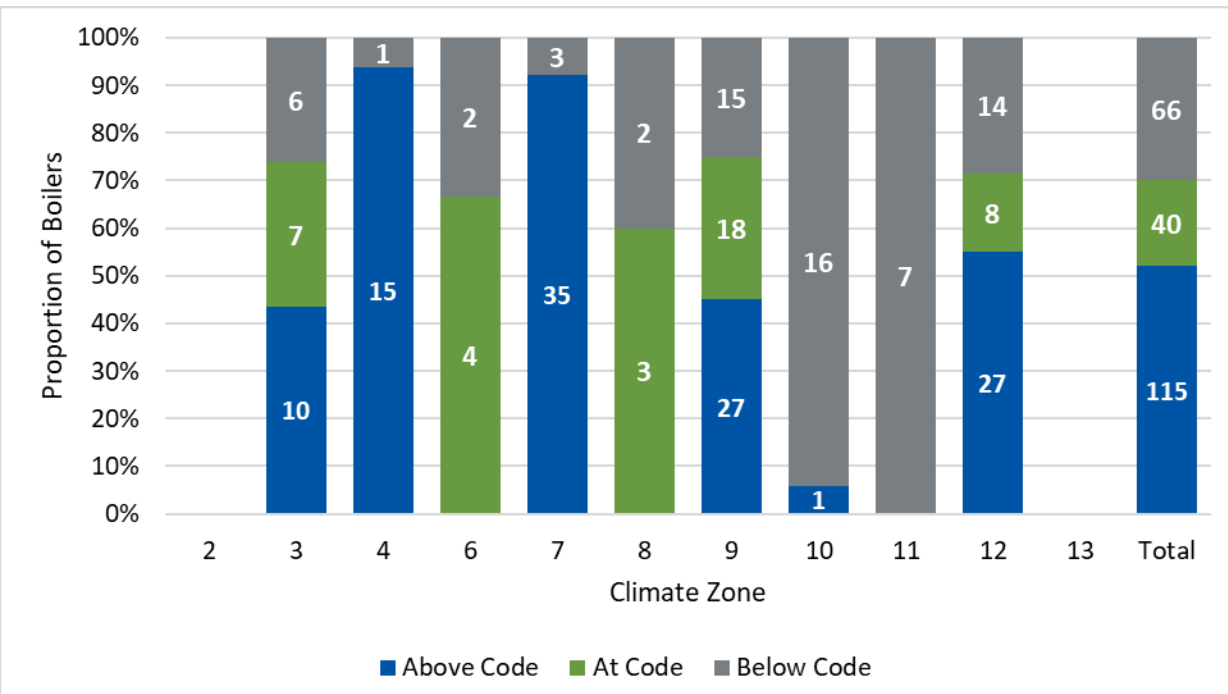
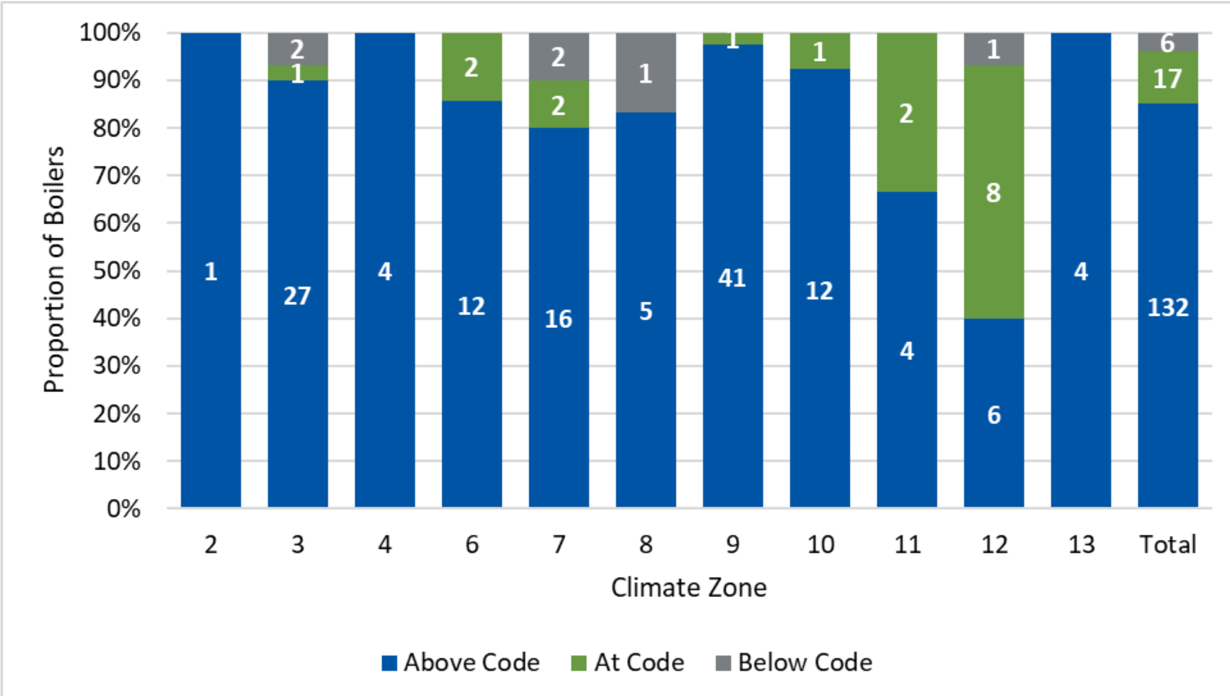


Figure 10. Above-Code, To-Code, and Below-Code Boiler Count by Climate Zone, >300-2500 kBtu/h



5 Market Assessment Results

In this study, meters served as the proxy for residential multifamily complexes. Cadmus characterized the boiler market within each IOU territory and across the three territories using results from the site visits and online or phone surveys with building owners and operators. Boiler- and building-level information collected on a per-meter basis in conjunction with meter population data provided by the IOUs allowed Cadmus to assess population-wide boiler market and multifamily building characteristics. The study sample represents residential multifamily complexes that have at least one gas IOU meter serving 40 or more dwelling units, built before 2001, with a central boiler serving the dwelling units.

The IOUs provided a subset of their multifamily account meters to Cadmus. The IOUs excluded meters if annual gas usage fell below a threshold determined through discussion between the IOUs and Cadmus, based on the determination that those meters were unlikely to serve central boilers serving multiple dwelling units. The usage limits used by the IOUs in their response to Cadmus data requests is described in *Customer Data Screening and Sampling Methods*.

During site visits, Cadmus often counted or observed boilers that were not behind the sampled meters but that served residential multifamily buildings. Cadmus checked for additional meters at each sampled meter address (and in each sampled complex) to avoid double-counting the quantity of boilers, dwelling units, and buildings in each residential complex. In some cases, Cadmus found no other meters in the same residential complex in the IOU data. However, Cadmus incorporated these boilers in its market assessment to better capture the true population of boilers serving residential multifamily buildings in the IOU territories.

The market assessment results for boiler characteristics and counts are applicable at two levels:

- Market assessment results for boiler characteristics incorporate information gathered for all observed boilers, including those behind sampled and those behind unsampled meters (when they were accessible to Cadmus). Including the additional observed boilers behind unsampled meters at sites with sampled meters enabled Cadmus to provide a more robust characterization of boiler characteristics in the IOU territories.
- Market assessment results for building, dwelling unit, and boiler quantities incorporate residential complex-level counts. Including counted buildings, dwelling units, and boilers in addition to those observed enabled Cadmus to develop a wider characterization of buildings, dwelling units, and boiler counts in the IOU territories.

Cadmus developed the site visit sampling plan for this study such that it could estimate boiler population and key characteristics with 90% confidence and ±10% precision. Assuming that boiler characteristics would be similar within building age categories, Cadmus stratified the population of boilers by the ages of the buildings they served. Analyzing the collected data (as noted under the *Data Collection Results* section) and reviewing the final distribution of IOU meter populations across age strata, led to the following findings:

- Cadmus did not observe the correlations it expected between building age and boiler age or efficiency.

- Cadmus found that for 15% of the sampled meters, the pre-screened building age (from Cadmus), changed during the survey (from the IOU customer), and then again during the site visits (from the site contact), thereby compounding the uncertainty about the distribution of meters in each building age stratum.

Therefore, to increase the efficiency of the sample, Cadmus combined the building age strata to present the market assessment results stratified by IOU only. The market assessment results for boiler population and key boiler characteristics statewide meet ±10% precision at 90% confidence. Each section that follows responds to a research question posed at the beginning of the study.

5.1 Multifamily Boiler Population Stock and End-Uses Served

Table 61 shows the population of study-eligible meters and boilers across all IOUs and building-age categories. Dedicated DHW boilers comprised the majority of the equipment, and domestic water heating was the end-use served the most. Pool heating boilers were the next prevalent.

Table 61. Multifamily Boiler Population Stock in California Gas IOU Territories(1)

IOU	Number of Meters(2)	Quantity of Boilers				
		Dedicated DHW Boilers	Dedicated Space Heating Boilers	Combined Space Heating and DHW Boilers	Pool Heating Boilers	All End Uses
PG&E	1,592***	4,957***	257**	218*	167**	5,599***
SoCalGas	4,361***	9,413***	545*	291*	872**	11,121***
SDG&E	914**	5,105	376	54	376	5,911
Total	**6,867*** **	**19,475** **	**1,178** **	**563** **	**1,415** **	**22,631** **

(1) Cadmus indicated the precision of each estimate at a 90% confidence level using the following asterisks: *** for ±5% precision or better, ** for ±5.1-10% precision, * for ±10.1-15% precision, and no label when precision was over ±15%.
(2) The population of meters included here are based on the data provided by the IOUs, which Cadmus screened for master and common area meters serving 40 or more dwelling units built before 2001.

Table 62 shows the average number of buildings and boilers per site estimated for the population of eligible sites in the California Gas IOUs' territories. On average, Cadmus estimated that there are about four buildings per eligible site in PG&E and SDG&E territories, and about half that in SoCalGas' territory.

Across all end uses, Cadmus estimated that eligible sites have between 2.6 and 6.5 boilers. The majority of these are dedicated DHW boilers—across all IOUs, Cadmus estimated there are about 2.8 dedicated DHWs per eligible site, compared to less than one dedicated space heating, combined, or pool heating boilers. Note that due to a limited sample size, Cadmus was unable to estimate the number of boilers per eligible site for those in SDG&E's territory with a precision of ±15% or less.

Table 62. Multifamily Average Number of Boilers per Site in California Gas IOU Territories(1)

IOU (2)	Buildings	Average Number of Boilers per Site				
		Dedicated DHW Boilers	Dedicated Space Heating Boilers	Combined Space Heating and DHW Boilers	Pool Heating Boilers	All End Uses
PG&E	4.0***	3.1***	0.2**	0.1*	0.1**	3.5***
SoCalGas	2.1***	2.2***	0.1**	0.1*	0.2**	2.6***
SDG&E	4.2**	5.6	0.4	0.1	0.4	6.5
Total	**2.8*** **	**2.8** **	**0.2* **	**0.1** **	**0.2**	**3.3*** **

(1) Cadmus indicated the precision of each estimate at a 90% confidence level using the following asterisks: *** for ±5% precision or better, ** for ±5.1-10% precision, * for ±10.1-15% precision, and no label when precision was over ±15%.
(2) The population of meters included here are based on the data provided by the IOUs, which Cadmus screened for master and common area meters serving 40 or more dwelling units built before 2001.

5.2 Multifamily Boiler Population Vintage

Table 63 shows the average boiler age by IOU. Boiler ages vary within IOU territory and between end uses served by boilers. Cadmus observed the oldest boilers in PG&E and SoCalGas territories and the newest in SDG&E territory. Average boiler age ranged from brand new up to 19 years old.

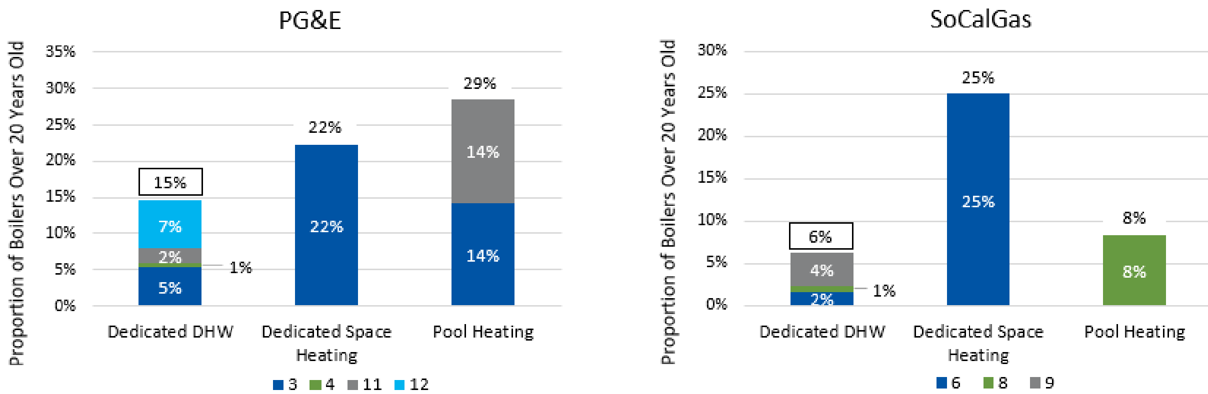
Table 63. Multifamily Boiler Population Vintage in California Gas IOU Territories(1)

IOU (2)	Average Age of Boilers - Years				
	Dedicated DHW Boilers (n=317)	Dedicated Space Heating Boilers (n=16)	Combined Space Heating and DHW Boilers (n=4)	Pool Heating Boilers (n=16)	All End Uses (n=353)
PG&E	10.2 ***	14.3	-	17.0	10.6***
SoCalGas	9.5***	18.7	9.0*	6.3	9.7***
SDG&E	3.2***	0.0 (3)	-	-	3.0***
Overall	**8.9*** **	**13.6**	**9.0* **	**9.6**	**9.2*** **

(1) Cadmus indicated the precision of each estimate at a 90% confidence level using the following asterisks: *** for ±5% precision or better, ** for ±5.1-10% precision, * for ±10.1-15% precision, and no label when precision was over ±15%.
(2) The population of meters included here are based on the data provided by the IOUs, which Cadmus screened for master and common area meters serving 40 or more dwelling units built before 2001.(2) The population of meters included here are based on the data provided by the IOUs, which Cadmus screened for master and common area meters serving 40 or more dwelling units built before 2001.(3) One boiler was manufactured in 2019.

Figure 11 shows the proportion of boilers in operation that were 20 or more years old. Close to 30%, 22%, and 15% of pool heating, dedicated space heating, and dedicated DHW boilers, respectively, were operating at or beyond their EUL in PG&E territory. In SoCalGas territory, the percentages were 8%, 25%, and 6% of pool heating, dedicated space heating, and dedicated DHW boilers, respectively. Cadmus did not find any boilers operating at or beyond their EUL in SDG&E territory.

Figure 11. Proportion of Boilers Operating At or Beyond EUL



A box indicates that estimates achieved 15% precision with 90% confidence.
Results are color-coded for distinct climate zones.

Table 64 provides estimated numbers of boilers in the population that were at least 20 years old. Comparing these numbers with the total boiler population stock shown in Table 61 indicates that overall, 7% of boilers (regardless of end-use served) are operating at or beyond the EUL of 20 years. This proportion is 15%, 7%, and 0% in PG&E, SoCalGas, and SDG&E territories (the results at the IOU level are imprecisely estimated with greater than 15% precision with 90% confidence).

Table 64. Multifamily Boiler Population At Least 20 Years Old in California Gas IOU Territories(1)

IOU (2)	Estimated Number of Boilers in the Population At Least 20 Years Old				
	Dedicated DHW Boilers	Dedicated Space Heating Boilers	Combined Space Heating and DHW Boilers	Pool Heating Boilers	All End Uses
PG&E	722	57	0	48	827
SoCalGas	579	136	0	73	788
SDG&E	0	0	0	0	0
Overall	**1,301**	**193**	**0**	**120**	**1,615**

(1) Cadmus indicated the precision of each estimate at a 90% confidence level using the following asterisks: *** for ±5% precision or better, ** for ±5.1-10% precision, * for ±10.1-15% precision, and no label when precision was over ±15%.
(2) The population of meters included here are based on the data provided by the IOUs, which Cadmus screened for master and common area meters serving 40 or more dwelling units built before 2001.

5.3 Multifamily Boiler Population Efficiency

Table 65 shows the relative efficiencies for boilers observed during site visits. Pool heating boilers tend to be of lower relative efficiency than those serving other end uses, on average achieving a relative efficiency of 81% across all IOUs. Boilers serving other end uses were more similar to each other, with higher efficiencies ranging from 82% to 88% across all IOUs. Across all end uses, each IOU comprised boilers of similar efficiencies.

Table 65. Multifamily Boiler Population Efficiency in California Gas IOU Territories(1)

IOU (2)	Rated Efficiency (3)				
	Dedicated DHW Boilers	Dedicated Space Heating Boilers	Combined Space Heating and DHW Boilers	Pool Heating Boilers	All End Uses
PG&E	86%**	85%	85%	81%	86%***
SoCalGas	85%**	83%	85%	81%	84%**
SDG&E	88%**	83%	82%	84%	87%**
Overall	**86%****	**84%**	**85%**	**81%**	**85%****

(1) Cadmus indicated the precision of each estimate at a 90% confidence level using the following asterisks: *** for ±5% precision or better, ** for ±5.1-10% precision, * for ±10.1-15% precision, and no label when precision was over ±15%.
(2) The population of meters included here are based on the data provided by the IOUs, which Cadmus screened for master and common area meters serving 40 or more dwelling units built before 2001.
(3) Cadmus did not differentiate between thermal efficiency and other efficiency metrics. Results across all efficiencies are compiled in this table.

5.4 Multifamily Boiler Population Input Capacity

Table 66 shows average input capacity (in kBtu/h) per boiler end-use and IOU. As anticipated, dedicated DHW boilers had lower input capacities than space heating boilers across all IOUs. Dedicated space heating boilers had the highest average input capacity overall. Combined space heating and DHW boilers had the second-highest input capacities but were less often estimated with precision better than 15% (with 90% confidence). Cadmus observed that pool-heating boilers tended to have the lowest input capacity overall. Across end uses, boilers in SDG&E's territory had lower average input capacity than the other IOUs—this is consistent with the average boiler input capacity results by end use.

Table 66. Multifamily Boiler Population Input Capacity in Gas IOU Territories(1)

IOU (3)	Average Input Capacity (kBtu/h)				
	Dedicated DHW Boilers	Dedicated Space Heating Boilers	Combined Space Heating and DHW Boilers	Pool Heating Boilers	All End Uses
PG&E	380***	1,484**	1,000 (2)	390*	448***
SoCalGas	476***	1,476**	1,275	274***	534***
SDG&E	292***	843**	926 (2)	335	347***
Overall	**397*****	**1,294****	**1,147**	**316****	**459*****

(1) Cadmus indicated the precision of each estimate at a 90% confidence level using the following asterisks: *** for ±5% precision or better, ** for ±5.1-10% precision, * for ±10.1-15% precision, and no label when precision was over ±15%.
(2) Cadmus was unable to determine an estimate's precision because there was no variability between units (including when only one unit was observed).
(3) The population of meters included here are based on the data provided by the IOUs, which Cadmus screened for master and common area meters serving 40 or more dwelling units built before 2001.

5.5 Multifamily Boiler Population To-code and Under-code Proportions

Cadmus assessed the proportion of boilers that met California's 2019 Title 20 and Title 24 efficiency standards for appliances and buildings, respectively. Cadmus assessed code compliance metrics including boiler efficiency, whether an automatic flue damper was present, whether an automated hot water temperature setting control was in place, and, for dedicated DHWs, circulation pump control strategy and the length of coverage and thickness of insulation on pipes. Cadmus assessed code compliance based on mandatory requirements in 2019 Title 20 and Title 24. Therefore, below-code boilers may have been to- or above-code when originally installed.

Table 67 shows the proportion of boilers to code in the market. Cadmus calculated a precision more than ±15% at a 90% confidence level for the results in this table. For all end uses, boiler efficiency standards are defined by whether, for input capacities of more than 300 kBtu/h, relative efficiency exceeds 82%, or for lower input capacities, whether relative efficiency exceeds 80%. The results indicated that a large proportion of boilers in all IOUs are to code or above code in both input capacity bins. Fewer boilers with input capacities larger than 300 kBtu/h were below code than boilers with lower input capacities—on average, 18% of boilers with lower input capacities were below code across all IOUs, compared to just 2% of boilers with larger input capacities.

Table 67. Multifamily Boiler Population Proportion of Above Code, To Code, and Under Code Boilers(1)(3)

IOU (2)	≤300 kBtu/h			> 300 kBtu/h		
	Above Code	To Code	Below Code	Above Code	To Code	Below Code
PG&E	34%	10%	18%	30%	7%	2%
SoCalGas	20%	18%	14%	46%	2%	1%
SDG&E	43%	0%	23%	27%	4%	2%
Overall	**33%**	**15%**	**18%**	**37%**	**6%**	**2%**

(1) Cadmus indicated the precision of each estimate at a 90% confidence level using the following asterisks: *** for ±5% precision or better, ** for ±5.1-10% precision, * for ±10.1-15% precision, and no label when precision was over ±15%.
(2) The population of meters included here are based on the data provided by the IOUs, which Cadmus screened for master and common area meters serving 40 or more dwelling units built before 2001.
(3) Cadmus did not differentiate between thermal and other efficiency metrics, and results across all efficiencies are compiled in this table.

Figure 12 shows the distribution of equipment types that comprise below-code boilers in the IOU territories. The majority of below-code boilers were dedicated DHW boilers or pool-heating boilers in PG&E and SoCalGas' territories. In SDG&E territory, only dedicated DHW boilers were below code for input capacities less than or equal to 300 kBtu/h, while only dedicated space heating boilers were below code for larger input capacities. Note that Cadmus only observed six below-code boilers with input capacities greater than 300 kBtu/h, and the distributions provided below may not accurately reflect the distribution of below-code boilers with large input capacities in the population.

