Heat Pump Customer Questions Study

Final Report

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Executive Summary

To identify the barriers that the next wave of potential heat pump adopters face, for this study, researchers collected and analyzed public comments made in online forums by Californians considering heat pumps for space conditioning and/or water heating in their homes.

Posts and comments from online forums, social media, news sites, and video platforms, e.g., Reddit and YouTube, were gathered using Python-based and automated social media scraping. Data was compiled from posts made by users in California and around the United States.

A combination of computational and qualitative analysis techniques were used to identify the concerns and barriers discussed by potential heat pump customers on online platforms. Word embedding methods turned text into numerical data that represents the meanings of words in a complex, multi-dimensional space. Then, clustering methods were used to group similar posts from online users based on their meaning. Clusters were then used as a baseline for qualitatively identifying and typologizing concerns and barriers of potential heat pump customers.

The analysis focused on online discussion comments posted by "potential buyers" in California, defined as those who express active interest in purchasing heat pumps in their online comments. Identified barriers to heat pump adoption fell into the following categories: costs, information deficits, home infrastructure, performance, and gatekeepers.

Cost-related barriers refer to both initial and operating costs, as well as challenges related to rebates and financial incentives. Online discussions revealed three primary concerns related to upfront costs: prohibitively high total costs that lead to abandoning purchasing plans, skepticism about contractor pricing practices, and frustration with the limited options for reducing installation costs. Potential buyers also expressed confusion over rebate eligibility and described difficulties with navigating the complex incentives landscape.

Concerns about operating costs were particularly acute for Pacific Gas and Electric (PG&E) customers, suggesting that utility rates pose a greater barrier to heat pump adoption in some service territories than others. Many potential buyers indicated that using solar photovoltaics (PV) to power heat pumps is an effective — and sometimes the only — method to contain operating costs. Some viewed solar as essential to offset operating costs.

Various types of **information deficits** pose challenges to heat pump adoption in California. For example, potential buyers expressed confusion about basic heat pump knowledge, struggling to differentiate between various heat pump systems. They also reported encountering conflicting or incomplete advice from contractors and online forums. Additionally, the lack of accessible and trustworthy sources of information has made it difficult for potential buyers to learn about heat pumps independently, leaving them uncertain about which systems best suit their needs and how to navigate the technical and financial aspects of installation.

Challenges related to **home infrastructure** — particularly the adequacy of electrical panels, insulation, and ductwork — were frequently raised by potential buyers in California. They expressed concerns about the cost, time, and inconvenience associated with upgrades that may be needed to

ensure their home infrastructure is suitable for heat pump installation.

Public comments indicated that concerns about heat pump **performance** are prevalent. Many comments from potential buyers reflected doubts about the thermal comfort and efficiency heat pumps can deliver. Noise was a concern for some as well.

Contractors and landlords acting as **gatekeepers** presents another barrier to heat pump adoption that potential buyers face. Some online comments reported that contractors are reluctant to recommend heat pumps, even in cases where rebates and incentives are available. Renters face challenges due to restrictions on property modifications and landlord reluctance to invest in heat pumps.

To gain additional insights, researchers made comparisons among comments posted by potential buyers across Northern, Central, and Southern California; between Californians interested and not interested in installing a heat pump; and between Californians and residents of other states.

A gap analysis was conducted to explore the extent to which the information California utilities' energy efficiency programs provide on their web-based resources aligns with the questions and concerns that California consumers have about heat pumps. Opportunities and recommendations for addressing customers' questions and concerns are identified in this report, including gaps in available resources, priority topics for education materials, and principles of best practice for customer education. The research outlines practical options for existing heat pump programs, such as those run by California's investor-owned utilities (IOUs) and municipal utilities, to educate customers, allay their concerns, and build confidence in purchasing heat pumps.

Abbreviations and Acronyms

Acronym	Meaning
AC	Air conditioning
ADU	Accessory dwelling unit
ASHP	Air-source heat pump
BTU	British thermal unit
COP	Coefficient of performance
FAQ	Frequently asked questions
HDBSCAN	Hierarchical Density-Based Spatial Clustering of Applications with Noise
HPWH	Heat pump water heater
HSPF	Heating seasonal performance factor
HVAC	Heating, ventilation, and air conditioning
IOU	Investor-owned utility
IRA	Inflation Reduction Act
kWh	Kilowatt-hour
LADWP	Los Angeles Department of Water and Power
LLM	Large language model
NEEA	Northwest Energy Efficiency Alliance
PG&E	Pacific Gas and Electric
PV	Photovoltaic
RQ	Research question
SCE	Southern California Edison
SDG&E	San Diego Gas & Electric
SEER	Seasonal energy efficiency ratio
SMUD	Sacramento Municipal Utility District

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Introduction

Air-source heat pumps (ASHPs) for replacing gas-powered water and space heating are a keystone technology in efforts to decarbonize buildings (Gaur et al., 2021) and are identified as a priority in CalNEXT's Technology Priority Map for heating, ventilation, and air conditioning (HVAC).[1] Heat pumps have the potential to save approximately 60 percent of total residential heating energy consumption and reduce greenhouse gas emissions by 13.1 million metric tons of carbon dioxide equivalent ($MMTCO_2e$) if installed in homes throughout California.[2] To date, only five percent of homes in California use heat pumps for space conditioning (Olano, 2022) and only two percent for water heating.[3] Utility programs in the state offer rebates to address the high initial costs of heat pumps, but market adoption must expand beyond the early adopters to achieve the Governor's goal of installing six million heat pumps by 2030. Promoting adoption will require addressing customers' questions and concerns about heat pumps.

The Opinion Dynamics' (2022) heat pump market characterization study lists upfront cost, noise, indoor unit aesthetics, climate performance, cost-benefit, complexity, zonal heating, and utility bill costs as significant issues for customers. This report has been a primary source of information on California customers' concerns about heat pumps. However, because the study relies on third-party, e.g. contractor, reports of customers' perspectives and data collected from early adopters, this data may not adequately incorporate the views of later adopters. Later adopters are likely to have less knowledge and motivation to install heat pumps than early adopters, and there is currently limited understanding of this group compared to early adopters.

In contrast, the current study collects data directly from the next wave of potential heat pump adopters. Using recently available web scraping and artificial intelligence (AI)-assisted data cleaning techniques, this study is able to convey potential adopters' pressing concerns about heat pumps by homing in on the specific topics discussed in online forums.

The goal of this project is to collect and analyze public comments from Californians considering heat pumps for space conditioning and/or water heating in their homes to identify the barriers that the next wave of potential adopters face. The study addresses three critical research questions (RQs):

1. What are the most common questions, comments, and concerns about heat pumps among California's residential electricity customers?
2. What insights do their comments and questions provide about the experiences of prospective heat pump adopters?
3. What insights do these comments reveal about potential adopters' impressions of heat pump performance, quality of service, and non-energy impacts?

[1] https://calnext.com/resources/hvac/
[2] Applying a 50% emission reduction (Brockway & Delforge, 2018) to the estimated 1.8 MTCO2e per California household (CARB GHG Emissions Inventory, 2021).
[3] https://cal-cca.org/heat-pumps/

This research also identifies information gaps in existing heat pump programs, such as those run by California's IOUs and municipal utilities. Utility programs must address these gaps to educate customers, allay their concerns, and build their confidence in purchasing heat pumps.

Background

Early adopters of residential space conditioning and water heating heat pumps in California were driven by several motivations. They were interested in saving money on energy bills through greater energy efficiency, reducing their carbon footprint, and striving for greater energy independence from natural gas, often in combination with onsite electricity generation. Early California adopters also sought enhanced comfort and convenience, e.g., with ASHPs, through precise temperature control, enhanced energy management, and heating and cooling system integration (Antonopoulos et al., 2024; Opinion Dynamics, 2022). Early adopters of heat pump water heaters (HPWHs) were motivated by the opportunity for enhanced comfort through the volume, temperature, and timing of hot water. Despite these potential benefits, adoption has lagged in California (Davis, 2024). If the state is to meet its target of six million heat pumps by 2030, the number of heat pumps sold each year in California needs to more than triple — from 151,000 to 472,000 (Ayers, 2022).

The most commonly cited and thoroughly documented barrier to heat pump adoption is their high upfront costs compared to alternatives (Ahmad, 2023; Andrew et al., 2024; Antonopoulos et al., 2024; Balcombe et al., 2014; Bastian & Cohn, 2022; Becker et al., 2023; Decuypere et al., 2022; Edwards et al., 2023; Galley, 2024; Gaur et al., 2021; Heiskanen & Matschoss, 2017; Malhotra et al., 2023; Michelsen & Madlener, 2016; Opinion Dynamics, 2022; Peñaloza et al., 2022; Poblete-Cazenave & Rao, 2023; Smart Energy Consumer Collaborative [SECC], 2023). According to the U.S. Department of Energy (DOE) (2023), the national average cost for equipment and installation is $6,900–8,600 for ASHPs and $2,230–2,450 for HPWHs. For ASHPs, upfront costs may also include electrical panel upgrades, improvement to home insulation for the system to function efficiently, and gas line disconnections, all of which can add significantly to the total cost and complicate the installation process in terms of time and customer cognitive load (Bastian & Cohn; Brown et al., 2023; Wall et al., 2024). Thus, consumer investment in residential heat pumps for space conditioning and water heating generally is most attractive to prospective adopters who are building a new home or replacing old equipment (Bastian & Cohn), particularly if they plan to live in the home long enough to recover initial costs through energy bill savings (Ahmad, 2023; Balcombe et al., 2014; Heiskanen & Matschoss, 2017; Chitchyan, 2022).

California has the highest total cost to install an ASHP in the United States, with a median of over $21,000.[4] Comparatively, the median total cost in California to install a natural gas furnace is around $4,000 (Opinion Dynamics, 2022), and it costs between $5,100–6,200 to install a 14 seasonal energy efficiency ratio (SEER) central air conditioning unit (Remodeling California, n.d.), indicating a total cost of $9,000–10,000 to upgrade both heating and cooling with a furnace and air conditioning system. This suggests that installing a residential heat pump may cost up to twice as

[4] https://www.energysage.com/heat-pumps/costs-and-benefits-air-source-heat-pumps/

much as installing a gas furnace and central air conditioning system. Federal, state, and local incentives can help bridge the gap, and have already stimulated some adoption. In a survey of heat pump adopters who received the TECH Clean California program rebate (Kisch et al., 2022), 93 percent indicated that the incentive was at least somewhat important in their decision to install an ASHP or HPWH. There is some evidence that a pay-as-you-save model, where the utility pays the upfront costs of installation and recovers it through bill charges, may also be effective at boosting heat pump adoption (Brown et al., 2023).

Energy prices present another economic barrier to heat pump adoption in California (Davis, 2024). Heat pumps can reduce operating costs when replacing less efficient electric heat source equipment or when switching to electric from another, more expensive, fuel source. However, in California, electricity prices are high and natural gas prices are low. Concerns about increased utility bills is therefore a major deterrent of heat pump adoption, according to several studies (Ahmad, 2023; Opinion Dynamics, 2022; Becker et al., 2023). Energy price volatility and uncertainty further undermine adoption (Decuypere et al., 2022).

Non-economic barriers to heat pump adoption have also been identified in the literature, including knowledge gaps. Many consumers in California and elsewhere remain unaware of heat pumps (Balcombe et al., 2014; Decuypere et al., 2022; Edwards et al., 2023; Galley, 2024; Heiskanen & Matschoss, 2017; IEA, 2022; Kisch et al., 2022; Meles & Ryan, 2022; Michelsen & Madlener, 2016; Peñaloza et al., 2022; Poblete-Cazenave & Rao, 2023). A 2020 statewide poll in California found that nearly two-thirds of respondents were unaware or unfamiliar with heat pumps for either space conditioning or water heating (Metz & Everitt, 2020). Similarly, a 2023 study by Pacific Consulting Group found that a minority of California consumers surveyed were familiar with either ASHPs or HPWHs (34 percent and 39 percent, respectively). Familiarity with heat pumps was lower among renters than homeowners (Pacific Consulting Group, 2023).

Beyond basic awareness, consumers lack knowledge of central aspects of heat pump technologies such as the potential for energy savings, installation requirements, and long-term costs (Becker et al., 2023; Chitchyan, 2022; SECC, 2023; Zanetti, 2021). There are deficiencies in information accessibility (Taylor et al., 2023) and quality of public information available about heat pumps. Consumers can encounter overly technical, (Wall et al., 2024), conflicting and outdated (Balcombe et al., 2014), and unclear information (Becker et al., 2023; Chitchyan, 2022) regarding upfront costs, necessary home modifications, and long-term maintenance of heat pumps. Researchers have called for clearer and more accessible information and processes surrounding government subsidies, tax credits, and other financial support programs meant to encourage heat pump adoption (Zanetti, 2021; Antonopoulos et al., 2024), which could be especially helpful for low-income households (Balcombe et al., 2014; SECC, 2023).

Other barriers related to customer knowledge gaps about heat pumps include misconceptions about equipment characteristics and performance. For example, some California customers are concerned about ASHP performance in extreme climates, particularly cold weather conditions (Opinion Dynamics, 2022) despite extensive field evaluations and reputable studies demonstrating that modern ASHPs are both effective and efficient in these environments (Higa et al., 2024; Wilson et al., 2024). As natural gas remains the dominant energy source for space and water heating in

California, accessible and accurate information is crucial for instilling confidence in potential adopters of the performance of heat pump technologies as well as informing them of heat pump maintenance routines and operating practices (Balcombe et al., 2014; Becker et al., 2023). Lack of familiarity and the perception of ASHPs as new or uncommon can cause consumers to hesitate to invest in heat pumps because of concerns about the technology rapidly evolving and thus potentially becoming outdated, or it being difficult to find experienced contractors (Chitchyan, 2022; Wall et al., 2024). The shortage of trained ASHP and HPWH installers is in fact a documented problem in some regions (Chitchyan, 2022; Ahmad, 2023; Bastian & Cohn, 2022; Malhotra et al., 2023; IEA, 2022), leading to longer wait times and higher costs for consumers (Decuypere et al., 2022). Space constraints can also be an issue for ASHP installation, which involves indoor and outdoor equipment (Balcombe et al., 2014; Becker et al., 2023). Several studies indicate that consumers are also concerned about ASHPs and HPWHs being noisier than more conventional equipment (Chitchyan, 2022; Opinion Dynamics, 2022; Wall et al., 2024), though it is rarely the case.

