Research and Analyze the Infrared Heaters Market

Project Number ET22SWG0007

GAS EMERGING TECHOLOGIES PROGRAM (GET)

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ICF

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Acknowledgments

ICF is responsible for this project. This project, ET22SWG0007, was developed as part of the Statewide Gas Emerging Technologies Program (GET) under the auspices of SoCalGas as the Statewide Lead Program Administrator. Frank-Eric Ngamassi conducted this technology evaluation with overall guidance and management from ICF Technical Lead, Steven Long. For more information on this project, contact steven.long@ICF.com.

Disclaimer

Abbreviations and Acronyms

Abbreviations	Meaning
AHRI	Air-Conditioning Heating and Refrigeration Institute
ANSI	American National Standard Institute
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineer
Btuh	British Thermal Units per Hour
CAN	Canadian Standards Council
CSA	Canadian Standards Association
EE	Energy Efficiency
ELVHIS	European Association of Luminous Radiant Gas Heater Manufacturers
GET	Gas Emerging Technology
IF	Infrared Factor
IMC	Incremental Measure Costs
IR	Infrared
kW	Kilowatt
MBtuh	Thousands of British Thermal Units per Hour
NFPA	National Fire Protection Association
OEM	Original Equipment Manufacturer
REV	Radiant Emission Value
SME	Subject Matter Expert

Executive Summary

The Gas Emerging Technologies (GET) program conducted a study to analyze and research the market of gas infrared (IR) heating technologies in California and provide actionable recommendations of the technology and gaps for further study.

The goal of this study was to understand the major opportunities—improved energy efficiency, proper equipment selection, and the use of standards—in different gas IR heating applications. In this process, we identified several barriers to implementing these measures in California, including an apparently small IR heaters market, limited product standards, and negative incremental costs for some measures with mixed baselines. In this study, we looked at high-intensity IR heaters, low-intensity IR heaters, wall/celling mounted patio heaters, construction heaters, and chicken brooders.

The first step of the study was to conduct a literature review on gas IR heaters to get an understanding of the technology and application. Original equipment manufacturers were then interviewed about their products, their design types, and the radiant efficiency standards they follow.

This study also reviewed relevant standards. A key finding was identifying multiple potential standards, including the current standard on radian efficiency: AHRI 1330-2015. The standard was developed to guide manufacturers to utilize proper methods of radiant heater testing. However, based on interviews with the original equipment manufacturer (OEM), this standard is vague and not required.

Four targeted customer sectors were surveyed based on the OEM comments, which consisted of 85 customers. The survey helped paint a picture of the IR heater market and some barriers to adopting IR heaters in California.

Additionally, program managers in colder states gave us a sense of how many IR heaters rebate applications they received over the last 5 years. These interactions show that the IR heater market is limited in California and even in the other states with rebate programs and colder climates.

Introduction

Efficient heating systems for industrial facilities, like warehouses, have been an overlooked opportunity, until recently, due to the growth of the thriving e-commerce industry. Infrared heating is one way to heat these larger spaces by using electromagnetic waves to transfer energy from the infrared source to the object without heating the air in between, thereby limiting heat loss and energy costs.

Seen as an efficient alternative to commonly used forced air unit heaters, some Northeast and Midwest utilities provide incentives for the implementation of IR heaters. In this study, we investigated the market potential of specific IR heaters in California for possible utility offers and proposed actionable recommendations. Facilities such as warehouses, restaurant patios, auto shops, manufacturing plants, and chicken brooders are some of the areas we investigated that could benefit from the use of IR heaters within California.

Background

Radiant infrared energy, which was discovered in the mid-1700s during the industrial revolution, is the oldest form of heating. However, it was only in World War II that it was widely adopted. The military recognized this heating method and used it for drying materials. This heating process quickly replaced more expensive fuel-consuming equipment like convection ovens. [1]

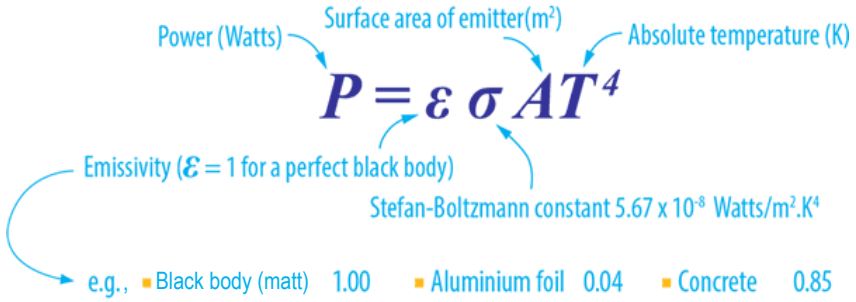
An infrared heater, generally seen near the ceiling of warehouses and restaurant patios, is a heat transfer process that uses panels or tubes. These panels or tubes get heated using a fuel source and then emit short-wave infrared radiation that travels until a solid object is encountered. Even though the infrared heaters can be mounted high above the floor level, the IR energy they emit only converts to long wave heat energy once it strikes the floor or objects near ground level. [2] Heat is then partially absorbed and re-radiated to the surroundings. The result is warm floors, warm feet, and better-directed energy use. By contrast, forced air heating results in warm air stratification. Using the warehouse example, warm air must stratify from high up at the ceiling level down to the floor level where the workers are. The result is cold floors, cold feet, and high ceiling temperatures, which results in wasted heat energy at the upper levels of the warehouse. [3]

Applying infrared heating to heat floor-level workers and objects effectively and efficiently in large spaces requires careful review of radiant efficiency, equipment design, and selection. Radiant efficiency measures how much thermal energy is converted into radiant heat. [4] In the proper applications, IR heaters with higher efficiency translate into better comfort, more efficient heating, and a lower cost of heating than traditional forced air systems.

Infrared Heating Heat Transfer

To understand the concept of radiant efficiency, it is necessary to look into the science behind radiant energy. The primary heating mode is radiation heat transfer, rather than convection, which is used by other heating sources. IR heating can be illustrated by the Stefan–Boltzmann law, which describes the power radiated from a black body in terms of its temperature. Specifically, the Stefan–Boltzmann law states that the radiant power of an object in thermal equilibrium is proportional to the fourth power of temperature and directly proportional to its surface area, as shown in Equation 1.

Equation 1: Stefan–Boltzmann law describes the total radiant heat power emitted from a surface is proportional to the fourth power of its absolute temperature.



The law implies that the radiant output can change with different heating materials and surface areas and can increase exponentially with relatively small temperature changes. Therefore, each heater model must be tested as the overall heater size, heat output, and configuration, which will affect radiant output. However, IR energy does not depend on air for transmission and is converted to heat upon absorption by the material being heated. Because air and gases absorb very little IR energy, the IR heating process enables efficient heat transfer, making its application more energy efficient than other heating methods if the heating need is a small part of an otherwise unheated facility.

Assessment Objectives

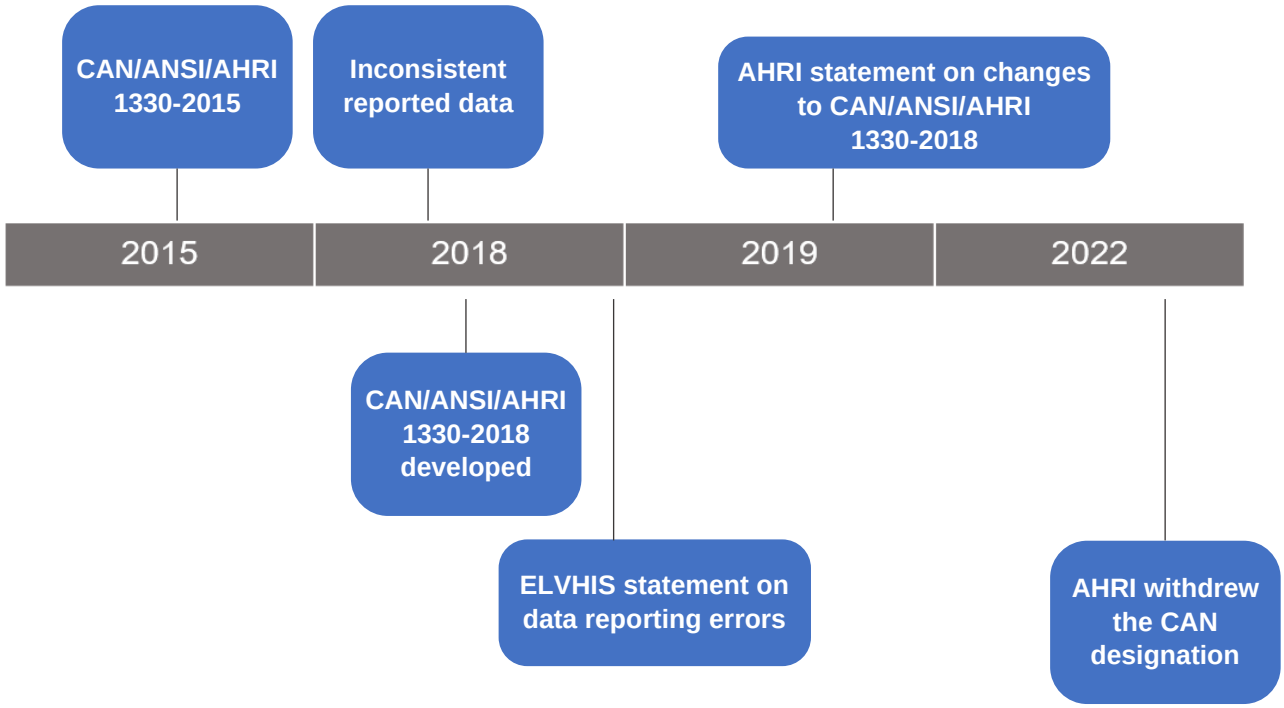
The objective of this research was to evaluate the gas infrared heating technology and its market status in California. This was achieved by:

1. Explaining radiant efficiency, testing, rating methods, and standards.
2. Looking into different types of IR heaters and their applications
3. Gathering market information and end-user data through subject matter expert interviews and field visits and understanding the barriers and opportunities in the market.
4. Providing recommendations on the potential adoption of EE programs.