Figure 12. Proportion of Below-Code Boilers by Equipment Type

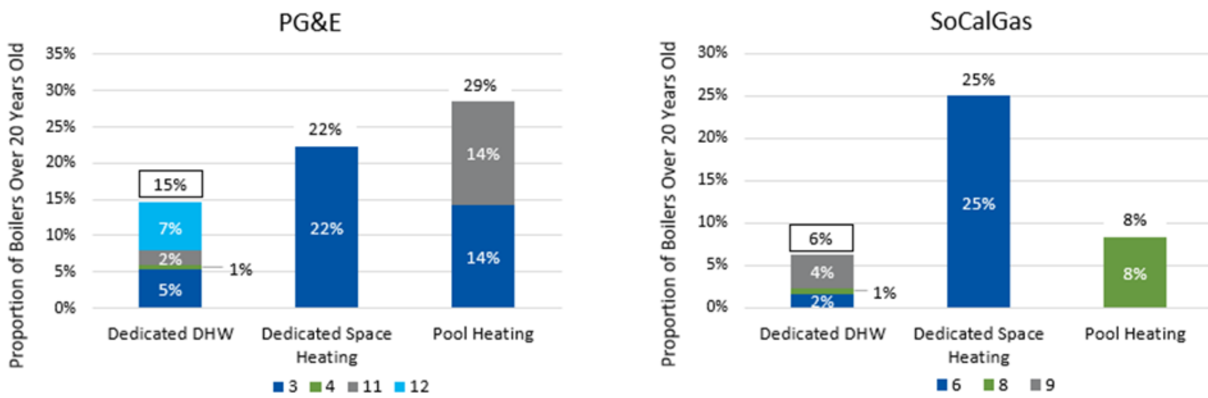


Table 68 shows the proportion of boilers in each IOU by end use that have an automated flue damper. About one-third of the dedicated DHW and dedicated space heating boilers were to-code and had automated flue dampers—this result is consistent across IOUs. However, none of the combined space heating and DHW or pool heating boilers had automated flue dampers in any territory.

Table 68. Proportion of Boilers With Automated Flue Dampers[1]

IOU [3]	Automated Flue Damper Present				
	Dedicated DHW Boilers	Dedicated Space Heating Boilers	Combined Space Heating and DHW Boilers	Pool Heating Boilers	All End Uses
PG&E	27%	33%	0% [2]	0% [2]	26%
SoCalGas	29%	13%	0% [2]	0% [2]	25%
SDG&E	35%	0%	0% [2]	0% [2]	29%
Overall	**29%***	**17%**	**0% [2]**	**0% [2]**	**26%***

[1] Cadmus indicated the precision of each estimate at a 90% confidence level using the following asterisks: *** for ±5% precision or better, ** for ±5.1-10% precision, * for ±10.1-15% precision, and no label when precision was over ±15%.
[2] Cadmus was unable to determine an estimate's precision because there was no variability between units (including when only one unit was observed).
[3] The population of meters included here are based on the data provided by the IOUs, which Cadmus screened for master and common area meters serving 40 or more dwelling units built before 2001.

Table 69 shows the proportion of dedicated space heating, combined space heating and DHW, and pool heating boilers in the IOUs' territories that have an automated hot water temperature control. About 70% of dedicated space heating boilers in PG&E territory and 60% of dedicated space heating boilers in SoCalGas' territory included controls for automatically adjusting hot water temperatures, though Cadmus could only estimate the proportions with 20% relative precision by end use. None of the boilers observed in SD&GE's territory had automated hot water temperature controls.

An overall smaller proportion of combined space heating and DHW boilers included automated hot water controls, but those in SoCalGas' territory were compliant at a rate of 50%. None of the pool heating boilers included automated hot water temperature controls, consistent across IOUs.

Table 69. Proportion of Boilers with Automated Hot Water Temperature Control(1)(2)

IOU (3)	Automated Hot Water Temperature Control Present (Non-Dedicated DHWs)			
	Dedicated Space Heating Boilers	Combined Space Heating and DHW Boilers	Pool Heating Boilers	All Non-Dedicated DHW Boilers
PG&E	71%	0% (2)	0% (2)	29%
SoCalGas	63%	50%	0% (2)	30%
SDG&E	0% (2)	0% (2)	0% (2)	0% (2)
Overall	**45%**	**25%**	**0% (2)**	**22%**

(1) Cadmus indicated the precision of each estimate at a 90% confidence level using the following asterisks: *** for ±5% precision or better, ** for ±5.1-10% precision, * for ±10.1-15% precision, and no label when precision was over ±15%.
(2) Cadmus was unable to determine an estimate's precision because there was no variability between units (including when only one unit was observed).
(2) The population of meters included here are based on the data provided by the IOUs, which Cadmus screened for master and common area meters serving 40 or more dwelling units built before 2001.
(3) Cadmus was unable to determine the statistical significance of the estimate because it only observed one unit or because there was no variability in characteristics between units.

Cadmus assessed the code compliance of dedicated DHW pump controls at the meter level. According to Title 24 2019 section 110.3, service hot water systems with circulating pumps should have automatic controls to turn the system off. Pump systems that had demand control, loop aquastat, temperature modulation, or timers were considered to meet code. Table 70 shows the proportion of dedicated DHW boilers that complied with the code for circulation pump strategies and met this code requirement. Most boilers were non-compliant with California's pump circulation strategy code across all IOUs and DHW configurations. Tankless boilers in SDG&E territory showed the highest compliance rate at 50%, but Cadmus was unable to estimate these proportions with any reasonable level of precision.

Table 70. Proportion of Boilers with Pump Control Meeting Compliance(1)(2)

IOU (3)	Pump Control Present (Dedicated DHWs)			
	Sidearm	Stand-Alone	Tankless	All Dedicated DHW Boilers
PG&E	19%	18%	25%	19%
SoCalGas	16%	26%	0%(2)	17%
SDG&E	0%(2)	10%	50%	12%
Overall	**17%**	**17%**	**11%**	**16%**

(1) Cadmus indicated the precision of each estimate at a 90% confidence level using the following asterisks: *** for ±5% precision or better, ** for ±5.1-10% precision, * for ±10.1-15% precision, and no label when precision was over ±15%.
(2) Cadmus was unable to determine an estimate's precision because there was no variability between units (including when only one unit was observed).
(3) The population of meters included here are based on the data provided by the IOUs, which Cadmus screened for master and common area meters serving 40 or more dwelling units built before 2001.

Cadmus assessed compliance with California codes and standards requirements for pipe insulation. Table 71 shows compliance rates for the length of pipe covered by insulation, and Table 72 shows compliance rates for the thickness of insulation used. The majority of boilers in all strata had at least some insulation coverage, though very few had complete coverage. Boilers with at least some insulation tended to use insulation that does not meet code (less than one inch thick)—average insulation thickness for boilers with least partial coverage was 0.36, about one-third of the thickness of compliant insulation.

Table 71. Proportion of Boilers with Adequate Pipe Insulation Coverage[1]

IOU [2]	Pipe Insulation Coverage (Dedicated DHWs)		
	All	Partial	None
PG&E	4%	70%	27%
SoCalGas	11%	45%	44%
SDG&E	6%	44%	50%
Overall	**7%**	**56%**	**37%**

[1] Cadmus indicated the precision of each estimate at a 90% confidence level using the following asterisks: *** for ±5% precision or better, ** for ±5.1-10% precision, * for ±10.1-15% precision, and no label when precision was over ±15%.
[2] The population of meters included here are based on the data provided by the IOUs, which Cadmus screened for master and common area meters serving 40 or more dwelling units built before 2001.

Table 72. Proportion of Boilers with Code-Compliance Pipe Insulation Thickness[1]

IOU [3]	Pipe Insulation Thickness (Dedicated DHWs)			
	Above Code	To Code	Low	None
PG&E	2%	36%	36%	27%
SoCalGas	0%[2]	22%	35%	44%
SDG&E	6%	6%	38%	50%
Overall	**2%**	**26%**	**35%**	**37%**

[1] Cadmus indicated the precision of each estimate at a 90% confidence level using the following asterisks: *** for ±5% precision or better, ** for ±5.1-10% precision, * for ±10.1-15% precision, and no label when precision was over ±15%.
[2] Cadmus was unable to determine an estimate's precision because there was no variability between units (including when only one unit was observed).
[3] The population of meters included here are based on the data provided by the IOUs, which Cadmus screened for master and common area meters serving 40 or more dwelling units built before 2001.

5.6 Multifamily Boiler Population Technical Potential for Select Efficiency Measures

Cadmus calculated the technical potential for a limited list of measures focused on gas boiler efficiency upgrades and add-on retrofits (see Appendix H). Table 73 shows the 20-year cumulative technical potential for boiler equipment measures by both measure and IOU. Cadmus estimated the highest total potential for boiler equipment measures in SoCalGas territory, followed by PG&E and then SDG&E. This is due to the following:

- SoCalGas had nearly four times as many multifamily meters in the population eligible for this study as PG&E (4,361 vs. 1,592) and nearly five times as many as SDG&E (4,361 vs. 914).
- SDG&E had more boilers per meter than PG&E (4.67 vs. 2.53 for sites with one or more boilers with input capacity of ≤300 kBtu/h, 2.6 vs. 1.62 for sites with one or more boilers with input capacity of >300 kBtu/h)
- PG&E boilers tended to be higher efficiency than either SoCalGas or SDG&E (27.1% under code vs. 31% and 33.9% for SoCalGas and SDG&E, respectively).

Table 73. Summary of Cumulative 20-Year Technical Potential for Boiler Equipment Measures (therms)[1]

Input Capacity Range	PG&E		SoCalGas		SDG&E		Total
Measure	≤ 300 kBtu/h	>300-2500 kBtu/h	≤ 300 kBtu/h	>300-2500 kBtu/h	≤ 300 kBtu/h	>300-2500 kBtu/h	
Title 24 Code Efficiency Hot Water Boiler, 82% AFUE ≤300 kBtu/h, 80% Et >300-2500 kBtu/h	21,959	4,077	55,478	9,497	22,655	47,304	160,970
High Efficiency Boiler, AFUE 90%	60,995	107,070	198,750	63,315	3,166	52,560	485,857
Premium Efficiency Boiler, AFUE 94%	52,560	86,112	171,264	50,921	35,573	42,272	438,702
Advanced Efficiency Boiler, AFUE 95+%	37,560	60,861	122,388	35,990	25,421	29,876	312,097
Total		***431,194***		***707,604***		***258,827***	***1,397,625***

[1] The population of meters included here are based on the data provided by the IOUs, which Cadmus screened for master and common area meters serving 40 or more dwelling units built before 2001.

Table 74 shows the 10-year cumulative technical potential for boiler retrofit measures by measure and IOU. The technical potential for boiler retrofit measures is approximately 3.5 times the energy savings for boiler retrofit measures. The largest energy savings measures are on-demand boiler circulation pump control, insulating currently uninsulated piping, and installing automated flue dampers. These three measures are currently required by code in new construction, but there are many boiler systems in the existing building stock that do not have these measures installed.

Unlike equipment measures, which Cadmus assumed would be installed as the equipment turns over, the retrofit measures can be installed at any time. Therefore, Cadmus calculated the technical potential for retrofit measures over a 10-year period.

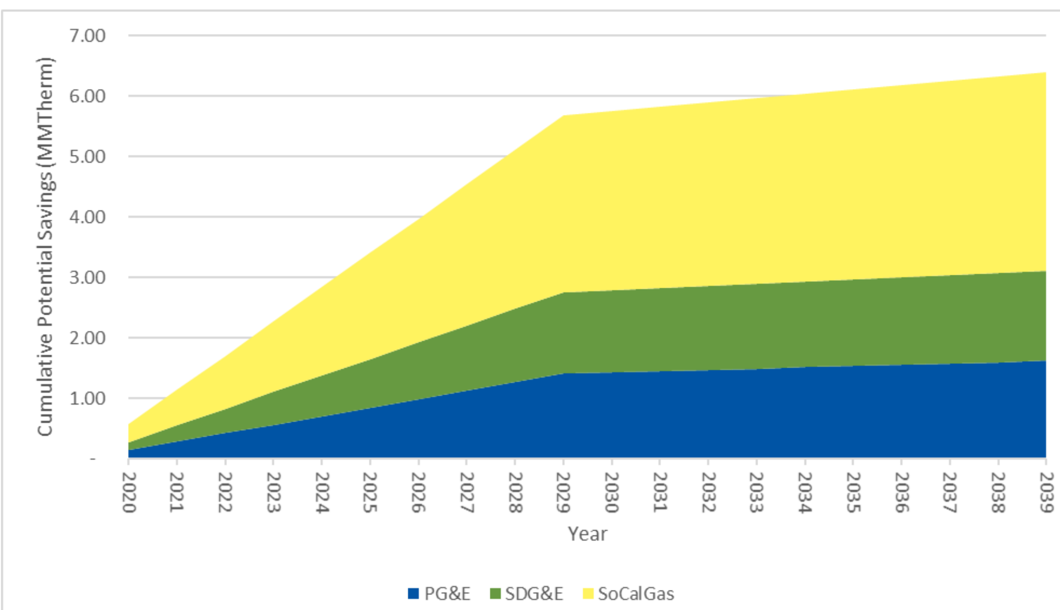
Table 74. Summary of Cumulative 10-Year Technical Potential for Boiler Retrofit Measures (therms)[(1)]

Input Capacity Range	PG&E		SoCalGas		SDG&E		Total
Measure	≤300 kBtu/h	>300-2500 kBtu/h	≤300 kBtu/h	>300-2500 kBtu/h	≤300 kBtu/h	>300-2500 kBtu/h	
On-demand Boiler Circulation Pump Control		600,782		976,667		761,160	2,338,609
Boiler Pipe Insulation - to Code (Uninsulated Pipe) [(2)]		133,769		363,938		133,856	631,562
Boiler Pipe Insulation - to Code (Low Thickness Insulation Pipe) [(2)]		16,662		8,107		11,597	36,365
Boiler Pipe Insulation - Above Code (1.5" Thickness) [(2)]		8,751		12,605		4,211	25,568
Boiler Pipe Insulation - Above Code (2" Thickness) [(2)]		8,373		12,060		4,029	24,462
Boiler Pipe Insulation - Above Code (2.5" Thickness) [(2)]		6,970		10,039		3,354	20,362
Automated Flue Damper	79,299	219,299	122,098	932,704	50,694	150,809	1,554,904
Boiler Improvements – Economizer	56,029	21,255	84,762	0	2,599	34,784	199,427
Boiler Improvements - Tune-up		35,646		46,989		41,078	123,713
Total		**1,186,835**		**2,569,968**		**1,198,172**	**4,954,974**

[(1)] The population of meters included here are based on the data provided by the IOUs, which Cadmus screened for master and common area meters serving 40 or more dwelling units built before 2001.
[(2)] The potential calculated is for insulating the exposed pipe length between the boiler and the building (or the exit point from the boiler equipment room).

Figure 13 shows the cumulative potential savings by utility for all measures. The rate of cumulative increase in technical potential decreases in 2029, since the cumulative savings do not include additional potential for boiler retrofit measures.

Figure 13. Cumulative 20-year Technical Potential Savings for Boiler Equipment and Retrofit Measures in Study-eligible Meters



5.7 Multifamily Boiler Repair Market Insights

Table 75 shows the maintenance schedules for boilers in the market across all end-uses. The majority of boilers in each IOU territory received regular maintenance at least annually—55% of boilers across all IOUs received maintenance more than once per year, and an additional 19% received maintenance once per year. Few boilers received maintenance less than once per year, but 27% of boilers were only maintained irregularly. Results were generally consistent across IOUs. The vast majority of boilers with irregular maintenance or maintenance less than annually (more than 90% in each IOU territory) served dedicated DHW end uses.

Table 75. Boiler Population Frequency of Maintenance(1)

IOU (2)	Maintenance Schedule			
	More Than Once Per Year	Once Per Year	Less Than Once Per Year	Irregular
PG&E	50%*	22%	1%	27%
SoCalGas	46%	19%	6%	30%
SDG&E	70%*	7%	-	23%
Overall	**55%***	**19%**	**5%**	**27%**

(1) Cadmus indicated the precision of each estimate at a 90% confidence level using the following asterisks: *** for ±5% precision or better, ** for ±5.1-10% precision, * for ±10.1-15% precision, and no label when precision was over ±15%.
(2) The population of meters included here are based on the data provided by the IOUs, which Cadmus screened for master and common area meters serving 40 or more dwelling units built before 2001.

5.8 Multifamily Building Characterization

Cadmus counted the total number of buildings and dwelling units at each site and calculated the average number of buildings and dwelling units. Cadmus used meter population data provided by the IOUs, and screened by Cadmus, to estimate the total number of buildings and dwelling units in the population. Because sites were only eligible for site visits if one meter at the site met the study eligibility criteria, this multifamily building characterization is limited by the study eligibility criteria for this market assessment.

Table 76 shows the total number of residential multifamily buildings served by boilers in the IOU territories. Across IOUs, the distribution of building ages for buildings served by central gas-fired boilers on complexes with sampled meters remained consistent—on average, buildings counted during the study were 45 years old, corresponding to a construction year of 1974.

Table 76. Total Number of Multifamily Buildings and Average Number of Buildings Served per Boiler(1)(2)

IOU	Average Age of Building	Total Number of Buildings	Average Number of Buildings Per Boiler
PG&E	45.4**	6,293**	1.12**
SoCalGas	44.7**	8,976**	0.81**
SDG&E	44.5**	3,869*	0.65*
Total	**45.0*** **	**19,139*** **	**0.85*** **

(1) Cadmus indicated the precision of each estimate at a 90% confidence level using the following asterisks: *** for ±5% precision or better, ** for ±5.1-10% precision, * for ±10.1-15% precision, and no label when precision was over ±15%.
(2) This multifamily building characterization is limited by the eligibility criteria for this market assessment.

Table 77 shows the total number of dwelling units in the population of residential multifamily buildings in this market study. Cadmus estimated that there are over 670,000 dwelling units in the IOU territories. The average number of dwelling units per building ranges between 28 and 37, and the average number of dwelling units per boiler ranges between 18 and 41.

Table 77. Total Number of Dwelling Units, Average Number of Units Per Building, and Per Boiler (1)(2)

IOU	Total Number of Dwelling Units	Average Number of Dwelling Units per Building	Average Number of Dwelling Units Per Boiler	Average Number of Dwelling Units Per Meter
PG&E	227,102**	36**	41**	143***
SoCalGas	334,723**	37***	30***	77***
SDG&E	108,287*	28*	18*	119**
Total	**670,112*** **	**35*** **	**30*** **	**98*** **

(1) Cadmus indicated the precision of each estimate at a 90% confidence level using the following asterisks: *** for ±5% precision or better, ** for ±5.1-10% precision, * for ±10.1-15% precision, and no label when precision was over ±15%.
(2) This multifamily building characterization is limited by the eligibility criteria for this market assessment.

5.9 *Comparison of Results with Previous Market Studies in California*

As noted in literature review conclusions in *Appendix A. Literature Review Methods and Results* section of this report, previously available data addressing multifamily building boiler population and characteristics in California are extremely rare. However, national surveys and statewide saturation surveys contain multifamily dwelling unit population data, and Cadmus estimated the number of buildings. We found potential savings estimates for on-demand circulation pump controls in the 2019 P&G study. Our comparison of the data from previous studies with the results of this study are included below.

5.9.1 Comparison of Multifamily Building and Dwelling Unit Population

Table 78 shows the comparison between the number of large multifamily buildings calculated by Cadmus in this study with those calculated using the 2016 American Communities Survey (ACS). Though the results align, it should be noted they are not directly comparable and the number of buildings calculated by Cadmus should be larger. The number of buildings calculated in this study encompasses all buildings on multifamily complexes that had a meter serving more than 40 dwelling units, built before 2001, with a central boiler, and which may contain buildings smaller than 50 units.

Table 78. Comparison of Estimated Number of Multifamily Buildings Between This and Previous Studies

IOU Territory	Number of Large Multifamily Buildings (50 Units or More) (2)		Number of Buildings in Multifamily Complexes that Had One Study-Eligible Meter(1)
	2016 ACS	2016 ACS (Built Pre-2000)	2019 California Statewide Multifamily Boiler Market Assessment
PG&E	5,067	3,872	6,293
SoCalGas	6,618	1,072	8,976
SDG&E	1,463	5,300	3,869
Total	**13,148**	**10,244**	**19,139**

(1) A study-eligible meter is a master or common area meters serving more than 40 dwelling units, built before 2001, with a central boiler. (2) For a detailed description of how Cadmus calculated these estimates, refer to Literature Review Conclusions section in this report.

Table 79 shows the comparison between number of dwelling units calculated by Cadmus using the 2016 ACS and the 2009 Residential Appliance Saturation Study (RASS). Cadmus estimates for this market assessment align with the 2016 ACS but are more than double those estimated using the 2009 RASS.

Table 79. Comparison of Number of Dwelling Units Between This and Previous Studies

IOU Territory	Number of Units in Multifamily Buildings (with 50 or more Units) Built Prior to 2000 [2]		Number of Units in Multifamily Complexes that Had One Study-Eligible Meter [1]
	2016 ACS	2009 RASS	2019 California Statewide Multifamily Boiler Market Assessment
PG&E	255,429	119,673	227,102
SoCalGas	393,531	162,230	334,723
SDG&E	81,431	42,610	108,287
Total	**730,211**	**324,512**	**670,112**

[1] A study-eligible meter is a master or common area meters serving more than 40 dwelling units, built before 2001, with a central boiler.
[2] For a detailed description of how Cadmus calculated these estimates, refer to Literature Review Conclusions section in this report.

5.9.2 Comparison of Technical Potential for On-demand Boiler Circulation Pump Control

The common measure between the technical potential estimated here and the potential presented in the 2019 P&G study discussed in *Appendix A. Literature Review Methods and Results* is the on-demand boiler circulation pump control measure (referred to as water heating controls in the 2019 P&G study). The inputs used to calculate the technical potential in this study are detailed in *Appendix I. Technical Potential Calculation Inputs.*

The technical potential calculated in this study is not directly comparable with the potential calculated in the 2019 P&G study because this study had a smaller scope. The 2019 P&G study assessed potential for the multifamily sector as a whole, whereas Cadmus calculated the potential for multifamily residential complexes that have at least one meter serving 40 or more dwelling units built before 2001 with a central boiler serving the dwelling units.

Cadmus estimated 2.3 MMtherms of cumulative technical potential savings for the on-demand boiler recirculation pump control measure over the next 10-year period. The 2019 P&G study estimated over 271 MMtherms of cumulative technical potential saving over the next 10-year period for this measure (with additional potential for the low-income sector). The potential for the on-demand boiler circulation pump control measure is different by two orders of magnitude. Figure 14 shows the cumulative savings of the on-demand boiler circulation pump control measure as calculated by Cadmus for this study.

Because the two studies used different population sizes, Cadmus reviewed the per-unit saving assumptions in the 2019 P&G study for this measure. The 2019 P&G study calculated the potential for this measure by extrapolating per-dwelling unit estimates to the population. Cadmus calculated the potential not by using a per-dwelling unit estimate, but rather by determining the baseline usage from input capacity and efficiency data (from this study), multiplying by the equivalent full load hours, applying savings factors to the baseline usage from various literature sources, and extrapolating to the population of meters estimated in this study. We used the equivalent full load hours from the DEER database by climate zone, estimated to be between 500-700 hours depending on the utility.