The literature reviewed above sheds light on the types of questions and concerns California residential consumers may have about ASHPs and HPWHs. However, there are several limitations of the current understanding of these consumer concerns. First, studies have often grouped together multiple heat pump technologies and assessed their market barriers in aggregate (Ahmad, 2023), while also incorporating heat pumps into broader categories of "low-carbon heating" (Becker et al., 2023), "decarbonization" (Antonopoulos et al., 2024), or "microgeneration" (Balcombe et al., 2014) technologies. Consumer adoption motivations and barriers specific to ASHPs or HPWHs are unlikely to be fully and most accurately captured with these methods. Furthermore, many studies discuss factors contributing to heat pump adoption inferred from market data or based on input from contractors and program administrators (Bastian & Cohn, 2022; Decuypere et al., 2022; Opinion Dynamics, 2022), whereas fewer studies have gathered data directly from residential customers to understand their adoption motivations and hesitations. Most of the studies that directly represent the customer voice have been conducted outside California, e.g., in the United Kingdom, broadly (Chitchyan, 2022) and Scotland (Wall et al., 2024). While there are surely generalities in consumer experiences and perceptions of heat pumps, adoption rates are strongly correlated with geography, climate, and energy prices (Brown et al., 2023; Davis, 2024), making it crucial to understand the unique perspectives of California residential customers in order most effectively promote ASHP and HPWH adoption. This project fills an important research gap by gathering information directly from prospective adopters in California about their questions and concerns with heat pump technologies.

One place such questions and concerns can be found is online platforms that facilitate peer-to-peer information sharing. The most frequently used platform — Reddit — garnered roughly 550 million new posts in 2024, with 2.72 billion comments and interactions on those posts. Research suggests these platforms are valuable consumer resources for several reasons. First, online discussion platforms reduce the cognitive barriers associated with gathering information through several different mechanisms (Savolainen, 2015). As an interactive media, online discussion platforms allow consumers to post their questions and receive personalized responses from the community of platform users. Alternatively, users can search for questions similar to their own and learn from the ensuing discussion among their peers. Delivery of targeted information avoids "information overload" and the cognitive strain that more comprehensive sources may provoke (Savolainen,

2015). In addition, as trusted sources, online discussion platforms reduce the cognitive strain of verifying information collected on their sites.

Online discussion platforms are also persuasive sources of information because they leverage "social proof" (Subathra et. al, 2023). By providing information on user experience — through comments that approximate customer testimonials — online discussion forums allow potential adopters to rely on others' judgments, bypassing the need to process complex technical information. Discussions in online platforms can also signal shifting social norms, making heat pump adoption seem more common and accepted. Research shows that social norms are powerful drivers of technology adoption (Subathra et. al, 2023).

In addition to being an approachable and persuasive source of information for users, online discussion platforms offer researchers a rich source of data that can be analyzed to understand users' questions and concerns about heat pumps. This research study leverages that opportunity to provide insights on customer barriers to heat pump adoption.

Objectives

The objective of this research is to describe the nature of the questions and concerns prospective heat pump adopters have shared in public online forums to more clearly identify the informational barriers to heat pump adoption that currently inhibit uptake by California residents. This research aims to articulate how the next wave of likely heat pump customers perceive the barriers they face and to identify opportunities for utility programs to develop effective materials to address prospective adopters' questions and concerns.

Methodology and Approach

This section describes how the data for the study was collected and analyzed.

Data Collection

For the reasons described above, the research team systematically collected and analyzed discussions from online platforms where individuals share their questions, concerns, and experiences about residential heat pumps. Using Python-based web scraping tools, we gathered posts and comments from multiple online forums, including Reddit, DoItYourself.com, HeatingHelp.com, Houzz.com, HomeOwnersHub, and YouTube. The data collection process employed a combination of Google "site:" searches and platform-specific search features to identify content containing "heat pump" or "mini-split" and their linguistic variations. For each relevant page, we captured multiple data points, including all posts on that page as well as the date, author information, title, URL, and associated tags for each post.

To enable comparative analysis among California regions and between California-specific and national perspectives, we implemented a two-pronged approach to geographic classification. First,

we directly scraped 13 California-specific subreddits[5] defined by their geographic scope, including r/California, r/BayArea, r/LosAngeles, and r/Fresno, to capture geographic diversity within the state. Second, when analyzing content from national platforms, we identified California-based posts through explicit location indicators such as user flair or tag, location mentions, or contextual details within the post. These California-identified posts were integrated into our California-specific dataset to facilitate comparisons with the national sample.

For this analysis, we defined two groups of posters: "Interested," i.e., individuals who have expressed an active interest in purchasing heat pumps, and "Not Interested." The original search prompts included more granular user categories, including "Potential Buyer," "Not Interested in Buying," "Has Product," "Seeking Information," and "Other." The breakdown of posts by group is presented in Table 1. The groups were identified through iterative prompt engineering that compared AI to human classification on a subset of posts until they matched. The final prompt that agreed consistently with our classification of potential buyers included the following text: "users who are considering buying a heat pump and are either in the early research phase, actively getting quotes, or planning to install a heat pump or mini split." The "Not Interested" group was defined by this prompt: "The user expresses a concern that indicates they do not want to purchase a heat pump or mini split."

Table 1: Breakdown of Comments by Interest Classification

Classification	Count	Percentage
Not Interested in Buying	471	13.1%
Has Product	1180	32.8%
Other	455	12.6%
Potential Buyer	646	17.9%
Seeking Information	848	23.6%

Based on our qualitative analysis of user engagement patterns and quantitative assessment of discussion themes, we consolidated the initially distinct categories of "Potential Buyer" and "Seeking Information" into a unified "Interested" classification. This consolidation reflects our observation that

[5] Subreddits are distinct forums or communities within the social media platform Reddit. Each subreddit focuses on a specific topic, interest, or theme and has its own unique URL (reddit.com/r/[name]), rules, moderators, and subscriber base. Users can join multiple subreddits based on their interests, creating a personalized feed of content. Popular subreddits cover a range of topics (e.g., news, science, technology, hobbies, entertainment, niche interests). Within these communities, users can post content, comment on others' posts, upvote or downvote content, and engage in discussions specific to that community's focus.

individuals actively seeking information about heat pumps, while at an earlier stage in the adoption cycle than those explicitly planning purchases, demonstrated similar underlying motivations. The initiative required to seek out detailed information about heat pump systems suggests an implicit interest in potential adoption, even in the absence of immediate purchase intent. Categories of "Has Product" and "Other" were excluded from our analysis, as they did not contribute directly to our primary research objective of identifying adoption barriers among potential future adopters.

The research team conducted extensive qualitative analysis, manually reviewing over one-quarter of collected posts to verify the accuracy of the automated classification system and performing independent qualitative coding of the posts. This systematic review process revealed no overt indicators of artificial content generation among the collected posts, which typically manifests through identifiable linguistic patterns such as formulaic phrasing, repetitive content structures, atypical grammatical constructions, or syntactic anomalies characteristic of large language model outputs. Posts containing specific manufacturer references were minimal and, when present, appeared within authentic decision-making contexts rather than displaying patterns consistent with coordinated marketing efforts. Combining automated classification with extensive manual review provides high confidence in the authenticity of the collected data representing genuine consumer perspectives on residential heat pump adoption barriers.

The final dataset comprised 8,414 total posts, 1,966 of which were from users in California with the remaining 6,448 originating from users elsewhere in the United States. As Table 2 shows, roughly three-quarters of the California posts were classified as "Interested" and 471 as "Not Interested." Analysis of posts from national users were limited to those classified as “Interested.” The majority (95 percent) of California data originated from Reddit, while the national posts were primarily (75 percent) collected from DIY sites. This disparity in data sources stems from our targeted search for California-specific discussions about heat pumps which was enabled by the geographically defined subreddits (e.g., r/BayArea, r/LosAngeles). Few users of the other sources (i.e., DIY sites, YouTube) indicated their geographic location so comparatively little data from California residents was gathered from those sites.

Table 2: Breakdown of Online Posts Analyzed by Source

	California		United States
	Interested	Not Interested	Interested
Reddit	1,403	459	792
DIY Sites	83	2	4,841
YouTube	9	12	815

		California	United States
Total	1,495	471	6,448

It is evident in Table 2 that Reddit yielded most data analyzed for this study. This is unsurprising given the platform's high visibility in search engine results for heat pump-related queries, which highlights its role as a primary information source for potential adopters conducting preliminary research on heat pumps. Reddit has a particularly active user base. According to Backlinko,[6] as of the third quarter of 2024, the platform boasted 97.2 million daily active users, with 49.6 percent based in the United States. Average daily minutes spent on the site demonstrate deep engagement: 20 minutes (newly registered users), 35 minutes (users registered for over five years), and 45 minutes (users registered for over seven years). Reddit's users are relatively young; nearly half (44%) posting from the U.S. are 18-29 years old, while those aged 30-49 make up another 31%.[7] This latter group overlaps with the average age of first-time homebuyers in the U.S. (38 years), though in general most homeowners (60%) are over 45 years old.[8] While we cannot precisely determine the average age of homeowners on Reddit, many posters in our data explicitly indicated homeownership suggesting they are likely among older Reddit users and among younger homeowners.

Reddit's structure encourages active engagement by enabling the creation of specialized communities or "subreddits," which can serve as an ideal environment for fostering discussions about heat pumps, sharing user experiences, and providing easily accessible information to potential adopters or others seeking information about the technology. This structure also provides distinct methodological advantages through topic-specific communities, specifically geographic subcommunities that allow regional market analysis, and unmoderated user discussions that capture authentic exchange of information.

We evaluated several alternative data sources (manufacturer platforms, e-commerce sites, review platforms, social media networks, and Quora) but found significant limitations in their ability to capture pre-adoption decision-making processes. These platforms either lacked relevant discussions about purchase considerations or presented technical challenges for systematic data collection.[9]

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[6] https://backlinko.com/reddit-users

[7] Oberlo. (2024). Average age of Reddit user. Retrieved March 18, 2025, from https://www.oberlo.com/statistics/average-age-of-reddit-user

[8] Callis, R. R. (2023, July 25). Younger householders drove rebound in U.S. homeownership. U.S. Census Bureau. Retrieved March 18, 2025, from https://www.census.gov/library/stories/2023/07/younger-householders-drove-rebound-in-homeownership.html

[9] Manufacturer platforms demonstrated content limitations due to curated marketing materials, data quality concerns from filtered customer feedback, and limited representation of adoption barriers. E-commerce platforms proved unsuitable as residential heat pump systems typically require professional installation and are predominantly purchased through HVAC contractors, resulting in limited relevant user-generated content and installation-specific discussions. Review platforms focused primarily on installed systems and contractor-centric feedback rather than pre-purchase decision-making data. Social media networks presented technical constraints, including data access restrictions, private group segmentation,

Analysis

This section describes the analytic techniques used to conduct the research.

Computational and Qualitative Methodology

To identify the concerns and barriers of potential heat pump customers on online platforms, we employed a combination of computational and qualitative analysis techniques. Our approach used word embedding methods to represent the discourse in high-dimensional semantic space, followed by clustering methods to identify highly related posts by online users. We then used these identified clusters as a baseline for qualitatively identifying and typologizing concerns and barriers of potential heat pump customers.

Our first step after data collection — one dataset was national and the other drawn from California-based online groups and forums — was to distinguish between posts to identify which posts were made by users who were potential buyers of heat pump products. To achieve this, we used OpenAI's newest model, GPT-4o, to classify posts and distinguish between users who are already customers or might be seeking general information and those who are actively interested in purchasing heat pump products. We chose GPT-4o for this task due to its advanced ability to understand natural language and its capacity to discern subtle contextual differences in user intent. We validated the classification of the posts through manual review as well as an iterative process of adjusting the prompt given to GPT-4o until the classification matched our own.

After identifying the relevant posts, we embedded them using OpenAI's text-embedding-3-large model. We chose this model for its high performance in capturing semantic relationships and its ability to generate rich, contextual embeddings that adapt to surrounding context and can capture the multiple ways a word may be used. Through these embeddings, we created a representation of the posts in high-dimensional space, where the position and direction of each vector encodes semantic information derived from the contextual relationships between words in the large text corpora used to train the model (Mikolov, 2013). We focused our embeddings on the pieces of text that directly discussed heat-pump technologies so that our analysis captured the most relevant content, though the surrounding language was retained in the dataset for reference to ensure the meaning was correctly interpreted.

We then clustered the embedded text using the Hierarchical Density-Based Spatial Clustering of Applications with Noise (HDBSCAN) algorithm (Campello et al., 2013). HDBSCAN is an unsupervised clustering method that excels at finding clusters of varying densities and shapes without requiring a predefined number of clusters. Unlike other clustering algorithms, HDBSCAN automatically determines the number of clusters based on the data's density structure. This makes it particularly

and limited systematic collection capabilities. These limitations create a high potential for sampling bias. We collected supplementary data from Quora, which yielded approximately 22,000 heat pump-related posts. However, when we applied our classification analysis, zero posts met our potential buyer criteria. We attribute this outcome to the platform's design, which favors general knowledge queries, professional and technical respondent bias, and limited authentic decision-making discourse. Quora's emphasis on broad educational content rather than specific purchase-related discussions made it unsuitable for capturing potential adopters' concerns.

suitable for exploratory data analysis where the number of natural clusters is unknown. HDBSCAN also has the advantage of identifying noise points that don't belong to any cluster, which can be useful for detecting outliers or unique data points in the text corpus.

Using clustering algorithms on embedded text to identify distinct topics is a scientifically valid technique that is used for academic and industry research. For example, clustering embedded customer reviews, as generated by language models, to identify distinct topics is now a common and well-researched practice (An et al., 2023; Nainggolan & Purba, 2020).

Following the computational analysis, we conducted a qualitative analysis of the clustering results. We employed thematic analysis, a method for identifying, analyzing, and reporting patterns, i.e., themes, within data. This thematic analysis allowed us to interpret the computational results in a meaningful way, identifying and typologizing the key concerns and barriers expressed by potential heat pump customers. Our research team developed a framework of 12 distinct categories to classify barriers to heat pump adoption (Figure 1). To enable consistent application of these codes across the full dataset, we developed and refined a large language model (LLM) prompt through multiple iterations, testing the automated classifications against human-coded samples until we achieved consistent agreement. The final coding framework encompasses technical barriers (like equipment performance and infrastructure requirements), financial considerations (including initial costs, operating expenses, and incentive programs), informational challenges (such as knowledge gaps and conflicting advice), and institutional barriers (including contractor and landlord-related issues). Each post was assigned multiple codes when appropriate, allowing us to capture overlapping concerns and complex adoption barriers.

Quantitative Analysis

Simple frequency statistics were calculated to facilitate comparisons between comments posted by potential buyers across Northern, Central, and Southern California; between Californians interested and not interested in installing a heat pump; and between Californians and residents of other states. T-tests were used to determine whether differences between groups were statistically significant. A co-occurrence matrix was generated to quantify the co-occurrence of subthemes. Sentiment analysis was also performed to validate our comparison of subthemes.