1.0 Radiant Efficiency Standards

Industry leaders in North America and Europe have developed standards and regulations to help guide manufacturers with the proper radiant efficiency test methods. An accurate metric for measuring radiant efficiency has been developing and evolving over the years. This task has proven quite challenging as the concepts and formulas are steeped in principles and laws of physics and calculus. [5] Efforts to obtain reliable measurement metrics and provide accurate and meaningful data to consumers have been an industry priority.

Figure 1: Pictorial timeline of Standard 1330's evolution



1.1 CAN/ANSI/AHRI 1330-2015

The AHRI Standard 1330-2015 has been endorsed by AHRI, ANSI, and the CAN since January 2015. This standard applies to gas-fired high-intensity and low-intensity infrared heaters with input up to 117.5 kW (400,000 Btu/h) per burner for indoor or outdoor installation. For North America, the recognized standard is CAN/ANSI/AHRI 1330, commonly referred to simply as "1330." Concerned about the reliability of AHRI 1330-2015, the president of the ELVHIS, in July 2018, drafted a letter to AHRI. Within the letter, he stated that they found discrepancies in the IR factor and the data was not reproducible. [6]

Following these controversies, in August 2022, AHRI withdrew the CAN designation from this edition. There is no direct explanation from the CAN to explain this, however an OEM speculated that the remarks from ELVHIS and the inaccurate publishing of test results probably played a part in their decision.

The standard was updated in 2018, and publication is still pending as of May 2023. [5] The purpose of the standard is to establish definitions, test requirements, and rating requirements to be used for the guidance of the infrared heating industry, manufacturers, engineers, contractors, and end users. It is important to note that conformance to this standard is voluntary, and conformance cannot be claimed or implied for systems that do not fall within the standard's purpose or scope. Even within the scope of the standard, no minimum rating is required as the standard establishes a rating system and not an efficiency requirement. Contrasting this, and due to the ever-evolving nature of standards and the current industry push toward greater fuel efficiency, it is increasingly more likely that a minimum radiant rating will be set in the future.

1.2 Fundamental Concepts of the Evolution of Radiant Efficiency Standards

The two versions of the standard introduce a couple of concepts that were developed to evaluate the IR products.

Gross Radiant Coefficient: Heat emitted by the infrared heating appliance through the appliance's radiation plane divided by the gross heat input of the test gas. This can be interpreted as the usable heat radiated by the system divided by the input to determine a ratio.

Infrared Factor: A published rating under AHRI 1330-2015 version based on the Gross Radiant Coefficient. The Infrared Factor, or "IF," categorizes the radiant coefficient into ratio increments of 0.05 in a range of IF-7 through IF-15. A ratio of 0.35 and below corresponds to the minimum rating, an IF-7. Currently, the Infrared Factor chart has a maximum of IF-15, equivalent to a gross radiant coefficient of 0.7 or above. This factor allows for the quick side-by-side comparison of multiple appliances and provides a neutral footing for all gas-fired radiant units. Due to errors in the original test methods and equipment, data produced during testing was not always accurate or reliable. One slight discrepancy could change the reported IF by several categories. Without a meaningful reporting metric, the testing and related claims become worthless.

In 2018, the standard's proposed reporting requirements were updated for specific data to be reported alongside the REV. At this time, this standard had not been adopted.

Table 1. Summarizes the differences between the two versions of the standard. As the test methods and equipment were refined, 1330-2015 was revised in 2018 to remove the IF and replaced it with REV. While REV is also based on the GRC, it is more precise than the IF, with a broader reporting range, as shown in Table 1. [5]

Table 1: Infrared factor and radiant emission value

	Infrared Factor (IF) - 1330-2015		Radiant Emission Value (REV) - 1330-2018 (Proposed)	
Typical Range	7-15		80-120	
Reporting Requirements	Infrared Factor Model Number Heat Input, kW Length of Exchanger Tube Min. Mounting Angle if not tested in a horizontal position (deg.)		Radiant Emission Value Model Number Heat Input, kW Length of Exchanger Tube Min. Mounting Angle if not tested in a horizontal position (deg.)	
	IF	**GRC Range**	**REV**	**GRC Range**
	7	≤ 35%	80.3	30%
	8	36-40%	84.9	35%
	9	41-45%	89.3	40%
	10	46-50%	93.3	45%
	11	51-55%	97.1	50%
	12	56-60%	100.6	55%
	13	61-65%	103.9	60%
	14	66-70%	106.9	65%
	15	> 70%	109.8	70%

The Radiant efficiency rating system was developed as a tool to compare one infrared heater to another. At its core, it is a marketing tool that provides another way for consumers to choose a product that best suits their needs. However, radiant efficiency is only one piece of the puzzle and is not an all-encompassing design tool. To have a genuinely efficient heating system, selecting the appropriate heaters must be done by considering the myriad of design factors beyond radiant efficiency and correctly applying those factors.

2.0 Types of IR Heaters

There are five primary different types of natural gas IR heaters; Low-Intensity heaters, High-Intensity heaters, Construction heaters, and wall/celling mounted and mushroom type Patio heaters. The initial focus of this study was going to be on low and high intensity IR heaters. However, interaction with customers and OEMs coupled with field visits showed that their

utilization in California is limited. The focus was then shifted to wall/ceiling mounted patio IR heaters as they were mainly observed at restaurants during the field visits.

2.1 Low-Intensity Heaters

Low-intensity heaters as seen in figure 3 below, are also known as tube heaters, positive/negative pressure heaters, radiant heaters, stick heaters, tube brooders, or pipe heaters. Hot exhaust gases travel through the tube inside, resulting in tube surface temperatures commonly in the 800-1100°F temperature range. They can be vented and commonly can use fresh air for combustion. The low-intensity gas infrared heater is the most popular choice for heating in the industrial, commercial, and agricultural sectors.

An advanced feature of low-intensity infrared tube heaters is the utilization of two-stage controls. A two-stage infrared heater is characterized by its ability to operate in pre-set "high" and "low" fire modes (100% input in high fire and 65% input in low fire). Field reports and studies performed by RDM Engineering of Ontario, Canada, have proven a minimum fuel savings of 12% and a reduction of on/off cycles up to 30% with most of the heater operation in low fire. [7] A two-stage heater with thermostats allows application specific design flexibility based upon possible worse-case environmental changes. In addition to fuel savings, reduced on/off cycles, and design flexibility, additional benefits of two-stage heaters include faster heat recovery, higher downstream tube temperatures, longer flame, and longer equipment life.

Figure 2: Low-intensity IR heater. They are generally found at warehouses and auto shops. [8]

2.2 High-Intensity Heaters

High-intensity heaters are also known as box heaters, unvented heaters, spot heaters, luminous heaters, or plaque heaters. Combustion occurs on a ceramic tile surface with surface temperatures of approximately 1800°F, with 30,000 Btu/h to 160,000 Btu/h. Higher temperatures result in higher combustible clearance. Direct-fired operation releases products of combustion into a properly ventilated heated space. They are often used in a high bay or high air change applications for complete, spot, and partial heating of commercial, industrial, sports facilities, and hospitality applications. High-intensity heaters work with high temperatures at the ceramic surface and emit heat rays to the specified area(s). They require high mounting heights due to an open flame that covers a ceramic surface. High-intensity heaters also have a reflector to help direct the heat where it needs to go. These are used to spot-heat areas with few workers and are typically unvented; therefore, the space will need proper ventilation to dissipate combustion gases released.

Figure 3: Image of a high intensity IR heater. They are commonly used in areas with high air infiltration like hockey rinks and furniture plants. [9]

2.3 Construction Heaters

Construction Heaters are also known as salamanders, spot heaters, portable construction heaters, and tank-top heaters. Combustion turns a ceramic or stainless-steel emitter red hot. They are used in spot heat applications and as warm-up stations. While commonly used in outdoor applications, units may also be used in industrial applications or temporarily inside buildings under construction or repair. These construction heaters should not be used in residential applications. These heaters were not covered by this study.

Figure 4: Portable construction IR heater. [10]

2.4 Patio Heaters

There are multiple types of Patios Heaters. Patio Heaters can be suspended/wall/ceiling mounted radiant, mushroom-style, Ceramic or stainless-steel radiant emitters. They are designed to heat a concentrated outdoor area. There are permanent or portable products that may be deck mounted or suspended. The fucus in this study was on the suspended/wall/celling mounted radiant heaters, and not the other types of patio heaters. These heaters seen in figure 6 are generally found suspended on the exterior walls of the buildings and were quickly adopted by restaurants when outdoor dining became prominent during COVID. Some other types of patio heaters commonly seen at restaurants can be seen in appendix 2.