The difference between the two estimates can be explained by the factors described below. This review suggests that the per-dwelling unit savings and the initial technology saturations for on-demand circulation pump control should be reevaluated in the next P&G study.

- The 2019 P&G study referred to estimated savings from a workpaper that estimated average savings of 22.64 therms per dwelling unit and multiplies that by the forecasted number of dwelling units.[15] This estimate is based on a Title 24 2013 codes and standards enhancement initiative (CASE) report,[16] which modeled savings for on-demand circulation pump controls. The CASE report calculated 1,014 therms and 1,255 therms for low-rise and mid-rise multifamily buildings respectively, with 44 and 88 units each. However, the work paper savings represent average low-rise building type savings divided by 44 units adjusted for California climate zones. Cadmus calculated the average savings of 284 to 944 therms per meter, depending on utility. Cadmus determined the average overall boiler input capacity per meter to be 753 to 3,109 kBtu/h, depending on utility. Cadmus took the average equivalent full load hours across all territories to be 506 to 692 hrs/yr from DEER database data. Typical gas saving for this measure was estimated to be 6% of the baseline energy consumption based on a Department of Energy study.[17] Cadmus multiplied the per meter savings by the total population of study-eligible meters calculated through this study, which was 6,867 meters across all three utility territories. For comparisons, the per dwelling unit savings for this measure as calculated by Cadmus is 4.38 therms.
- The 2019 P&G study assumes initial technology saturation is 2% across all residential multifamily units. This study found an initial technology saturation of 14% across the study-eligible meters in the three gas IOU territories for boiler that have some type of pump control. Cadmus used boiler pump saturation and pump control applicability factors, by IOU, resulting from its site visits to calculate the potential for this measure.

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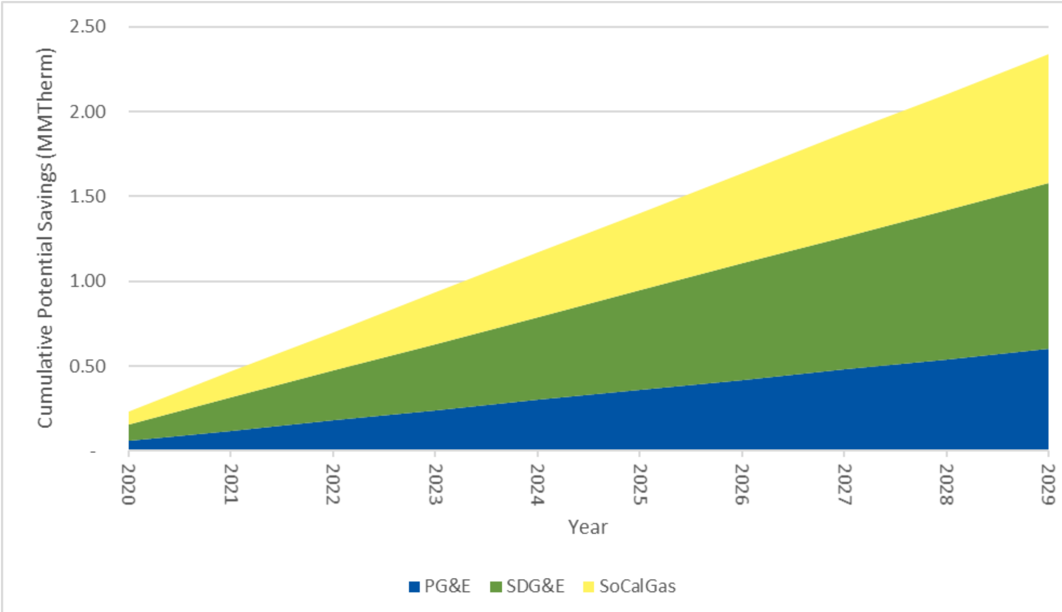
15 Southern California Gas Company. *On-Demand Pump Control for Central Domestic Hot Water Systems.* Workpaper WPSCGODE091116. Revision 5. December 2013

16 California Utilities Statewide Codes and Standards Team. *Codes and Standards Enhancement Initiative (CASE) - Multifamily Central DHW and Solar Water Heating - 2013 California Building Energy Efficiency Standards*. September 2011.

17 U.S. Department of Energy. *Control Strategies to Reduce the Energy Consumption of Central Domestic Hot Water Systems.* June 2016. Available at: https://www.nrel.gov/docs/fy16osti/64541.pdf

Figure 14. Cumulative 10-year Potential Measure Savings for Boiler Circulation Pump Demand Control in Study-Eligible Meters



6 Conclusions and Recommendations

This section presents Cadmus' high-level conclusions and recommendations for future direction, research, and analysis in this area for the Study Team. The results apply to boilers in multifamily complexes with at least one meter serving 40 or more dwelling units and built before 2001 in the IOU territories.

Conclusion 1. In this market study, a majority of boilers behind multifamily meters (86%) solely served DHW end-uses. Pool-heating and dedicated space-heating boilers constituted 6% and 5% of the population, respectively. Only 2.5% of boilers served both DHW and space-heating end-uses. *(See Section 5.1 Multifamily Boiler Population Stock and End-Uses Served)*

Conclusion 2. While Cadmus did not find evidence suggesting that a majority of boilers are old and operating beyond their EULs, boiler-age data suggested that 22% and 25% of dedicated space-heating boilers in PG&E and SoCalGas territories, respectively, operated at or beyond their EULs. Additionally, data suggest that 30% of pool-heating boilers in PG&E's territory operate at or beyond their EULs. Overall, 7% of boilers were at least 20 years old and operated at or beyond their EULs. Cadmus did not visit any boilers operating at or beyond their EULs within SDG&E's territory. Dedicated space-heating boilers had higher average input capacities, suggesting that they are larger and more expensive to replace. *(See Sections 5.2 Multifamily Boiler Population Vintage* and *5.4 Multifamily Boiler Population Input Capacity)*

> **Recommendation 1:** In their efforts to replace older, less-efficient boilers, PG&E and SoCalGas should consider focusing on dedicated space-heating boilers, and PG&E should consider focusing on pool-heating boilers. PG&E and SoCalGas may consider increasing program marketing or incentive amounts for high-efficiency replacements in these boiler categories.

Conclusion 3. Cadmus did not find older boilers in older buildings. Data collected through site visits showed boilers of all ages and efficiency levels among buildings in each 20-year age strata. The data did not show a correlation between building age and boiler age. Given limited program participation data from the IOUs, and limited indication of previous program participation from site-visit contacts, Cadmus could not establish the program's influence on replacements of old boilers. *(See Section 5.2 Multifamily Boiler Population Vintage)*

Conclusion 4. Cadmus calculated technical potential as 3.5 times higher for boiler retrofits (add-on or maintenance measures) than for boiler equipment replacements. Cadmus conducted a limited technical potential analysis for gas boiler equipment replacements (resulting in efficiency improvements) and retrofit measures (such as circulation pump demand-control, boiler pipe insulation, automated flue damper, economizer, and tune-ups). Cadmus calculated 1.4 and 4.9 MMtherms of technical potential for boiler equipment and retrofit measures, respectively, and Cadmus calculated the highest total potential for equipment and retrofit measures in SoCalGas territory (3.27 MMtherms), followed by PG&E (1.62 MMtherms) and SDG&E (1.46 MMtherms). *(See Section 5.6 Multifamily Boiler Population Technical Potential for Select Efficiency Measures)*

Conclusion 5. A comparison of technical potential savings calculated in this study and in the 2019 Energy Efficiency Potential and Goals Study (2019 P&G study) for the on-demand circulation pump control measure suggests that per-dwelling unit savings and initial saturation assumptions for this measure should be reevaluated in the next P&G study. The technical potential calculated in this study cannot be directly compared with the potential calculated in the 2019 P&G study due to this study's smaller scope. A comparison of per-dwelling unit savings (22.86 therms used in the 2019 P&G study versus 4.38 therms calculated in this study) and the initial technology saturation (2% in the 2019 P&G study versus 14% in this study) for the on-demand recirculation pump control measure suggests that these assumptions should be re-evaluated in the next P&G study. *(See Section 5.9 Comparison of Results with Previous Market Studies in California)*

> **Recommendation 2:** To increase the accuracy of its potential estimates in the multifamily water heating sector, the CPUC should consider re-evaluating estimates of per-dwelling unit savings and initial saturation for the on-demand pump control measure in the next P&G study.

Conclusion 6. Multifamily building decision-makers remain hard to reach. A coordinated phone outreach campaign, coupled with high incentives ($200 per site visit completed), proved key in reaching this group of IOU customers and in achieving the targeted sample size for site visits. Mailed postcards and emails were very helpful in getting the word out about the study, but the most productive outreach mode in recruiting participants was by phone. Cadmus found that IOU customer databases often did not contain accurate phone or email contact information for decision-makers of multifamily buildings, hence relying heavily on internet searches to find accurate contact information. It is difficult and costly for the IOUs to obtain and maintain current contact information for multifamily buildings. *(See Appendix F. Phone and Email Outreach Dispositions)*

> **Recommendation 3:** Given the difficulty in reaching multifamily building decision-makers and the high cost of data collection, Cadmus recommends future researchers and the IOUs consider a coordinated phone outreach approach, coupled with incentives, that allows for data collection about multiple research topics, or about the building and equipment as a whole, as opposed to data collection focused on a specific technology.

Conclusion 7. Cadmus' literature review confirmed a gap in previously available data about boilers in California residential, multifamily buildings, including numbers installed, end-uses served, input capacity, age, and efficiency. This study fills the gap in previously available data for boilers in the PG&E, SDG&E, and SoCalGas territories. This market assessment answers critical questions about the quantity, age, type, code compliance, and efficiency of boilers in large residential, multifamily building complexes with at least one meter serving 40 or more dwelling units built before 2001. *(See Appendix A. Literature Review Methods and Results)*

Conclusion 8. Additional research is needed to understand multifamily building owner/operator decision-making processes to assist in targeted program planning and utility intervention to encourage replacements of older boilers and installations of retrofit measures. The original RFP contained additional research questions for Phase 2 of this study, focused on understanding multifamily building owner/operator decision-making processes. Though Cadmus did not find a significant proportion of boilers operating beyond their EULs, Cadmus did estimate a large potential for boiler retrofit measures. Cadmus' literature review indicated that structural barriers remain regarding high IOU program uptake in the multifamily market, particularly for whole-building upgrades. Understanding how multifamily building owners and operators make decisions would help the IOUs target programs, not just for boiler replacements and retrofits but also for other whole-building energy efficiency improvements in the multifamily residential building sector. *(See Section 5.6 Multifamily Boiler Population Technical Potential for Select Efficiency Measures* and *Appendix A. Literature Review Methods and Results)*

> **Recommendation 4:** The IOUs and the CPUC should consider additional research to assist in targeting programs for multifamily customers in response to current state decarbonization priorities in the building sector. This additional research should build upon data collected through previous IOU multifamily customer segmentation and needs assessment studies, in addition to insights gathered from previous California multifamily program process evaluations.

Appendix A.Literature Review Methods and Results

Literature Review Methods

Cadmus reviewed recent relevant literature about the multifamily gas boiler market to inform subsequent research. Cadmus followed these three steps:

1. Identify key secondary sources and parameters
2. Complete a literature review tracking template to indicate the relevance of each key secondary source to key parameters
3. Summarize the findings

A detailed description follows for each step.

Step 1. Identified Key Sources and Parameters

Cadmus identified the parameters required to thoroughly understand the size of the multifamily gas boiler market and to estimate the size and technical potential savings for boiler replacement and retrofits. Cadmus particularly sought to quantify the following parameters for large multifamily buildings (50 units or larger) with central gas boiler systems. The building size limit was reduced during the screening and recruitment phase of the project, to 40 units or larger as explained in this report.

Multifamily Building Characteristics:

- Number of buildings
- Age of buildings
- Number of dwelling units in buildings
- Rented vs. owned dwelling units
- Market rate or rent-assist
- Buildings with central gas water heating
- Buildings with central gas space heating

Boiler Characteristics:

- Capacity
- Age
- Service end uses
- Efficiency
- Control strategies
- Maintenance schedule
- Operation schedule
- Add-ons (e.g., automated flue damper)
- Boilers with economizers
- Number of circulation loops per building
- Potential for retrofits (e.g., demand control circulation pump, tune-up and maintenance)
- Pipe insulation value

To identify key sources for the literature review, Cadmus referred to the sources listed in the Schedule A Scope of Work, included in the March 2017 Request for Proposal for Multifamily Boiler Market Study that initiated this project. Cadmus added recent multifamily program process evaluations that had been completed at the time Cadmus conducted its literature review (February 2018), the 2016 U.S. Census Bureau American Community Survey (ACS), and the 2009 U.S. Energy Information Administration's (EIA) Residential Energy Consumption Survey (RECS). Table A-1 provides a detailed bibliography.

Step 2. Completed a Literature Review Tracking Template

Cadmus created a spreadsheet-based data collection template to track the relevance of reviewed secondary sources to key parameters. We provided this data template to the study manager before initiating the literature review. The template allowed the Cadmus team to compare secondary sources and identify any knowledge gaps or discrepancy areas across the literature.

Step 3. Summarized Literature Review Findings

Cadmus examined the secondary sources identified in Step 1 to accomplish the following:

- Extract data specific to the multifamily boiler market
- Lay out the context and comparison points for new data (to be collected during site visits)
- Identify data gaps to be filled with new data

Cadmus documented challenges and opportunities for efficiency improvements in this market segment, as reported in prior studies. We compared findings across sources to develop a robust profile and identified areas that require further research.

The RFP issued for this study included a list of key relevant sources for the literature review. Cadmus added to this list and categorized the list by their topic areas and summarized the literature review findings under each topic area. For its literature review, Cadmus reviewed the following sources:

Table A-1. Sources for Literature Review

Name of the Publication	Author	Year
Market Studies Needs Assessment		
Market Studies Needs Assessment	Opinion Dynamics	2015
CPUC and IOU Saturation Surveys		
2009 California Residential Appliance Saturation Study (RASS)	KEMA	2010
2012 California Lighting & Appliance Saturation Study (CLASS)	KEMA	2014
Multifamily Water Heating Measure Potential		
Potential and Goals (P&G) Study for 2018 and Beyond	Navigant	2017
2019 Energy Efficiency Potential and Goals Study	Navigant	2019
Residential Solutions Workbook Phase I: Market View	Research Into Action	2014
Residential Solutions Workbook Phase II: Measure View	Research Into Action	2014
Multifamily Market Segmentation		
Needs Assessment for the Energy Savings Assistance and the California Alternate Rates for Energy Programs Vol 1	Evergreen Economics	2016
Needs Assessment for the Energy Savings Assistance and the California Alternate Rates for Energy Programs Vol 2	Evergreen Economics	2016
ESA Program Multifamily Segmentation Study	Cadmus	2013
2010-2012 PG&E & SCE Multifamily Property Owners & Managers General Population Survey Study	Cadmus	2013
Multifamily Program Process Evaluations		
2013–2015 Residential Roadmap 2015 Multifamily Focused Impact Evaluation	DNV GL	2017
2010-2012 PG&E and SCE Multifamily Energy Efficiency Rebate Program (MFEER) Process Evaluation and market characterization Study	Cadmus	2015
Southern California Multifamily Program Process Evaluation 2014-2015	Evergreen Economics	2017
SCE and SoCalGas Energy Upgrade California—Multifamily Pilot Process Evaluation	Opinion Dynamics with SBW	2017

Literature Review Results

Findings from the literature review of these topic areas are provided below:

Multifamily Market Gas Water Heating Study Needs

The 2015 Market Studies Needs Assessment (Opinion Dynamics Corporation [ODC] 2015) recommended a set of market studies for energy end uses that the California Public Utility Commission (CPUC) and the investor-owned utilities (IOU) should prioritize for the following five to 10 years. For the one- to three-year, short-term timeframe, the study suggested several new studies based on high relative importance but low market knowledge.

ODC assessed the availability of market knowledge qualitatively, based on ODC's compilation of relevant market data in California, and identified the residential hot water and commercial boiler market characterization as a short-term market study need. Although the 2015 market studies' needs assessment did not specifically recommend conducting a multifamily boiler market study, multifamily boilers lay at the intersection of the residential water heating and commercial boiler markets.

California Statewide Energy Efficiency Potential and Goals Study

The RFP issued for this study requested a review of The Energy Efficiency Potential and Goals Study for 2018 and Beyond (Navigant 2017), which was current at the time of the RFP issuance and when Cadmus conducted the literature review in March 2018. Cadmus then updated its literature review in October 2019 with the results of the 2019 Energy Efficiency Potential and Goals Study (Navigant 2019) (referred to as the 2019 P&G study).

The 2019 P&G study developed estimates of energy and demand savings potential in the IOU territories from 2020-2030. This study informs CPUC saving goals, which in turn guide planning of the IOU program portfolios and the state's forecasting for energy procurement. The CEC has historically used the potential and goals studies to develop its forecast of additional achievable energy efficiency (AAEE) potential. Senate Bill 350 (SB350) required doubling AAEE by 2030. The 2019 P&G study served as an input to setting the SB350 target. The study included a base case scenario and four alternatives built around policies and program decisions that are within the sphere of influence of the CPUC and its stakeholders collectively. The alternatives set different potential modeling parameters for the cost-effectiveness measure screening threshold, incentive levels, program marketing and outreach, and Behavior, Retrocommissioning, and Operational (BRO)s program assumptions, and the impact of financing programs.

The only multifamily gas water heating measure in the 2019 P&G study relevant to this market study is the on-demand circulation pump control measure for central domestic hot water systems in multifamily buildings.[18] The 2019 P&G study refers to a SoCalGas workpaper,[19] which estimates gas and electric savings of 22.64 therms and 27.91 kWh, respectively, per multifamily dwelling unit. The 2019 P&G study assumes a 2% initial technology saturation.

Figure A-1 shows this measure's cumulative gas technical savings potential for three California Gas IOUs.[20]

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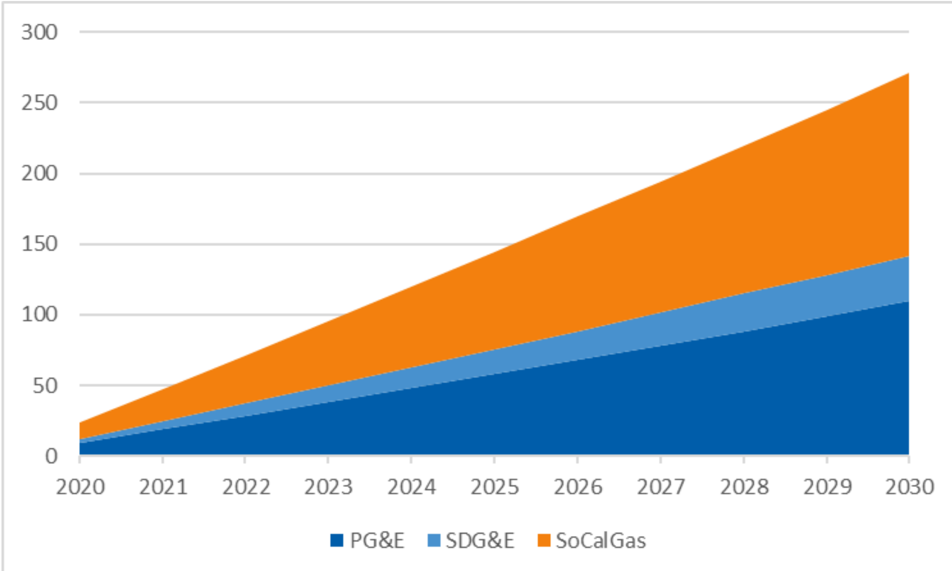
[18] The other gas water heating measure assessed in the P&G study for residential multifamily buildings was drain heat recovery.

[19] Southern California Gas Company. *On-Demand Pump Control for Central Domestic Hot Water Systems.* Workpaper WPSCGODE091116. Revision 5. December 2013.

[20] The P&G study identified economic and market potential in addition to technical potential for energy efficiency measures and programs. As Cadmus' market study focused on technical potential, we only referenced the technical potential savings from the P&G study.

Figure A-1. Cumulative 10-year Gas Technical Savings Potential for Multifamily On-Demand Circulation Pump Controls on Boilers (MMtherms)



Source: 2019 Energy Efficiency Potential and Goals Study (Navigant 2019), Measure-Level Results Workbook

Table A-2 shows the cumulative gas and electric energy technical savings potential for multifamily, on-demand circulation pump controls identified in the 2019 P&G study.

Table A-2. Cumulative 10-Year Gas Technical Savings Potential for Water Heater Control Measure in Multifamily Residential Sector (MMTherm)[(1)]

Utility	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
PG&E	9	19	28	38	48	58	68	78	89	99	109
SoCalGas	11	23	34	46	57	69	81	93	105	117	129
SDG&E	3	6	9	11	14	17	20	23	26	29	33
Total	**23**	**47**	**71**	**95**	**120**	**144**	**169**	**194**	**220**	**245**	**271**

[(1)] For multifamily on-demand circulation pump controls on boilers.
Source: Measure-Level Results Workbook in Navigant. *2019 Energy Efficiency Potential and Goals Study.*

California Residential Solutions Workbook

The IOUs have also tracked potential impacts from various water heating measures through development of the California Residential Solutions Workbook (RSW). A residential energy efficiency program planning support tool, the RSW provides order-of-magnitude saturation, market share, and technical savings potential estimates for a set of residential energy efficiency measures. The IOUs based the RSW on California or nationwide evaluations, engineering studies, and market characterization reports.

The first phase of RSW development (Research Into Action 2014) provided a market overview for 132 residential devices (including residential gas water heaters and boilers, and a detailed market review for

21 selected high-priority devices (including residential gas water heaters, but not boilers). RSW presents data by dwelling unit and groups single-family and multifamily data together.

Table A-3 provides an overview of market data available for residential gas boilers and water heaters during RSW's Phase 1. Based on the RSW, boilers represent a 1% share of California IOU households, compared to an 88% share for residential gas water heaters.

For comparison, the RSW also includes market data from the U.S. Environmental Protection Agency's ENERGY STAR® program. The program estimates a much larger portion of efficient units being purchased in the boiler market than shown in the RSW. Because ENERGY STAR certification applies to residential boilers with an input capacity of 300,000 kBtu/h or less,[21] ENERGY STAR's market share and the estimated annual savings apply to just a slice of the national multifamily buildings market.