Gap Analysis

Content analysis was performed to identify the type and quality of information on heat pumps currently available to consumers via web-based resources that were identified through three targeted search methods. The first method entailed reviewing the webpages of 31 federal, state, and utility programs that offer financial incentives to reduce the cost of installing space conditioning heat pumps and HPWHs (Table 3 in Appendix A) that were identified in the research team's previous work on heat pump programs (Outcault et al., 2024). The second method involved using the search function embedded in the five major California utilities' websites[10] to search using keywords related

[10] The five major utilities in California providing electric service include: Pacific Gas and Electric Company (PG&E), serving over 5.5 million customers, Southern California Edison (SCE), serving nearly 5.1 million customers, San Diego Gas &

to heat pumps, including “heat pumps FAQ,” “heat pump questions,” and “heat pumps.” The third method included using Google to search for “utility acronym plus heat pump FAQs” and “utility acronym plus heat pump questions,” e.g., “PG&E heat pump FAQs” and “PG&E heat pump questions.” Because Google yields so many results, we limited the scope to the first 10, non-sponsored, utility-hosted resources. These search methods aim to mimic the ways potential adopters may attempt to locate information, e.g., looking up prominent programs, searching their utility website, or searching on Google. In this way, the gap analysis identifies what potential adopters may encounter as they seek information about their questions and concerns from their local utility programs promoting heat pumps to their customers.

Information from all web resources was documented by the research team, and common topics, depth and breadth of coverage, and accuracy and accessibility of information were analyzed. We compared findings from different sources against the ideal or desired information, as demonstrated in the analysis of Reddit posts, to identify current gaps. These gaps are discussed at length in the subsequent sections.

Findings

This section presents findings from our analysis of online discussions among California residents considering or inquiring about heat pump adoption. Most comments, questions, and concerns centered around the challenges and considerations of transitioning from traditional HVAC systems, particularly gas furnaces and air conditioners, to heat pump technology for space conditioning, though we did observe references to HPWHs in the discourse. Through our analysis of these online discussions, we identified several recurring barriers to heat pump adoption among California residents. These are compared with the informational resources made available through energy efficiency programs in the state to identify priority areas to address.

Customer Comments, Questions, and Concerns

Our analysis of online discussions among California residents revealed several challenges in the transition to heat pump technology. Across various forums, social media platforms, and comment sections, five primary barriers emerged consistently. Figure 1 illustrates the relative frequency of each broad barrier and related subtopics. Echoing findings of the Opinion Dynamics (2022) report, heat pump costs emerged as the most frequently mentioned concern among the online posts analyzed (51.5 percent of all comments). This is followed by information deficits (21.4 percent), home infrastructure (10.5 percent), equipment performance (10.5 percent), and gatekeepers (6.2 percent).

Electric Company (SDG&E), serving over 800,000 customers, Los Angeles Department of Water and Power (LADWP), serving 1.6 million customers, and Sacramento Municipal Utility District (SMUD), serving 649,557 customers.

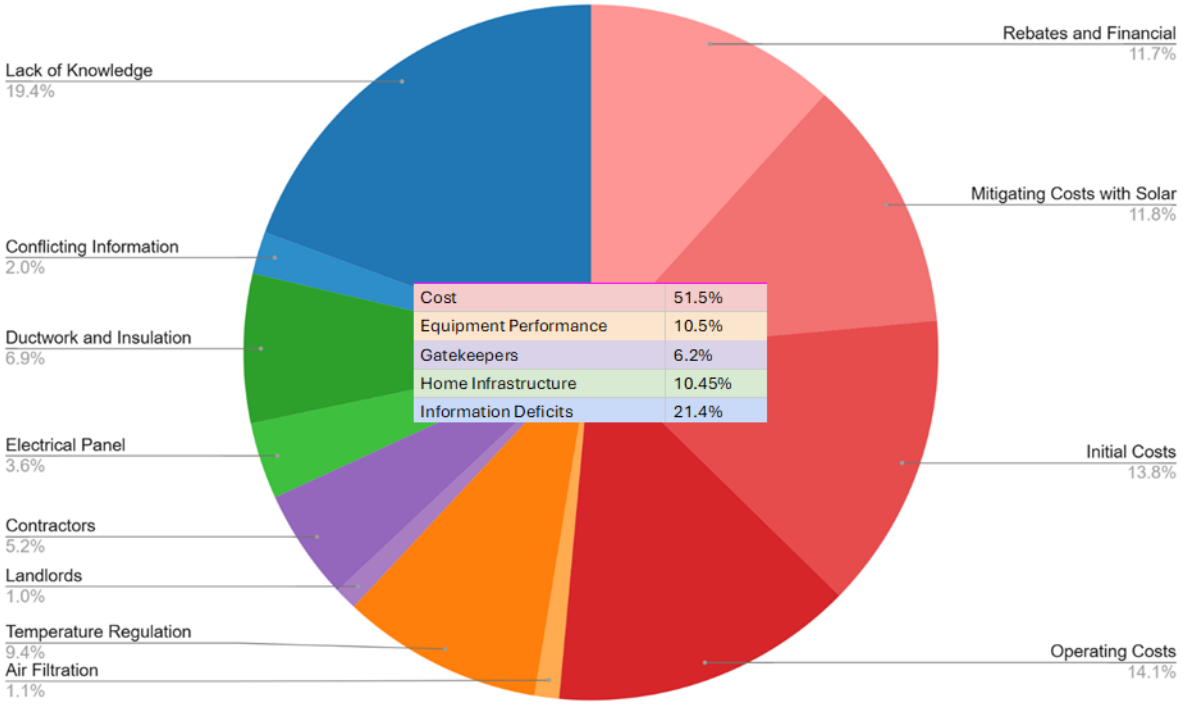

Figure 1: Frequency of topic among "Interested" group's comments.

Figure 2 shows the co-occurrence of different topics, i.e., how often pairs of topics appeared together in the dataset. The strength of the relationships is indicated by numerical values, with higher numbers and darker colors signifying stronger co-occurrences, and lower numbers and lighter colors indicating weaker or less frequent connections. This allows for a clear comparison of which topics are most frequently discussed in conjunction with one another.

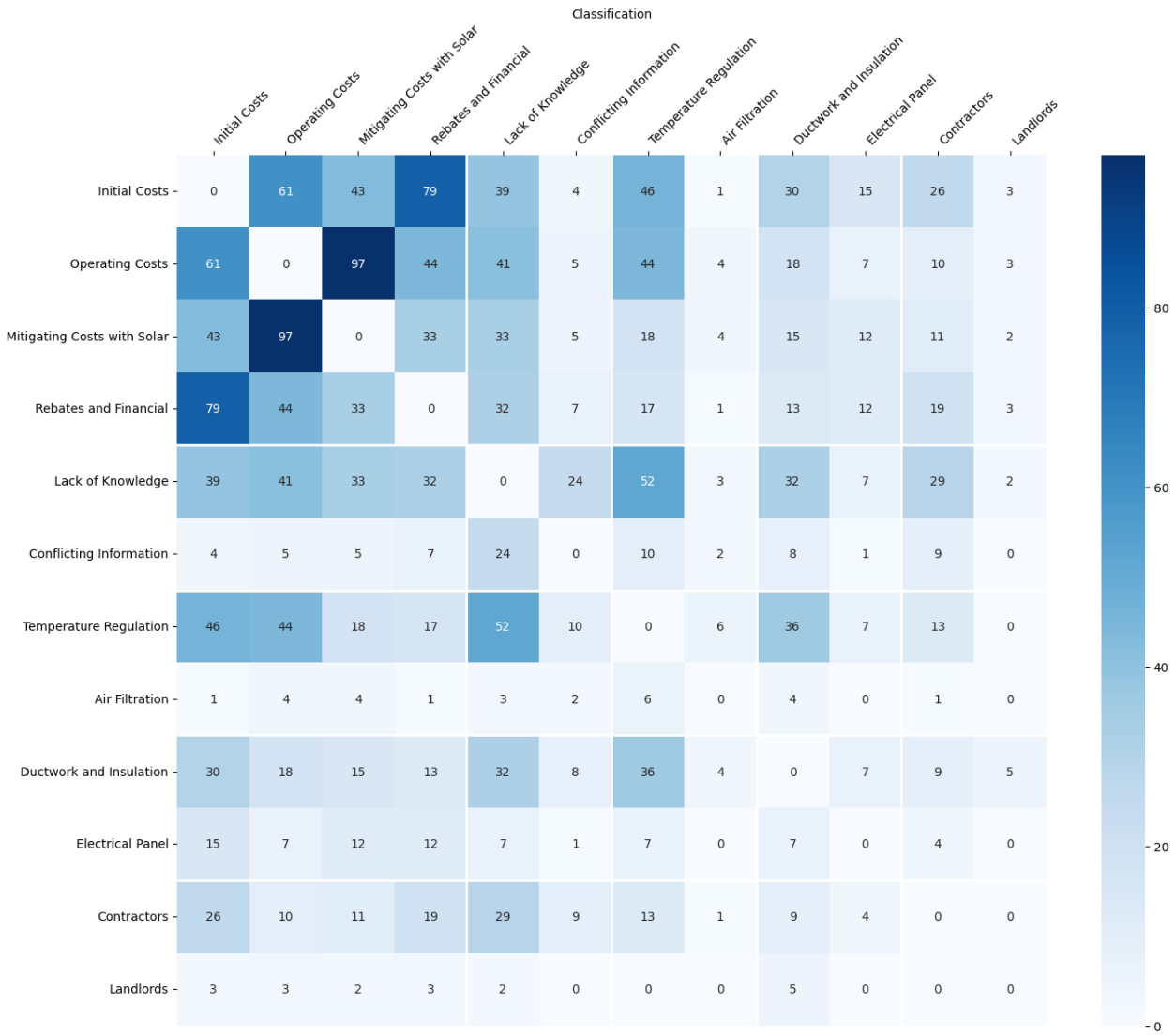

Figure 2: Co-occurrence matrix of classifications grouped by category and sorted by frequency.

The co-occurrence matrix validates our classification methodology and indicates which barriers to adopting heat pumps are interconnected. The strong co-occurrences among financial categories, e.g., *Initial Costs* and *Rebates and Financial* (79) or *Operating Costs* and *Mitigating Costs with Solar* (97), highlight that the methodology successfully clusters interrelated financial barriers. The strong relationship between *Operating Costs* and *Mitigating Costs with Solar* (97) supports our qualitative findings that potential adopters who were interested in reducing the operating costs of heat pumps looked to solar energy as a mitigation strategy.

It is also worth noting that *Lack of Knowledge* co-occurs across diverse categories in the matrix, such as *Temperature Regulation* (52), *Ductwork and Insulation* (32), and financial topics. This crosscutting pattern suggests that knowledge gaps are not confined to a single aspect of heat pump adoption but appear in discussions on technical, financial, and infrastructure topics.

In the following sections, the barriers identified in the analysis are organized into and discussed according to themes and subthemes. In this section, we analyze barriers to heat pump adoption through three dimensions. To address RQ1, we quantify questions and concerns of California residential customers, identifying key barriers in technology adoption. For RQ2, we examine how prospective adopters navigate decision-making around technical requirements, financial incentives, and installation processes. For RQ3, we focus on comfort, energy efficiency, and reliability expectations to evaluate perceptions of heat pump performance.

Costs

California posters expressed many concerns and questions related to the direct costs associated with heat pumps, including initial costs, rebates and incentives, and operating costs. The potential for solar panels to mitigate operating costs of heat pumps was also discussed in online posts.

INITIAL COSTS

Initial costs — and skepticism as to the legitimacy of those costs — emerged as an oft-cited barrier to heat pump adoption among California residents, mentioned in 13.8 percent of posts analyzed. Californians additionally indicated skepticism about contractor pricing practices. Some potential buyers expressed doubt about the fairness and transparency of quoted prices, as exemplified by this quote:

> *I just got a quote for installing a hybrid heat pump water heater for $16k. There was no line item for the labor, just the materials. I did a little research and could see that the materials were marked up 400%. So, deducting that, this leaves about $12k for labor. If the install takes 12 hours (which seems a bit high, but what do I know), that's $1000/hour* (Santa Cruz Reddit User).

Potential buyers explained attempts to reduce initial costs in various ways, such as direct equipment purchase to avoid contractor markups. In these quotes, several Californians describe the strategies they employed to control costs:

> *I started looking into online prices of the much superior mitsubishi central ducted system and found their 3-ton system costs just $6154. Add to it the other costs like pads, line set, permit etc etc and I guess it would still be under $9k minus labor. I am wondering if someone can suggest some installer in the bay area who can install such a system that I buy online myself (Bay Area Reddit User).*

> *Just for an experiment, I purchased a Mr Cool DIY 1 ton 22 seer mini split from costco for 1350$ including taxes, installed it myself... things get more interesting when I check similar mini split units from throwaway brands on Ebay. They're literally $500 a 1-ton unit with 16.5 seer rating... total money spent would be 5500$ if I get it installed by someone else, or less than 3k if I install it all myself (San Jose Reddit User).*

> *Currently I've got a quote for $25k that includes redo[ing] the ductwork, permits, the equipment, and installation. Is $25k a fair market price of this scope of work? Does anyone*

buy the equipment themselves and only hire contractors for the rest of the work? I suppose that will be cheaper (San Jose Reddit User).

Concerns about the initial cost to install a heat pump are often multifaceted. As the following quote from a Southern California resident illustrates, large differentials in contractor quotes, mistrust in cost information, and early retirement of existing equipment, among other issues, make high costs even less palatable:

> *I've had two quotes but their opinions and prices were hugely varying…Both companies suggested replacing the AC and the furnace to a heat pump setup. But my current heater seems to work fine…My questions are: Should I spend the extra money to switch to a heat pump setup when my current furnace works fine and is rarely used (SOCAL winters rarely dip below 40)…Any advice is appreciated. Hard to find trustworthy advice from salespeople (California Houzz User).*

The data suggests that, while some customers attempt to find workarounds to high contractor prices, such as seeking unlicensed installers or waiting for off-peak seasons, these strategies introduce additional time, complexity, and risk to the installation process. The combination of high total costs, skepticism about pricing practices, and limited cost reduction options appears to deter many potential adopters, even those who express interest in the technology's benefits.

REBATES AND FINANCIAL INCENTIVES

Given concerns about the high cost of heat pumps, some comments (11.7 percent) express an eagerness to take advantage of the various rebate programs available for heat pump installations. Financial incentives can prompt potential adopters to think positively about the return on investment that heat pumps offer, as this quote indicates:

> *There are so many incentives for heat pump water heaters at the federal, state, and local level that when paired with their lower operating costs than gas heaters, it's an economic nobrainer to go with a heat pump as long as you have the right space for it (*Bay Area Reddit User).