Figure 5: Suspended patio heater

2.5 Chicken Brooders IR Heaters

Chicken brooders are a chick's first home. They are ideally supposed to be as warm and secure as their mother. Brooder IR heater (figure 7) is a type of heater known to simulate the warmth of their mother. For adequate coverage of the brooders, and safety of the

chicks, manufacturers recommended a mounting height is a minimum of 6 ft. This type of IR heater is not part of this study; however, we investigated heating at poultry facilities.

Figure 6: Brooders IR heaters. [11]

3.0 Subject Matter Expert Interviews & Field Visits

Interviews of subject matter experts were conducted to gain key insights from subject matter experts (SMEs) in the Infrared heaters industry. Field visits were also conducted to validate what was discussed with the subject matter experts and ultimately get input from customers about infrared heating at their facilities in California. These interactions aimed to investigate Infrared (IR) heaters' opportunities in commercial and industrial sectors with different end-uses in California and identify barriers to deploying IR heaters.

3.1 Audience

For the study to be successful, we had to target appropriate audiences. We looked at three different sources of customers to collect data.

- A list of 14 OEMs and 11 distributors across the United States and Canada was drafted. These OEMs were chosen because they played a significant role in developing the standards for radiant efficiency (see section 3.3.2).

- Furthermore, to have a good understanding of user experience and some barriers to adoption, likely customers in California with IR heaters were contacted.
- Finally, different utilities across the United States that implement IR heater incentives were contacted to understand the volume and deemed measure requirements.

A total of three original equipment manufacturers from various organizations were interviewed, and input from eighty-five customers was gathered.

The interviewed customers were from the restaurants, auto-shops, warehouses, and chicken brooder industries. Data from multiple energy efficiency programs offering these measures was also obtained.

Table 2 summarizes the response rates. As shown, there was a 21% response rate from the OEMs, 0% response rate from the distributors, and a 92% response rate for the customers. In the early stages of the project, the customers were primarily contacted through phone calls. However, due to lack of responsiveness, we decided to visit their locations to request their participation. None of the distributors agreed to participate as they claimed the questions asked would warrant them releasing customers' information, with a lot of them hanging up on us. The detailed responses can be found in appendix 4.

Table 2: OEMs, customers, and utility response rate

Audience	Total Contacted	Total Responded/Accepted to participate	Response Rate
OEMs	14	3	21%
Distributors	11	0	0%
Auto-shops	30	30	100%
Restaurants	31	31	100%
Warehouses	18	11	61%
Poultries	13	13	100%
Utility Contacts	3	2	67%

3.2 Survey Questionnaire/Interviews

Three questionnaires were developed for the SMEs: one for the OEMs, the other for the customers/end users, and the last one for the utility program.

The questions developed for the OEMs were divided into three sections:

- The first section covered general information about the OEM's market presence in the United States and California.
- The second section was focused on product and technology information.

- The third section covered the IR heating Market and adoption barriers.

The questions developed for the customers/end users focused on:

- Market adoption
- Market barriers
- Hours of use

The questions developed for the utilities focused on:

- The Requirement for application
- Volume of IR heater projects received.

Survey and interview questions for all groups can be found in Appendices 3 & 4.

3.3 OEMs Responses

3.3.1 OEM Market Presence

The OEMs interviewed sold various gas-fired products across the United States, infrared heaters being one of them. Given the nature of the products the OEMs, their presence is primarily mostly seen in the colder regions of the United States such as the east coast and mid-west states. With the sales data kept confidential, the OEMs pointed out the infrared heaters they manufacture are ideal for use at warehouses, restaurants, auto shops and poultry brooders. The customer survey ultimately focused on these segments.

3.3.2 OEM Product Technology Details

This section provides an understanding of the OEMs conformance to standard AHRI-1330. As seen in section 3.1, the manufacturers produce different products that are used in different sectors; thus, they have a diversified pool of products. Some of those products are low-intensity IR heaters, high-intensity IR heaters, patio heaters and poultry brooders that were noted in section 2.0.

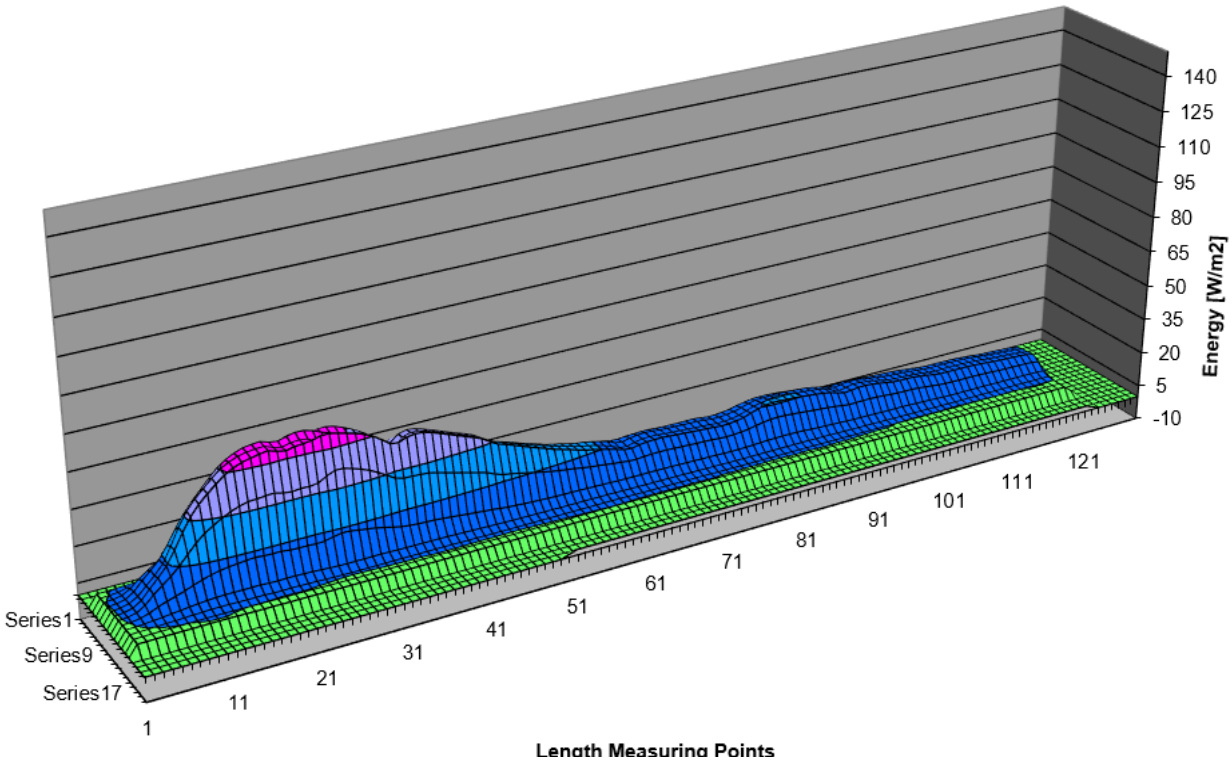
Product Standards

Initial investigation yielded information that standards had been developed for this class of heating products. The OEMs mentioned their collaboration with the AHRI and the European Leading Association of Radiant Gas Heaters Manufacturers to develop AHRI 1330-2015, the current radiant efficiency standard. Although this standard was developed to streamline and guide manufacturers to utilize proper methods of radiant heater testing, compliance is currently voluntary. All OEMs had common concerns with the standard as test results

presented some laboratory and data errors. Respondent 1 stated that the standard AHRI 1330-2015 is not clear, and it causes a lot of confusion about the testing requirements. They said that "we consider the application and required heat pattern when testing and certifying." As seen in Figure 1, many manufacturers have testing labs in-house, while others test their products in Europe. Figure 2 is a sample result of a tested product ideal for car wash bays and animal confinements. "Heaters used in animal confinement and car wash bays are good examples of units that you would not want a high radiant factor; you would want more even heat" - Respondent 1

Figure 7: Infrared Gas Heater Testing Laboratory

Figure 8: Sample testing results



Other certification standards mentioned by the OEMs are:

- F2644-07(2019): the Standard Test Method for the Performance of Commercial Patio Heaters,
- ANSI Z223.1 (NFPA 54): the National Fuel Gas Code, which provides minimum safety requirements for designing and installing fuel gas piping systems in homes and other buildings.
- ANSI 83.20/CSA 2.34, the standard on the performance and installation of gas burning appliances.

3.3.3 OEM Market Adoption and Barriers to Adoption

The OEM surveys responses indicated there were three primary barriers to further adoption of gas IR heaters in California. These include:

- The lack of knowledge about infrared heating technology
- The push for electrification
- Initial costs

As mentioned by respondent 1, the lack of knowledge about IR heating technology plays a big role in its lack of adoption. Respondent 3 on the other hand state that, the initial cost of implementing these technologies is a major barrier especially for California, because of the push for electrification in the United States, some customers do not see the need to invest in the gas IR heater technology. To help bring more awareness to their IR heaters and other similar products, associations like AHRI and ASHRAE partner to sponsor yearly trade shows to help manufacturers showcase and educate the masses on their products. Another way to drive the market to adoption, manufacturers share information on their websites of different utility incentive programs that help the customers with implementation costs. The programs also have a list of distributors to help end users implement the products.

3.4 Customers

Based upon the conversation with the OEMs, customer surveys were targeted to four primary customer types as indicated below:

Looking at the end users, eighty-five customers were surveyed:

- 13% were warehouses
- 35% auto shops
- 36% restaurants (some chains)
- 15% from chicken brooders

These sectors were chosen based on the feedback obtained from the OEMs, and the locations surveyed were selected randomly, but weighed to northern California, where expected usage of gas IR heaters would likely be higher. Each of the sections below outlined the types of data that were collected. The sections below outline the findings of each surveyed group.