Table A-3. Penetration and ENERGY STAR Market Share Estimates for Residential Boilers, Water Heaters, and Gas Space Heaters

	Household Penetration (California)(1)					ENERGY STAR Market Share (U.S.) *Percentage of New Unit Shipments*	ENERGY STAR Estimated Annual Unit Savings (U.S.) *(therms)*
Reference Year	2000	2003	2005	2009	2012	2013	N/A
Boilers	1%	1%	1%	1%	1%	58%	60
Gas water heaters	90%	81%	89%	84%	88%	4%	80

(1) The RSW bases household penetration estimates on California residential appliance saturation surveys from 2003 and 2009, and on California appliance and lighting saturation surveys in 2000, 2005, and 2012.
Source: Research Into Action. *Residential Solutions Workbook Phase 1*. 2014.

The RSW's second phase (Research Into Action 2015) provided a set of measure-level workbooks that aggregated and displayed energy and market data for four high-priority residential devices, including residential water heaters. The RSW Phase 2 Residential Water Heaters' Measure-Level Workbook focused on water heaters serving a single residential unit. Therefore, market data presented in the RSW measure-level workbook for water heaters was not relevant to this California Statewide Multifamily Boiler Market Assessment Study.

California Residential Appliance Saturation Study

The 2009 California Residential Appliance Saturation Study (RASS) (Kema 2010) provided saturation and energy consumption estimates for 27 electric and 10 natural gas residential end uses and appliances in the PG&E, Southern California Edison (SCE), SDG&E, SoCalGas, and Los Angeles Department of Water and Power territories. The study relied on a mail/online survey and billing data analysis. Kema obtained end-use saturations for 24,464 electric, individually metered and 1,257 electric, master-metered households.

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21 U.S. Environmental Protection Agency. *ENERGY STAR Program Requirements: Product Specification for Boilers Eligibility Criteria.* Version 3.0.

Table A-4 shows unit energy consumption, and Table A-5 shows gas water heating and space heating saturations, as estimated in the 2009 RASS by utility and multifamily building type and reported in Volume 2 of the 2010 RASS report. The 2009 RASS apartment building unit classification counts ended at five or more units; therefore, this information was unavailable for multifamily buildings with 50 or more units.

Gas water heating unit energy consumption was 183 therms, with 55% saturation for apartments in buildings with five or more units. Note that this consumption was estimated as an average across all gas water heating equipment (including central systems and individual unit storage systems).

Table A-4. 2009 RASS Unit Energy Consumption (therms) for Gas Water and Space Heating

	5+ Unit Apt	All Housing Types		
	All Gas IOUs	PG&E	SDG&E	SoCalGas
Household Total	150	405	298	328
Primary Gas Space Heating	31	213	100	102
Secondary Gas Space Heating	49	129	56	43
Gas Water Heating(1)	183	188	175	200

(1) The total average household gas energy usage for multifamily buildings with five or more units was higher than average usage for gas water heating in this building type as gas water heating (shown in Table A-5) has a 55% saturation in this building type. For the remaining 45% of households' in this building type, gas water heating unit energy consumption likely was close to zero.

Source: Table 2-21 and 2-24 of the 2009 RASS (Kema 2010).

Table A-5. 2009 RASS Saturation for Gas Water and Space Heating

	5+ Unit Apt	PG&E	SDG&E	SoCalGas
Primary Gas Space Heating	0.88	0.95	0.93	0.91
Secondary Gas Space Heating	0.00	0.01	0.00	0.00
Gas Water Heating	0.55	0.88	0.88	0.86

Source: Table 2-21 and 2-24 of 2009 RASS (Kema 2010).

Cadmus also accessed and queried the RASS webtool to obtain multifamily building population estimates—by gas IOU and age strata—for homes using gas water or space heating.[22] The 2009 RASS age strata coincided with significant years in the history of energy policy, such as to California Title 24's Part 6 Building Energy Efficiency Standards' effective years.

Table A-6 shows the 2009 RASS estimate of multifamily households by gas utility for buildings with five dwelling units or more. The table shows the most accurate count of households in the 2009 RASS database. Of the households in multifamily buildings with five or more units, 50% were in SoCalGas territory, followed by 38% in PG&E gas territory, and 12% in SDG&E gas territory.

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22 The RASS webtool is available online. California Statewide Residential Appliance Saturation Study. https://webtools.dnvgl.com/rass2009/

Table A-6. Estimate of Multifamily Households by Gas Utility (Buildings with Five Units or More)

Gas Utility	PG&E	SDG&E	SoCalGas	Total
Count of Households	469,032	153,579	623,075	**1,245,686**
Percentage of Households	37.7%	12.3%	50.0%	**100%**

Source: 2009 RASS (Kema 2010), webtool query.

Table A-7 shows the 2009 RASS estimate of multifamily households (by gas utility in seven building-age strata) in buildings with five units or more. As of 2009, one-half of all dwelling units were built prior to 1975; only 11% of all dwelling units were built after 2001. Table A-7 shows a smaller total number of multifamily households in buildings with five units or more than that shown in Table A-6. This is because Cadmus applied additional filters to the survey data—in this case stratifying the total household counts in various age strata. There were fewer responses to the age question and some invalid responses that were removed in the data cleaning process by the 2009 RASS authors, which reduced the total number of households reported in this table compared with the previous one.

Table A-7. 2009 RASS Estimate of Multifamily Households by Age Strata (Buildings with Five Units or More)

Building Age	PG&E		SDG&E		SoCalGas		Total	
	Count	%	Count	%	Count	%	Count	%
Before 1975	210,528	52%	43,577	41%	244,292	51%	498,397	50%
1975-1977	19,464	5%	6,599	6%	26,184	5%	52,247	5%
1978-1982	33,169	8%	8,032	7%	44,528	9%	85,729	9%
1983-1992	66,263	16%	31,448	29%	73,998	15%	171,709	17%
1993-1997	4,638	1%	6,592	6%	30,023	6%	41,253	4%
1998-2000	21,575	5%	6,133	6%	13,183	3%	40,891	4%
2001-2008	49,917	12%	4,988	5%	50,782	11%	105,687	11%
Total(1)	**405,554**	**100%**	**107,369**	**100%**	**482,989**	**100%**	**995,912**	**100%**

(1) This table adds age strata and reduces total counts of households to those with age data provided in survey responses, hence the total number of households shown are lower than those shown in Table A-6.
Source: Webtool query in Kema. *2009 RASS.* 2010.

Table A-8 shows the 2009 RASS estimate of multifamily households (by gas utility in seven age strata) that indicated having a primary gas water heater. The 2009 RASS did not contain information about central-to-the-building versus individual-to-the-unit gas water heating systems. Note that saturations shown in Table A-8 are lower than those shown above in Table A-3 (from the RSW Phase 1 workbook) because the RSW combined data for single-family and multifamily buildings.

Table A-8. 2009 RASS Estimate of Multifamily Households by Age Strata with a Gas Water Heater (Buildings with Five Units or More)

	PG&E	SDG&E	SoCalGas	Total	Total Number of Dwelling Units
Before 1975	50%	62%	54%	53%	498,397
1975-1977	86%	5%	68%	67%	52,246
1978-1982	60%	25%	54%	54%	85,729
1983-1992	50%	47%	50%	49%	171,710
1993-1997	81%	98%	75%	80%	41,253
1998-2000	30%	13%	85%	45%	40,890
2001-2008	49%	57%	78%	63%	105,687
Total(1)	**52%**	**51%**	**59%**	**55%**	**995,912**

(1) This table adds age strata and reduces total household counts to those with age data provided in the survey responses, hence the total number of households are lower than those shown in Table A-6.

Source: 2009 RASS (Kema 2010), webtool query.

To estimate the number of dwelling units served by a central gas boiler, Cadmus queried the 2009 RASS population estimates for respondents who said hot water gas radiators provided their primary means of heating in their households. Table A-9 shows the query results. The results indicate that 2% of multifamily households had a central boiler.

Table A-9. Multifamily Households with a Primary Hot Water Gas Radiator (Multifamily Buildings with Five Units or More)

Gas Utility	Hot Water Gas Radiator	No Hot Water Gas Radiator	No Response	Not Applicable	Total
PG&E	13,283	400,513	22,229	33,006	469,031
	3%	85%	5%	7%	100%
SDG&E	5,022	129,986	1,607	16,963	153,578
	3%	85%	1%	11%	100%
SoCalGas	11,805	532,640	27,312	51,319	623,076
	2%	86%	4%	8%	100%
Total	**30,111**	**1,063,139**	**51,148**	**101,288**	**1,245,686**
	2%	**85%**	**4%**	**8%**	**100%**

Source: 2009 RASS (Kema 2010), webtool query.

California Lighting and Appliance Saturation Survey

The 2012 California Lighting and Appliance Saturation Survey (CLASS) (DNV GL 2012) collected home characteristics, lighting, and appliance data from a sample of single-family, multifamily, and mobile home residences with individually metered electric accounts. The data were stratified by IOU and climate zone and addressed questions related to saturation and efficiency characteristics for use in understanding future energy savings as well as potential and past accomplishments in the residential sector.

Though the 2009 RASS relied on the mail/online survey results of 24,464 individually metered and 1,257 master-metered households, 2012 CLASS targeted individually metered electric customers and involved 1,987 site visits. As such, 2012 CLASS excluded approximately 5% of the population of multifamily buildings in the three gas IOU territories. The multifamily building characterization results of CLASS 2012, therefore, should be viewed with that caveat in mind.

Table A-10 breaks down water heating system characteristics in multifamily residences of five units or more (n=202). In addition to the data presented in the table, 23% of multifamily residences of five units or more had domestic hot water pipe insulation.

Table A-10. Water Heating System Characteristics (Multifamily Buildings with Five Units or More)

Water Heating System	PG&E	SDG&E	SoCalGas	Total
Gas Storage	49%	54%	83%	**59%**
Propane Storage	2%	1%	0%	**1%**
Electric Storage	8%	6%	4%	**6%**
Gas Instantaneous	2%	1%	2%	**2%**
Electric Instantaneous	0%	0%	0%	**0%**
Common Boiler	12%	1%	0%	**5%**
Common Building	28%	36%	9%	**26%**
Total	**37%**	**39%**	**24%**	**100%**

Source: 2012 CLASS.

U.S. Census Bureau American Community Survey

Every year, the United States Census Bureau conducts the ACS to update the social and economic characteristics of U.S. communities.[23] Cadmus downloaded relevant 2016 ACS data at the zip code level and mapped them to California IOUs' service territory lists that specified zip codes and respective climate zones.[24] Cadmus then summarized ACS data, addressing key research parameters by climate zone within each IOU's service territory. Despite the granularity of zip code-level data, territorial overlap occurred among IOUs, as described in Table A-11.

[23] More information on the ACS is available online: https://www.census.gov/programs-surveys/acs/

[24] Service territory lists for PG&E, SCE, and SDG&E were publicly available and acquired from online sources. Cadmus obtained SCE's service territory list for a 2007 study.

Table A-11. IOU Service Territory Overlap

Zip Code Service Territory Characterization	Percentage of Population
Exclusive to a single IOU	90.0%
Shared by two or more IOUs	6.4%
Not matched to IOU service territory lists(1)	3.6%
Total	**100%**

(1) Service territory lists for PG&E and SDG&E were publicly available and acquired from online sources. Cadmus obtained SoCalGas's service territory list for a 2007 study.
Source: 2016 ACS.

The ACS provided building size stratification, allowing Cadmus to narrow down the review to large multifamily buildings (with 50 or more dwelling units). Table A-12 shows the number of large multifamily buildings built before 2000, estimated using ACS data. Table A-13 shows the percentage of rented units in all large multifamily buildings, including those built after 2000.

Table A-12. Number of Dwelling Units in Large Multifamily Buildings by IOU (Buildings with 50 Units or More)

IOU Territory	Housing Type		Percentage
	All	Large Multifamily Built Before 2000(1)	
PG&E	5,929,603	255,429	4.3%
SDG&E	1,360,411	81,431	6.0%
SoCalGas	6,925,672	393,531	5.7%
Total	**14,215,686**	**730,211**	**5.1%**

(1) Estimated using percentage of occupied units in large multifamily buildings built before 2000.
Source: 2016 ACS.

Table A-13. Renter Profile in Large Multifamily Buildings (Buildings with 50 Units or More)

IOU Territory	Housing Type(1)		Percentage
	Occupied Units(2)	Rented Units	
PG&E	307,592	278,496	91%
SDG&E	97,300	84,792	87%
SoCalGas	448,624	410,528	92%
Total	**853,516**	**773,816**	**91%**

(1) Includes large multifamily buildings built after 2000.
(2) Excludes vacant units.
Source: 2016 ACS.

Estimating Number of Buildings

ACS data provided estimates for the total number of dwelling units by housing characteristics but not by the total number of buildings. The ACS categorized the units in each building into these property sizes:

- 1 unit, detached
- 1 unit, attached
- 5 to 9 units
- 10 to 19 units

- 2 units
- 3 to 4 units
- 20 to 49 units
- 50 or more units

Table A-14 presents the cumulative percentage of units by property size from the 2016 ACS. To calculate the number of buildings, Cadmus applied a method that was initially developed for a 2013 process evaluation of the Multifamily Energy Efficiency Rebate (MFEER) program for PG&E and SCE (Cadmus 2013).[25] In estimating the number of buildings, Cadmus divided the number of units per property-size category by each property-size midpoint. For example, the number of buildings with 5 to 9 units would be estimated as 1,091,156 ÷ 7 ≈ 155,879. As stated by Cadmus in its 2013 report, “The estimate is rough, but it is worth making to obtain an important number.”

The midpoint for the property size central to this research (50 or more units) could not be calculated using this method as its range had no upper bound. Cadmus estimated the midpoint by using a logarithmic regression of other property size midpoints on the cumulative percentage of the total distribution, solved for the value of 100% for each IOU (Cadmus 2013).

Table A-14. Cumulative Percentage of Units by Housing Type

Property Size	Midpoint	PG&E	SDG&E	SoCalGas
2 units	2	10.7%	6.0%	6.9%
3 to 4 units	4	31.9%	21.1%	23.7%
5 to 9 units	7	51.5%	43.4%	43.3%
10 to 19 units	14.5	66.6%	61.9%	60.7%
20 to 49 units	34.5	79.7%	76.2%	78.3%
50 or more units	Estimated	100.0%	100.0%	100.0%

Source: 2016 ACS.

Table A-15 shows the number of units in large multifamily buildings, the regressed midpoint for *50 or more units*, and the number of buildings estimated using the described methodology.

Table A-15. Estimated Number of Large Multifamily Buildings by IOU (Buildings with 50 Units or More)

IOU Territory	Large Multifamily Buildings (50+ Units)			
	Number of Units	Regressed Midpoint	Number of Buildings	Buildings Built Pre-2000
PG&E	334,033	65.9	5,067	3,872
SDG&E	111,122	76.0	1,463	1,072
SoCalGas	491,405	74.2	6,618	5,300
Total	**936,560**	**70.0**	**13,148**	**10,244**

Source: 2016 ACS

25 Cadmus. *2010–2012 PG&E and SCE Multifamily Energy Efficiency Rebate Program (MFEER) Process Evaluation and Market Characterization Study*. pp. 16-17. April 15, 2013.

U.S. Census Bureau American Housing Survey

The United States Census Bureau conducts the American Housing Survey (AHS) every two years to provide a current and continuous series of data on selected housing and demographic characteristics.[26] Cadmus used 2015 AHS data to estimate the number of units in large multifamily buildings (50 units or more) by income designation, according to the federal poverty level (FPL), as shown in Table A-16. Cadmus also estimated the number of buildings applying the methodology previously described.

Table A-16. Estimated Number of Large Multifamily Buildings by Income

Income Level	Number of Units(1),(2)	Number of Buildings(2)
Less than 50% of FPL	86,000	1,229
50%–99%	82,400	1,177
100%–149%	67,500	964
150%–199%	68,200	974
200% of FPL or more	395,300	5,674
Total	**699,500**	**9,993**

(1) Rounded to the nearest hundred.

(2) Does not sum perfectly due to rounding errors.

Source: 2015 AHS.

U.S. Energy Information Administration Residential Energy Consumption Survey

The Energy Information Administration (EIA) conducts the Residential Energy Consumption Survey (RECS) roughly every five years to collect highly detailed building shell and energy equipment information to characterize building stock. Cadmus relied on 2009 data despite the availability of newer data (2015). The 2009 survey collected and summarized data at the state level, whereas the 2015 survey did so at the regional level (California plus four other West Coast states). In Cadmus' estimation, the 2009 data, while older, characterized California building stock characteristics more precisely than the 2015 data.

Buildings in California comprised 1,606 observations of the 2009 RECS dataset, with 64 observations (4%) specific to multifamily buildings of 50 units or more built prior to 2001. The data lack granularity, presenting difficulties in attributing characteristics to specific climate zones and/or IOU service territories, but they still provided a high-level overview of older, large, multifamily buildings in California:

- 67% were three stories or taller
- 88% of tenants were renters (with 2% occupying rent-free)
- 8% had a steam or hot water space heating system
  - 5% used natural gas
  - 3% used electricity

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26 More information is available online: https://www.census.gov/programs-surveys/acs/

- 97% had storage water heaters
  - 73% used natural gas
  - 20% used electricity
  - 3% used propane or liquefied petroleum gas

Needs Assessment for the Energy Savings Assistance and the California Alternate Rates for Energy Programs

In its Needs Assessment for the Energy Savings Assistance (ESA) and the California Alternate Rates for Energy Programs (2016), Evergreen Economics conducted interviews, surveys, focus groups, a literature review, and secondary data analysis to determine areas of energy burden and insecurity, evaluate unique customer needs, develop beneficial energy efficiency measures, and assess barriers related to income documentation. The report focused primarily on the needs of low-income households and helped characterize the multifamily market.

Evergreen Economics counted the number of California households by income category, and, using survey methods, estimated the percentage of multifamily residence renters at each income level. Combining these results produced a statewide estimate of rented multifamily residences, as shown in Table A-17. The estimates included multifamily buildings of all sizes (two or more units).

Table A-17. Estimated Number of Multifamily Renters

Income Category	Number of California Households	Percentage of Multifamily Renters	Estimated Number of Multifamily Renters
Low Income 1 (up to 100% FPL)	1,873,603	53%	989,069
Low Income 2 (101%– 200%)	2,260,457	41%	927,543
Moderate Income 1 (201%–300%)	1,806,217	37%	671,825
Moderate Income 2 (301%–400%)	1,433,616	42%	600,854
High Income (over 400% FPL)	5,080,479	30%	1,510,413
Total	**12,454,372**	**38%**	**4,699,704**

Source: Needs Assessment for the ESA and the California Alternate Rates for Energy Programs (Evergreen Economics 2016).

The needs assessment reported that a household's energy burden (the percentage of income spent on energy bills) increased as income decreased. Multifamily homes, which skewed more heavily to lower-income populations, faced greater energy burdens relative to not only single-family homes (generally), but also to other low-income households. As their energy usage already was low, these homes offered less potential or opportunities to save energy. Low-income and some moderate-income households also reported energy insecurity (the self-reported struggle to pay energy bills).

As many as 30% of the households with household income less than 300% of the FPL (see Table A-17) struggled often or constantly with such insecurity, with roughly half of these concerned that increasing or enhancing their conservation behavior would negatively impact their families' health. While low-income households, including those facing energy burdens and insecurities, employed energy conservation practices consistent with moderate- and high-income households, the report concludes these households would benefit from additional behavioral and educational opportunities.

ESA Program Multifamily Segment Study

The ESA Program Multifamily Segment Study report (Cadmus 2013) developed a detailed picture of and established segment profiles for California's low-income multifamily market by conducting surveys, interviews, data analysis, energy efficiency program comparisons, and research on funding and financing options available to low-income multifamily properties.

Study results indicated multifamily households made up about 22% to 23% of all California households. In total, California had 1.175 million low-income multifamily households, comprising roughly 42% of multifamily households, 32% of low-income households, and 9% of all California households. Using 2011 U.S. Census Bureau ACS and AHS data, Cadmus estimated the number of low-income multifamily buildings in each IOU service territory. The estimates shown in Table A-18 account for multifamily properties with five units or more and assumes an average property size of roughly 11 units.

Table A-18. Estimated Number of Low-Income Multifamily Units and Buildings

IOU Territory	Low-Income Multifamily Units	Low-Income Multifamily Buildings			
		Total	Market Rate	Rent-Assisted	Large (50+ Units)
PG&E	377,015	33,889	25,893	7,996	1,956
SDG&E	591,929	52,812	7,752	9,196	599
SoCalGas	116,904	10,546	43,616	2,794	2,970
Total	**1,045,848**	**97,247**	**77,261**	**19,986**	**5,525**

Source: ESA Program Multifamily Segment Study (Cadmus and Research Into Action 2013).

Process Evaluation of the MFEER Program (2010-2012)

For its 2010–2012 program years, Cadmus conducted a process evaluation of the MFEER program (2013 MFEER process evaluation) (Cadmus 2013), which included three components:

- Rental Property and Contractor Market Characterization Study
- Program Process Evaluation
- General Population Survey for Property Owners and Managers (detailed results published in a separate Cadmus report)

For its multifamily market characterization, the 2013 MFEER process evaluation focused on PG&E and SCE territories, and relied on results from the 2009 RASS and 2009 ACS. Cadmus provided several key findings relevant to this California Statewide Multifamily Boiler Market Assessment Study:

- About 26% of PG&E's residential households and 31% of SCE's residential households lived in multifamily buildings of two or more units, and about three-quarters of those households were rent-payers.
- Across the two utility service areas, 18% (PG&E) and 20% (SCE) of households lived in multifamily buildings with 50 or more units. Multifamily buildings with 50 or more units constituted 1% (PG&E) and 2% of the total multifamily building population.
- As of 2009, only 9% and 7% of multifamily buildings were constructed after 2000.

These findings support the California Statewide Multifamily Boiler Market Assessment Study's focus on older and larger multifamily buildings.

Regarding decision-making, the MFEER process evaluation emphasized the challenge of the "split incentive," given 90% of renters in the multifamily sector paid their own electric utility costs.

The 2013 MFEER process evaluation, however, noted that over two-thirds of owners of multifamily property owners said they were the sole decision-makers regarding new equipment purchases. On the other hand, 62% of property managers could not make equipment purchasing decisions on their own. These findings emphasized the importance of engaging property owners in energy efficiency upgrade decisions (and in efforts to recruit properties for the California Statewide Multifamily Boiler Market Assessment Study).

Process Evaluation of Southern California Multifamily Programs (2014–2015)

The Southern California Multifamily Program Process Evaluation of 2014–2015 (Evergreen Economics 2017) reviewed the program processes for all multifamily programs offered by SDG&E, SCE, and SoCalGas, including ESA, Energy Upgrade California Multifamily (EUC), MFEER, and the Middle Income Direct Install program. This evaluation coincided with a shift by these three IOUs to a more comprehensive program design, which sequenced multifamily program interventions, provided a single contact point for customers, and addressed building benchmarking.