Given the critical importance of financial incentives in offsetting high initial costs to install a heat pump, some Californians reported waiting for financial incentives before purchasing a heat pump, as in these two sample quotes:

> *Any updates on the availability of tax incentives from the inflation reduction act for replacing my hvac with a heat pump? I'm waiting to pull the trigger and that until the incentives come through (Bay Area Reddit User).*

> *I'm still waiting on the heat pump rebate program from the IRA to take effect. supposed to happen this year? Maybe? (California Reddit User).*

Uncertainty about when financial incentives will become available adds complexity to the heat pump

adoption process, which involves coordinating several steps, as this quote illustrates:

> *Has anybody converted to a heat pump recently? I've been using this guide, but it's not very clear when the discount/rebate is available. Don't want to waste the contractor's time getting quotes if the discount is not even available yet. I make under 80% of the income for my area, so I qualify for the full discount (*Bay Area Reddit User).

Exploring available incentives is a critical step for potential heat pump adopters. Given the availability of federal, state, local, and utility incentives, Californians are gathering information from multiple sources. One Orange County resident, for example, highlighted at least three incentives they were hoping to obtain: the $2,000 federal tax credit, a $1,000 state rebate, and local initiatives such as Irvine's grant program. The sheer number of programs offering financial incentives is overwhelming and “confusing” to some Californians.

Differences in the terminology used by various programs is a specific source of confusion for potential adopters who are trying to determine their eligibility for incentives, as one Bay Area resident described:

> *I'm looking to upgrade my current 2005 SEER 11 unit with a new SEER 14 heat pump. I'm hoping to get some insight into the process if you've done this before and which rebates you've used (if any). Between TECH Clean California, BayRen and PG&E, I'm a little confused on which rebates I'm eligible for* ***as they seem to have different terminology for which heat pumps are eligible*** *(*Bay Area Reddit User).

OPERATING COSTS

Operating costs arising from high electricity rates also emerged as a significant barrier to heat pump adoption in California. Fourteen percent of comments analyzed highlighted concerns that, despite greater energy efficiency, the high cost of electricity (now or in the future) makes operating heat pumps expensive, as expressed in these quotes:

> *I am conflicted between replacing the AC/gas furnace with the same but more current or go toward the all electric option we are being funneled. With PGE unrelenting, and absurd, volumetric rates electricity seems like it is the more expensive option (Bay Area Reddit User).*

> *Even if a heat pump was feasible, we’re worried about what skyrocketing electricity costs would mean for our monthly expenses (California Reddit User).*

Many concerns about the cost to operate heat pumps in California implicitly drew comparisons between the cost of electricity versus gas service, as in the previous quote. Other online posts stated the comparison more explicitly, as in this analysis:

> *I'm doing my best to calculate what a winter heat pump bill would look like as opposed to a standard AC/gas furnace package unit. In doing so, I've found that the therm to kWh conversion rate is 29.3 kWh per therm... Heat pumps are, on average, 4x more efficient, right? Let's assume the temperature outside allows it to remain at 4x so we can get a best case scenario. So if I divide 29.3 by 4, I get 7.325 kWh. Therefore, 1 therm equals 7.325*

kWh at a COP of 4, correct? At my rates I outlined above, that means that the cost difference would be $2.40 for gas (1 therm) and 7.325 kWh at $.52/kw would be $3.80, or 29% higher usage for the heat pump for roughly 4 months out of the year (Central California Reddit User).

The stark difference in utility electricity costs between service territories also influences Californians' attitudes about the affordability of operating heat pumps. A Sacramento resident who moved from SMUD to PG&E territory shared their experience with dramatically higher bills despite using less heating:

With my old home, our heater was a heat pump so it was all electric and I would keep my house at 72 and my bill was nothing, like $100-$150 for electric per month… I have been keeping my home at 67, it's cold and we all need layers and my bill is projected to be $200. 2003 home, 1900 sqft. It blows me away how expensive PG&E is, the price for kWh is literally 3x what SMUD is (Sacramento Area Reddit User).

MITIGATING COSTS WITH SOLAR PV

Given the high cost of electricity across most of California, pairing heat pumps with solar PV is a frequently cited strategy for enhancing heat pumps' financial payback and appears in 11.8 percent of analyzed posts. The following quotes emphasize how impactful solar PV is on heat pumps' return on investment and the influence that has on the decisions potential adopters make:

We are located in South Orange County California […] Heat pumps don't seem like a great idea considering the high electricity costs out here (again, SDGE reportedly has the highest in the nation). If we had solar then maybe, but that's not the case and no plans to go solar in the near future (HeatingHelp User).

I don't have solar yet, but I will eventually, which makes the heat pump pill a bit easier to swallow (California Reddit User).

Aligning the capacity of heat pump and solar PV systems, over the year or a particular season, is a consideration for some Californians. As these quote convey, maximizing the heat pump's use of solar energy is critical to the economics of the purchase:

I DO have solar, but it's not sized for [a] full heat pump system. If it's >15kWh per day extra, this is way too much. If an AC unit, on average, doesn't use more than a few additional kWh per day then maybe it could make sense? Just trying to justify the additional cost to upgrade to a heat pump (California Reddit User).

I need to replace old ac/gas furnace units in my house. I am trying to figure out if heat pumps in San Diego are worth it. […] I have solar which covers most of the electric. Summer bills are $500 per month currently. Winter bills are $20-50 per month. My concern is that with less sunlight in the winter, I won't be able to make enough power to run electric heat pumps (California Reddit User).

Some posts reflect customers' consideration of the holistic cost, and benefit, of adopting a heat

pump. For example, after receiving a high quote from a local contractor, one used asked if the price is reasonable given solar, electricity prices, and air conditioner use:

> *Is this a reasonable price? I also have solar, how do I know if a heat pump makes sense? Especially given CA electricity prices for overconsumption? Given we only use the AC for 4-6 weeks per year* (California Houzz User).

Information Deficits

Information deficits — in the form of lack of knowledge and conflicting information — are recurring themes in the comments posted by California-based online users, and are further explored below.

LACK OF KNOWLEDGE

Of the online comments analyzed, 19.4 percent indicate that customers struggle with a lack of knowledge about heat pumps. Many are confused about basic functionalities and differences between system types. Potential buyers often struggle to understand the technical details, installation requirements, and suitability for their homes, leading to delayed decisions and uncertainty about the best choice for their needs. For example, one Bay Area user expressed confusion between mini-splits and heat pumps, seeking clarity on ductwork requirements and mentioning a preference for mini-splits due to allergies. Similarly, a San Diego resident was uncertain whether a heat pump could meet their needs for both heating and cooling and wondered about potential drawbacks.

> *I thought heat pumps and mini splits were the same thing but I think there are differences and have a question. Mini Splits go in each room and do not require ductwork. It looks like heat pumps require ductwork. I eventually want to get away from ductwork due to allergies and maintenance so it seems like a minisplit is the way to avoid ducts? (Bay Area Reddit User).*

Another online poster found the additional complexity of choosing between different heat pump systems confusing, slowing their decision-making process.

> *I am having a Solar/battery system installed and decided to look into replacing our old gas furnace and air conditioner with a heat pump.* ***I thought it would be as easy as Googling Heat Pump reviews to compare them but found out that there are Split Heat Pumps, Heat Pump Systems and Hybrid/Dual-fuel Systems, so the complexity of figuring out what I need keeps growing*** *(California Reddit User).*

The following quote conveys a similar sense of confusion experienced by a San Francisco user trying to decide which type of heat pump system would keep their family comfortable:

> *I am looking for a heat pump replacement for my heating and cooling needs, but want to make sure no one in my family is ever too cold. What am I looking for? Split Heat Pump, Heat Pump System or Hybrid/Dual-fuel System? […]* ***I read that a furnace should be available, along with a Heat Pump, for times it's too cold for the Heat Pump to be effective*** *(California Reddit User).*

Other comments reflect a lack of information about more nuanced aspects of heat pump operation, e.g., performance, costs, and non-energy impacts, as this quote illustrates:

> *How much did your electric bill increase during the winter compared to an ultrahigh efficiency furnace? efficiency ratings how important were the seer2, eer2, and hspf2 ratings in your decision? Did you find that higher rated systems significantly reduced your utility costs? and did you aim for ratings that qualify for federal credits? variable speed units if you opted for a variable speed unit, did it make a big difference in noise reduction compared to your old ac condenser? (Orange County Reddit User).*

One California user based in the Lake Tahoe Area posted on GreenBuildingAdvisor, asking for an online resource to compare heat pump products, similar to ConsumerReports.com:

> *CR does not have reviews for things like heat pump water heaters, ductless mini splits, etc. Is there a similar type of website that has comparisons like CR does but for home mechanical stuff? [… I] use this same process for as many things as I can (California GreenBuildingAdvisor User).*

CONFLICTING INFORMATION

A small fraction of California-based posts — two percent of those analyzed — reported users receiving contradictory advice from contractors and forums regarding heat pumps' efficiency, noise levels, and overall feasibility. For example, a Sacramento user faced mixed messages about heat pump operating costs:

> *I'm hearing mixed messages on some forum where I posted saying that heat pumps would cost a ton to run in winter (*Sacramento Reddit User).

A Bay Area resident encountered conflicting opinions about heat pump noise levels:

> *One guy said heat pumps are louder, the others the opposite* (Bay Area Reddit User).

Contractors' conflicting recommendations leave consumers unsure about the right choices for their specific situations, especially when dealing with old homes or complex installations. The following quotes provide three such examples:

> *Hey everyone, I'm in the middle of remodeling my home, and the ducted HVAC system is due for an upgrade. I'm torn between going with a full heat pump system or a heat pump paired with a gas furnace. I've gotten two bids with different recommendations and pricing […] one company recommended a full heat pump system, while the other suggested pairing it with a gas furnace (Orange County Reddit User).*

> *[I'm] purchasing a home and installing AC. [I] may as well update the furnace, too, but I'm conflicted as I'm receiving quotes from multiple HVAC companies and one of them has tried to push me to go with the heat pump. The others are leaning more towards the traditional furnace (San Diego Reddit User).*

We've received some mixed feedback from HVAC companies about the feasibility of installing a ducted heat pump. One company said our home was too energy inefficient for a heat pump to work effectively. Another said a heat pump was feasible (California GreenBuildingAdvisor User).

Home Infrastructure

Challenges related to home infrastructure, e.g., electrical panel upgrades and insulation, were frequently raised by California commenters.

DUCTWORK AND INSULATION

The compatibility of existing ductwork and insulation was also raised by Californians considering heat pump adoption, accounting for 6.9 percent of analyzed posts. The relationship between ductwork capacity and heat pump sizing is one technical concern raised in discussions. Users noted that older ductwork designed for traditional furnaces may not be suitable for or needed by heat pumps, which operate differently, as the following quote illustrates:

Something that is overlooked is the fact that heat pumps aren't really designed to work with older ductwork systems (Sacramento Reddit User).

The need to align heat pumps and ductwork appears to create some confusion about whether heat pumps require "special ducts," as these posts demonstrate:

Does the heat pump system use the ducts and vents that are already in the home from the gas furnace or does it require something different? (San Diego Reddit User).

[Mini Split] has different ductwork standards than furnaces, so even though your house has existing duct work especially if it wasn't fully redone since the house was built it likely requires new ductwork (San Jose Reddit User).

Home insulation also appears to be a critical factor that customers consider in regard to overall heat pump effectiveness. One user emphasized how building envelope characteristics affect potential energy savings:

Heat pumps are more efficient than furnaces and in theory you can have a single ac/heat pump unit. But the cost to own may not be any lower. More importantly, focus on insulation. Air leaks are by far the biggest source of energy loss so I would fix those first. Then think about adding extra insulation (Bay Area Reddit User).

These infrastructure concerns are particularly significant for owners of older homes, where both ductwork replacement and insulation upgrades may be necessary for optimal heat pump performance, as the following quotes exhibit:

When I look at the cost difference between gas and electric heat I can't figure out how to make electric heat (heat pump) work in my old home. A modern build that's substantially more energy efficient is likely a different story (Bay Area Reddit User).

I don't believe homes were built with much insulation back then. In today's code, people are putting in R31 in new constructions in CA. That's a huge difference (San Jose Reddit User).

New construction is a world different than older remodeled homes. If you compared an older home (40 years) to a brand new construction of similar size, the older home probably would use 3-4 times the energy. All of that is heating / cooling and water heating. Even remodeled older homes aren't nearly as energy efficient as new construction (Sacramento Reddit User).

Californians also question how existing ductwork and insulation may impact their eligibility for financial incentives, examined in the Costs section of this report. Many seek advice on online platforms to address the uncertainty, as this quote exemplifies:

Has anybody gotten the SMUD heat pump rebate with old ductwork? One of the requirements is must pass Title 24 via hers cf3r and/or if new ductwork is installed, it must be insulated to r8. We are looking to replace the 20 year old hvac and if we can use this $3,500 rebate, we might look into installing a heat pump instead. Our ductwork is r4.2 and I am wondering if that will come into play during the hers testing somehow. Has anybody passed hers testing with old ductwork? What is your rvalue and how did it go? (Sacramento Reddit User).

ELECTRICAL PANEL

Nearly four percent of users' posts analyzed expressed concerns about the capacity of their home's electrical panel to support the addition of heat pumps. Some simply noted the necessity of upgrading the panel ahead of installing a heat pump, as in this example:

My electric panel is maxed out and I would need a service upgrade [...] I would probably finish out my heat pump project [because] those things are so darned efficient (Bay Area Reddit User).

Others lamented the cost, time, or inconvenience of having to upgrade their electrical panel, as in these examples:

I looked into a heat pump furnace and water heater a couple of years back as I needed to replace both. I have solar panels that produce more electricity than I use each year so it would make sense, but the cost to upgrade my electrical panel from 90A service to 200A+ is just way too much. I'd do it if there were more generous rebates, but right now it doesn't make any sort of financial sense. Hopefully a mandate will come with rebates and assistance as well (California Reddit User).

It's not just the electrical panels. In my home, the electrical panel and hot water heater are at opposite ends of the building. We just replaced the hot water heater last year and wanted to go electric. The total quote was almost $30,000 because they had to tear up the interior walls to run new electrical lines across the house[...] We just installed a gas unit instead (California Reddit User).

Equipment Performance

Californians posed questions and concerns about heat pump performance, particularly related to temperature regulation and air filtration.

TEMPERATURE REGULATION

Questions and concerns about thermal comfort accounted for 9.4 percent of the posts analyzed, suggesting some interested buyers are not confident in heat pumps' general performance. For example, one Californian asked:

> *How does the heat pump do during the winter? Is it warming your house enough? On par with a gas furnace?* (Bay Area Reddit User).

A subset of the concerns about heat pump performance relate to their effectiveness in extreme heat, as these quotes illustrate:

> *I am advised by vendors to replace [my heating system] with [a] heat pump tech[nology rather] than [a] traditional gas furnace as we have solar. I am also advised that heat pumps can bridge up to 35F change between outdoor/indoor temperatures. Which leads me to my question: during heat waves of 110F or so, will the heat pump be effective? (*California Reddit User).
>
> *How well did the heat pumps work a couple years ago when it was so hot we had rolling blackouts? I'm considering a heat pump but want to avoid complaints from my wife and children if cooling is insufficient in a heat wave (Orange County Reddit User).*
>
> *I've been curious about the performance of heat pumps in this weather. I wasn't sure they'd perform well when it's Hades-hot outside* (Central Valley Reddit User).