3.4.1 Warehouses

From conversation with the OEMs, and from case studies reviews, warehouses seemed to dominate the utilization of infrared heaters (See appendix 1 for case studies). However, in California, all 11 warehouse managers that were contacted claimed to have refrained from using any heating system at their facilities. When asked how they kept warm, they said the weather in northern California (where most of the warehouses were inspected or contacted) did not warrant any heating [Respondent W8]. We were told If it did get cold, hats, beanies, and jackets were used [Respondents W1, W2, W6]. This showed a lack of demonstrated need for the sector is a market barrier to adoption.

3.4.2 Auto Shops

Limited use of IR (or any) heating was also observed with the auto shops in Northern California; only two locations had gas IR heating; one had theirs in operation, and at the other location, it was not used. Respondent A9, the shop owner with the heater not being used mentioned that the previous owner had it installed before they acquired the space more than five years ago, and they have not had to use it. On the other hand, at the shop with the heater being used, respondent A6, the store manager has had good experiences with them; he stated that the heaters are primarily used when temperatures outside get below 60°F, regardless of the season.

3.4.3 Chicken Brooders

Respondent 3 mentioned that poultry production in the agriculture sector generally makes use of IR heating. After reaching out to multiple facilities, most used different versions of heating. Although a few looked at IR heaters when deciding what type to purchase, the product and implementation costs were high and caused them to pursue other heating methods such as using heat blowers, while others used a type of heating known as little giant red lamps. Respondent P1 claimed that the little giant lamps are more convenient for their application than the IR heaters, because they are less expensive, and can be moved around in the barn more easily. Respondent P7, who uses radiant heating at their barn mentioned they were phasing them out, as they were redesigning the barn and would not need the heaters anymore.

3.4.4 Restaurants

The study site and in person surveys showed that the restaurant industry dominated the utilization of IR heaters in the sampling we did in both Northern and Southern California. Much of the work in Northern California was done in person, while chains in both Northern and southern California were contacted via phone.

As COVID shook the world in the medical industry, it did the same in the hospitality industry. Many restaurant owners had to restructure the layout of their restaurants; outside dining became the norm (respondent 2). With this came the need for exterior heating. One hundred percent of the restaurants surveyed had some patio heating, with about 70% having gas infrared heaters. These restaurants varied from small fast-food spots with IR heating in the drive-through lane to larger chains with multiple heating units mounted on their exteriors in northern and southern California locations. The different store managers mentioned they were easy to operate and manage.

As part of the surveys/audits, we obtained data for operating hours. The noted run time for the heaters varied per location, and it was difficult to quantify how long they were on and what season they were operated. Many heaters are integrated into the building's energy

management system, while others are entirely controlled manually. When asked how often they turned on the heaters, one restaurant manager said they were turned on upon customer request, while others said they would have them on as soon as temperatures fell to the mid-50s °F. [Appendix 4]

Although many restaurants were highly interested in energy efficiency options, the managers claimed that implementation and operational costs play a significant role when deciding on technologies (Table 3). After speaking with a manager [Respondent R14] from a chain restaurant in Southern California and asking if all the locations had IR heating, he mentioned that three restaurants had infrared gas heating, while two others installed some during the COVID pandemic, as outdoor dining became more prominent. He noted that each location made its own decisions and that the cost of these heaters makes it hard for some of their chains to install them. His counterpart in Northern California mentioned that only one of the restaurants uses infrared gas heating. He went on to say that if it had not been for COVID, they would not have installed any.

Table 3: Restaurant's interests in energy efficiency options

Interest in energy efficiency options	Response
Highly Interested	39%
Interested	35%
Neutral	26%
Not interested	0%

When selecting what type of heater was better for their restaurants, some managers chose those that looked pretty, while others said they chose the cheapest options. Respondent R2 in Northern California mentioned that they have three restaurants; one of the restaurants used gas infrared heaters, and the other two used electric infrared heaters. He praised the heating output of the gas infrared heater and claimed that they are upgrading the heating for the other stores to infrared gas heating. He asked if we ran any incentive program for this to help with the implementation costs.

3.4.4.1 Restaurants Operating Hours Analysis

To assess the viability of IR heating for the restaurants, we utilized both restaurant manager responses and TMY3 weather data to project estimated annualized operating hours. Estimating how long the patio heaters were on required deeper analysis as the customers did not track the running time. Some customers mentioned that the heaters were turned on upon request, while others turned them on if the weather reached a certain temperature. For this analysis, we assumed that infrared heaters were to be turned on when temperatures were between 50°F and 60°F (Some managers turn on the IR heaters as soon as temperatures fall in the mid-50s °F (Respondent R12)); If temperatures got below 50°F,

we considered it too cold for outside dining, and the heater will not need to be on for temperatures above 60°F

According to the limited customers survey responses, the restaurants operated heaters for an average of 11 hours per day (This also includes locations where IR heaters were not found). Table 4 represents the hours of use of the targeted restaurants. To be consistent with our analysis, we assumed 11 hours per day for hours of restaurant operation (11 AM to 10 PM). Using the Typical Meteorological Year (TMY3) data, we obtained the common climatic information for the 16 climate zones of California. TMY is a dataset that provides hourly weather data for a specific location based on 30 years of historical weather observation. Table 5 presents the results of the analysis.

Table 4: Targeted restaurant's hours of use. The locations are renamed for privacy.

Industry	Location	Hr/Week	Hr/Day
Restaurant	R1	91	13
	R2	84	12
	R3	78	11
	R4	71	10
	R5	103	15
	R6	98	14
	R7	50	7
	R8	31.5	5
	R9	98	14
	R10	85	12
	R11	40	6
	R12	93	13
	R13	83.5	12
	R14	93	13
	R15	70	10
	R16	86	12
	R17	84	12
	R18	95	14
	R19	71	10
	R20	50	7
	R21	55	8
	R22	81	12
	R23	65	9
	R24	44	6
	R25	75	11
	R26	84	12
	R27	66	9
	R28	70	10
	R29	86	12
	R30	72	10
	R31	68	10
		Average hours open per day	11

Table 5: Estimated IR heaters hours of operation by CA climate zones

California Climate Zones	Referece City	Hours IR heaters assumed to be turned "ON" per year	Hours IR heaters assumed to be turned "ON" per day
1	Eureka	2285	6
2	Napa	1264	4
3	Oakland San Francisco	1798	5
4	San Jose	1376	4
5	Santa Maria	1374	4
6	Los Angeles (LAX)	1032	3
7	San Diego	1056	3
8	Long Beach	1099	3
9	Los Angeles (Civic Center)	1056	3
10	Riverside	927	3
11	Red Bluff	1034	3
12	Stockton	941	3
13	Fresno	751	2
14	Barstow	785	2
15	Brawley	543	2
16	Bishop	761	2

We can see from the data that the regions in climate zone 1 would largely benefit from patio heating given the large number of hours observed between when outside temperatures are between 50°F and 60°F. The data also indicates that regions in climate zones 13 through 16 may not need much heating given the low number of hours observed.

The cost-effectiveness of patio IR heaters was a metric we planned on calculating. However, based upon the standards evaluation, there is no clearly defined baseline standard for the technology; thus, we did not calculate the cost-effectiveness beyond the estimated hours of use.

3.5 Utility Program Offerings in the United States

Commercially installed infrared tube heaters are one way that buildings can utilize a more energy-efficient heating option. Several rebate programs across the US provide customers and building owners the ability to offset the initial purchase price of the IR heating equipment in their utility territories. [12] During our review of these programs, and the supporting data, we learned of several barriers for potential utility offerings.

These include:

- Limited/unclear standards (as previously noted)
- Unclear efficiency options with mixed baselines which would not likely be accepted in California for retrofit measures

- Negative Incremental Measure Costs (IMCs) (for New construction relative to installing unit heaters as a base case)

In a 2015 study conducted by Navigant Consulting Inc. for utilities in New England, New York, Maryland, Delaware, and the District of Columbia, for new construction measures, negative incremental costs were observed for high intensity IR heaters across input MBtuh ranges with conventional gas fired unit heaters baselines. [13] However, low intensity IR heaters had higher incremental costs than conventional gas fired unit heaters. See Table 6 for a summary.

The Navigant study points out that on average, the high intensity IR heater, seen as an efficient alternative to conventional gas fired unit heaters, costs less to implement, and advised rebate programs against providing incentives. Note that their baseline for the study was a gas fired unit heater, which would not necessarily be a baseline for a retrofit application. If the more likely baseline (a less efficient IR heater) were selected, then there is currently no clear way to different among them.

Table 6: Infrared heaters incremental cost (labor costs and material costs) [13]

Size Category	Incremental Cost Factor ($/unit)	
	High Intensity	Low Intensity
Up to 50,000 BTUh	-294.34	$469.97
> 50,000 BTUh up to 150,000 BTUh	-277.94	$421.74
> 150,000 BTUh up to 175,000 BTUh	-263.89	$380.40
Greater than 175,000 BTUh	-254.52	$352.84

Table 7 provides a list of programs that offer a rebate for installing Infrared heaters along with the rebate amount and the requirements to qualify. These programs are for utilities in the mid-west and east coast states. As seen in the table, installing low intensity heaters is the minimum requirement to receive an incentive. Although not specified in requirements, the general sense is that these heaters are for interior use. Furthermore, we spoke to two program managers to understand the volume of projects their programs received for IR heaters in the last 5 years. One said that they received fifty-three rebate applications [Respondent 4] for low intensity IR heaters between 2018 and 2023, while the other said they received sixteen [respondent 5]. The applications were for heaters at auto shops, warehouses, manufacturing plants, and school bus garages. Data for utilities that offer rebates for IR heaters on the west coast could not be found, and no utility offered incentives for patio heating.