The report provided several recommendations to improve program delivery in the context of a comprehensive approach to maintain consistency and predictability in program offerings, and to systematically record and track customer-specific, energy-saving opportunities during IOU staff and program interactions with customers. This study, similar to the 2013 MFEER process evaluation, noted that MFEER participation continued to focus largely on lighting measures, leaving other efficiency opportunities largely unaddressed (Evergreen Economics 2017).

Process Evaluation of SCE and SoCalGas Energy Upgrade California Multifamily Pilot (2013–2015)

The 2013–2015 SCE & SoCalGas Energy Upgrade California Multifamily Pilot Process Evaluation (ODC 2017) reviewed the EUC pilot program, observing that structural barriers remain to high program uptake in the multifamily market. Based on property owners interviewed, these barriers remained for the following reasons:

- The timing of in-unit retrofits and upgrades were highly dependent on tenant turnover
- Additional costs and risks were associated with program participation (such as combustion appliance safety testing required for customers participating in gas measures through the EUC Pilot)
- Customers need additional information to benchmark their property portfolios, determine upgrade or retrofit needs at each property, find the right program match for a property's needs, and monitor property performance over time.

Literature Review Conclusions

The combined data from the above sources provided the following estimates for key variables addressed in this literature review.

Multifamily Building Characteristics

Number of Buildings

The 2016 ACS and the 2013 ESA Program Multifamily Segment Study (which relied on data from the 2011 ACS and the 2011 AHS) produced similar estimates for the number of large multifamily buildings in each IOU. Table A-19 shows the 2016 ACS and 2013 ESA Program Multifamily Segment Study estimates for large multifamily buildings. Cadmus extrapolated the 2013 ESA Program Multifamily Segment Study estimates from Table A-18, assuming 42% of multifamily buildings were low-income.

The literature review suggests that the three gas IOU territories contain around 13,150 large multifamily buildings, with 10,244 built prior to 2000.

Table A-19. Estimated Number of Large Multifamily Buildings (50 Units or More)

IOU Territory	2016 ACS	2016 ACS (Built Pre-2000)	2013 ESA Program Multifamily Segment Study
PG&E	5,067	3,872	4,657
SDG&E	1,463	1,072	1,426
SoCalGas	6,618	5,300	7,071
Total	**13,148**	**10,244**	**13,155**

Number of Units and Age of Buildings

The 2016 ACS estimated the number of large multifamily properties (50 units or more) built prior to 2000. Per the 2016 ACS, large multifamily units built before 2000 comprised 78% of large multifamily units and 23% of all multifamily units of five units or more. The 2009 RASS suggests 89% of all multifamily units were built before 2001. Using 2016 ACS estimates about the age of large multifamily units (shown in Table A-12), Cadmus estimated the number of large multifamily units built before 2000, according to 2009 RASS data (shown in Table A-6). The total number of multifamily households in buildings with five units or more, as estimated by the 2016 ACS (3,218,848), was more than 250% larger than for the 2009 RASS (1,245,686). Accordingly, Table A-20 shows 2016 ACS estimates are about 225% larger than those form the 2009 RASS.

Table A-20. Estimated Number of Units in Large Multifamily Buildings Built Prior to 2000 (50 Units or More)

IOU Territory	2016 ACS	2009 RASS
PG&E	255,429	119,673
SDG&E	81,431	42,610
SoCalGas	393,531	162,230
Total	**730,211**	**324,512**

The midpoint methodology (explained under the Estimating Number of Buildings section above) converts Table A-20 results into the estimated numbers of buildings built prior to 2000, as shown in Table A-21. The more recent ACS has a larger sample size, hence ACS results are more reliable for stratifying the multifamily building population by age.

Table A-21. Estimated Number of Large Multifamily Buildings Built Prior to 2000

IOU Territory	2016 ACS	2009 RASS
PG&E	3,872	1,815
SDG&E	1,072	561
SoCalGas	5,300	2,185
Total	**10,244**	**4,561**

Renter Profile

The 2016 ACS provided the most precise and salient estimate of rented units in large multifamily buildings: 91% statewide, ranging from 87% to 92% by IOU (shown in Table A-13).

The 2013 ESA Program Multifamily Segment Study report estimated that 94% of low-income multifamily households were renters, and the increased rental rate among low-income households aligned with Cadmus' understanding of the financial burdens faced by low-income households. Furthermore, 21% of low-income multifamily renters live in rent-assisted households, ranging from 17% to 26% by IOU (see Table A-18).

Buildings with Gas Space and Water Heating

Per the 2009 RASS, among multifamily buildings with five units or more, gas space and water heating saturations were roughly 88% and 55%, respectively. The 2012 CLASS estimate of 61% of multifamily buildings five units or more that had gas water heating aligned closely with the 2009 RASS findings.

Boiler Characteristics and Retrofit Potential

The 2019 P&G study addressed the 10-year potential savings for a limited set of gas water heating measure in the multifamily sector including water heating controls and drain heat recovery. The P&G study calculated the savings for on-demand circulation pump controls based on a 22.64 therms per dwelling unit estimate and extrapolated those savings to the estimated number of dwelling units in the IOU territories.

Cadmus did not find data regarding boiler characteristics in previously available studies in California.

Summary of Knowledge Gaps in Multifamily Boiler Market Characterization

Table A-22 summarizes secondary sources reviewed and the information levels Cadmus found for each key parameter. Sources where Cadmus found adequate data supporting the literature review are marked "yes"; sources where Cadmus found some data supporting the literature review are marked "some."

As noted in the table, data addressing multifamily building boiler characteristics in California were extremely rare. However, national surveys and statewide saturation surveys contain multifamily *dwelling unit* population data, and Cadmus estimated the number of *buildings* (which would be closer to the number of boilers). Population estimates became less precise with additional stratifications based on age. Previous IOU low-income program segmentations, needs assessments, and multifamily program process evaluations offer a wealth of insights into the challenges and opportunities posed by efficiency improvements in this market.

Table A-22. Literature Review Summary of Key Parameters in Key Sources

Key Parameters Reviewed	P&G study	RSW Phase 1	RSW Phase 2	2009 RASS	2012 CLASS	2009 RECS	2016 ACS	2015 AHS	ESA Needs Assessment	ESA Segment Study	2013 MFEER Process Evaluation	2017 Southern California Multifamily Process Evaluation	2017 EUC Process Evaluation
Multifamily Building Population Characteristics													
Population	-	-	-	yes	-	some	yes	some	some	some	yes	-	-
Age	-	-	-	yes	-	some	yes	some	some	some	yes	-	-
Number of Dwelling Units	-	-	-	yes	-	some	yes	some	some	some	yes	-	-
Rented vs. Owned Dwelling Units	-	-	-	yes	-	some	yes	some	some	some	yes	-	-
Market Rate vs. Rent Assisted	-	-	-	-	-	some	yes	some	some	some	yes	-	-
Buildings with Central Gas Water Heating	-	some	-	some	some	some	some	some	-	-	-	-	-
Buildings with Central Gas Space Heating	-	some	-	some	some	some	some	some	-	-	-	-	-
Rental vs. Condominium Buildings	-	-	-	some	-	some	some	some	-	-	-	-	-
Low-Rise vs. High-Rise Buildings	-	-	-	-	-	-	-	some	-	-	-	-	-
Boiler Population Characteristics													
Capacity	-	-	-	-	-	-	-	-	-	-	-	-	-
Age	-	-	-	-	-	-	-	-	-	-	-	-	-
Service End Uses	-	-	-	-	-	-	-	-	-	-	-	-	-
Efficiency	-	-	-	-	-	-	-	-	-	-	-	-	-
Control Strategies	-	-	-	-	some	-	-	-	-	-	-	-	-
Potential for Retrofit (e.g., on-demand circulation pump control)	yes	some	-	-		-	-	-	-	-	-	-	-
Pipe Insulation	-	-	-	-	some	-	-	-	-	-	-	-	-
Challenges and Opportunities for Efficiency Improvements in the Multifamily Market													
	-	-	-	-	-	-	-	-	Yes	yes	yes	yes	yes

Appendix B.Outreach Postcard, Email, and Reminder Email

Figure B-1. Postcard Front

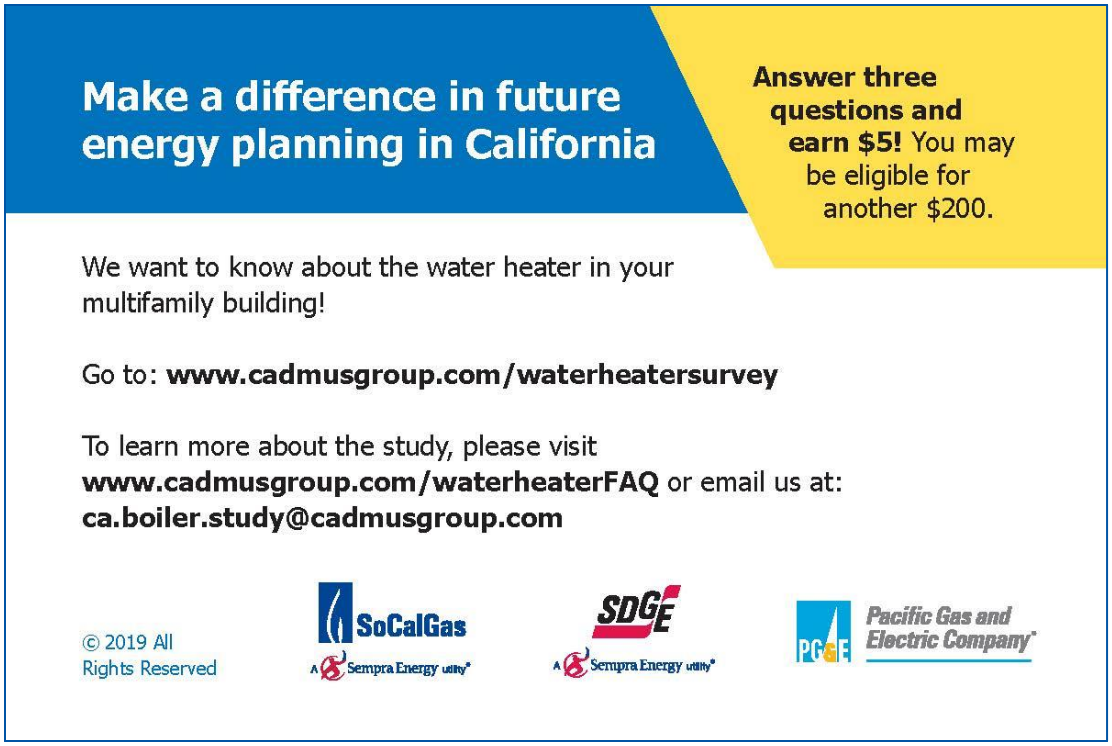

Figure B-2. Postcard Back

Email Invitation

Subject: Join **[Utility]** and make a difference in California energy planning

Many building owners and property managers in California have received this **$200 gift card**, would you like to be one of them?

Answer a few quick questions about your multifamily building and you will receive a **$5 electronic gift card** for coffee on us**. I**f your building is eligible, we will call you back to schedule a site visit. **You will receive a $200 VISA gift card for completing a site visit.***

If you are listed as contact for multiple buildings, there are multiple IDs included in this email. If necessary, please forward the link along with the ID(s) to the person(s) most familiar with the building(s). We offer a gift card for each completed building survey.

Click the link below and enter the 7-digit ID for each building:
www.cadmusgroup.com/waterheatersurvey

[Building 1 Street Address] [City]
[Survey ID 1]

[Building 2 Street Address] [City]
[Survey ID 2]

[Building 3 Street Address] [City]
[Survey ID 3]

[Building 4 Street Address] [City]
[Survey ID 4]

[Building 5 Street Address] [City]
[Survey ID 5]

[Building 6 Street Address] [City]
[Survey ID 6]

[Building 7 Street Address] [City]
[Survey ID 7]

[Building 8 Street Address] [City]
[Survey ID 8]

[Building 9 Street Address] [City]
[Survey ID 9]

[Building 10 Street Address] [City]
[Survey ID 10]

Cadmus is administering this study on behalf of SoCalGas, San Diego Gas & Electric Company, and Pacific Gas & Electric Company**. The frequently asked questions page has answers to most commonly asked questions about the study: https://cadmusgroup.com/waterheaterFAQ

If you have additional questions, you can contact me by calling 424-732-4123 or emailing ca.boiler.study@cadmusgroup.com.

Sincerely,

Sahar Abbaszadeh, AIA | Associate

Cadmus | 1620 Broadway, Suite G | Santa Monica, CA 90404

Office: 424.732.4123

* You must be a multifamily building owner or operator to participate in the study. We offer one gift card per utility account. A limited number of gift cards are available while supplies last.

** This Multifamily Boiler Market Assessment is funded by California utility customers and administered by SoCalGas, San Diego Gas & Electric Company, and Pacific Gas & Electric Company under the auspices of the California Public Utilities Commission.

Email Reminder

Subject: Reminder: Join **[Utility]** and tell us about your building

Would you be interested in a **$200 gift card**? You can help **[Utility]** assess the stock of boilers and water heaters operating in its territory.

Answer a few quick questions about your multifamily building and you will receive a **$5 electronic gift card** for coffee on us**. I**f your building is eligible, we will call you back to schedule a site visit. **You will receive a $200 VISA gift card for completing a site visit.***

If you are listed as contact for multiple buildings, there are multiple IDs included in this email. If necessary, please forward the link along with the ID(s) to the person(s) most familiar with the building(s). We offer a gift card for each completed building survey.

Click the link below and enter the 7-digit ID for each building:
www.cadmusgroup.com/waterheatersurvey

[Building 1 Street Address] [City]
[Survey ID 1]

[Building 2 Street Address] [City]
[Survey ID 2]

[Building 3 Street Address] [City]
[Survey ID 3]

[Building 4 Street Address] [City]
[Survey ID 4]

[Building 5 Street Address] [City]
[Survey ID 5]

[Building 6 Street Address] [City]
[Survey ID 6]

[Building 7 Street Address] [City]
[Survey ID 7]

[Building 8 Street Address] [City]
[Survey ID 8]

[Building 9 Street Address] [City]
[Survey ID 9]

[Building 10 Street Address] [City]
[Survey ID 10]

Cadmus is administering this survey on behalf of SoCalGas, San Diego Gas & Electric Company, and Pacific Gas & Electric Company**. The frequently asked question page has answers to most commonly asked questions about the study:https://cadmusgroup.com/waterheaterFAQ

If you have any questions, you can contact me by calling 424-732-4123 or emailing ca.boiler.study@cadmusgroup.com.

Sincerely,

Sahar Abbaszadeh, AIA | Associate

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Appendix C.Outreach and Recruitment Process and Timeline

Figure C-1 shows Cadmus' phone, email, and outreach recruitment flow chart, starting with sample frames and ending with completion of site visits. Study Sample Frame

Figure C-1. Multifamily Boiler Market Assessment Customer Outreach and Recruitment Process

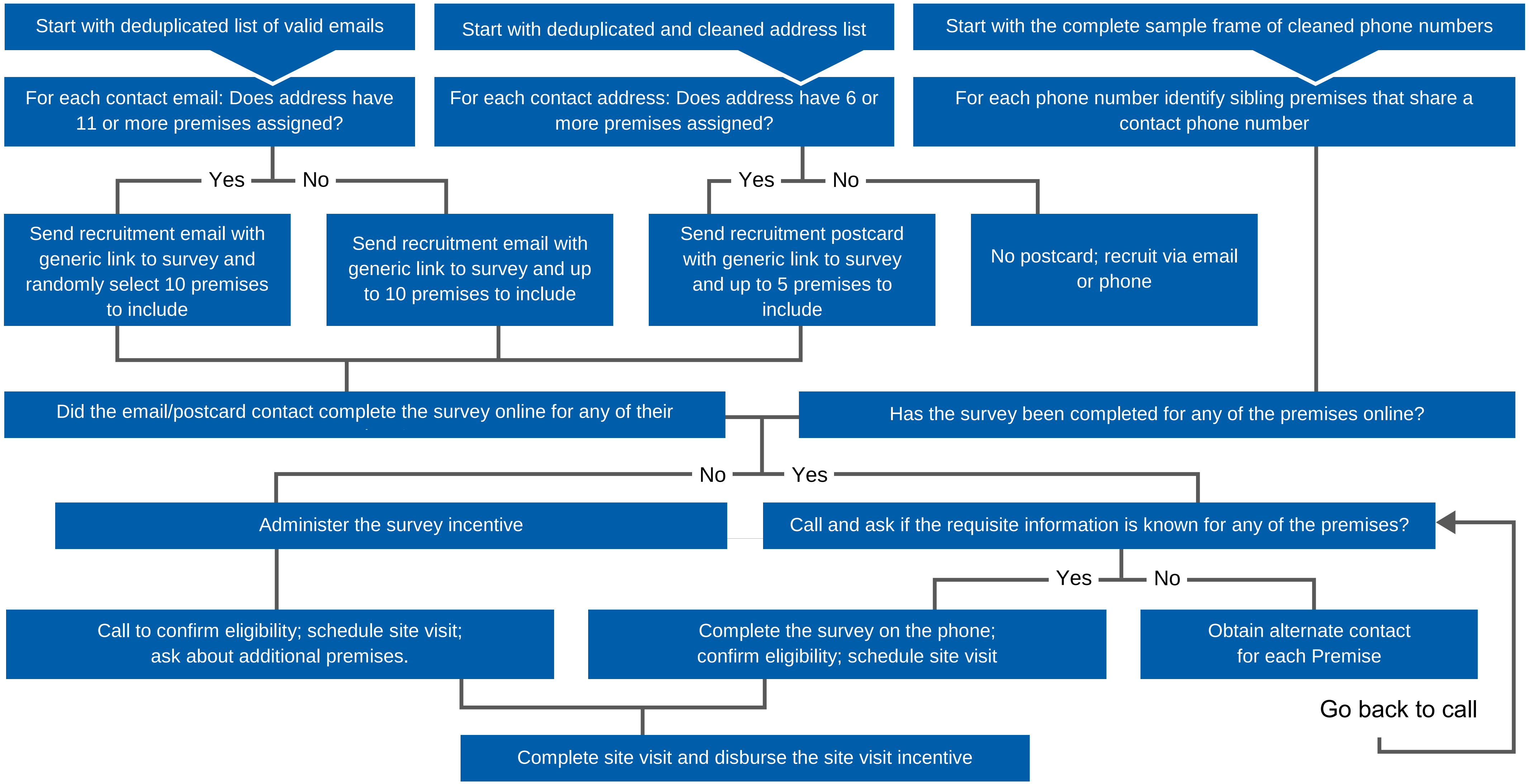

Table C-1 shows that Cadmus began outreach in March 2019 and completed site visits in August 2019.

Table C-1. Multifamily Boiler Market Assessment Outreach Schedule in 2019

Activity	Delivery Date	March				April				May					June				July				August				
		8	15	22	29	5	12	19	26	3	10	17	24	31	7	14	21	28	5	12	19	26	2	9	16	23	30
Obtained Approval of Outreach Materials	11/30/2018																										
Completed Sample Frames	1/11/2019																										
Completed Survey Programming	2/15/2019																										
Mailed Postcards	3/4/2019	■																									
First Round of E-mails	3/7/2019	■																									
First Round of Reminder E-mails	3/12/2019		■																								
Second Round of E-mails	4/16/2019							■																			
Second Round of Reminder E-mails	4/23/2019								■																		
Third Round of E-mails	6/18/2019																■										
Third Round of Reminder E-mails	6/25/2019																	■									
Fourth Round of E-mails	8/2/2019																						■				
Phone Outreach	8/23/2019		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	
Scheduling	8/23/2019		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	
Site Visits	8/27/2019			■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■

Appendix D.Outreach Phone Call Script

Recruitment Script

It is likely that callers will need to speak to several contacts at a property management firm, before reaching the correct person who:1) can respond to the questions in the survey and 2) make a decision to allow for a site visit.

When possible, be politely persistent and ask if there is another contact you could speak to if you encounter someone that is not a decision maker. The correct contact will vary site to site but will often be either a building or property owner or manager – someone who knows the building and is authorized to make decisions (for example, to allow Cadmus to conduct a site visit). A receptionist, phone operator, administrative assistant, would not be the right contact. If you speak to a contact that suggests that they will relay your message to another contact, politely suggest that you would be happy to send an email to this contact if they share the email address, or that you could send an email explaining the study that could be forwarded to the other contact.

A1. **[IF THERE IS CONTACT NAME]** Hi, I'm calling from Cadmus on behalf of **[UTILITY].** This is not a sales call, we're conducting a study funded by **[UTILITY]**. Can I speak with **[CONTACT NAME]**?

[IF NO NAME] Hi, I'm calling from Cadmus on behalf of **[UTILITY]**. This is not a sales call, we're conducting a study funded by **[UTILITY]**. May I speak with the building owner or property manager responsible for building located at **[ADDRESS/PROPERTY NAME]**?

[If that person is not at this phone number, confirm that they would be best contact and then ask for their name and phone number and start again. If not the best contact then continue to A2]

1. (Yes) **[CONTINUE TO A3]**
2. (No or not a convenient time) **[ASK IF YOU CAN ARRANGE A MORE CONVENIENT TIME OR IF YOU CAN LEAVE A MESSAGE FOR A MORE APPROPRIATE PERSON]**

98. (Don't know) **[ASK TO SPEAK WITH SOMEONE WHO KNOWS AND BEGIN AGAIN]**
99. (Refused) **[THANK AND TERMINATE]**

A2. Maybe you could help me determine the best person to speak to. We're conducting a study on behalf of **[UTILITY]** looking at boilers in multifamily buildings throughout California. I am calling because this phone number is listed as the contact number for building located at **[ADDRESS]**.

We're providing $5 pre-paid Starbucks gift cards for answering a few questions that should only take a couple of minutes. These questions will also help us determine if your building qualifies for a site visit as part of this study. If we complete a site visit at your location, we're providing a $200 pre-paid VISA gift card to thank you for participating in this study.

We need to talk to someone who knows:

- The total number of apartments/dwelling units in **[ADDRESS]**
- The year the building(s) was/were built
- Whether or not the building(s) has/have a central gas-fired boiler and/or central gas-fired water heater.

Do you know who the best person is to speak to about **[ADDRESS]**?