AIR FILTRATION

Heat pump performance concerns with respect to air filtration were conveyed in 1.1 percent of posts made by Californians. For example, one user asked about ventilation options for ductless mini-splits in a mild coastal climate, questioning whether heat pumps are effective against wildfire smoke filtration:

> *I know that in California, in particular, a lot of new "ADU's" [Accessory Dwelling Unit] and small homes are being built with ductless HVAC systems.* ***I hear so much about heating these units with 'Mini-Splits' but no-one (energy consultants included) seems to mention ventilation****...Has anyone come across a good return air filtration system for wildfire smoke that can be set up without a ducted system?* (Petaluma, California, GreenBuildingAdvisor User).

Another California user, building a house in a wildfire-prone area, sought advice on how to integrate ventilation solutions with heat pump systems to maintain good indoor air quality during fire seasons when opening windows isn't viable:

> *I'm building an 1000 sq ft ADU in coastal California, climate zone 3c and need some advice*

on mechanical systems. […] We are experiencing increasingly long periods (3+months) of terrible air quality due to wildfire smoke and my goal is to build this house very air tight and to prioritize indoor air quality. With that in mind I am trying to find an economical system for ventilation and perhaps makeup air. My energy consultant didn't understand why I would want a HRV/ERV installed- maybe because of the small size of the unit. She said if it feels stuffy, crack a window. Well, that's not a great option in fire season anymore. 1st question: What stand alone unit would work best for ventilation that incorporates good filtration. […] Whats the best way to either incorporate this system for makeup air for bathroom vent van and range hood or to have another system that also brings in CLEAN air (GreenBuildingAdvisor California User).

Gatekeepers

Californians raised concerns about contractors and landlords who, in a variety of ways, pose barriers to adopting heat pump technology.

CONTRACTORS

Contractors are critical "middle actors" between heat pump manufacturers and customers. They are often the ones providing prospective customers with information on and access to heat pumps, thus playing a vital role in promoting, or hindering, heat pump adoption. Comments from Californians reveal several types of barriers associated with contractors. Such comments accounted for 5.2 percent of posts analyzed. Several users noted the dearth of trained installers, as in this comment:

> *There is a huge shortage of contractors that know how to do systems like those (Bay Area Reddit User).*

Some users reported struggling to find what they believe to be reputable installers of heat pump systems. A recurring theme in posts from California data is the difficulty in finding trustworthy heat pump installers, as demonstrated by the following quotes:

> *Can you recommend a good HVAC company for getting a heat pump? We've had trouble finding one* (Bay Area Reddit User).

> *I'm looking to install a heat pump and get a new a/c as well. I've heard there's lots of shady companies out there. Do you guys have any recommendations?* (Orange County Reddit User).

Contractor resistance also appears as a recurring theme in comments made by potential heat pump adopters in California. These quotes illustrate the challenge this poses for customers interested in installing a heat pump:

> *I've been looking to get a mini-split heat pump installed to replace an old traditional system, but the two "top rated" contractors I've called were very reluctant to recommend the system entirely, even after we discussed the major rebates being handed out* (Bay Area Reddit User).

> *My builder was getting quotes for a heat pump install from his usual HVAC contractors and prices were disproportionately high, as well, for equivalently priced equipment. Definitely got the impression they just weren't interested in the job and preferred to stick with traditional installs* (Santa Cruz Reddit User).

Contractor reluctance seems to stem from their preference for traditional HVAC installations and limited heat pump expertise, evidenced by inflated quotes and a shortage of trained installers. Other examples of contractors posing a barrier to heat pump adoption are shared in the section above on Conflicting information.

LANDLORDS

Renters expressed impediments to heat pump adoption related to building owners, accounting for one percent of posts analyzed. Some mentioned unspecified barriers, as this quote illustrates:

> *Speaking of climate change, everyone in [San Francisco] should buy a heat pump. I wish my landlord would allow me to install one! (California Reddit User).*

Some renters attributed the barrier to landlords' reluctance to invest in system upgrades. The following quote reflects one renter's assessment of the issue:

> *[…] If a unit has forced air heating, it isn't that expensive to retrofit, but landlords are often cheap […] even to the point of shooting themselves in their own feet. That said, if the building does not have forced air systems, it can be much more expensive, though mini-splits have seriously lowered the cost (Sacramento Reddit User).*

Others noted limitations related to restrictions on the modifications they are allowed to make to the property, as expressed in this quote:

> *A mini-split requires external components that need holes to be drilled to connect. I'm renting and can't do that. I would love to find one I can just stick on the wall. I think I've seen some like that (San Jose Reddit User).*

Comparative Analysis

This section answers RQ2 — What insights do their comments and questions give us about the experiences of prospective heat pump adopters? — through several comparative analyses.

Regional Differences

Given variations in climate, utility rates, heat pump prevalence, and other factors, the research team conducted an exploratory analysis to identify potential differences across Northern, Central, and Southern California. Figure 3 shows that most concerns appeared with relatively similar frequency across the three regions, with a few exceptions. *Mitigating Costs with Solar* was a higher priority in the Bay Area (13.9 percent) compared to Central Valley (7.6 percent) and Southern California (11.3 percent; $p>0.05$). Conversely, *Rebates and Financial Incentives* were emphasized more in the Central Valley (18.4 percent) than in the Bay Area (11.9 percent) or Southern California (10.5

percent; *p>0.05*). *Temperature Regulation* also showed regional distinction, being cited more frequently in Southern California (12.8 percent) and Central Valley (11.3 percent) than in the Bay Area (7.1 percent; *p>0.05*). Non-significant trends include slightly higher *Operating Costs* concerns in Southern California (18.1 percent) and a marginal increase in such concerns in Central Valley. Overall, while regional priorities align broadly on most issues, financial strategies, e.g., mitigating costs and rebates, and climate-related needs, e.g., temperature regulation, show meaningful divergence.

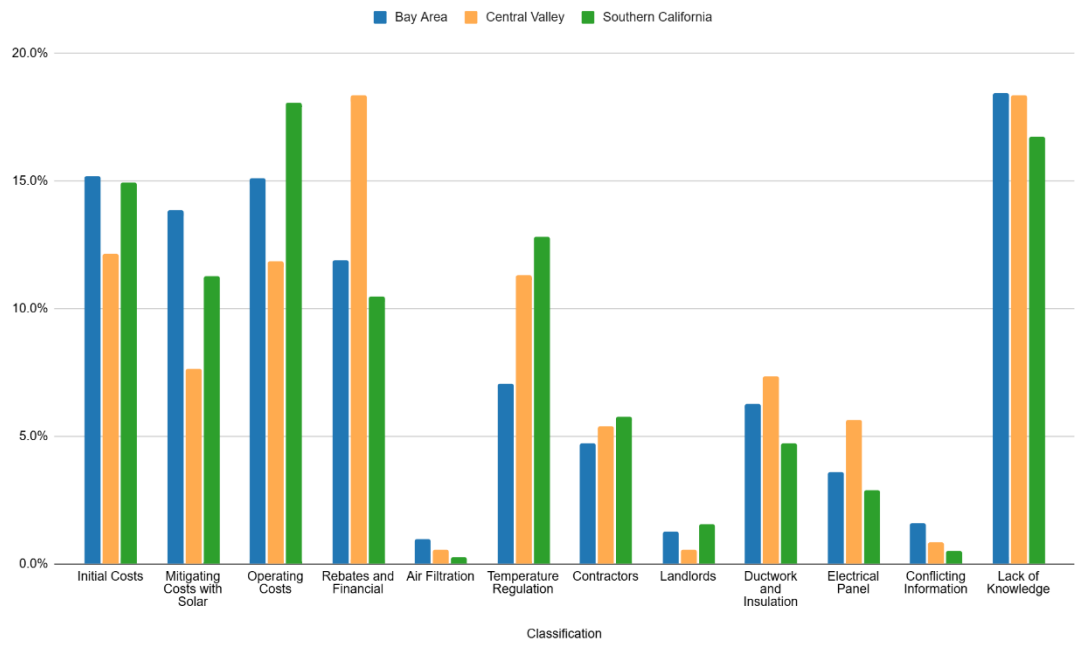

Figure 3: Frequency of topics by California region.

Perspectives of Those Not Interested in Heat Pumps

To understand how users who express a lack of interest in adopting heat pumps differ from those who show interest in adopting heat pumps, whose comments were analyzed in detail above, the research team conducted a comparative analysis of the frequency with which topics appeared in their online posts. Here, platform users who are "Not Interested" are defined by their expression of a lack of interest in adopting a heat pump in their online posts, as described above.[11] The relative frequency of topics posted by "Interested" users versus the "Not Interested" group is shown in Figure 4. Comments on initial and operating costs appeared more frequently among the "Not Interested" group, as did comments about temperature regulation. By contrast, the "Interested" group was more likely to mention lack of knowledge or rebates and financial incentives.

[11] It is important to note that the "Not Interested" group that appears in the data we analyzed represents a very particular subset of customers who are not interested in heat pumps, i.e., those who post comments on heat pumps, which is not typical of those disinterested in purchasing a heat pump.

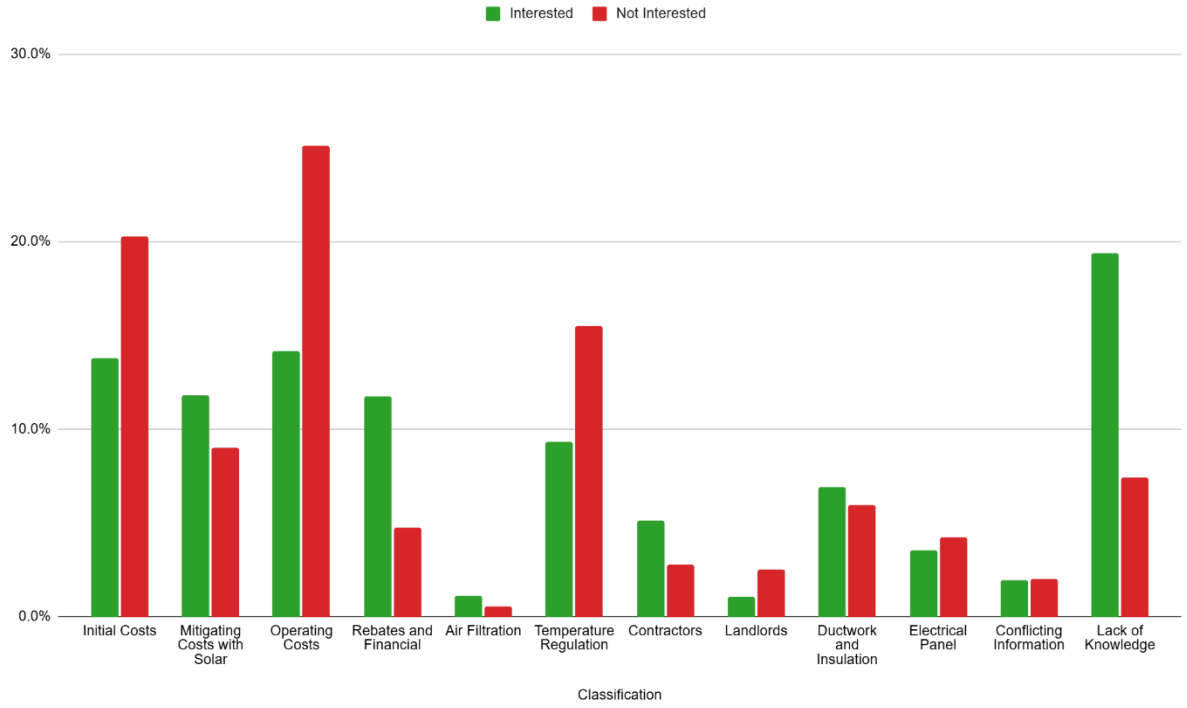

Figure 4: Frequency of topic, "Interested" versus "Not Interested" groups.

The reluctance to adopt heat pumps among the "Not Interested" group stems from a combination of financial, practical, and attitudinal barriers. The chart above reveals the differences in the frequency of comments relating to various themes when comparing the "Interested" and "Not Interested" groups. A qualitative analysis of the nature of the comments expressed by the "Not Interested" group is also illuminating.

COSTS

While initial costs were a significant concern for both the "Interested" and "Not Interested" groups, they were more prevalent among the "Not Interested" group (20.2 percent) compared to the "Interested" group (13.8 percent). For the "Not Interested" group, the high initial cost was explicitly cited by some as the reason for their lack of interest, as this quote illustrates:

> *I looked at doing a heat pump, but the upfront cost just gave me too much heartburn… a furnace with new AC ran about $13k just by itself (Sacramento Reddit User).*

Among the "Not Interested" group, concerns about initial installation costs are compounded by the perception that contractor markups are excessively high. Some comments mentioned possible strategies to circumvent high costs. Though the "Interested" group posted similar comments, the nature of the comments differs significantly — for the "Not Interested" group, these concerns are seen as roadblocks, whereas for the "Interested" group, they are framed more as challenges to overcome. Several quotes highlight this distinction:

> *A heat pump requires a massive upfront investment. all of the ac contractors know you'll get a tax credit now too so they've jacked up their prices by an equivalent amount (Bay Area Reddit User).*
>
> *Licensed HVAC guys will charge $12k-$20k for this job... and none of them will install equipment you buy online. You must purchase through them and pay their markup. It took me a year to find a guy to do this for my mom's house... Pretty sure this was the worker for one of the bigger HVAC companies just doing a side job (San Jose Reddit User).*
>
> *You're screwed, unless you are planning to install it yourself. You are stuck with this price. And don't even think about ordering an AC unit online and finding an AC company to install it for you. Most will want to supply equipment and do install (Bay Area Reddit User).*
>
> *Do not go heat pump, you will regret it. I am an installer/service tech, so I do know what I'm talking about. [...] HVAC surpasses the automotive repair scam industry. A $20 contractor will cost you $250, and it's a 5-minute replacement job (Sacramento Reddit User).*

Even with subsidies, users argued that incentives are insufficient or restrictive, such as federal rebates requiring applicants to be "Bay Area dirt poor to qualify" (California Reddit User).

Operating costs were also cited more frequently by the “Not Interested” group (25.1 percent) than the “Interested” group (14.1 percent). As one “Not Interested” user calculated, "electric heat is 3x the cost of gas to run," (California Reddit User) even with heat pumps' higher efficiency. Another noted:

> *I calculated it out. At 35¢/kWh it's just not worth it to go for an electric heat pump or water heater. At 17¢ it starts to make a ton of sense (Bay Area Reddit User).*

Some users in the “Not Interested” group mentioned the relatively high price of electricity in PG&E territory and its impact on heat pump operating costs, which, in turn, affects customer appetite, as reflected in these quotes:

> *With PG&E rates the way they are, converting to a heat pump doesn't seem currently logical (California Reddit User).*
>
> *If PG&E wanted to promote electrification all they would have to do is halve their absurd electric rates (California Reddit User).*

LACK OF KNOWLEDGE

The “Not Interested” group was more confident in their knowledge of heat pumps than the “Interested” group, with only 7.4 percent of comments from the former expressing concern about lack of knowledge compared to 19.4 percent of comments from the latter. The research team’s analysis did not explore whether the “Not Interested” group, in fact, has more heat pump knowledge than the “Interested” group.