Table 7: Rebate programs for IR heaters offered by utility companies in the Midwest and East Coast states.

Utility Company	Rebate	Incentive Requirements	Ref
New Jersey's Clean Energy Program	$500 per unit up to 100 MBtuh and $300 per unit over 100 MBtuh	Low intensity infrared heaters	[14]
Minnesota Energy Resources	$250 per unit	Low intensity infrared heaters	[15]
Mass Save	$750 per unit	Low intensity infrared heaters	[16]
Energize Connecticut	$850 per unit	Must have Low Intensity to qualify. Pre-approval and a post-inspection from the participating utility are required if the rebate total exceeds $7,500. Rebates are available to commercial and industrial natural gas customers.	[17]
CenterPoint Energy	$250 per unit for	Low intensity infrared heaters	[18]
PGW EnergySense	Depends on applications	Low-Intensity Infrared Heater	[19]
DTE Energy Efficiency Program for Business	$1.30 per MBtuh	Low intensity infrared heater designed for indoor use	[20]
Consumers Energy Business Energy Efficiency Programs	$9.00 per MBtuh (For customers with both gas and electric accounts)	Low intensity and High intensity infrared heater	[21]
Consumers Energy Business Energy Efficiency Programs	$5.00 per MBtuh (For customers with just gas accounts)	Low intensity and High intensity infrared heater	[21]

The technical resource manual (TRM) of different states was investigated to understand the baseline assumption used and their methods for calculating IR heaters energy savings. Although their methods for calculating the savings varied based on the geographical locations, their baseline assumptions were similar; they all used the conventional warm air unit heaters as baseline [22] [23] [24]. With many IR heaters in California found in restaurants patios, these assumptions would not apply.

4.0 Data Collection Challenges

Throughout this project phase, the major challenge encountered was the OEM's, distributor's, and customer's (end users) unresponsiveness and unwillingness to share data. This may be partially attributed to the small California IR heater market, proprietary sales data concerns, and concerns about the survey being a scam. In the end, most of the successful customer surveys ended up being done in person or with targeted contacts (chains), rather than through the use of anonymous surveys.

Phone calls to the end users were the primary method of customer acquisition in the early stages of the study; however, due to lack of responsiveness, we had to find a new strategy. There was significantly more success when we went to customer sites to ask for their participation in this study. Also, this state-wide project naturally makes it difficult to equitably gather data from customers in all sixteen climate zones in California, so likely users were targeted in Northern California.

5.0 Findings

Conversations with OEMs demonstrated that Infrared heaters are very popular at warehouses, auto shops, chicken brooders, and restaurants; however, as found in this study, we have found several barriers to implementing these as a measure with a mixed baseline in California. These concerns include:

- Small California market for IR heaters
- Limited uptake of this offer, even states with higher heating loads as feedback from project managers showed that even in colder states, the volume of rebate applications for IR heaters in the last five years was low, which also points against adopting the measure.
- Unclear standards for setting a baseline.
- Negative IMC (note the different technology baseline)

Based upon this study, due to the factors above, adopting the IR measures with mixed baselines we studied is not warranted.

6.0 Conclusions

The goal of this study was to research and analyze the market of IR heating technologies to provide actionable recommendations of technologies and gaps for further study for incorporation into gas EE programs. Although we identified at least five different types of IR heating technologies, we ended up focusing on one that had some potential in the

California Market. That one was the suspended and wall mounted IR heaters used in restaurants.

To conduct this study, multiple market actors were contacted, including OEMs, distributors, utility program managers, and end use customers. Despite challenges in obtaining data from surveys and doing a broader market study, we were able to identify several barriers that would have to be overcome in offering energy efficiency measures for the types of IR heaters studied.

The study findings paint **a picture of a limited IR heater market** in California that appears mostly focused on IR heating for restaurants. This is the primary barrier that exists, likely due to the mild California climate.

OEMs were interviewed to get their insights on infrared technology. A common concept discussed was the unclarity of standard AHRI 1330. Due to its complexities, **the standard is not enforced, and compliance is voluntary**. This is the second key barrier, as without a viable standard and/or related test methods, it will be hard to quantify product savings for energy efficiency offers.

Utility programs in other states that offer rebates for installing low-intensity and high intensity IR heaters have mixed technologies baselines, and possible negative incremental costs; thus, **no clear efficiency requirement currently exists in those types of offers.**

These are the third and fourth barriers that could more readily be overcome.

The last observed barrier was the **low volume of IR heater rebate application utilities in the colder states received.** So even in places that have a much larger IR heater market, **interest in incentive programs for IR heaters was relatively low.** This could be due to several other factors that were not studied.

Although the initial focus of this research was the High-intensity and low-intensity infrared heaters, the field visits and customer interaction showed that their utilization in California is limited. Of the types of heaters we studied, patio wall mounted/ suspended IR heaters, mainly observed at restaurants, were the type primarily observed. There is some opportunity to further study these and establish clear standards.

There currently is no apparent means to establish the baseline or measure cases to create a clean efficiency offer with mixed baselines, so we would not recommend moving forward with offers for these types of measures at this point.

Appendices

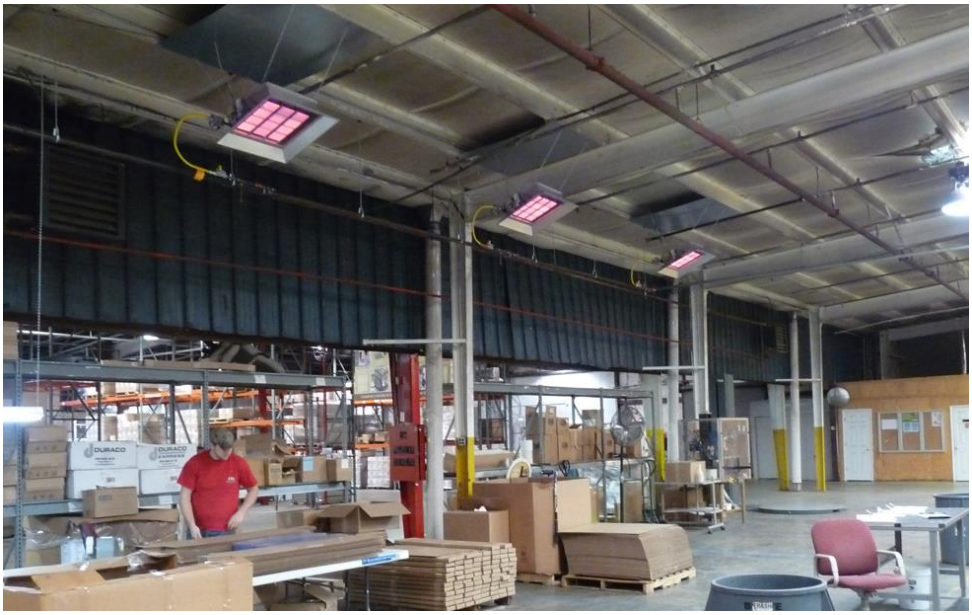
Appendix 1. Applications and Case Studies

1.1 Warehouse in a Furniture Plant

A warehouse is an excellent potential application for retrofit, e.g., replace forced air units with IR heaters if it is required to heat the space above 60°F. Overhang door openings can introduce much outside air into the space. Workers are packing and loading products into truck trailers during regular operations. In the case of the warehouse in a furniture plant, the gas consumption was cut from more than 10,000 therms/yr to less than 4,000/yr therms. The results include changing the temperature setting from the original 70°F to 65°F and adding a night setback. Maintaining a lower air temperature inside is possible since the warehouse partition surfaces possess a higher temperature. It is estimated that preserving the same thermal comfort, it is possible to maintain the air temperature by 5°F compared to a room heated by forced air heating. It is believed that with the application of the classical heating method, the rise of temperature by 1°F equals a 3.3% increase in energy consumption. [25]

Figure 9: Low-intensity IR heaters in a clothing distribution center [26]

Figure 10: High-intensity IR heaters at a furniture plant [26]



1.2 Auto Services Garage

Auto services garages usually have 18 to 20-foot ceilings and many over-hang doors. Traditionally auto services garages are heated by forced air gas unit heaters. The temperature inside is set at 65°F or higher. Due to door openings, it is challenging to maintain garages at a comfortable temperature with forced air heating. The benefit of IR heating is to keep the heat on the floor and on the employees, and the side benefit is to quickly heat the cars that are brought in for service and minimize the effect of the door opening on the temperature of the spaces.

Appendix 2. Commonly Observed Gas Infrared Heaters In Restaurants

Restaurants appear to dominate the infrared gas heating market in California. Below are some commonly observed types and their specifications.

1. A 25,000 BTU/hr. patio heater. The restaurant manager said this type is installed in at least 30 chains. Although this is powered by natural gas, this type was selected because it could also use propane for fuel, and they wanted to keep their options open.

Figure 11: Commonly observed patio heater.

2. The input heating rate for the infrared gas heating below could not be determined; however, the restaurant manager stated that this model produced better heating than the ones they had installed at the other location. Those at different locations use electric infrared heaters.