1. (Yes, person you are speaking to is correct contact) **[SAY "THANKS, COULD WE COMPLETE A FEW QUESTIONS NOW TO SEE IF YOUR LOCATION QUALIFIES FOR A SITE VISIT? WE ARE OFFERING A $5 STARBUCKS GIFTCARD JUST FOR COMPLETING THESE QUESTIONS" AND CONTINUE TO QUALTRICS SURVEY WITH SURVEY ID.]**
2. (Yes, different contact than person you are speaking to) **[ASK FOR NEW CONTACT'S NAME AND NUMBER AS WELL AS THE NAME OF THE PERSON YOU ARE SPEAKING TO. WHEN YOU REACH NEW CONTACT, SAY "HI, I WAS SPEAKING TO [INSERT NAME OF FIRST CONTACT] AND THEY SUGGESTED THAT I SPEAK TO YOU." THEN SKIP TO QUESTION A3]**

98. (Don't know) **[ASK IF THERE IS ANYONE ELSE THAT YOU COULD SPEAK TO SUCH AS PROPERT MANAGER, BUILDING MANAGER, OR FACILITIES MANAGER AND BEGIN AGAIN]**
99. (Refused) **[THANK AND TERMINATE]**

[IF NEEDED, THE SURVEY QUESTIONS ARE:

- **NUMBER OF UNITS AT THE PREMISE ADDRESS? – 40 OR MORE IS TAGGED AS POSSIBLY ELIGIBLE**
- **NUMBER OF UNITS IN COMPLEX? –**
- **NUMBER OF BUILDINGS IN COMPLEX? –**
- **YEAR BUILT? – BEFORE 2001 IS ELIGIBLE**
- **IS THERE A CENTRAL BOILER/WATER HEATER SERVING UNITS USED FOR RESIDENTIAL SPACE OR WATER HEATING? – YES IS ELIGIBLE**

98. **IF [ACCOUNT IS FAILING ELIGIBILITY DUE TO NUMBER OF UNITS AT ADDRESS ONLY] AND IF [ACCOUNT IS TAGGED AS ELIGIBLE], BEFORE SCHEDULING, PLEASE CHECK: HOW MANY UNITS DO EACH OF THE METERS (ASSOCIATED WITH CENTRAL BOILER/WATER HEATER) SERVICE? – RECORD UNDER COLUMN BG – 40 OR MORE IS ELIGIBLE]**

A3. Hi, **[UTILITY]** is conducting a multifamily boiler market assessment and we are calling on **[UTILITY]'S** behalf. We sent a postcard with details about this study to your address that you may have seen. We're providing a $5 pre-paid Starbucks gift card for answering a few questions over the phone. We are asking about:

- The total number of apartments/dwelling units in **[ADDRESS]**
- The year the building(s) was/were built
- Whether or not the building(s) has/have a central gas-fired boiler and/or central gas-fired water heater.

Your responses will also help us determine if your building qualifies for a site visit as part of this study. If your building qualifies for the study and is selected for participation, then we would send one of our engineers to complete a site visit at your location and provide a $200 pre-paid VISA gift card to thank you for participating. Is this a good time for you to answer our questions?

1. (Yes) **[CONTINUE TO QUALTRICS SURVEY WITH SURVEY ID]**
2. (Unsure) **[REFERENCE NOTES AND FAQS BELOW TO PROVIDE ANSWERS TO RESPONDENT'S QUESTIONS/CONCERNS. IF RESPONDENT AGREES TO SCREENER QUESTIONS THEN SKIP TO SECTION B. IF RESPONDENT IS STILL UNSURE, ASK IF THERE IS ANOTHER CONTACT THAT YOU COULD SPEAK TO REGARDING THE STUDY AND RESTART SCRIPT WHEN SPEAKING TO NEW CONTACT. IF CONTACT DECLINES TO SHARE OTHER CONTACT OR ANSWER SCREENER QUESTIONS THEN [THANK AND TERMINATE]**.
3. (No) **[ASK IF YOU COULD SPEAK TO ANOTHER CONTACT REGARDING THE STUDY AND RESTART SCRIPT WHEN SPAEKING TO NEW CONTACT. IF RESPONDENT IS UNWILLING TO CONNECT YOU TO A DIFFERENT CONTACT THEN [THANK AND TERMINATE]**

99. (Refused) **[THANK AND TERMINATE]**

FAQS

[IF NEEDED] We're providing $5 pre-paid Starbucks gift cards for completing these brief questions—this should only take a couple of minutes.

[IF NEEDED] This is not a sales call, we're conducting a study funded by **[UTILITY]**. Any responses that you provide will be kept confidential.

[IF NEEDED, THE SURVEY QUESTIONS ARE:

- **NUMBER OF UNITS AT THE PREMISE ADDRESS? – MORE THAN 40 IS TAGGED AS POSSIBLY ELIGIBLE**
- **NUMBER OF UNITS IN COMPLEX? –**
- **NUMBER OF BUILDINGS IN COMPLEX? –**
- **YEAR BUILT? – BEFORE 2001 IS ELIGIBLE**
- **IS THERE A CENTRAL BOILER/WATER HEATER USED FOR RESIDENTIAL SPACE OR WATER HEATING? – YES IS ELIGIBLE**

98.**IF [ACCOUNT IS FAILING ELIGIBILITY DUE TO NUMBER OF UNITS AT ADDRESS ONLY] AND IF [ACCOUNT IS TAGGED AS ELIGIBLE], BEFORE SCHEDULING, PLEASE CHECK: HOW MANY UNITS DO EACH OF THE METERS (ASSOCIATED WITH CENTRAL BOILER/WATER HEATER) SERVICE? – RECORD UNDER COLUMN BG – 40 OR MORE IS ELIGIBLE]**

WHAT IS THE PURPOSE OF THIS STUDY? [UTILITY] would like to learn more about the types of boilers that are currently operating in multifamily buildings throughout its service territory. This study will help determine the potential energy savings generated by incentivizing efficient boilers in the future. To complete this study, we are visiting over 100 multifamily buildings throughout the state and recording details of their existing boilers.

WHAT WILL YOU DO WHEN YOU VISIT? Our engineer will visit at a time that is convenient for you and view the central boiler in your location. They will record details of the boiler make and characteristics. They will also have a few questions about characteristics of your building in general. They will only need to enter the boiler or mechanical room in your location—they do not need to enter any individual units or apartments.

HOW LONG WILL IT TAKE? The visits are typically taking about an hour to complete. The visit could take up to 60 minutes depending on the layout of your location.

WHAT'S THE DEAL WITH THE GIFT CARDS/WHAT DO WE GET?

First, we're providing $5 pre-paid Starbucks gift cards for answering a few questions that should only take a couple of minutes. These questions will help us determine if your building qualifies for an additional site visit as part of this study. If we complete a site visit at your location, we're providing a $200 pre-paid VISA gift card to thank you for participating in this study. The pre-paid VISA gift cards, can be used anywhere that you would normally use a credit card.

WHAT ARE YOU DOING WITH THE INFORMATION YOU COLLECT? We will combine the results of over 100 site visits throughout the state to compile a report that presents a general market characterization of boilers in California multifamily buildings. We will not present any individual site's data, only the aggregated results of participating sites. Your data and responses will be kept strictly confidential.

HOW DO I KNOW THIS IS NOT A SCAM/LEGITIMACY CONCERNS? We will not attempt to sell you any goods, equipment, or services through this study. The study is funded by **[UTILITY]** and there is no charge for participating. If you would like to confirm the validity of this study, I can provide you with the contact information of the person responsible at each of the utilities involved in the study.

[IF NEEDED, PROVIDE CONTACT PERSON ACCORDING TO THE UTILITY THAT IS ASSIGNED TO THE CONTACT:

San Diego Gas and Electric (SDG&E): Contact customer service at 800-411-7343 or Esther Chen (EChen@semprautilities.com, 858-774-9608)
Pacific Gas and Electric (PG&E): Contact customer service at 877-660-6789 or Alyssa Bruner (ARBV@pge.com, 415-973-3046)
SoCalGas: Contact customer service at 877-238-0092 or Kim Sides (KSides@semprautilities.com, 213-244-3890)

Appendix E.Recruitment and Screening Survey Instrument

CA Multifamily Boiler Online Screening Survey

Mode

- Postcard invitation with landing page and passcode-linked utility and site address
- Email invitation sent using mail merge (not Qualtrics), containing individual links for each property (no passwords)
- Survey Report and links for phone follow-up by Cadmus in Qualtrics
- Track quotas by utility, limited gift cards

General Instructions

- Programming instructions are in red **[LIKE THIS]**
- Instructions for how entry fields should be displayed on screen are green **[LIKE THIS]**

Variables to be Pulled into Survey

- ExternalDataReference [Survey ID listed in postcard address block]
- UTILITY [PG&E, SDG&E or SoCalGas, for read in and quotas]
- BUILDING ADDRESS [read in, should be properly capitalized]
- Mode [mail or empty, required to apply passcode and logic]
- SurveyTaken [empty, required to avoid duplicate attempts]

Quotas

Table 1. Number of Sampled Customers and Targeted Completes for Phone and Online Surveys

Utility	Telephone and Online Surveys	
	Sampled Customers	Targeted Completes
PG&E	1,426	315
SDG&E	804	85
SoCalGas	3,064	305
Total	5,294	705

A. Introduction

[START HERE IF INVITATION MODE=MAIL]

Please enter your 7-digit Survey ID that is located on the back of the postcard:

[**RECORD ID].**

[IF SURVEY ID DOES NOT MATCH SURVEY LIST, SHOW END OF SURVEY MESSAGE BELOW]

"Oops! We cannot find a match, but we really value your input. Please email ca.boiler.study@cadmusgroup.com or call Sahar Abbaszadeh at 424-732-4123 and we'll get you to the right survey."

[IF SURVEY WITH THIS ID WAS ALREADY COMPLETED, SHOW END OF SURVEY MESSAGE BELOW]

"Oops! Looks like someone already completed this survey, but we really value your input. Please email ca.boiler.study@cadmusgroup.com or call Sahar Abbaszadeh at 424-732-4123 and we'll get you to the right survey."

[START HERE IF INVITATION MODE=E-MAIL OR PHONE]

A1. Thanks for your interest in this study. Our records show you or your organization is listed for a building at the following address:

[BUILDING ADDRESS]

[UTILITY]® would like to learn more about the types of boilers and water heaters operating in multifamily buildings throughout its territory. This study will help **[UTILITY]** design incentive programs to better serve customers like you.

To complete this study, we are conducting a brief online survey (it usually takes 3 to 5 minutes). **We will send you a $5 Starbucks electronic gift card, if you answer five simple questions about the building.*** You may also be eligible for a $200 gift card, if your building participates in the full study. **

[UTILITY] has hired our energy-efficiency consulting firm, Cadmus, to conduct the study. We will not attempt to sell you any goods, equipment, or services through this study and there is no charge for participating. If you would like to confirm the validity of this study, please please contact the study manager at **[UTILITY]** on the FAQ page at: https://cadmusgroup.com/waterheaterFAQ

* You must be a multifamily building owner or operator and complete the survey to receive a $5 gift card. We offer one gift card per utility account. Gift cards are available while supplies last.

** Your responses will also help us determine if your building qualifies for a site visit as part of this study. There is no obligation to participate in site visits after this survey. If we complete a site visit at your location, we will provide a $200 pre-paid VISA gift card as our thank you. We are visiting over 100 multifamily buildings throughout the state and capturing details about their boilers and water heaters. Participation involves a brief site visit from a Cadmus engineer who will record the gas fired boiler make, model and characteristics. The engineer only needs access to central boiler/water heating equipment and does not need to enter any individual units or apartments.

*** This Multifamily Boiler Market Assessment is funded by California utility customers and administered by SoCalGas, San Diego Gas & Electric Company, and Pacific Gas & Electric Company under the auspices of the California Public Utilities Commission.

A2. **[NEXT PAGE]** Do you know the following information for **[BUILDING ADDRESS]?**

The total number of apartments/dwelling units in the building(s)

The year the building(s) was/were built

Whether or not the building(s) has/have a central gas-fired boiler and/or central gas-fired water heater.

1. Yes
2. No

A3. **[IF A2= 2]** Please enter the contact details of the person who will be able to provide this information for **[BUILDING ADDRESS]** and we will contact them. Thanks!

1. Name**[RESPONSE REQUIRED]**
2. Phone number **[VALIDATE]** **[RESPONSE REQUIRED]**
3. Best day/time to call
4. Email (if preferred)

[IF A2= 2] Thank you for providing the contact information for someone who is familiar with **[BUILDING ADDRESS]**. We will follow up with them shortly. **[END OF SURVEY]**

B. Screener Questions

[ASK SECTION IF A2= 1]

B1. Please indicate whether the property at **[ADDRESS]** is a multifamily property: **[FORCED RESPONSE]**

1. Yes, this property is a multifamily property, consisting of one or more apartment or condo-style residential buildings. **[CONTINUE TOB2]**
2. No, this property is not a multifamily property. It consists of one or more single-family, duplex, or townhome style residential buildings.

[IF B1=2, SHOW END OF SURVEY MESSAGE BELOW]

"I'm sorry, this survey is about multifamily residential buildings. This location does not qualify to participate in the survey. If you received another link or a code for an additional building, we invite you to take the survey again, by clicking on the link or using the new passcode **[END OF SURVEY**]"

B2. Great! Let's continue. How many apartments/dwelling units are there at **[ADDRESS]**? If there are multiple buildings in the same property, provide the total number of dwelling units that share that same address. **[FORCED RESPONSE]**

1. **[INCLUDE ENTRY FIELD WHERE RESPONDENTS CAN ENTER NUMERIC RESPONSES FROM 1-999]**

B3. Including the building(s) at **[ADDRESS],** how many total multifamily residential buildings are there at the residential complex?

1. **[INCLUDE ENTRY FIELD WHERE RESPONDENTS CAN ENTER NUMERIC RESPONSES FROM 1-999]**

B4. **[ASK IF B3<>1]** Including the dwelling units at **[ADDRESS],** how many total dwelling units are there at the residential complex?

1. **[INCLUDE ENTRY FIELD WHERE RESPONDENTS CAN ENTER NUMERIC RESPONSES FROM 9,999]**

B5. What year was the property at **[ADDRESS]** constructed? If there are multiple buildings at this address, please enter the year the oldest building was constructed.

1. **[INCLUDE ENTRY FIELD WHERE RESPONDENTS CAN ENTER YEAR FROM 1800 TO 2018]** **[CONTINUE TO B7]**

B6. **[ASK IF B5 IS BLANK]** Was the oldest building at the property constructed before January 1st, 2001? **[FORCED RESPONSE]**

1. Yes
2. No

B7. Does the property at **[ADDRESS]** have one or more central gas-fired boiler or central gas fired water heater used for residential space heating or water heating? **[FORCED RESPONSE]**

1. Yes, my property has one or more central gas-fired boilers or central water heaters that serve multiple dwelling units. **[CONTINUE TO B8]**
2. No, my property has individual gas water heaters and/or space heaters, each serving only one dwelling unit. **[SKIP TO B11]**
3. No, my property does not have any gas fired boilers, gas water heaters, or gas space heaters **[SKIP TO B11]**

B8. Have you ever had the central boiler(s) or water heater(s) inspected for insurance or tested for flue gas? The test is also called a boiler combustion test, or NOX emission test. There are mandatory tests every couple of years for air quality management.

We are not interested in whether the equipment passed the inspection or air quality test. However, the test results contain valuable information about the equipment make, model, and efficiency that will help us prepare for the site visit.

1. Yes, the equipment has had a flue gas test and/or inspection.
2. No, the equipment has not had a flue gas test or inspection.
3. Don't know

B9. **[ASK IF B8=1]** Can we obtain a copy of the most recent test results?

1. Yes
2. No
3. Don't know

B10. **[ASK IF B9=1]** Please upload a copy of the test results or email to Sahar Abbaszadeh at ca.boiler.study@cadmusgroup.com or fax to (617) 673-7001. **[PROVIDE FILE UPLOAD BUTTON]**

[IF B2=40 OR GREATER AND; B5 IS BEFORE JANUARY 1ST, 2001 OR B6=1; AND B7=1 THEN SKIP TO C1. OTHERWISE, CONTINUE TO B11]

B11. Thank you for completing the survey! Based on your responses, the property at **[ADDRESS]** does not qualify for a site visit.

We would like to send you a $5 Starbucks gift card for answering our questions today. We will send an electronic gift card to your email address. Please enter it below and watch for an email from Starbucks within two weeks. If you cannot accept a gift card at your place of work, you may leave these fields blank.

If you received another link or a code for an additional building, we invite you to take the survey again, by clicking on the link or using the new passcode.

Note: We offer one gift card per utility account. Gift cards are available while supplies last.

1. **[PLEASE INCLUDE ENTRY FIELDS FOR "NAME," "PHONE NUMBER", AND "EMAIL ADDRESS" PLEASE INCLUDE A BUTTON LABELED "SUBMIT" UNDERNEATH THE ENTRY FIELDS. IF THE SUBMIT BUTTON IS CLICKED AND ANY OF THE FIELDS DO NOT HAVE AN ENTRY, PLEASE HAVE AN ERROR MESSAGE APPEAR SAYING "PLEASE FILL IN THE REQUIRED INFORMATION BEFORE CLICKING "SUBMIT".] [END OF SURVEY]**

C. Gift Card Details/Contact Details

C1. Thanks for completing the survey!

Congratulations, your location is qualified for a site visit. Our engineers will review the location and details of all qualifying buildings and schedule visits between February 2019 and August 2019. It is possible that we will not need all qualifying sites to participate in the study. We will contact you to let you know if your site is selected for the study.

If your site is selected for the study, we will schedule a convenient time for the visit, and you will receive $200 at the completion of the site visit.

We would like to send you a $5 Starbucks electronic gift card to thank you for completing this brief survey. Please enter your contact information on the next page so that we can send you the $5 gift card and follow up with you if your site is selected for a site visit.

C2. Please fill in all fields below. If your location is selected for our study, we will contact you to arrange a convenient date for our site visit.

We will also use this information to send you your $5 Starbucks gift card. We will send you an electronic gift card via Starbucks. If you cannot accept a gift card at your place of work, please indicate that below.

If you received another link or a code for an additional building, we invite you to take the survey again, by clicking on the link or using the new passcode.

Note: We offer one gift card per utility account. Gift cards are available while supplies last.
[MULTIPLE RESPONSES ALLOWED TO ALLOW FOR CONTACT INFORMATION ENTRY AND CHECKING NOT ABLE TO ACCEPT GIFT CARDS.]

1. Name: **[TEXT ENTRY BOX]**
2. Email address: **[TEXT ENTRY BOX]**
3. Phone Number:
4. I am not allowed to accept a gift card at my place of work.

Appendix F. Phone and Email Outreach Dispositions

Overall Cadmus completed 282 surveys with PG&E, SoCalGas, and SDG&E customers. The mailed postcards and the emails sent to the addressed in the outreach sample frames included a link to the online recruitment and screening survey. All modes of outreach used the same online survey platform. Cadmus tracked phone outreach survey completes and although Cadmus knows which surveys were completed outside of its phone outreach efforts, Cadmus could not distinguish whether the survey was completed as a result of its postcard or email outreach. Cadmus found that the IOU customer databases often did not contain accurate phone or email contact information for decision-makers of multifamily buildings and relied heavily on internet searches to find accurate contact information and conducted outreach on the phone.

Table F-1. shows the disposition of customers contacted via phone and Table F-2 shows the number of surveys completed via phone outreach vs. mail/email outreach. A coordinated phone outreach campaign coupled with high incentives ($200 per site visit completed) was key in reaching this group of IOU customers and achieving the targeted sample size for site visits. Mailed postcards and emails were very helpful in getting the word out about the study, but the most productive mode of outreach to recruit participants was by phone.

Table F-1. Disposition of Phone Outreach to Customers by Utility

Reason	PG&E	SDG&E	SoCalGas
Total Calls Placed	**503**	**346**	**632**
Follow-up Needed	90	240	420
Invalid Phone Number	7	10	13
Left Voicemail	104	39	84
No Answer and No Voicemail Option	1	3	2
Not Multi-Family (Hotel, Hospice, Dormitory, etc.)	85	-	-
Refused	69	25	31
Sibling Scheduled	14	1	1
Wrong Phone Number	4	1	3
Survey Completed on Phone	67	9	17
Survey Completed on Phone and Site Visit Scheduled	62	18	61

Table F-2. Number of Surveys Complete via Phone Outreach vs. Mail/Email Outreach

Reason	PG&E	SDG&E	SoCalGas
Total Surveys Completed	**145**	**33**	**104**
Completed via Phone Outreach	129	27	78
Complete via Email/Mail Outreach	16	6	26

Appendix G. On-Site Data Collection Form

Instructions
1. Save one workbook (.xlsx) per site visit.
2. All site-level data will be collected on the "SampledSiteInfo" Tab. There will be one "SampledSiteInfo" tab per workbook. Field Technicians can append more rows to the bottom of the current data collection prompts if there are more than 2 Unsampled Building Types.
3. Sampling for this project is done at the meter level. A sampled meter may serve one or more sampled buildings, in which case all those buildings are considered sampled buildings for data collection.
4. Treat buildings of the same age and construction type as same building type. For example, 10 buildings on a sampled site, built around the same year, consisting of five 5-story buildings, and five 3-story buildings should be documented as two building types. Treat physically separate structures as individual buildings. Buildings wrapped around or connected to a shared podium parking are counted as one.
5. Information on boilers and DHW systems feeding buildings supplied by the sampled Meter will be collected in the blue 'Boilers-BuildingType1' and 'DHW-BuildingType1' tabs. Building type 1,2,X is an identifier of a building or group of buildings being served by the equipment. Gray tabs can be used and duplicated as needed if there is more than one building type identified.
6. The current 'Boilers' and 'DHW' tabs have room for 5 boilers and DHW systems (labeled as A-E). If the building includes more than 5 boilers or DWH systems, create a new column and label the ID as the next alphabetic letter (F, G, H, I, J, etc.).
7. If there are buildings that are not served by the Sampled Meter, collect appropriate information under "Unsampled Building" headers on SampledSiteInfo Tab. The Technician can add more unsampled buildings as needed (Unsampled Building Type 3+) below the "Unsampled Building Type 2" section. This can happen in large developments of 4-8 unit buildings where several groups of buildings may be on separate meters than sampled.
8. Boiler refers to units supplying heat for space heating. DHW refers to units supplying domestic hot water. For units that provide both, we are capturing equipment specs in the "Boiler" tabs.
9. If any data prompt is vague or unclear, click or tap on the prompt in column A. An info box will pop up with more clarification.
10. Do not enter data into gray cells.
11. Do not leave any inputs blank. If you cannot gather the data for any reason, please describe why in the input cell. If input cell is a dropdown, choose "CND" for "Could Not Determine" and then explain further in General Boiler Notes
12. Prompts with the symbol, "↕", denote that the input is a drop-down menu
13. When collecting information in a boiler room serving one or more building types, collect information for all central gas heating or water heating equipment - even if the equipment is exclusively serving a nonresidential purpose in the complex such as pool, laundry, etc.