HOME INFRASTRUCTURE

As with the “Interested” group, the “Not Interested” group mentioned ductwork requirements among

their issues with heat pumps, as shown in the following comments:

> *One of the problems with heat pumps is that they won't work well with old ductwork as the original design assumed very hot air produced by a furnace, not slightly warm air produced by a heat pump (California Reddit User).*

> *[A] typical furnace starts at 70,000 BTU/h… you would need [a] 5.5-ton heat pump to equal output of a gas furnace. Your ductwork might not keep up with 5.5. Typically, old ductwork can take a 3-ton unit (California Reddit User).*

The need to align heat pumps and ductwork has led to confusion about whether heat pumps require "special ducts," which in turn raises concerns about added costs, as this exchange between posters reveals:

> *Wait what?!?!? Does it require special ducts? Does the heat pump itself cost $20k? At that price I'd suffer and do my own ductwork… (California Reddit User 1).*

> *No special ducts required but apparently heat pumps need bigger ducts for air flow. So going from [a] gas furnace to heat pumps needs new ductwork which means more labor-intensive work which means $$$ (California Reddit User 2).*

EQUIPMENT PERFORMANCE

Performance concerns regarding temperature regulation were also noted, with the "Not Interested" group expressing significantly more concerns (15.5 percent of comments) compared to the "Interested" group (9.4 percent). As one user from the "Not Interested" group claimed:

> *Heat pumps only work if there's enough humidity in the air (California Reddit User).*

GATEKEEPERS

The "Not Interested" group displayed significantly different interactions with gatekeepers compared to the "Interested" group. While both groups encountered resistance from contractors, the "Not Interested" group more frequently cited contractor skepticism as validation of their decision not to adopt heat pumps. Their comments often referenced contractors who actively discouraged heat pump installation, presenting this as expert confirmation of their concerns about the technology. For example, one user remarked:

> *I literally had two contractors try to talk me out of spending a lot more money and both suggested I should just fix my current system which has some problems. I said I wanted to upgrade for the long-term efficiency and to take advantage of my solar electricity. But they warned it wouldn't be as cozy… (California Reddit User).*

The landlord-tenant relationship also manifests differently, as some landlords in the "Not Interested" category cited previous negative experiences with heat pumps as justification for not considering them in their properties. These perspectives suggest that gatekeeper resistance may impede adoption among those interested in heat pumps and reinforce existing skepticism among those predisposed against the technology.

SENTIMENT ANALYSIS

We ran a sentiment analysis to validate our comparisons between the “Interested” and “Not Interested” groups. As Figure 5 shows, the “Not Interested” group expressed overwhelmingly negative sentiment across all categories compared to the more neutral and occasionally positive sentiment of the “Interested” group. Overall, the “Not Interested” group generally expressed their opinions about heat pumps more negatively, with one user criticizing policies like gas appliance bans as "virtue signaling" (California Reddit User).

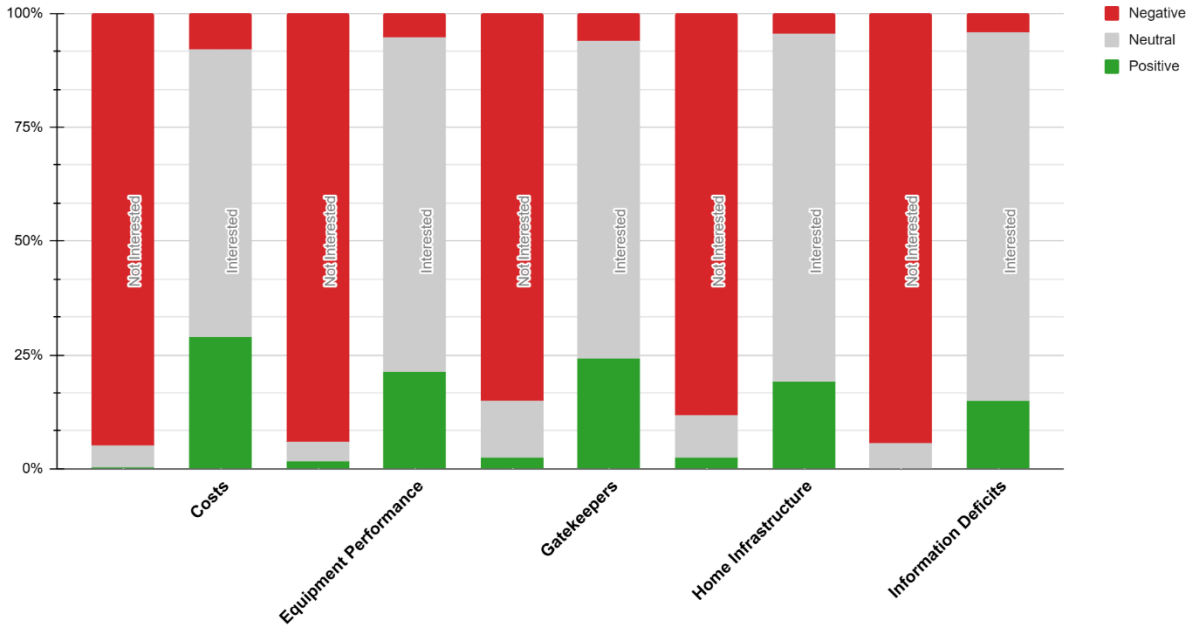

Figure 5: Sentiment comparison, “Interested” versus “Not Interested” groups.

The “Not Interested” group represents an important market segment, and understanding their reasons for resistance could provide insights into broader barriers to heat pump adoption. Furthermore, the influence of “Not Interested” individuals on the information ecosystem that potential buyers interact with could influence the adoption trajectories of the latter. Uncovering these concerns can shed light on strategies that may ignite increased interest and convince more households to consider heat pump technology.

National Customers’ Perspectives

California is promoting heat pumps within a broad national context defined by federal rebates, varying climates, wide-ranging utility rates, and divergent heat pump adoption rates. Comparing Californians’ barriers to heat pump adoption to those of individuals in other states provides insights into the unique and shared challenges of promoting heat pump uptake. To that end, we conducted an exploratory analysis to identify potential differences between the comments, questions, and concerns posted by Californians and residents of other states. Figure 6 shows the relative frequency of topics occurring in posts by potential heat pump buyers and information seekers from California

versus other states.[12] All of the differences are statistically significant, except for the concern about contractors as gatekeepers. The analysis shows that *Lack of Knowledge* is the dominant barrier nationally, appearing in 36.4 percent of comments — nearly twice as frequently as in California (19.4 percent). This discrepancy could be due to the higher prevalence of heat pumps in many states, particularly in the Southeast, where adoption rates are as high as 40 percent in some states.[13]

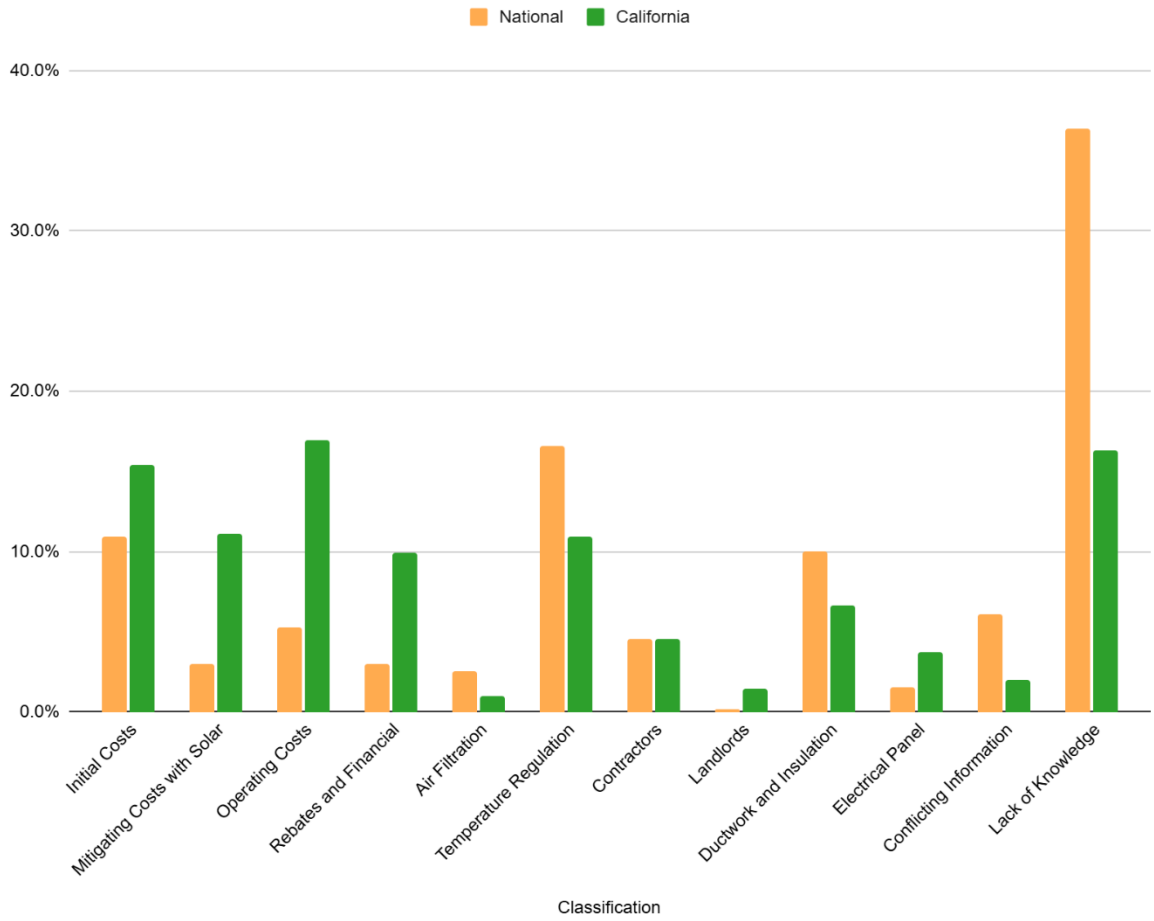

Figure 6: Comparison of "Interested" users in California and the United States.

The national group also cited concerns about *Temperature Regulation* in a higher percentage of comments (16.6 percent) compared to Californians (9.4 percent). This is unsurprising, given California's relatively mild climate. However, the nature of the concerns expressed differ. While users in the national sample often discussed heat pump effectiveness in cold climates, California residents focused more on the ability of heat pumps to handle extreme heat. In regions like the Central Valley and Southern California, potential buyers worried about the system's capacity to provide sufficient

[12] The figure represents data collected across multiple online platforms, however the same general difference between California and national users are evident if the analysis is restricted only to comments made on Reddit.
[13] https://www.canarymedia.com/articles/heat-pumps/chart-which-states-have-the-most-heat-pumps

cooling during heat waves when temperatures can exceed 100°F.

Conversely, Californians were more likely than their national counterparts to make comments related to *Mitigating Costs with Solar* (11.8 percent vs. 3.0 percent). A sizeable minority of homeowners in the state shared views that solar energy as essential to offset the high electricity costs associated with heat pumps. This dynamic is largely absent in the national analysis, where discussions focused more on heat pump performance and cost without the added complexity of integrating renewable energy sources. California's emphasis on renewable energy, driven by state mandates and incentives, means that homeowners often consider how heat pumps align with either existing or planned solar installations.

Comments about *Rebates and Financial Incentives* were also more prevalent among Californians than in the national discourse (11.7 percent vs. 3.0 percent). While confusion around rebates and financial incentives was present in both groups, it was much more pronounced among Californians, perhaps because they face a complex landscape of federal, state, and local programs. Coordinating these incentives introduces complexity and often delays adoption as potential buyers await new incentives. This reflects California's strong push for energy-efficient upgrades, but also highlights how the sheer number of rebate options can overwhelm potential adopters.

Rental properties present another area of divergence. While not a top-tier concern in California (1.0 percent of responses), it is notably more prevalent there than nationally, where it is nearly absent (0.2 percent). In our national data, the issue of heat pump adoption in rental units is almost nonexistent. However, in California — which has the highest proportion of renters in the United States[14] — this topic surfaces as a recurring, albeit minor, barrier. California renters in our sample reported challenges in upgrading to energy-efficient systems, often due to landlords' reluctance to invest in heat pumps or permit structural modifications, e.g., drilling for external components. Even low-cost retrofits face resistance, leaving renters with limited options. This disparity underscores how California's unique rental market amplifies a virtually negligible hurdle in the national sample.

As discussed above, several points of divergence have emerged between California residents' barriers to heat pump adoption and those observed at the national level. While there are overarching themes such as contractor resistance, knowledge gaps, and infrastructure concerns, the unique regional characteristics of California — ranging from its energy policies to climatic conditions — create distinct challenges not reflected in the online discussions on national platforms.

Gap Analysis

The research presented above identifies five topics that frequently appear in comments posted by Californians seeking information about or potentially interested in buying a heat pump. Given the critical importance of information availability to address customers' questions and concerns regarding heat pump adoption, a gap analysis was conducted. This analysis compared the heat pump education topics addressed by California's energy efficiency programs in their web-based resources, e.g., FAQs lists and fact sheets, with the priority topics identified in this research. The gap

[14] https://www.google.com/url?q=https://www.statista.com/statistics/1440437/renter-households-size-usa/&sa=D&source=docs&ust=1728912289185859&usg=AOvVaw2tngDXlibdSjzlQk4k_2Ms

analysis was used to pinpoint opportunities for addressing the customer questions and concerns identified by our research, as described in the later Opportunities to Address Customer Questions and Concerns section.

As mentioned in the Methodology and Approach section, web-based heat pump resources were identified through three methods: a search of energy efficiency programs promoting heat pumps, a targeted search of heat pump-related content on California utilities' websites, and a Google search using keywords "heat pump questions," "heat pump FAQs," and each utility name.