Figure 12: Unique style of patio heater

3. This photo was taken by one of the manufacturers from a restaurant in Illinois. The input heating of the gas infrared heater is 40,000 BTU/hr. They stated that customers were amazed by how warm they are when temperatures reach in the low 30s °F (which may be less typical in most California locations during eating hours).

Figure 13: IR Heater for a restaurant in Illinois

Appendix 3. Survey & Interview Questions

Questions developed for Original Equipment Manufacturers (OEM) & Distributors

Section A: General info

I may want to allow them to abstain from answering individual questions if they cannot answer for various concerns.

- Do you offer natural gas products (Y/N)? *If No, thank them, and end the interview.*
- Can you talk a bit about your presence in the U.S.? How big is your California market? Could you provide the annual/cumulative counts (or LF) of your IR heaters installed in CA, if possible? Can you refer us to a group that might provide industry-level data if not?
- Can you provide the estimated % of sales for different sectors:
    - Industrial
    - Commercial
    - Agriculture
    - Other: _____
- Can you provide the estimated % of sales for different end-use customers:
    - Warehousing
    - Auto-service
    - Greenhouses
    - Food processing
    - Other: _____
- Who are your distributors and contractors for California customers? *(For Manufacturers only)*
- Who are the OEMs for the product you represent? And contractors? (*For Distributors only)*

Section B: Product and technology details

- For your products, can you provide the following data: *(or reference specs/ website)*
    1. Model numbers
    2. Heat input, kW (BTU/h)
    3. Range of Lengths of heat exchanger tube, including length of U-bends and elbows measured through the centerline (radiant tube infrared heaters only)
    4. What's the standard equipment and installation cost/LF by design type?
    5. **Infrared Factor or REV** Test Results
    6. Minimum test angle (shall be specified if it is not tested in a horizontal position, Deg)
    7. Energy Efficiency options
    8. Control Options

- *If unclear:* Do you sell High-intensity and low-intensity IR heaters? Which one is more popular for any specific applications
- Can you comment on your use of the standards for product testing and certification: AHRI 1330-2015 (IF), AHRI 1330-2018 (REV), or EU standard
- Where do you get your products tested?
- Can you provide more insights into your product's current offerings and new technologies (controls, thermostats, burners, shields, etc.?)
- Can you share insights on the recent or future trends in IR heaters' new technologies and add-ons?

Section C: Market and Technical Barriers to Adoption

- How important are energy-efficient options for the products you sell (1-5, 5 is most important)?
- Can you share your insights on barriers to market adoption in CA (1-5 Scale, five is most important)?
  - Lack of Education for Designers
  - Lack of Education for Building Owners/Operators
  - Difficult Regulatory environment (AQMD and others)
  - Lack of incentives
  - Other:_____
- What barriers are phased into the technology and installation in California (1-5 Scale, five is most important)?
  - Competing technologies
  - Installation complexity
  - Unclear Standards
  - Other:_____
- What following options would help drive the market adoption of your more efficient technologies? (1-5 Scale, five is most important)
  - Lower cost
  - Incentives
  - Marketing
  - Education for end-users
  - Ease of installation
  - Ease of maintenance
  - Testing and Rating Standards
  - Other: _____

Section D: Future outlook and what would facilitate increased sales of efficient products?

- What types of incentives would best support efficient products?
- Where are the most significant sectors and end-users in CA?
- Can you provide more insights into new technologies (controls, thermostats, burners, shields, etc.)?
- Could you share any customer contact info for us to interview?

Questions developed for Customers (End users)

1. What types of activities are done at your facility?
    a. How large?
    b. HOU

2. Do you have heaters at the facility?
    a. If yes, what type of heaters do you have
        i. What is the fuel powering them (Gas or Electric)
    b. If not, why not?
    c. How do you control them? Integrated into the BMS (Building management system)

3. What is your interest level in energy efficiency options? (Scale 1-5):

4. What would be the driver if you were to replace the heater?
    a. First Cost
    b. Operating cost
    c. Efficiency
    d. Heat output
    e. Ease of use

5. Do you make use of Infrared heaters?
    a. If yes, what type do you make use of?
    b. For what purpose do you use heaters?
    c. What challenges are faced with the maintenance of the heater?

Appendix 4. Survey & Questions Responses

Unless directly quoted, the responses were paraphrased. The responses are in blue.

Respondent 1.

Section A: General info

- Do you offer natural gas products (Y/N)?
  - *Yes; Both electric and natural gas products. (Low intensity heaters, High intensity heaters, Patio heaters, Unit heaters, Portable heaters, LED lighting, Process burners)*
- Can you talk a bit about your presence in the U.S.? How big is your California market? Could you provide the annual/cumulative counts (or LF) of your IR heaters installed in CA, if possible?
  - *Headquarters is in Warren, MI. Most sales activities in other areas are done through the distributor pipeline.*
- Can you provide the estimated % of sales for different sectors: N/A
  - Industrial
  - Commercial
  - Agriculture
  - Other: _____
- Can you provide the estimated % of sales for different end-use customers: N/A
  - Warehousing
  - Auto-service
  - Greenhouses
  - Food processing
  - Other: _____
- Who are your distributors and contractors for California customers?
  - *Our distributor's contacts can be found on the website* (Infrared Heaters Distributor Locator - Radiant Heaters (reverberray.com))

Section B: Product and technology details

- For your products, can you provide the following data: *(or reference specs/ website)*
  - *Directed us to look on their website for specs and technical documents.*
- *If unclear:* Do you sell High-intensity and low-intensity IR heaters? Which one is more popular for any specific applications
  - *Yes, we do sell High and low intensity IR heaters.* Both products are pretty popular in warehousing applications.

- Can you comment on your use of the standards for product testing and certification: AHRI 1330-2015 (IF), AHRI 1330-2018 (REV), or EU standard.
    - *"There is a lot of confusion surrounding this. Presently AHRI 1330 is voluntary, so we have it in the back of our minds while testing/certifying new products. We also consider the application and required heat pattern when testing and certifying. Heaters used in animal confinement and car wash bays are good examples of units that you would not want a high radiant factor, you would want more even heat."*
- Where do you get your products tested?
    - *The products are tested in-house. The testing lab is ISO/IEC 17025-Certified. This allows for testing new products in short amounts of time compared to the months a process like this could take at another testing lab*. (See Figure 2 for the test lab)
- Can you share insights on the recent or future trends in IR heaters' new technologies and add-ons?
    - *Due to COVID, Patio heating is a technology that started dominating the market in the last two to three years*.

Section C: Market and Technical Barriers to Adoption

- How important are energy-efficient options for the products you sell (1-5, 5 is most important)?
    - *5: Products are designed to be as energy efficient as possible*.
- Can you share your insights on barriers to market adoption in CA (1-5 Scale, five is most important)?
    - Lack of Education for Designers: *1. We are committed to continuous educational efforts. Annual training seminars are offered to focus on developing the distribution network, safety, and technologies*.
    - Lack of Education for Building Owners/Operators: *5. Ignorance of technology and standards is a barrier*.
    - Difficult Regulatory environment
    - Lack of incentives: *2 Not sure about the CA incentive programs. However, incentive programs could help offset the cost of some of these technologies*.
- What barriers are phased into the technology and installation in California (1-5 Scale, five is most important)?
    - Competing technologies: *5. The push to electrification sees some customers deferring to some other similar electric technologies. This is observed across the USA, not just in CA*.
    - Installation complexity: *2. With the help of a qualified technician, the installation of these products is not complex, given that the proper guidelines are followed*.

  - Unclear Standards: *5. As discussed, unclear standards play a significant role in the barrier to adoption.*
- What following options would help drive the market adoption of your more efficient technologies? (1-5 Scale, five is most important)
  - Lower cost: *4*
  - Incentives: *2*
  - Marketing: *4*
  - Education for end-users: *5*
  - Ease of installation: *2*
  - Ease of maintenance: *3*
  - Testing and Rating Standards: *5*

Respondent 2.

The interview questions were emailed Respondent 2 for their responses, but they however provided a general response regarding IR technology.

"Infrared or radiant heat is one of the most efficient ways to transfer heat from one body to another. Heat is transferred from a radiant surface to an object or person directly without the necessity of heating water such as hydronic heating, or air as in forced air heating. Because we are not heating the air, infrared heaters can effectively spot heat selective areas inside a building or heat people outdoors. Infrared heat is also very effective for many industrial applications transferring its heat directly into the product as required. Applications range from annealing glass, forming plastics to drying paint. Commercially It has long been used in conveyorized Pita bread ovens, cooking of tortillas, and the making of tortilla chips. Infrared burners will also be found in restaurants, melting the cheese on Mexican dishes, providing the sizzle for steak, and increasing performance and efficiency in griddles and fryers.

Ceramic gas burners produce high-intensity infrared. The three major advantages of gas-fired burners are: 1) faster heat up; 2) efficiency from direct transfer of heat; and 3) very low NOX emissions. The ceramic infrared gas burner is one of the key technologies for producing infrared. By producing a flame bed of approximately 1/16 of an inch over a ceramic element, this type of burner efficiently heats the ceramic element to 1600 degrees Fahrenheit to produce an infrared wavelength peaking at 2.4 microns. It is this wavelength that most easily transfers heat energy from one object to another.