Glossary / Detailed Prompt Instructions			
Tab	Heading	Prompt	Description
SampledSiteInfo	-	*Sampled Building Address*	This the main address of the site or apartment complex. This will be the address you use to navigate to the site. Most often, it will be the address to leasing office or main building.
SampledSiteInfo	-	*Site willing to participate in follow-up panel?*	The utility is interested in conducting a follow-up study to this. We are asking if the contact would be interested in us including their names in the survey/interview panel for that study. The follow-up study does not include additional site visits (as far as we know). It will involve a participation reward of some kind and likely focus on understanding the decision-making process for making energy efficiency retrofits to the boiler/gas DHW equipment
SampledSiteInfo	Unsampled Building Type 1, 2	*Number of Buildings at Complex*	This is the number of UNSAMPLED buildings (type 1,2, etc) at the complex.
Boilers	Boiler Specs	*Is this a Redundant Boiler?*	A redundant boiler is a unit that only gets used if another boiler is being shut down for repairs.
Boilers / DHW	Building Data	*Avg Number of Rented Units Per Building (Market Rate)*	Does not need to account for vacancies
Boilers / DHW	Building Data	*Avg Number of Rented Units Per Building (Affordable/Rent-assist)*	Does not need to account for vacancies
Boilers / DHW	Building Data	*Has Contact supplied boiler combustion results?*	Only necessary for boilers over 2.5MBTUh
Boilers / DHW	Boiler Specs / DHW Specs	*Input capacity in kBtu/h*	1 kbtu/h = 1 MBH; 1,000 kbtu/h = 1MMBTU
Boilers / DHW	Boiler Specs / DHW Specs	*Net output capacity in kBtu/h*	Only enter if output capacity is labeled as "Net"
Boilers / DHW	Boiler Specs / DHW Specs	*Gross output capacity in kBtu/h*	Only enter if output capacity is labeled as "Gross"
Boilers / DHW	Boiler Specs / DHW Specs	*Output capacity (unspecified) in kbtu/h*	Enter if output capacity is unspecified on nameplate
Boilers / DHW	Boiler Specs / DHW Specs	*Rated Efficiency*	If there is no rated efficiency on the nameplate or Energy Guide label, enter "CND"
Boilers / DHW	Boiler Specs / DHW Specs	*Efficiency Units*	If no combustion testing results provided or Energy Guide label is not present, enter "CND"
Boilers / DHW	Burner Specs	*Burner Make*	If packaged boiler, there will be no burner make/model
Boilers / DHW	Burner Specs	*Burner Model*	If packaged boiler, there will be no burner make/model
Boilers / DHW	Burner Specs	*Premixing?*	The fuel is premixed with combustion air prior to entering burner canister
Boilers / DHW	Burner Specs	*O2 Trimming?*	Modulates intake oxygen to maximize combustion efficiency
Boilers / DHW	Burner Specs	*Flue Gas Recirculation?*	Used to warm intake air for higher combustion efficiency
Boilers / DHW	Boiler Characteristics / DHW Characteristics	*Location*	If it's in an enclosed space, it's interior (e.g. mechanical room on the roof)
Boilers / DHW	Boiler Characteristics / DHW Characteristics	*Boiler Year of Manufacture*	May need to lookup make/model on-line (AHRI database)
Boilers / DHW	Boiler Characteristics / DHW Characteristics	*Boiler Year of Install*	Look for service tag on boilers; Otherwise, ask site contact
Boilers / DHW	Boiler Characteristics / DHW Characteristics	*Date of Last Major Repair*	Look for service tag on boilers; Otherwise, ask site contact
Boilers / DHW	Boiler Characteristics / DHW Characteristics	*Description of Repair*	Look for service tag on boilers; Otherwise, ask site contact
Boilers / DHW	Boiler Characteristics / DHW Characteristics	*Date of Previous (Regular) Maintenance*	Look for service tag on boilers; Otherwise, ask site contact
Boilers / DHW	Boiler Characteristics / DHW Characteristics	*Regular Maintenance Schedule*	How often are the boilers tune-up? Service tag might show history. Otherwise, ask site contact.
Boilers	Boiler Characteristics	*HWT setpoint*	Ignore for boilers not providing space heating
Boilers	Boiler Characteristics	*Is there an automatic means for adjusting HWT?*	Ignore for boilers not providing space heating
Boilers / DHW	Boiler Characteristics / DHW Characteristics	*Economizer Present?*	Uses exhaust gas to preheat feedwater
DHW	DHW Specs	*End Use*	This field needs to be filled out first before entering data. Once filled out, gray cells denote that the info was already captured in the Boiler Tab.
DHW	DHW Specs	*Enter boiler ID*	Input the associated boiler ID (A,B,C,D, etc) from this building. Ignore if cell is gray
DHW	DHW Specs	*DHW Boiler Under Sampled Meter?*	Input the associated boiler ID (A,B,C,D, etc) from this building. Ignore if cell is gray
DHW	DHW Specs	*Space Heat/DHW Configuration*	Sidearm = Hot water is made using a boiler and stored in a separate tank; Tankless = On-Demand DHW (no tank)
DHW	DHW Specs	*Dedicated DHW Configuration*	Stand Alone Tank = Water is heated and stored in an integrated unit; Sidearm = Hot water is made using a boiler and stored in a separate tank; Tankless = On-Demand DHW (no tank)
DHW	Miscellaneous	*DHW recirculation Pump Control Strategy*	Constant= pump always on; Loop aquastat = aquastat turns pump on/off to maintain loop temp; Timer = pump on during peak periods; Temp modulation= lowers loop setpt when low demand is expected; Demand control= pump is controlled based on flow demand of system
DHW	Miscellaneous	*Total Storage Tank Gallons*	If no tank fed off of boiler, input zero

Data Collection Prompt	Input
Cadmus Account ID (Prepopulated)	
Sampled Meter ID (Prepopulated)	
Residential Complex Name	
Gas Utility ↕	
Contact Person 1	
Contact Phone 1	
Contact Email 1	
Contact Person 2	
Contact Phone 2	
Contact Email 2	
Sampled Building Address	
City	
Zip	
Field Tech 1 Name	
Field Tech 2 Name	
Site Visit Date	
Total Number of Res MF Buildings at Complex	
Total Number of Res MF Buildings Served by the Sampled Meter	
Has site participated in previous gas utility programs? ↕	
Notes Regarding Previous Gas Utility Program Participation (e.g. When, Where, and What Measure)?	
General Site Notes	
Gift Card Number	
Site willing to participate in follow-up panel?	
Unsampled Building Type 1	
Number of Buildings at Complex	
Number of Dwelling Units in Each Building (if applicable)	
Number of Dedicated Space Heating Boilers in Each Building	
Number of Dedicated DHW Boilers in Each Building	
Number of Boilers Providing Both Space Heating and DHW Heating (Combined) in Each Building	
Year of Building Construction	
Representative Year of Manufacture of Boilers (if applicable)	
Additional Building Notes	
Unsampled Building Type 2	
Number of Buildings at Complex	
Number of Dwelling Units in Each Building (if applicable)	

Number of Dedicated Space Heating Boilers in Each Building	
Number of Dedicated DHW Boilers in Each Building	
Number of Boilers Providing Both Space Heating and DHW Heating (Combined) in Each Building	
Year of Building Construction	
Representative Year of Manufacture of Boilers (if applicable)	
Additional Building Notes	
Unsampled Building Type 3	
Number of Buildings at Complex	
Number of Dwelling Units in Each Building (if applicable)	
Number of Dedicated Space Heating Boilers in Each Building	
Number of Dedicated DHW Boilers in Each Building	
Number of Boilers Providing Both Space Heating and DHW Heating (Combined) in Each Building	
Year of Building Construction	
Representative Year of Manufacture of Boilers (if applicable)	
Additional Building Notes	

Data Collection Prompts	BOILER ID A	BOILER ID B	BOILER ID C	BOILER ID D	BOILER ID E
Building Data					
Number of Buildings Served by these boilers					
Avg Year of Building Construction					
Avg Number of Inhabitable Floors Per Building					
Avg Conditioned Sqft Per Building					
Avg Number of Dwelling Units Per Building					
Avg Number of Rented Units Per Building (Market Rate)					
Avg Number of Rented Units Per Building (Affordable/Rent-assist)					
Note any major building renovations in the past year					
Has Contact supplied boiler combustion results?					
Note the in-unit space heating equipment (e.g. baseboard electric), and any gas equipment on the meter not included in the tool					
General Building Notes					
# of space heating circulator pumps (total)					
# of space heating circulator pumps that are nonoperational					
Boiler Specs					
Boiler Under Sampled Meter? ↕					
Is Boiler Operational? ↕					
Is this a Redundant Boiler? ↕					
General Boiler Notes					
Boiler type ↕					
End use ↕					
Boiler make					
Boiler model					
Boiler serial					
Condensing? ↕					
Input capacity in kBtu/h					
Net output capacity in kBtu/h					
Gross output capacity in kBtu/h					
Output capacity (unspecified) in kbtu/h					
Rated Efficiency					
Efficiency Units ↕					
Combustion Efficiency (if available)					
Burner Specs					
Burner Make					
Burner Model					
Has the Burner ever been replaced? ↕					
Combustion Control ↕					
Was Combustion Control an add-on? ↕					
Premixing? ↕					
Was Premixing an add-on? ↕					
O2 Trimming? ↕					
Was O2 Trimming an add-on? ↕					
Flue Gas Recirculation? ↕					
Was Flue Gas Recirc an add-on? ↕					
Boiler Characteristics					
Location ↕					
Boiler Year of Manufacture					
Boiler Year of Install					
Date of Last Major Repair					
Description of Repair					
Date of Previous (Regular) Maintenance					
Regular Maintenance Schedule ↕					
HWT setpoint					
Is there an automatic means for adjusting HWT? ↕					
Boiler Economizer Present? ↕					
Automated Flue Damper Present? ↕					
VFD on Combustion Fans? ↕					
Estimated Total Length of Accessible HW Piping in Unconditioned Spaces (ft)					

Estimated Total Insulated Length of Accessible HW Piping in Unconditioned Spaces (ft)					

Data Collection Prompts	DHW ID A	DHW ID B	DHW ID C	DHW ID D	DHW ID E
Building Data					
Number of Buildings Served by these boilers					
Avg Year of Building Construction					
Avg Number of Inhabitable Floors Per Building					
Avg Conditioned Sqft Per Building					
Avg Number of Dwelling Units Per Building					
Avg Number of Rented Units Per Building (Market Rate)					
Avg Number of Rented Units Per Building (Affordable/Rent-assist)					
Note any major building renovations in the past year					
Note the in-unit space heating equipment (e.g. baseboard electric), and any gas equipment on the meter not included in the tool					
Has Contact supplied boiler combustion results?					
General Building Notes					
DHW Specs					
End Use					
Enter boiler ID					
DHW Boiler Under Sampled Meter?					
Space Heat/DHW Configuration					
Dedicated DHW Configuration					
General DHW Notes					
Make					
Model					
Serial					
Condensing?					
Input capacity in kBtu/h					
Net output capacity in kBtu/h					
Gross output capacity in kBtu/h					
Output capacity (unspecified) in kbtu/h					
Rated Efficiency					
Efficiency Units					
Combustion Efficiency (if available)					
Burner Specs					
Burner Make					
Burner Model					
Has the Burner ever been replaced?					
Combustion Control					
Was Combustion Control an add-on?					
Premixing?					
Was Premixing an add-on?					
O2 Trimming?					
Was O2 Trimming an add-on?					
Flue Gas Recirculation?					
Was Flue Gas Recirc an add-on?					
DHW Characteristics					
Location					
Year of Manufacture					
Year of Install					
Date of Last Major Repair					
Description of Repair					
Date of Previous (Regular) Maintenance					
Regular Maintenance Schedule					
DHW Setpoint					
Economizer Present?					
Automated Flue Damper Present?					
VFD on Combustion Fans?					
Miscellaneous					
DHW System Includes Recirculation Loop?					
# of DHW recirculator pumps present					
# of DHW recirculator pumps that are nonoperational					
DHW recirculation Pump Control Strategy					
DHW Pipe Insulation Material					
DHW Pipe Insulation Thickness (in)					
Estimated Total Length of Accessible DHW Piping (ft)					
Estimated Total Insulated Length of Accessible DHW Piping (ft)					
Total Storage Tank Gallons					
Storage Tank Make					

Storage Tank Model					
Storage Tank Serial					
Tank Wrap Present?					

Appendix H. Water Heater Code Requirements

Cadmus checked the following 2019 Title 20 and Title 24 efficiency standards mandatory requirements to identify below-code, to-code, and above-code boilers:

- Title 20 Appliance Efficiency Regulations, "The manufacturer shall equip each gas, oil, and electric hot water boiler (other than a boiler equipped with a tankless domestic water heating coil) with automatic means for adjusting the temperature of the water supplied by the boiler to ensure that an incremental change in inferred heat load produces a corresponding incremental change in the temperature of water supplied."
- Title 20 Appliance Efficiency Regulations, "Have power venting or an automatic flue damper. An automatic vent damper is an acceptable alternative to an automatic flue damper for those unit heaters where combustion air is drawn from the conditioned space"
- Title 20 Appliance Efficiency Regulations, gas hot water boilers with an input capacity ≤300,000 Btu/hr shall have a minimum AFUE rating of 82%.
- Title 20 Appliance Efficiency Regulations, gas steam boilers with an input capacity ≤300,000 Btu/hr shall have a minimum AFUE rating of 80%.
- Title 20 Appliance Efficiency Regulations, gas hot water boilers with an input capacity between 300,000-2,500,000 Btu/hr shall have a minimum thermal efficiency of 80%.
- Title 20 Appliance Efficiency Regulations, gas steam boilers with an input capacity between 300,000-2,500,000 Btu/hr shall have a minimum thermal efficiency of 79%.
- Title 24 Section 110.3(c)2, "SHW systems with circulating pumps or with electrical heat trace have automatic controls that turn off the system during unoccupied periods."
- Title 24 Section 120.3, "Pipe insulation for space conditioning and service water-heating with fluid temperatures listed in Table 120.3-A have insulation levels as specified in subsection (a) and (b)."

Appendix I.Technical Potential Calculation Inputs

This appendix provides the calculation methodology used in the limited potential calculation of gas boiler efficiency upgrades and retrofits.

Boiler Replacement

Cadmus used the following equation to determine the annual energy savings per boiler replacement:

$$Annual\ Therm\ Savings = \frac{Capacity_{Input} * EFLH}{100} * (1 - Boiler_{BaselineEff} / Boiler_{MeasureEff})$$

The savings inputs Cadmus used for these calculations are shown in Table I-1.

Table I-1. Boiler Replacement Savings Inputs

Input	Assumption			Source
	PG&E	SoCalGas	SDG&E	
$Capacity_{Input}$ (Btu/h)	Varies by utility and boiler type			Average boiler input capacity based on site visits
Equivalent Full Load Hours (EFLH)	692	629	506	DEER Multifamily Boiler Hours in the interim California Workpaper SWHC004-01
$Boiler_{MeasureEff}$ (AFUE or Thermal Efficiency)	Varies by boiler type			Boiler efficiency based on measure definitions
$Boiler_{BaselineEff}$ (AFUE or Thermal Efficiency)	Existing Efficiency			Average efficiency of boilers that were below code based on Site visit data
	Code Baseline Efficiency - Varies by boiler type			2016 Building Energy Efficiency Standards, California Code of Regulations, Title 24, Part 6, Subchapter 2, Section 110.2, Table 110.2-K

Boiler On-demand Boiler Circulation Pump Control

Cadmus used the following equation to determine the annual energy savings per boiler pump control installation:

$$Annual\ Therm\ Savings = Boiler_{n\ per\ site} * \frac{Capacity_{Input} * EFLH}{100} * Factor_{Savings}$$

The savings inputs Cadmus used for these calculations are shown in Table I-2.

Table I-2. Boiler On-demand Boiler Circulation Pump Control Savings Inputs

Input	Assumption			Source
	PG&E	SoCalGas	SDG&E	
$Factor_{Savings}$ (%)	6%			USDOE, Control Strategies to Reduce the Energy Consumption of Central Domestic Hot Water Systems, 2016, Page 29. Available online: https://www.nrel.gov/docs/fy16osti/64541.pdf specific to On-demand Boiler Circulation Pump Control
Equivalent Full Load Hours (EFLH)	692	629	506	DEER Multifamily Boiler Hours in the interim California Workpaper SWHC004-01
$Boiler_{n\ per\ site}$	2.76	1.47	9.06	Average number of boilers per site (for sites where equipment was present) based on site visits

$Capacity_{Input}$ (Btu/h)	427	514	343	Average boiler capacity based on site visits (Only for boilers that had no existing mode of pump control installed)

Boiler Pipe Insulation

Cadmus used the following equation to determine the annual energy savings per boiler pipe insulation installation/improvement:

$$Annual\ Therm\ Savings_{Per\ Linear\ Foot} = \frac{Hours_{Annual} * \left(Heat\ Loss_{Baseline/ft} - Heat\ Loss_{Measure/ft}\right)}{100{,}000}$$

The savings inputs Cadmus used for these calculations are shown in Table I-3.

Table I-3. Boiler Pipe Insulation Savings Inputs

Input		Assumption			Source
		PG&E	SoCalGas	SDG&E	
$Heat\ Loss_{Baseline/ft}$ (Btu/h/ft) - Hourly	To code - pipes with no insulation	34.7	34.7	34.7	Calculated using 3E Plus v. 4.1, Assuming 125F water temperature, 1" pipe diameter. Available at: https://insulationinstitute.org/tools-resources/free-3e-plus/
	To code - existing pipe insulation	12.4	8.07	10.6	
	Above code - 1.5"	6.12	6.12	6.12	
	Above code - 2"	6.12	6.12	6.12	
	Above code - 2.5"	6.12	6.12	6.12	
$Heat\ Loss_{Measure/ft}$ (Btu/h/ft) - Hourly	To code - pipes with no insulation	6.12	6.12	6.12	Calculated using 3E Plus v. 4.1, Assuming 125F water temperature, 1" pipe diameter. Available at: https://insulationinstitute.org/tools-resources/free-3e-plus/
	To code - existing pipe insulation	6.12	6.12	6.12	
	Above code - 1.5"	5.01	5.01	5.01	
	Above code - 2"	4.35	4.35	4.35	
	Above code - 2.5"	3.91	3.91	3.91	
$Hours_{Annual}$ (hr)		8760			Hours in a year

Boiler Automated Flue Damper

Cadmus used the following equation to determine the annual energy savings per boiler flue damper installation:

$$Annual\ Therm\ Savings = \frac{Capacity_{Input} * EFLH}{100} * \left(1 - Boiler_{BaselineEff} / Boiler_{MeasureEff}\right)$$

The savings inputs Cadmus used for these calculations are shown in Table I-4.

Table I-4. Boiler Flue Damper Savings Inputs

Input		Assumption			Source
		PG&E	SoCalGas	SDG&E	
$Capacity_{Input}$ (Btu/h)	≤300,000 Btu/h	217	231	180	Average boiler capacity based on site visits
	>300,000 Btu/h	803	820	696	
Equivalent Full Load Hours (EFLH)		692	629	506	DEER Multifamily Boiler Hours in the interim California Workpaper SWHC004-01
$Boiler_{BaselineEff}$ (AFUE or Thermal Efficiency)	≤300,000 Btu/h	0.86	0.84	0.9	Boiler efficiency based on measure definitions
	>300,000 Btu/h	0.85	0.84	0.87	
$Boiler_{MeasureEff}$ (AFUE or Thermal Efficiency)		Baseline Efficiency +3%			LBNL - Dampers for Natural Draft Water Heaters: Technical Report, 2008. Available at: https://www.osti.gov/servlets/purl/961526. Study found flue damper reduced off-cycle standby losses, and improved efficiency by 3 percent.

Boiler Economizer

Cadmus used the following equation to determine the annual energy savings per boiler economizer installation:

$$Annual\ Therm\ Savings = \frac{Capacity_{Input} * EFLH}{100} * (1 - Boiler_{BaselineEff} / Boiler_{MeasureEff})$$

The savings inputs Cadmus used for these calculations are shown in Table I-5.

Table I-5. Boiler Economizer Savings Inputs

Input		Assumption			Source
		PG&E	SoCalGas	SDG&E	
$Capacity_{Input}$ (Btu/h)	≤300,000 Btu/h	217	231	180	Average boiler capacity based on site visits
	>300,000 Btu/h	803	820	696	
Equivalent Full Load Hours (EFLH)		692	629	506	DEER Multifamily Boiler Hours in the interim California Workpaper SWHC004-01
$Boiler_{BaselineEff}$ (AFUE or Thermal Efficiency)	≤300,000 Btu/h	0.86	0.84	0.9	Boiler efficiency based on measure definitions
	>300,000 Btu/h	0.85	0.84	0.87	
$Boiler_{MeasureEff}$ (AFUE or Thermal Efficiency)		Baseline Efficiency +7%			SoCalGas, Use of Non-Condensing Economizer on Boiler, 2012. Available at: https://www.gosolarcalifornia.ca.gov/tools/newCalcSys/Description/Use%20of%20economizers%20for%20a%20boiler.pdf. Study found for most small to medium size boilers, the energy savings can be in the range of 3% to 10% of the current energy use.

Boiler Tune-Up

Cadmus used the following equation to determine the annual energy savings per boiler tune-up:

$$Annual\ Therm\ Savings = \frac{Capacity_{Input} * EFLH}{100} * Factor_{Savings}$$

The savings inputs Cadmus used for these calculations are shown in Table I-6.

Table I-6. Boiler Tune-Up Savings Inputs

Input	Assumption			Source
	PG&E	SoCalGas	SDG&E	
$Capacity_{Input}$ (Btu/h)	427	514	343	Average boiler capacity based on site visits
Equivalent Full Load Hours (EFLH)	692	629	506	DEER Multifamily Boiler Hours in the interim California Workpaper SWHC004-01
$Factor_{Savings}$ (%)	1%			Benchmarked various sources (Able company[1], ESC[2], DOE[3], UIC[4], PG&E workpaper on boiler tune-up for dry cleaners[5]) that ranged from 0.5% to 14%. Used 1% as conservative estimate to avoid overstating the potential.

[1] Able Company. The Benefits of Adding Oxygen Trim to Single Point Positioning or Parallel Positioning Combustion Control Systems. At: http://www.ablecompany.com/assets/benefits-of-oxygen-trim.pdf
[2] Energy Solutions Center website: http://cleanboiler.org/learn-about/boiler-efficiency-improvement/efficiency-index/oxygen-control
https://www1.eere.energy.gov/manufacturing/tech_assistance/pdfs/steam4_boiler_efficiency.pdf
[3] U.S. Department of Energy. Energy Efficiency and Renewable Energy. Steam Tip Sheet #4: Improve Your Boiler's Combustion Efficiency. At:
https://www1.eere.energy.gov/manufacturing/tech_assistance/pdfs/steam4_boiler_efficiency.pdf
[4] Energy Resource Center. Boiler System Efficiency Program. http://www.erc.uic.edu/energy-efficiency/illinois-energy-now-programs/boiler-tune-up-program
[5] PG&E. Workpaper for Boiler Tuneup for Drycleaners. PGECOPRO107. 2016.