COSTS

Regarding costs, the websites analyzed focus primarily on financial incentives, particularly rebates and credits, which aim to offset the initial costs associated with purchasing and installing energy-efficient equipment. Additionally, the sites offer information regarding federal and state tax credits for energy-efficient home improvements, meant to reduce the overall expense of eligible upgrades. Most of the programs, however, do not offer information about the initial or operating costs that heat pump customers could expect, nor do they refer visitors to external sources of such information. One utility, SMUD, did provide initial cost information, featuring a table on their website with information about average installation prices for various types of HVAC heat pump systems and information about household factors such as size and duct location, which can impact cost.[15]

LACK OF KNOWLEDGE

The utility sites analyzed provide extensive information on eligibility requirements and application processes for their programs, e.g., PG&E's Energy Efficiency Financing Page FAQ[16] and SDG&E's FAQs.[17] However, few provide basic technical information about heat pumps themselves, including how they work and how they differ from traditional air conditioning systems. SCE stands out, as they do provide brief fact sheets, which exemplify how programs could incorporate basic technical information about heat pumps into their materials.[18,19] These fact sheets — one for HVAC heat pump systems and another for HPWHs — provide an overview of how each technology operates and a brief description of the benefits consumers could expect, and outline the variation of HVAC heat pump systems available and the variety of HPWH operating modes.

HOME INFRASTRUCTURE

None of the program websites reviewed offer any information about how heat pumps integrate with home infrastructure, e.g., insulation, ductwork, and electrical panels. Although a few programs mention that there are both ducted and ductless heat pumps, they do not provide guidance about which works best for a specific housing type or infrastructure. For example, although SCE's HVAC Heat Pump Systems Guide[20] is fairly detailed otherwise, on the topic of heat pump type, it merely

[15] https://www.smud.org/Rebates-and-Savings-Tips/Rebates-for-My-Home/Heating-and-Cooling-Rebates#HVAC
[16] https://www.pge.com/en/save-energy-and-money/energy-saving-programs/energy-efficiency-programs-for-businesses/energy-efficiency-financing.html#tabs-bac76e6de3-item-d45c0513a8-tab
[17] https://www.sdge.com/residential/my-account/frequently-asked-questions
[18] https://www.sce.com/factsheet/HeatPumpWaterHeaters
[19] https://www.sce.com/sites/default/files/inline-files/Heat%20Pump%20Overview%20Fact%20Sheet_WCAG.pdf
[20] https://www.sce.com/sites/default/files/inline-files/Heat%20Pump%20Overview%20Fact%20Sheet_WCAG.pdf

notes that "with many options to choose from, there is flexibility in selecting the best type of heat pump solution, based on household needs and savings goals."

EQUIPMENT PERFORMANCE

Heat pump performance is largely unaddressed by utility and program websites. Most sites do not provide any detailed information or performance data on equipment. Rather, they inform visitors of heat pump performance only in vague terms, referring to their "efficiency" and the "comfort" they provide without providing specifics like SEER and HSPF ratings. When heat pump performance is mentioned, it is sometimes in reference to energy bills. For example, SCE's website includes materials that describe heat pumps as energy-efficient technology that could potentially provide customers with bill savings. A SMUD page on heat pumps states, "Up to 40% of the energy used in your home goes to heating and cooling. Replacing your HVAC system with more efficient equipment will improve your comfort and save you money."[21] Many of the sites, however, do not even address heat pumps explicitly, referring instead to generic "system upgrades," as having the potential to save costs and elsewhere listing heat pumps as one of many available "system upgrades."

GATEKEEPERS

Several websites offer general guidance on finding a contractor who can help with HVAC or water heating system upgrades. For example, both SMUD[22] and Marin County[23] provide a "Find a Contractor" link. However, none of the sources provide information related to specific contractors with experience installing or maintaining heat pumps. In addition, most of the sources do not explicitly address the needs of landlords or tenants seeking information about heat pumps. One exception is SDG&E's homepage for the Energy Savings Assistance Whole Home Program, which provides a link for renters and landlords to learn more about energy efficiency upgrades. Although heat pumps are listed among potential upgrades, the site does not include more specific information on the technology itself.[24]

GENERAL CHARACTERIZATION

In general, the content provided on heat pump program websites is brief and general, highly specific, or an unhelpful combination of the two. For example, the top hit of the internal SMUD website search leads the user to a page entitled "Heat pump water heaters."[25] The first line of the site says, "Rebates up to $2,500" followed by this vague description, "Choosing a more efficient heat pump water heater can help you reduce your monthly water heating bills and lower your home's emissions from natural gas." Immediately underneath that statement is highly specific information: "Unit must meet NEEA Tier III or IV requirements for climate zone 12," followed by a "find a contractor" button. The contractor button is then followed by an "Other rebates" section which reverts back to vague language stating, "SMUD heat pump water rebates can be stacked with statewide and federal incentive programs including TECH Clean CA while funding is available." That information is followed

[21] https://www.smud.org/Rebates-and-Savings-Tips/Improve-Home-Efficiency/Heating-and-Cooling-Systems
[22] https://smudcontractornetwork.org/index.php
[23] https://www.marincounty.gov/departments/cda/sustainability/electrify-marin/find-contractor
[24] https://www.sdge.com/residential/pay-bill/get-payment-bill-assistance/assistance-programs/energy-savings-assistance-whole-home-program
[25] https://www.smud.org/Rebates-and-Savings-Tips/Improve-Home-Efficiency/Heat-pump-water-heaters

by a directive to “Ask your contractor about eligibility criteria and availability of other incentive opportunities” or to visit the Switch Is On, an outside source, for more information on incentives. The site leaves consumers with no real idea of what a heat pump is, how a heat pump works, whether they’re eligible, what type they would need, or anything beyond a general sense that they *could* receive some sort of incentive for installing one.

As is the case with the SMUD pages, more detailed information is typically only available to users by clicking on links to outside websites, e.g., switchison.org, when provided. Only two websites — SCE[26] and SMUD[27] maintain an explicit frequently asked questions (FAQ) section focused on heat pump information. Other programs provide FAQ-like information in the form of bullet points or brief paragraphs that included heat pumps, e.g., SDG&E,[28] SCE,[29] and Riverside Public Utility.[30] However, very few sites present information in question and answer formats, or allude to consumers having questions. If sites do allude to consumer questions, they typically provide contact details, e.g., email addresses and phone numbers, where consumers can request more information.

Overall, analysis of the information currently provided by programs suggests that it is spread across multiple platforms, requiring users to navigate different websites and documents to obtain a comprehensive understanding. Considering the information that is accessible using all three search techniques, the problem is not so much a gap in information as it is the lack of a single succinct source with reliable and digestible information on all of the key topics. As discussed earlier, this imposes a cognitive burden on customers seeking information on heat pumps from their local utility, reducing the likelihood they will retain or be convinced by the information provided.

Discussion

Costs play a major role in determining whether potential buyers move forward with heat pump installations. Analysis of online discussions revealed three primary financial concerns among California residents considering heat pumps: initial installation costs, ongoing operating expenses, and the complexity of available incentives. Incentives at the federal, state, and local levels have garnered a lot of interest. Many potential adopters are waiting for specific incentives, like IRA rebates, to become available before installing heat pumps. Others are trying to use incentives now, but are encountering challenges. Some struggle to navigate the various requirements and terminology used by different programs like TECH Clean California, BayREN, and utility-specific offerings. Others express confusion about eligibility criteria, the timing of availability, and how to combine incentives from different programs.

Many online forum users cited operating costs as a major barrier to heat pump adoption, providing detailed cost comparisons that suggest heat pumps may be more expensive to run than gas systems at current electricity rates. Many California residents also emphasized that combining heat pumps with solar PV is essential to offset the ongoing electricity costs of running heat pumps and to improve

[26] https://www.sce.com/factsheet/energy-savings-assistance-program
[27] https://www.smud.org/Rebates-and-Savings-Tips/Rebates-for-My-Home/Heating-and-Cooling-Rebates#HVAC
[28] https://www.sdge.com/residential/savings-center/tips/home-electrification
[29] https://www.sce.com/factsheet/HVACHeatPumpSystems
[30] https://www.riversideca.gov/utilities/residents/rebates/energy-rebates/air-conditioning-incentives

their return on investment, especially given California's expensive utility rates, particularly in PG&E territory. As a result, integration with solar PV is an additional factor influencing the decision to adopt heat pumps. For many California homeowners, the feasibility of switching to heat pumps is tied to whether their existing or planned solar setups can handle the increased electricity demand, particularly during the winter when solar production is reduced. This adds another layer of complexity to the decision-making process, as potential buyers must assess not only the performance of the heat pump but also the capacity of their solar systems.

The findings of this report reveal several **information deficits** that could hinder the adoption of heat pump systems in California. A key issue is the **lack of knowledge** among potential buyers, who at times discussed how they struggled to distinguish between different heating and cooling systems, such as mini-splits and heat pumps. Many users demonstrated confusion about the technical requirements of these systems and how they would integrate with their existing home infrastructure.

Further complicating matters, online users in the data analyzed discussed how they encounter **conflicting information** from contractors and online sources regarding the effectiveness, noise levels, and performance of heat pumps. This contradictory advice undoubtedly makes it difficult for potential buyers to confidently assess the suitability of heat pumps for their specific needs. For instance, some users reported being told that heat pumps are louder than traditional systems, while others reported the opposite, causing uncertainty about their potential impact on auditory comfort. Similarly, there are mixed messages about whether heat pumps can perform efficiently in older homes or during extreme weather conditions, leading to doubts about the quality of service they offer. Another possible challenge stems from the **lack of trustworthy sources** of information and reputable installers. Users in the data analyzed reported difficulty finding contractors they trust.

Another recurring theme in the data is **concerns about performance**, with respect to maintaining comfortable indoor temperatures. Several users in hot areas expressed skepticism about whether heat pumps can adequately cool homes during heat waves, while others in cooler regions questioned whether heat pumps can keep homes warm enough during the winter, especially in comparison to gas furnaces.

Lastly, **gatekeepers** such as landlords and contractors present additional barriers to heat pump adoption. Renters face challenges due to restrictions on property modifications and landlord reluctance to invest in energy-efficient systems. Renters in the data analyzed reported challenges with installing heat pumps because of the need to drill holes for external components or make other structural changes to their rental units. Even when upgrades are feasible, some renters complained that landlords are often unwilling to cover the costs. Contractors, too, can act as gatekeepers. Some potential buyers reported that contractors are reluctant to recommend heat pumps, even in cases where rebates and incentives are available. This resistance, coupled with conflicting advice, undermines potential buyers' confidence and complicates the process of selecting and installing a heat pump system.

Opportunities to Address Customers' Questions and Concerns

This section identifies opportunities and recommendations for addressing customer questions and concerns based on the key findings from this study. Research on cognitive barriers suggests that seeking information on heat pumps may be compromised by cognitive strain, i.e., increased mental effort required to process information and make decisions (Savolainen, 2015). For example, consumers might struggle to formulate specific questions about heat pumps, hindering online searches. Ineffective search strategies may lead to incomplete or misleading information about heat pumps, which in turn may result in reliance on inaccurate mental shortcuts rather than engagement in effortful information processing. Such cognitive barriers can lead consumers to stick with familiar heating systems like gas furnaces even when heat pumps might be more beneficial.

At the same time, providing consumers with too much information can create a cognitive barrier. Due to the novelty of heat pumps, cognitive strain is already high, as it automatically increases when individuals face unfamiliar choices. Trying to combat this novelty with too much complex information about heat pumps only exacerbates the problem. Lack of confidence in understanding complex heating systems can deter consumers from fully exploring heat pump options, lead to decision paralysis or, once again, push them to default to familiar options.

Instead, research scientists have found that providing clear, concise information about heat pumps is crucial. A 2024 study of Minnesota homeowners[31] found that simply explaining what a heat pump is was as effective as more complex messaging. This suggests that basic education about heat pumps should be a priority. Below, we summarize three formats — videos, FAQs, and testimonials — that can be used to effectively convey information about heat pumps in an accessible manner. Following that, we discuss how to address customer questions and concerns about heat pump costs. The section concludes with a brief overview of best practices when conveying information about heat pumps. Examples are drawn from programs promoting heat pumps elsewhere in the United States, examined in more detail in our previous CalNEXT study.[32]

Explainer Videos

Video is a useful format for providing basic education on how heat pumps work. Previous work by the research team has identified several examples of programs that use videos to address common customer questions. For instance, Electrify Everything Minnesota has made several social media posts with videos of operational heat pumps alongside brief facts about the technology.[33] The Love Electric website includes a one-minute and forty-six second YouTube video that explains how heat pumps operate in cold climates, a common concern for those unfamiliar with heat pump technology.[34] Figure 7 displays an image from a video that Hot Water Solutions uses to demystify

[31] https://www.route-fifty.com/emerging-tech/2024/09/why-people-arent-buying-heat-pumps-and-what-states-can-do-about-it/399635/

[32] https://calnext.com/wp-content/uploads/2024/06/ET23SWE0053_Insights-from-Innovative-Programs-on-Barriers-and-Opportunities-for-Heat-Pump-Adoption_Final-Report.pdf

[33] https://www.instagram.com/p/CwAoGkJNjms/

[34] https://youtu.be/R76jYliU5ok, https://loveelectric.org/additional-resources/, https://loveelectric.org/heating-cooling/

heat pumps by explaining how they work.[35]

Figure 7: Image from video explaining how heat pumps work.

Source: Hot Water Solutions: https://www.youtube.com/watch?v=f7KeX8bse-0

Frequently Asked Questions

Another relatively easy way for utilities to provide basic information about heat pumps is to use the FAQ) format. Sparrow, Liu, and Wegner's 2011 study of the "Google Effects on Memory," illuminates several key aspects of human information processing in the digital age. Their findings revealed that, when confronted with challenging questions, individuals are primed to think about websites as ready sources of information. At the same time, the researchers also found that people exhibit lower rates of recall for information when they anticipate future access to that information. This phenomenon implies that dedicated resource pages, such as FAQ pages, can function as reliable "external memory sources" (Sparrow, Liu, & Wegner, 2011; p. 776). Further, the study also demonstrated that individuals show enhanced recall for *location* of information rather than for the information itself. This finding underscores the potential value of well-organized resource pages, such as FAQs. Users may more easily remember that the answers to their questions can be found in the FAQ section, even if they don't recall the exact details of the information.

The findings from Sparrow, Liu, & Wegner (2011), our previous studies (Outcault et al., 2024), and the current study, suggest several benefits of incorporating FAQ pages into utility websites. By presenting information in an easily digestible format, these pages reduce cognitive load, enabling users to process content more effectively. They enhance user experience by providing quick access to answers, saving time and effort that would otherwise be spent searching for information. FAQ pages also improve information retrieval by serving as a clearly marked and accessible reference

[35] https://mywesthill.org/event/energize-workshop/

point.

Many programs have incorporated FAQs into their websites to address general questions about heat pump technology, e.g., How do heat pumps work?"[36] and "Why should I make the switch?"[37] Programs also use the FAQ format to address specific customer concerns. For example, Efficiency Maine's Homeowners' FAQ webpage answers questions such as "What are the advantages of heat pumps compared to window air conditioners?" and "Will insurance companies insure homes that are heated exclusively with heat pumps?"[38] FAQs are also an efficient way to address general cost concerns related to heat pumps, e.g., "How will heat pumps impact my energy bills?" and "Is heating with heat pumps less expensive than conventional heating systems at all temperatures?"[39]

FAQs may include a short list of questions that programs often encounter, but these webpages can also be developed into more thorough resources that are easy for customers to navigate. More in-depth FAQ pages benefit from additional structure to orient the user. For example, Energize! provides a detailed FAQ section containing categories of information that customers may be looking for, such as "Financial Questions" and "Before and After Installation."[40] In addition, while most FAQ answers are brief and broad, they can be augmented with embedded links to articles and program resources to provide additional information. This approach creates an accessible opportunity for customers to learn more information without the added burden of locating additional websites or documents (see Figure 8).