Industrial building heating in California can be one of the most beneficial ways to utilize high-intensity infrared. With infrared heaters it is unnecessary to heat the air in the entire building before people start to feel warm. Infrared heaters can easily be positioned where people work without heating storage areas and other non-active areas of the building. For example, an infrared heater can be placed over a shipping desk in a warehouse without the

rest of the building being heated. People can turn on an infrared heater and feel the heat within minutes allowing them to focus on their work instead of the cold.

Outdoor dining and other outdoor activities have become very popular with concerns about COVID. People are rediscovering the enjoyment of outdoor dining where the air is clean, where the lighting is natural, and noise is not echoing off the walls. Because infrared heaters don't heat people with hot air, they can be effective outside. This allows restaurants to extend the use of their patio even into cooler evenings and save the energy necessary to heat, air condition and ventilate their inside spaces.

Electric infrared heaters have also become popular for outdoor heating. Many times, the electric heater design utilizes a coil electrical wire inside a glass quartz tube. Unlike the gas-fired ceramic heaters which radiate all their infrared heat forward, the electrical element radiates its infrared energy in all directions relying on a reflector to direct heat toward the people. To get a significant amount of heat for an electric heater at least 10 kW of power and 240 volts is required. The efficiency is further reduced when you take into account the electrical transmission loss from the power plant, where gas-fired electric generators produce electricity at less efficient rates than the gas-fired heater produces heat. Natural gas combustion produces less CO2 than wood, coal, diesel or even propane. When used in ceramic gas burners, natural gas makes significantly less NOX than other types of burners

Infrared heat is transferred directly to people and objects making it difficult to measure its efficiency. There are three different types of efficiency that our industry has tried to address. These include: 1) combustion efficiency, 2) radiant efficiency and 3) useful heat (heat that heats people). Different test methods have been developed to measure these different types of heat outputs. The table below lists three different types and which standard they can be found:

Infrared Heater Standards		
Item No	**Description**	**Source**
F2644-07(2019)	Standard Test Method for Performance of Commercial Patio Heaters	ASMT
CAN/BSR/AHRI 1330	Performance Rating for Radiant Output of Gas Fired Infrared Heaters	AHRI
ANSI Z83.19	Gas-Fired High-Intensity Infrared Heaters	CSA

Our company is an Original Equipment Manufacturer not a distributor. As a result, we are unable to provide specific information or marketing data for infrared products. You will find our distributors listed on our website."

Respondent 3.

Section A: General info

- Do you offer natural gas products (Y/N)?
  - *Yes*
- Can you talk a bit about your presence in the U.S.? How big is your California market? Could you provide the annual/cumulative counts (or LF) of your IR heaters installed in CA, if possible? Can you refer us to a group that might provide industry-level data if not?
  - *Not a huge presence in CA, however, have influence in the Agricultural (poultry and pigs) and restaurants with patio. Patio heating was very popular during the months of COVID.*
- Can you provide the estimated % of sales for different sectors: *N/A*
  - Industrial
  - Commercial
  - Agriculture
  - Other: _____
- for California customers?
  - *The list of distributors can be accessed through the website.*

Section B: Product and technology details

- *If unclear:* Do you sell High-intensity and low-intensity IR heaters? Which one is more popular for any specific applications
  - *All product technical information can be found on the company's website.*
- Can you comment on your use of the standards for product testing and certification: AHRI 1330-2015 (IF), AHRI 1330-2018 (REV), or EU standard?
  - *Working with AHRI to develop AHRI 1330, the radian efficiency standard. It is going to measure the amount of radiant output of any appliance. Over the years, it has been a challenge to explain why radiant products are more efficient than conventional heating. AHRI 1330 should explain how the radiant technology is efficient. Every one of our products is certified in Europe to the CE standard.*
- Where do you get your products tested?
  - *The products are tested in Europe.*
- Can you provide more insights into your product's current offerings and new technologies (controls, thermostats, burners, shields, etc.?)
  - *Most of the current technologies are controlled using thermostats. The newer technologies have the capabilities of being controlled with a remote*

- Can you share insights on the recent or future trends in IR heaters' new technologies and add-ons?

Section C: Market and Technical Barriers to Adoption

  - How important are energy-efficient options for the products you sell (1-5, 5 is most important)?: *5. Efficiency, Reliability, and Safety are very important. When designing a product, you have to have the three.*

- Can you share your insights on barriers to market adoption in CA (1-5 Scale, five is most important)?
  - Lack of Education for Designers
  - Lack of Education for Building Owners/Operators
  - Difficult Regulatory environment (AQMD and others)
  - Lack of incentives
  - Other: *The push for electrification in the country, especially in CA, is a barrier. People do not see the need to adopt this technology; they are not required. The implementation cost could also be expensive for some end users.*
- What barriers are phased into the technology and installation in California (1-5 Scale, five is most important)?
  - Competing technologies
  - Installation complexity
  - Unclear Standards
  - Other:_____
- What following options would help drive the market adoption of your more efficient technologies? (1-5 Scale, five is most important)
  - Lower cost
  - Incentives
  - Marketing
  - Education for end-users
  - Ease of installation
  - Ease of maintenance
  - Testing and Rating Standards
  - Other: *Providing rebates. The most significant usage for SoCal gas has to be the outdoor product in the restaurant areas.*

Respondent 4.

- Does your program offer an incentive for Gas IR heaters? *Yes*
    - If yes, what applications do you see them being applied for? Over the last 5 years, how many IR Gas heaters applications did the program receive?
        - *Over the last 5 years, we received about 53 applications for gas IR heaters.*
        - *We've seen contractors install infrared heaters at auto shops, warehouses, and manufacturing plants, School bus garages.*
- What are the requirements to qualify for an incentive?
        - *The incentives currently offered are for low Intensity IR heaters that must use non-conditioned, outside air for combustion.*

Respondent 5.

- Does your program offer an incentive for Gas IR heaters? *Yes*
    - If yes, what applications do you see them being applied for? Over the last 5 years, how many IR Gas heaters applications did the program receive?
        - *16 rebate applications have been received in the last 5 years (We have not seen a lot come in recently).*
        - *A lot of them were for warehouses.*
- What are the requirements to qualify for an incentive?
        - *The incentives are for customers installing natural gas IR heaters for space heating applications.*
        - *For retrofit applications, the existing heating system must be forced air based.*
        - *The heaters have to be installed based on the manufacturer's recommendation.*

Raw data responses to customers' questions

1.0 Auto-shop

Location	HOU/Week	Do you have heaters at the facility?	How do you control the heaters?	What is your interest level in energy efficiency options?	What would be the driver if you were to replace the heater?	Do you make use of Infrared heaters? Benefits/challenges
A-1	11	No heating in the auto section. The mechanics use space heaters if necessary.	N/A	Highly interested in EE options	N/A	No
A-2	8	No heating	N/A	Interested in EE options	N/A	No
A-3	8	No heating	N/A	Interested in EE options	N/A	No
A-4	8	No heating	N/A	Highly interested in EE options	N/A	No
A-5	8	No heating	N/A	Interested in EE options	N/A	No
A-6	12	IR heating is in the lobby area, but one is in the work area.	They are controlled with the BAS	Highly interested in EE options	The operational cost and heating output	There is IR heating in the lobby/waiting area. Have great experiences with the IR heater. They are turned on when temperatures go below 60 degrees (Does not matter what the season is)
A-7	8	No heating	N/A	Highly interested in EE options	N/A	No
A-8	8	No heating	N/A	Neutral	N/A	No

Location	HOU/Week	Do you have heaters at the facility?	How do you control the heaters?	What is your interest level in energy efficiency options?	What would be the driver if you were to replace the heater?	Do you make use of Infrared heaters? Benefits/challenges
A-9	8	No heating	N/A	Interested in EE options	N/A	No
A-10	8	No heating	N/A	Neutral	N/A	No
A-11	8	No heating	N/A	Highly interested in EE options	N/A	No
A-12	8	No heating	N/A	Neutral	N/A	No
A-13	8	No heating	N/A	Interested in EE options	N/A	No
A-14	8	No heating	N/A	Neutral	N/A	No
A-15	8	No heating	N/A	Highly interested in EE options	N/A	No
A-16	8	No heating	N/A	Neutral	N/A	No
A-17	8	No heating	N/A	Interested in EE options	N/A	No
A-18	8	No heating	N/A	Neutral	N/A	No
A-19	8	No heating	N/A	Highly interested in EE options	N/A	No
A-20	8	No heating	N/A	Neutral	N/A	No
A-21	8	No heating	N/A	Neutral	N/A	No
A-22	8	No heating	N/A	Highly interested in EE options	N/A	No
A-23	8	No heating	N/A	Interested in EE options	N/A	No

Location	HOU/Week	Do you have heaters at the facility?	How do you control the heaters?	What is your interest level in energy efficiency options?	What would be the driver if you were to replace the heater?	Do you make use of Infrared heaters? Benefits/challenges
A-24	8	No heating	N/A	Interested in EE options	N/A	No
A-25	8	No heating	N/A	Interested in EE options	N/A	No
A-26	8	No heating	N/A	Interested in EE options	N/A	No
A-27	8	No heating	N/A	Interested in EE options	N/A	No
A-28	8	No heating	N/A	Highly interested in EE options	N/A	No
A-29	8	No heating	N/A	Interested in EE options	N/A	No
A-30	8	No heating	N/A	Neutral	N/A	No