Boiler Replacement and Retrofit Measure Technical Potential Inputs

Table I-7 contains the measure inputs to determine the technical potential. Saturation of equipment represents how many of meters had boilers within the size range identified and how many of boilers behind that meter were considered inefficient (e.g., available for upgrade). The applicability factor presents the technical feasibility constraints, for example, economizers were only considered as feasible for tankless boilers (hot water and steam). In addition, the applicability factor and measure competition share are multiplied to represent the percentage of meters that can feasibly receive the measure after accounting for competition with similar measures. Cadmus calculated these factors by extrapolating its observations during site visits to the population of meters in the IOU territories.

Table I-7. Technical Potential Measure Inputs

Utility	Measure Name	Baseline	Per Unit Definition for Savings	Savings (Therms/yr)	Measure Life (yrs)	Multifamily Units – Eligible Meters (Base Year)	Saturation of Equipment	Number of Units per Meter	Equipment Competition	Applicability Factor
PG&E	T24 Code Efficiency Hot Water Boiler, 82% AFUE, ≤300 kBtu	Average Existing Efficiency, ≤300 kBtu	Per Boiler	36	20	1,592	56%	2.53	100%	27%
SoCalGas	T24 Code Efficiency Hot Water Boiler, 82% AFUE, ≤300 kBtu	Average Existing Efficiency, ≤300 kBtu	Per Boiler	38	20	4,361	48%	2.23	100%	31%
SDG&E	T24 Code Efficiency Hot Water Boiler, 82% AFUE, ≤300 kBtu	Average Existing Efficiency, ≤300 kBtu	Per Boiler	22	20	914	71%	4.67	100%	34%
PG&E	T24 Code Efficiency Hot Water Boiler, 80% Thermal Eff, >300-2500kBtu	Average Existing Efficiency, >300-2500kBtu	Per Boiler	77	20	1,592	56%	1.62	100%	4%
SoCalGas	T24 Code Efficiency Hot Water Boiler, 80% Thermal Eff, >300-2500kBtu	Average Existing Efficiency, >300-2500kBtu	Per Boiler	129	20	4,361	70%	1.79	100%	1%
SDG&E	T24 Code Efficiency Hot Water Boiler, 80% Thermal Eff, >300-2500kBtu	Average Existing Efficiency, >300-2500kBtu	Per Boiler	440	20	914	59%	2.60	100%	8%
PG&E	High Efficiency Boiler, AFUE 90%, Average System Capacity, ≤300 kBtu/h	T24 Code Efficiency Hot Water Boiler, 82% AFUE, ≤300 kBtu	Per Boiler	134	20	1,592	56%	2.53	50%	40%
SoCalGas	High Efficiency Boiler, AFUE 90%, Average System Capacity, ≤300 kBtu/h	T24 Code Efficiency Hot Water Boiler, 82% AFUE, ≤300 kBtu	Per Boiler	129	20	4,361	48%	2.23	50%	66%
SDG&E	High Efficiency Boiler, AFUE 90%, Average System Capacity, ≤300 kBtu/h	T24 Code Efficiency Hot Water Boiler, 82% AFUE, ≤300 kBtu	Per Boiler	81	20	914	71%	4.67	50%	34%
PG&E	Premium Efficiency Boiler, AFUE 94%, Average System Capacity, ≤300 kBtu/h	T24 Code Efficiency Hot Water Boiler, 82% AFUE, ≤300 kBtu	Per Boiler	193	20	1,592	56%	2.53	30%	40%
SoCalGas	Premium Efficiency Boiler, AFUE 94%, Average System Capacity, ≤300 kBtu/h	T24 Code Efficiency Hot Water Boiler, 82% AFUE, ≤300 kBtu	Per Boiler	185	20	4,361	48%	2.23	30%	66%
SDG&E	Premium Efficiency Boiler, AFUE 94%, Average System Capacity, ≤300 kBtu/h	T24 Code Efficiency Hot Water Boiler, 82% AFUE, ≤300 kBtu	Per Boiler	116	20	914	71%	4.67	30%	34%

Utility	Measure Name	Baseline	Per Unit Definition for Savings	Savings (Therms/yr)	Measure Life (yrs)	Multifamily Units – Eligible Meters (Base Year)	Saturation of Equipment	Number of Units per Meter	Equipment Competition	Applicability Factor
PG&E	Advanced Efficiency Boiler, AFUE 95+%, Average System Capacity, ≤300 kBtu/h	T24 Code Efficiency Hot Water Boiler, 82% AFUE, ≤300 kBtu	Per Boiler	206	20	1,592	56%	2.53	20%	40%
SoCalGas	Advanced Efficiency Boiler, AFUE 95+%, Average System Capacity, ≤300 kBtu/h	T24 Code Efficiency Hot Water Boiler, 82% AFUE, ≤300 kBtu	Per Boiler	199	20	4,361	48%	2.23	20%	66%
SDG&E	Advanced Efficiency Boiler, AFUE 95+%, Average System Capacity, ≤300 kBtu/h	T24 Code Efficiency Hot Water Boiler, 82% AFUE, ≤300 kBtu	Per Boiler	124	20	914	71%	4.67	20%	34%
PG&E	High Efficiency Boiler, Thermal Eff 90%, Average System Capacity, ≥300 kBtu/h	T24 Code Efficiency Hot Water Boiler, 80% Thermal Eff, >300-2500kBtu	Per Boiler	623	20	1,592	56%	1.62	50%	24%
SoCalGas	High Efficiency Boiler, Thermal Eff 90%, Average System Capacity, ≥300 kBtu/h	T24 Code Efficiency Hot Water Boiler, 80% Thermal Eff, >300-2500kBtu	Per Boiler	573	20	4,361	70%	1.79	50%	4%
SDG&E	High Efficiency Boiler, Thermal Eff 90%, Average System Capacity, ≥300 kBtu/h	T24 Code Efficiency Hot Water Boiler, 80% Thermal Eff, >300-2500kBtu	Per Boiler	391	20	914	59%	2.60	50%	19%
PG&E	Premium Efficiency Boiler, Thermal Eff 94%, Average System Capacity, ≥300 kBtu/h	T24 Code Efficiency Hot Water Boiler, 80% Thermal Eff, >300-2500kBtu	Per Boiler	835	20	1,592	56%	1.62	30%	24%
SoCalGas	Premium Efficiency Boiler, Thermal Eff 94%, Average System Capacity, ≥300 kBtu/h	T24 Code Efficiency Hot Water Boiler, 80% Thermal Eff, >300-2500kBtu	Per Boiler	768	20	4,361	70%	1.79	30%	4%
SDG&E	Premium Efficiency Boiler, Thermal Eff 94%, Average System Capacity, ≥300 kBtu/h	T24 Code Efficiency Hot Water Boiler, 80% Thermal Eff, >300-2500kBtu	Per Boiler	524	20	914	59%	2.60	30%	19%
PG&E	Advanced Efficiency Boiler, Thermal Eff 95+%, Average System Capacity, ≥300 kBtu/h	T24 Code Efficiency Hot Water Boiler, 80% Thermal Eff, >300-2500kBtu	Per Boiler	885	20	1,592	56%	1.62	20%	24%
SoCalGas	Advanced Efficiency Boiler, Thermal Eff 95+%, Average System Capacity, ≥300 kBtu/h	T24 Code Efficiency Hot Water Boiler, 80% Thermal Eff, >300-2500kBtu	Per Boiler	814	20	4,361	70%	1.79	20%	4%
SDG&E	Advanced Efficiency Boiler, Thermal Eff 95+%, Average System Capacity, ≥300 kBtu/h	T24 Code Efficiency Hot Water Boiler, 80% Thermal Eff, >300-2500kBtu	Per Boiler	556	20	914	59%	2.60	20%	19%

Utility	Measure Name	Baseline	Per Unit Definition for Savings	Savings (Therms/yr)	Measure Life (yrs)	Multifamily Units – Eligible Meters (Base Year)	Saturation of Equipment	Number of Units per Meter	Equipment Competition	Applicability Factor
PG&E	Recirculation Pump Demand-Control	No Controls	Per Meter	489	15	1,592	95%	1.00	100%	81%
SoCalGas	Recirculation Pump Demand-Control	No Controls	Per Meter	284	15	4,361	88%	1.00	100%	89%
SDG&E	Recirculation Pump Demand-Control	No Controls	Per Meter	944	15	914	100%	1.00	100%	88%
PG&E	Boiler Pipe Insulation - to Code	Pipes with No Insulation	Per Foot	2.51	11	1,592	100%	113.81	100%	29%
SoCalGas	Boiler Pipe Insulation - to Code	Pipes with No Insulation	Per Foot	2.51	11	4,361	100%	59.45	100%	56%
SDG&E	Boiler Pipe Insulation - to Code	Pipes with No Insulation	Per Foot	2.51	11	914	100%	96.81	100%	60%
PG&E	Boiler Pipe Insulation - to Code	Existing Pipe Insulation	Per Foot	0.55	11	1,592	100%	113.81	100%	17%
SoCalGas	Boiler Pipe Insulation - to Code	Existing Pipe Insulation	Per Foot	0.17	11	4,361	100%	59.45	100%	18%
SDG&E	Boiler Pipe Insulation - to Code	Existing Pipe Insulation	Per Foot	0.39	11	914	100%	96.81	100%	34%
PG&E	Boiler Pipe Insulation - Above Code, 1.5"	Code Pipe Insulation	Per Foot	0.10	11	1,592	100%	113.81	50%	99%
SoCalGas	Boiler Pipe Insulation - Above Code, 1.5"	Code Pipe Insulation	Per Foot	0.10	11	4,361	100%	59.45	50%	100%
SDG&E	Boiler Pipe Insulation - Above Code, 1.5"	Code Pipe Insulation	Per Foot	0.10	11	914	100%	96.81	50%	98%
PG&E	Boiler Pipe Insulation - Above Code, 2"	Code Pipe Insulation	Per Foot	0.16	11	1,592	100%	113.81	30%	99%
SoCalGas	Boiler Pipe Insulation - Above Code, 2"	Code Pipe Insulation	Per Foot	0.16	11	4,361	100%	59.45	30%	100%
SDG&E	Boiler Pipe Insulation - Above Code, 2"	Code Pipe Insulation	Per Foot	0.16	11	914	100%	96.81	30%	98%
PG&E	Boiler Pipe Insulation - Above Code, 2.5"	Code Pipe Insulation	Per Foot	0.19	11	1,592	100%	113.81	20%	99%
SoCalGas	Boiler Pipe Insulation - Above Code, 2.5"	Code Pipe Insulation	Per Foot	0.19	11	4,361	100%	59.45	20%	100%
SDG&E	Boiler Pipe Insulation - Above Code, 2.5"	Code Pipe Insulation	Per Foot	0.19	11	914	100%	96.81	20%	98%
PG&E	Automated Flue Damper	No Automated Flue Damper	Per Boiler	51	15	1,592	56%	2.53	100%	69%
SoCalGas	Automated Flue Damper	No Automated Flue Damper	Per Boiler	50	15	4,361	48%	2.23	100%	52%
SDG&E	Automated Flue Damper	No Automated Flue Damper	Per Boiler	29	15	914	71%	4.67	100%	57%
PG&E	Automated Flue Damper	No Automated Flue Damper	Per Boiler	189	15	1,592	56%	1.62	100%	80%
SoCalGas	Automated Flue Damper	No Automated Flue Damper	Per Boiler	178	15	4,361	70%	1.79	100%	96%
SDG&E	Automated Flue Damper	No Automated Flue Damper	Per Boiler	117	15	914	59%	2.60	100%	92%

Utility	Measure Name	Baseline	Per Unit Definition for Savings	Savings (Therms/yr)	Measure Life (yrs)	Multifamily Units – Eligible Meters (Base Year)	Saturation of Equipment	Number of Units per Meter	Equipment Competition	Applicability Factor
PG&E	Boiler Economizer	No Economizer	Per Boiler	106	10	1,592	56%	2.53	100%	23%
SoCalGas	Boiler Economizer	No Economizer	Per Boiler	105	10	4,361	48%	2.23	100%	17%
SDG&E	Boiler Economizer	No Economizer	Per Boiler	62	10	914	71%	4.67	100%	1%
PG&E	Boiler Economizer	No Economizer	Per Boiler	395	10	1,592	56%	1.62	100%	4%
SoCalGas	Boiler Economizer	No Economizer	Per Boiler	371	10	4,361	70%	1.79	100%	0%
SDG&E	Boiler Economizer	No Economizer	Per Boiler	244	10	914	59%	2.60	100%	10%
PG&E	Boiler Tune-up and Maintenance	No Tune-up	Per Boiler	30	5	1,592	100%	2.76	100%	27%
SoCalGas	Boiler Tune-up and Maintenance	No Tune-up	Per Boiler	32	5	4,361	100%	1.47	100%	23%
SDG&E	Boiler Tune-up and Maintenance	No Tune-up	Per Boiler	17	5	914	100%	9.06	100%	29%

Appendix J. Standardized Recommendations

Study ID	Study Type	Study Title	Study Manager	Affected Workpaper or DEER
SCG0225.01	Market Assessment	California Statewide Multifamily Boiler Market Assessment	SoCalGas	N/A
Recommendation	**Summary of Findings**	**Additional Supporting Information**	**Best Practice / Recommendations**	**Recommendation Recipient**
1	**In this market study, a majority of boilers behind multifamily meters (86%) solely served DHW end-uses.**	Pool-heating and dedicated space-heating boilers constituted 6% and 5% of the population, respectively. Only 2.5% of boilers served both DHW and space-heating end-uses. *(See Section 5.1 Multifamily Boiler Population Stock and End-Uses Served)*		
2	**While Cadmus did not find evidence suggesting that a majority of boilers are old and operating beyond their EULs, boiler-age data suggested that 22% and 25% of dedicated space-heating boilers in PG&E and SoCalGas territories, respectively, operated at or beyond their EULs. Additionally, data suggest that 30% of pool-heating boilers in PG&E's territory operate at or beyond their EULs.**	Overall, 7% of boilers were at least 20 years old and operated at or beyond their EULs. Cadmus did not visit any boilers operating at or beyond their EULs within SDG&E's territory. Dedicated space-heating boilers had higher average input capacities, suggesting that they are larger and more expensive to replace. *(See Sections 5.2 Multifamily Boiler Population Vintage* and *5.4 Multifamily Boiler Population Input Capacity)*	In their efforts to replace older, less-efficient boilers, PG&E and SoCalGas should consider focusing on dedicated space-heating boilers, and PG&E should consider focusing on pool-heating boilers. PG&E and SoCalGas may consider increasing program marketing or incentive amounts for high-efficiency replacements in these boiler categories.	IOUs

Study ID	Study Type	Study Title	Study Manager	Affected Workpaper or DEER
3	**Cadmus did not find older boilers in older buildings.**	Data collected through site visits showed boilers of all ages and efficiency levels among buildings in each 20-year age strata. The data did not show a correlation between building age and boiler age. Given limited program participation data from the IOUs, and limited indication of previous program participation from site-visit contacts, Cadmus could not establish the program's influence on replacements of old boilers. *(See Section 5.2 Multifamily Boiler Population Vintage)*		
4	**Cadmus calculated technical potential as 3.5 times higher for boiler retrofits (add-on or maintenance measures) than for boiler equipment replacements.**	Cadmus conducted a limited technical potential analysis for gas boiler equipment replacements (resulting in efficiency improvements) and retrofit measures (such as circulation pump demand-control, boiler pipe insulation, automated flue damper, economizer, and tune-ups). Cadmus calculated 1.4 and 4.9 MMtherms of technical potential for boiler equipment and retrofit measures, respectively, and Cadmus calculated the highest total potential for equipment and retrofit measures in SoCalGas territory (3.27 MMtherms), followed by PG&E (1.62 MMtherms) and SDG&E (1.46 MMtherms). *(See Section 5.6 Multifamily Boiler Population Technical Potential for Select Efficiency Measures)*		

Study ID	Study Type	Study Title	Study Manager	Affected Workpaper or DEER
5	**A comparison of technical potential savings calculated in this study and in the 2019 Energy Efficiency Potential and Goals Study (2019 P&G study) for the on-demand circulation pump control measure suggests that per-dwelling unit savings and initial saturation assumptions for this measure should be reevaluated in the next P&G study.**	The technical potential calculated in this study cannot be directly compared with the potential calculated in the 2019 P&G study due to this study's smaller scope. A comparison of per-dwelling unit savings (22.86 therms used in the 2019 P&G study versus 4.38 therms calculated in this study) and the initial technology saturation (2% in the 2019 P&G study versus 14% in this study) for the on-demand recirculation pump control measure suggests that these assumptions should be re-evaluated in the next P&G study. *(See Section 5.9 Comparison of Results with Previous Market Studies in California)*	To increase the accuracy of its potential estimates in the multifamily water heating sector, the CPUC should consider re-evaluating estimates of per-dwelling unit savings and initial saturation for the on-demand pump control measure in the next P&G study.	CPUC Energy Division

Study ID	Study Type	Study Title	Study Manager	Affected Workpaper or DEER
6	**Multifamily building decision-makers remain hard to reach. A coordinated phone outreach campaign, coupled with high incentives ($200 per site visit completed), proved key in reaching this group of IOU customers and in achieving the targeted sample size for site visits.**	Mailed postcards and emails were very helpful in getting the word out about the study, but the most productive outreach mode in recruiting participants was by phone. Cadmus found that IOU customer databases often did not contain accurate phone or email contact information for decision-makers of multifamily buildings, hence relying heavily on internet searches to find accurate contact information. It is difficult and costly for the IOUs to obtain and maintain current contact information for multifamily buildings. *(See Appendix F. Phone and Email Outreach Dispositions)*	Given the difficulty in reaching multifamily building decision-makers and the high cost of data collection, Cadmus recommends future researchers and the IOUs consider a coordinated phone outreach approach, coupled with incentives, that allows for data collection about multiple research topics, or about the building and equipment as a whole, as opposed to data collection focused on a specific technology.	IOUs and CPUC Energy Division
7	**Cadmus' literature review confirmed a gap in previously available data about boilers in California residential, multifamily buildings, including numbers installed, end-uses served, input capacity, age, and efficiency. This study fills the gap in previously available data for boilers in the PG&E, SDG&E, and SoCalGas territories.**	This market assessment answers critical questions about the quantity, age, type, code compliance, and efficiency of boilers in large residential, multifamily building complexes with at least one meter serving 40 or more dwelling units built before 2001. *(See Appendix A. Literature Review Methods and Results)*		

Study ID	Study Type	Study Title	Study Manager	Affected Workpaper or DEER
8	**Additional research is needed to understand multifamily building owner/operator decision-making processes to assist in targeted program planning and utility intervention to encourage replacements of older boilers and installations of retrofit measures**.	The original RFP contained additional research questions for Phase 2 of this study, focused on understanding multifamily building owner/operator decision-making processes. Though Cadmus did not find a significant proportion of boilers operating beyond their EULs, Cadmus did estimate a large potential for boiler retrofit measures. Cadmus' literature review indicated that structural barriers remain regarding high IOU program uptake in the multifamily market, particularly for whole-building upgrades. Understanding how multifamily building owners and operators make decisions would help the IOUs target programs, not just for boiler replacements and retrofits but also for other whole-building energy efficiency improvements in the multifamily residential building sector. *(See Section 5.6 Multifamily Boiler Population Technical Potential for Select Efficiency Measures* and *Appendix A. Literature Review Methods and Results)*	The IOUs and the CPUC should consider additional research to assist in targeting programs for multifamily customers in response to current state decarbonization priorities in the building sector. This additional research should build upon data collected through previous IOU multifamily customer segmentation and needs assessment studies, in addition to insights gathered from previous California multifamily program process evaluations.	IOUs and CPUC Energy Division

Appendix K. Response to Public Comments

Comment #	Commenter (self-identify by Party, PA, etc.)	Page (as shown in MS Word document)	Comment/feedback/change requested	Evaluator's Response
1	Carol Yin	IESR	Would it be possible for the evaluation team to include an appendix with recommendations presented using the table from the CPUC Energy Division Impact Evaluation Standard Reporting Guidelines? Thank you! https://pda.energydataweb.com/api/downloads/1399/IESR_Guidelines_Memo_FINAL_11_30_2015.pdf	Yes. Added appendix J accordingly.
2	Nehemiah Stone	data for Table 74	The explanation below Table 74 only lists three of the code required items that could be retrofit onto existing boiler CDHW systems. One of the larger items required by T24 for these systems is a solar water heating system that meets the specs in RA4. There is no mention of this potential retrofit measure in the report. Can the authors explain why?	A solar water heating system is a prescriptive requirement for central water-heating systems serving multiple dwelling units in low-rise residential buildings according to Title 24 2019 subchapter 8 Low-rise Residential Buildings - Performance and Prescriptive Compliance Approaches. Cadmus only assessed code compliance for mandatory requirements, since assessing code compliance with prescriptive and performance code requirements would have required a whole-building energy model for each site beyond the scope of this study. To address this comment, we clarified references to code compliance in multiple sections of the report (including section 3.4 and Appendix H) to state the we examined mandatory code requirements only. Additionally, the technical potential estimate was a limited exercise with a defined scope and a particular set of measures focused on gas boiler efficiency upgrades, add-on retrofits, and maintenance as approved in the final research plan. Calculating the potential for adding solar water heating was outside the scope of this study. To address this comment, we added a paragraph to section 2.4 (limitations of the study) about the limited nature of the potential analysis.

3	Nehemiah Stone	Potential Measures	Among the list of potential replacement options for older boilers, there are four levels of boiler efficiency: T24 compliant, High Efficiency, Premium, and Advanced. the best of these has an efficiency of 95%. Since so many other efforts of the State are focused on decarbonization, and since the typical efficiency for a heat pump water heater is >300% (even greater than 100% accounting for generation and grid losses), by excluding them, the study does not adequately serve the State's needs. I suggest that the study should include examination of the potential savings using heat pumps and relying on cost projections developed in the recent study by E3.	To plan for future decarbonization in California, it is important to understand the installed gas boiler stock and its characteristics in the multifamily building sector. This study provides a detailed market assessment by examining the installed base of central boilers and water heaters in multifamily buildings built before 2001, with at least one gas IOU meter serving 40 or more dwelling units. The technical potential study approved in the final research plan, was limited to a specific set of measures focused on gas boiler efficiency upgrades, add-on retrofits, and maintenance. Studying the potential for replacing existing gas boilers with electric water heaters was outside of the scope of this study. Table 19 provides a detailed list of measures included in the limited technical potential study.