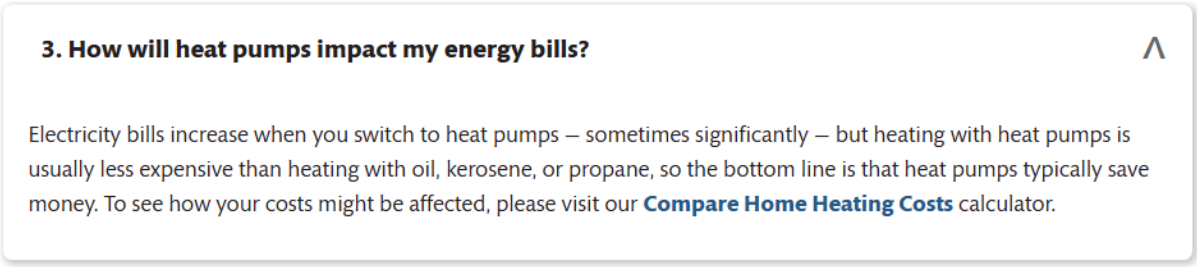

Figure 8: FAQ answers embedded with links to additional information on the Efficiency Maine FAQ webpage.

Source: https://www.efficiencymaine.com/heat-pumps-faq/

Testimonials

Our previous research on programs promoting heat pump adoption (Outcault, et. al., 2024) highlighted the fact that many feature the personal experiences of customers and contractors. As mentioned earlier, sharing customer testimonials can be an effective strategy because it leverages "social proof" and social norms (Subathra et. al., 2023). Peers can be a compelling and trusted source of education for customers, particularly because they are thought to be willing to share both positive and negative experiences with a technology (CPUC, 2011).

[36] https://www.energizekingcounty.org/faq
[37] https://www.dcseu.com/affordable-home-electrification#faqs
[38] https://www.efficiencymaine.com/heat-pumps-faq/
[39] https://www.efficiencymaine.com/heat-pumps-faq/
[40] https://www.energizekingcounty.org/faq

Our study found several formats that programs use to convey customer experience. Several programs present customer information in a written format, ranging in length. Some program websites feature short quotes, as illustrated in Figure 9. Others offer longer customer statements written by a local heat pump customer. For example, the Home Energy Navigator provides a library of written testimonials where homeowners describe the wide-ranging impacts, e.g., cost, comfort, and convenience, of their heat pump, providing real life examples of owner experiences.[41]

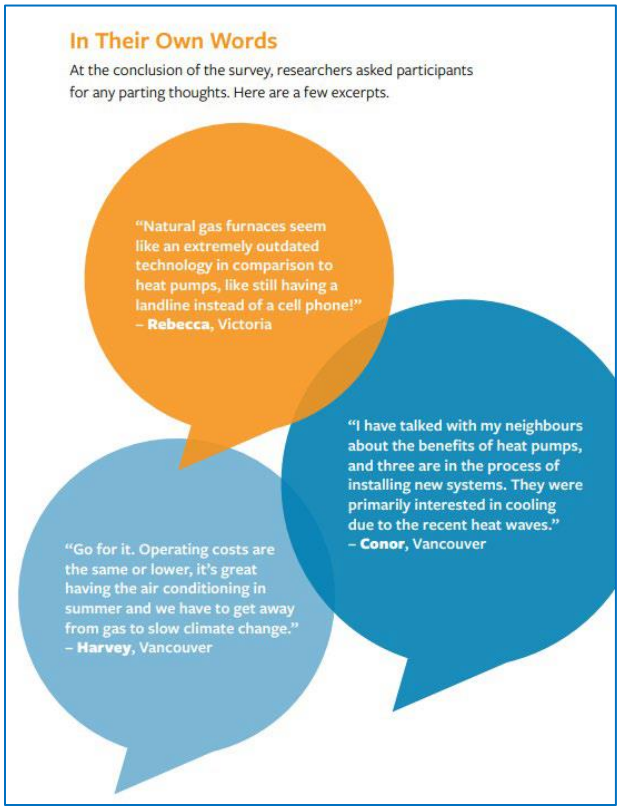

Figure 9: Quotes from heat pump owners featured in Making the Switch case study report.

Source: https://www.saanich.ca/assets/Community/Documents/MakeTheSwitch_SummaryReportFinal_MAY9.pdf

Some programs employ a longer case study format that includes details of the retrofit process as well as other aspects of the customer experience.[42] For example, the Air Source Heat Pump Collaborative of Minnesota maintains a repository of case studies sorted by technology, including both ductless and ducted heat pumps. The case studies emphasize reasonable operating costs, cold-climate performance, and reduced carbon emissions.[43] Similarly, MassLandlords includes case studies as part of the organization's blog so that landlords can hear about others' experiences firsthand, to better understand the costs and benefits of installing heat pumps.[44] Longer testimonials have the advantage of being powerful memory instruments: there is evidence that when

[41] https://homeenergynav.ca/testimonials/
[42] For examples of heat pump customer case studies, see https://loveelectric.org/case-studies/ and https://www.maringreenhometour.org/homes
[43] https://www.mnashp.org/mn-ashp-collaborative-cold-climate-air-source-heat-pump-pelican-rapids-mn
[44] https://masslandlords.net/deep-energy-retrofit-case-study-massachusetts-single-family-home/

testimonials are told as a story, customers can more easily retain the information (Moss, 2008).

Video has been used as a platform for sharing heat pump customer testimonials by several programs. For example, Make the Switch offers three short videos that document homeowners' "heat pump stories." In these brief (under two minute) videos, participants share their reasons for installing a heat pump and their experiences since installation, including the cost and environmental benefits of installing a heat pump.[45] Marin Green Home Tours offers roughly eight-minute video tours of local homes that have installed heat pumps for space conditioning and/or water heating.[46]

Customer testimonials, whether written or audio-visual, communicate peer endorsement of this technology. Contractor testimonials are also used to promote heat pump adoption. For example, Efficiency Maine's water heating program shares plumber testimonials featuring quotes such as: "I was a little hesitant to recommend them at first, but when customers started requesting them, I did some research. The short payback and ten-year warranty are what my customers want to see. Now I recommend them all the time."[47] Endorsements from other trusted third parties, e.g., community-based organizations, can also be used to address customer questions or concerns (Grid Alternatives, n.d.).

Addressing Heat Pump Costs

Given the prevalence of customer concerns related to heat pump costs, it is critical that programs address this topic. One way programs address questions and concerns about heat pump costs is qualitatively, through customer testimonials and case studies. Heat pump owners share their experience with heat pump costs as part of their "success stories." This anecdotal approach may be effective for addressing initial skepticism about high heat pump costs.

We found evidence that some programs take a quantitative approach to addressing concerns about heat pump costs. For example, numerous programs, e.g., BC Hydro,[48] PickHVAC Cooling and Heating Guide,[49] and Efficiency Maine's water heating[50] and HVAC[51] programs, have developed cost calculators that allow customers to enter specific information about their current systems and energy usage to generate customized estimates of operating costs or savings. In addition to a home energy cost and usage calculator,[52] Mississippi utility Singing River offers a mobile app that allows their customers, including those who have installed a heat pump, to track their operating costs and energy use.[53] Cost calculators can be a valuable tool for customers to obtain more precise cost information to inform their decision-making.

Best Practices in Customer Education

[45] https://www.saanich.ca/EN/main/community/sustainable-saanich/climate-change/climate-friendly-homes/making-the-switch.html#videos
[46] https://www.maringreenhometour.org/archives
[47] https://www.efficiencymaine.com/docs/EM-HPWH-Plumber-Testimonials.pdf
[48] https://www.bchydro.com/powersmart/residential/tools-and-calculators/heat-pump-cost-calculator.html
[49] https://www.pickhvac.com/central-air-conditioner/seer/savings-calculator/
[50] https://www.efficiencymaine.com/at-home/water-heating-cost-comparison/
[51] https://www.efficiencymaine.com/at-home/heating-cost-comparison/
[52] https://c03.apogee.net/mvc/home/hes/profile?utilityname=singingriver
[53] https://singingriver.com/smarthub/

Customer education materials should be compelling, convey targeted messaging, and use appropriate and effective language and visuals. Below we highlight some of the best practices that should guide the development of customer education resources on heat pumps.

Compelling education materials include messaging that is appropriate for the current level of knowledge that customers have about the relevant technology or program. It is often necessary to do background research on customer knowledge and attitude towards a technology to properly tailor the education materials for that audience, e.g., right tone, language, and personality (McCollum, 2019). Market segmentation, or creating education materials for specific segments of a customer base that have internal similarities (Moss, 2008), can be helpful in crafting effective materials for specific audiences. The goal of segmentation is to group similar customers such that outreach and education can be tailored to each subgroup. This can be more effective than using a single, more generic message for the entirety of the customer base. Framing information about a technology as a solution to a problem can also be an effective messaging strategy.

Any text included in customer education materials should be clearly communicated. Energy concepts should be discussed in lay terms that customers can easily understand, aiming for a sixth grade reading level. Acronyms and jargon should be avoided. When necessary to use technical terms, they should be clearly defined so that extensive background knowledge is not required to understand the message. Translating outreach materials into commonly spoken languages among the target audience makes the message more accessible.

Creating education materials that are visually appealing is also very important (Joseph, Keller & Ainsworth, 2016). The color scheme should align with the topic and tone of the message. Fonts used should be easy to read, i.e., avoid calligraphy, embellish, and cursive fonts. The design elements, e.g., color scheme, fonts, and logos, should be consistent across materials to garner familiarity, identification, and affiliation with the source of the education materials. The use of high-quality images can greatly enhance the visual appeal of education materials. Images can be used to depict the concepts being explained or represent the customer (Bonk, 2010; UFHealth, n.d.). In the case of the latter, using images of people that reflect the target demographic(s) garners greater attention and trust.

By leveraging the insights of this report, California utilities can develop resources that address customers' questions and concerns about heat pumps. Ensuring the resources are clear, targeted, and easy to locate can reduce the cognitive barriers associated with making informed decisions about heat pumps, and ultimately increase their adoption.

Future Research Opportunities

This study has identified several key barriers to heat pump adoption, many of which stem from information deficits and the cognitive challenges of navigating complex decisions. Further research is needed to explore these areas in more depth and to develop strategies to improve consumer understanding and confidence in heat pump technology. This section outlines several promising avenues for future inquiry.

Conducting in-depth qualitative studies with utility customers in California, including user experience research, interviews, and focus groups, would reveal potential adopters' information-seeking journeys, including the priority topics, the sources they consult, and the challenges they face at each stage of the decision-making process. These qualitative approaches could help unpack the "black box" of consumer decision-making about heat pumps, including how prospective buyers use online resources, the types of advice they find most persuasive, and how these online interactions shape their attitudes toward heat pump adoption.

Future research is also needed to test the effectiveness of different messaging strategies on reducing cognitive strain when consumers are learning about heat pumps. To identify the most effective communication methods, testing of different message formats, visual aids, and levels of technical detail is needed. Of particular importance is an investigation of how best to communicate the financial aspects of heat pump adoption, including upfront costs, operating expenses, and available incentives. This could include, for example, testing the efficacy of cost calculators, incentive navigators, and other tools to address customers' questions and concerns about heat pump costs.

Additional research is necessary to identify which sources of information are most trusted and why. Such studies could explore, for example, the most impactful combinations of information source (e.g., contractors, online platforms, utility programs, and government agencies) and topic (e.g., cost, performance, and comfort). Determining the impact of different types of sources on consumer confidence and decision-making would help inform an efficient allocation of resources among stakeholders that wish to educate customers about heat pumps.

By addressing these research areas, we can gain a better understanding of how consumers seek and process information about heat pumps. This knowledge will be crucial for developing targeted, effective educational programs that reduce cognitive barriers, build confidence in heat pump technology, and accelerate adoption rates in California and beyond.

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Appendix A. Heat Pump Programs

Table 3 lists the heat pump programs whose web-based resources were reviewed as part of the gap analysis.

Table 3. Heat Pump Program Web Resources

Entity	Program Name	Type
Federal		
Federal tax code	Energy Efficient Home Improvement Credit (25C)	Federal
Federal tax credit	45L New Energy Efficient Home Credit	Federal
State		
California Energy-Smart Homes	California Energy-Smart Homes Program	Publicly-owned utility (POU)
PG&E	California Energy-Smart Homes Program (existing homes)	IOU
PG&E	California Energy-Smart Homes Program (new homes)	IOU
SCE	HVAC Heat Pump Systems	IOU
SDG&E	SDGE Rebates	IOU
Self-Generation Incentive Program (SGIP)	SGIP HPWH program	State
TECH Clean California	Heat Pump Water Heater Incentives	State
TECH Clean California	Single Family HVAC Incentives	State
Local		

Entity	Program Name	Type
Alameda Municipal Power	Residential Energy Efficiency Rebate Program	POU
Anaheim Public Utilities	Residential Home Efficiency Rebate Program	POU
Burbank Water & Power	AC Replace Before it Breaks Program	POU
City of Lompoc Utilities	Residential Energy Efficiency Rebate Program	POU
City of Palo Alto Utilities	Residential Energy Efficiency Rebate Program	POU
Glendale Water and Power	Residential Energy Efficiency Rebate Program	POU
LADWP	Residential Energy Efficiency Rebate Program	POU
LADWP	Customer Rebate Program	POU
Lassen Municipal Utility District (LMUD)	Residential Energy Efficiency Rebate Program	POU
Lodi Electric Utility	Residential Energy Efficiency Rebate Program	POU
Marin County	Natural Gas Appliance Replacement Rebate Program	County
Modesto Irrigation District	Residential Energy Efficiency Rebate Program	POU
Pasadena Water and Power	Residential Energy Efficiency Rebate Program	POU
Pasadena Water and Power Department	Water Heater Rebate	POU
Plumas-Sierra REC	Residential Energy Efficiency Rebate Program	POU

Entity	Program Name	Type
Riverside Public Utilities	Residential Energy Efficiency Rebate Program	POU
Roseville Electric	Residential Energy Efficiency Rebate Program	POU
SCP	HPWH Rebate	POU
SMUD	Residential Energy Efficiency Rebate Program	POU
Truckee Donner Public Utility District	Residential Heat Pump Water Heater Rebate	POU
Truckee Donner Public Utility District	Heat Pump Heating (HVAC) System Rebate	POU