2.0 Restaurants

Location	HOU/Week	Do you have heaters at the facility?	How do you control the heaters?	What is your interest level in energy efficiency options?	What would be the driver if you were to replace the heater?	Do you make use of Infrared heaters? Benefits/Challenges
R1	91	No exterior heating	N/A	Highly interested in EE options	N/A	No
R2	84	Yes, we have propane and gas fired IR heaters outside the building.	They are controlled with the BAS	Highly interested in EE options	Heating output and aesthetics would be our biggest driver	We have three locations with IR heaters. The Palo alto location is the only one with gas-powered IR heating. They were purchased because of how nice they look and we are looking to replace the heating of the other locations with these gas ones. Additionally, these ones seem to have a better heating output than the electric ones.
R3	78	Yes, propane based heating	Propane	Highly interested in EE options	End of life/heating output	The propane-based heaters are practical. They are easy to move around the exterior dining tables. Regardless of the weather, we can serve a larger crowd most of the year.
R4	71	Propane based heating	Propane	Highly interested in EE options	Heating output	The IR heating used is powered by propane. There are no issues with them.
R5	103	Yes, electric IR heating	Controlled with the BAS	Highly interested in EE options	operational costs	No; Electric heater

Location	HOU/Week	Do you have heaters at the facility?	How do you control the heaters?	What is your interest level in energy efficiency options?	What would be the driver if you were to replace the heater?	Do you make use of Infrared heaters? Benefits/Challenges
R6	98	Propane based heating	N/A	Interested in EE options	heating output and operational cost	No; Electric heater
R7	50	Propane based heating	N/A	Highly interested in EE options	Operational	No; Electric heater
R8	31.5	Yes, there are six (6) linear IR heaters on the perimeter of the building.	Controlled on manually	Highly interested in EE options	heating output and operational cost	There are six linear IR heaters on the perimeter of the building. They are easy to operate, and we have yet to experience any maintenance issues with them. The heating output is excellent, allowing us to welcome a larger crowd even when conditions outside are slightly chilly.
R9	98	Yes, we have propane and gas fired IR heaters outside the building.	The heaters outside are integrated with the BAS.	Highly interested in EE options	First and operational costs would be the major driver to replace the heater	Yes, we have five linear (About 4 ft each) gas-powered IR heaters on the right side of our building. They are used less because there is limited sitting in that area. The other types of IR heating that we have are propane based. They are distributed by the larger sitting area outside.

Location	HOU/Week	Do you have heaters at the facility?	How do you control the heaters?	What is your interest level in energy efficiency options?	What would be the driver if you were to replace the heater?	Do you make use of Infrared heaters? Benefits/Challenges
R10	85	Yes, there is a mix of propane and electric heaters on the patio	They are controlled manually	Highly interested in EE options	Operational cost	We have electric IR heaters and propane heaters spread around the patio of our restaurant.
R11	40	Yes, gas IR heaters at some of the locations in	Remote controller	Highly interested in EE options	Operational & Maintenance cost	Yes, gas infrared heaters. The heating output is good, although the maintenance cost can be expensive.
R12	93	At least 30 Lazy dog restaurants in the USA have IR heating	They are controlled with the BAS	Interested in EE options	Heating output is the major driver, along with the first cost.	At least 30 of our facilities have gas IR heating. We can seat our customers outside all year long without any issues. The IR heaters are very easy to operate, and we haven't had any major maintenance issues. They are turned on as soon as the temperature fall below 55 F. Interested in participating in incentive programs to assist with energy efficiency projects.
R13	83.5	Yes	Remote controller	Highly interested in EE options	Operational cost	18 locations in California,
R14	93	Yes	Remote controlled	Interested in EE options	heating output	Yes; gas-powered IR heaters on the patio of the building. They work perfectly and have not had major maintenance problems

Location	HOU/Week	Do you have heaters at the facility?	How do you control the heaters?	What is your interest level in energy efficiency options?	What would be the driver if you were to replace the heater?	Do you make use of Infrared heaters? Benefits/Challenges
R15	70	Yes	controlled manually	Interested in EE options	Operational and maintenance costs	13 locations in California| The heating system is top notch. They keep the customers warm and allows us to open most of the year (even during the colder months)
R16	86	There are 9 locations in northern California. Only one of them has gas IR heaters. The other ones either have none or the propane-powered ones	Manually	Interested in EE options	Ease of use and heating output	There are 9 locations in northern California with two gas IR heaters on the side of the building. The heat output has been excellent over the years, but we are looking at replacing them now to more modern ones
R17	84	Yes; Gas IR heaters were installed outside during the pandemic	Manually	Neutral	First and operational costs	The heaters work perfectly but can be expensive to install. They got installed due to covid
R18	95	Yes; There are gas IR heaters	Controlled with the BAS	Neutral	Operational cost & heating out-put	9 ir gas IR heaters on the walls of the restaurant. The heat output is great, and no major challenges with them

Location	HOU/Week	Do you have heaters at the facility?	How do you control the heaters?	What is your interest level in energy efficiency options?	What would be the driver if you were to replace the heater?	Do you make use of Infrared heaters? Benefits/Challenges
R19	71	Yes	Manually	Interested in EE options	The Heating output	18 locations- 3 in NoCal. None with IR heating.| 15 in SoCal (at least 6 locations with Gas IR heating) The user experience it great. Only turned on upon request from the customers.
R20	50	Yes	Remote controlled	Interested in EE options	First cost	There are some heaters on the patio. A mixture of propane-based and gas-mounted heaters. They spot heat well, not major concerns.
R21	55	Yes	Integrated into the building automation system	Neutral	operational costs	No infrared heaters
R22	81	Yes	remote controlled	Highly interested in EE options	first cost	There are infrared heaters on the patio. They work very well and allow for outdoor sitting in the cooler temperatures
R23	65	Yes	remote controlled	Interested in EE options	heating output	There are 3 gas IR heaters on the patio. The heating output as there have not been any complaints from customers.
R24	44	Yes	remote controlled	Neutral	Operational Cost	No infrared heaters
R25	75	Yes, propane heating	Propane	Interested in EE options	The operational cost	propane

Location	HOU/Week	Do you have heaters at the facility?	How do you control the heaters?	What is your interest level in energy efficiency options?	What would be the driver if you were to replace the heater?	Do you make use of Infrared heaters? Benefits/Challenges
R26	84	Yes, propane heating	Propane	Interested in EE options	Heating output	We use propane heaters
R27	66	Yes	Remote controlled	Neutral	End of life/heating output	There are gas-powered IR heaters on the patio. They are turned on upon customer request. Maintenance is not complicated.
R28	70	Yes, Propane	Propane	Neutral	first costs	propane-based heaters
R29	86	Yes, Propane	Propane	Neutral	first costs	N/A
R30	72	Yes, gas IR heaters placed in the patio	They are controlled manually	Interested in EE options	Heating output	Gas powered IR heaters in the patio, very happy with them.
R31	68	No	Propane	Neutral	N/A	No, propane based

3.0 Warehouse

Location	HOU/week	Do you have heaters at the facility?	How do you control the heaters?	What is your interest level in energy efficiency options?	What would be the driver if you were to replace the heater?	Do you make use of Infrared heaters? Benefits/challenges
W1	168	No heating in the warehouse. Hats and jackets are worn if it gets cold. Space heating used in the offices	N/A	Interested in EE options	N/A	No
W2	168	No heating in the warehouse. Hats and jackets are worn if it gets cold. Space heating used in the offices	N/A	Interested in EE options	N/A	No
W3	168	No heating	N/A	Interested in EE options	N/A	No
W4	168	No heating	N/A	Neutral	N/A	No
W5	56	No heating	N/A	Highly interested in EE options	N/A	No
W6	56	No heating; We wear beanie and hats	N/A	Neutral	N/A	No
W7	56	No heating	N/A	Neutral	N/A	No
W8	56	No heating: It does not get cold enough in California for heating	N/A	Neutral	N/A	No
W9	56	No heating	N/A	Highly interested in EE options	N/A	No
W10	56	No heating	N/A	Neutral	N/A	No
W11	43	No heating	N/A	Neutral	N/A	No

4.0 Poultry

Location	HOU/Week	Do you have heaters at the facility?	How do you control the heaters?	What is your interest level in energy efficiency options	What would be the driver if you were to replace the heater?	Do you make use of Infrared heaters? Benefits/challenges
P1	N/A	Yes	N/A	Interested in EE options	First Cost	No infrared heater. Little giant red lamps are more convenient for their application. Less expensive and can easily be moved
P2	N/A	Yes	N/A	Neutral	Operating cost, heating output	No infrared heater. Little red lamps are used.
P3	N/A	No	N/A	Neutral	N/A	No heating
P4	N/A	Yes	N/A	Highly interested in EE options	Operating cost	Little giant red lamp
P5	N/A	Yes	N/A	Interested in EE options	Heating output	Little giant red lamp
P6	N/A	No	N/A	Neutral	N/A	No heating
P7	N/A	Yes, but redesigning barn to limit heating usage	N/A	Interested in EE options	First Cost	Radiant heaters, but they are getting faced out. Redesigning the barn so they wouldn't need much heating anymore.
P8	N/A	Yes	N/A	Interested in EE options	Heating output	Smaller farm. Uses smaller red lamps for the chicks.
P9	N/A	No	N/A	Neutral	N/A	No heating
P10	N/A	No	N/A	Interested in EE options	Heating output	No infrared heating. Heating blowers are used when necessary.
P11	N/A	No	N/A	Neutral	N/A	No heating whatsoever
P12	N/A	Yes	N/A	Neutral	Heating output	Uses little giant red lamps. No gas Infrared heater
P13	N/A	No	N/A	Neutral	N/A	No heating

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