Technical Analysis on Extending San José's All-Electric Requirement

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Executive Summary

The purpose of this report is to provide a technical evaluation of the feasibility of all-electric mid-and high-rise new construction buildings in order to inform the City's recommendations related to an extension of a natural gas infrastructure prohibition (i.e. all-electric building requirement) to new buildings over three stories. In partnership through the American Cities Climate Challenge, the City of San José ("City") worked with New Buildings Institute (NBI) as its technical partner to develop the City's adopted reach code and natural gas infrastructure prohibition ordinances. This report draws on NBI's expertise in building and policy design as well as several sources including: technical studies/reports, discussions with leading industry experts at a Building Electrification Experts' Roundtable ("Experts' Roundtable" or "Roundtable"), buildings conferences, webinars, and market research. The report evaluates and determines the feasibility of all-electric mid- and high-rise new construction based on three factors: 1) technical feasibility of all-electric equipment/systems, 2) cost effectiveness of all-electric new construction compared with mixed fuel, and 3) market feasibility which includes the availability of all-electric equipment, design expertise of building practitioners and market consumer preferences. The report concludes that the design and construction of all-electric buildings is technically feasible in mid-high-rise new construction, however, there are certain market challenges, including building practitioner awareness and training (particularly in designing for central water heating system in multifamily buildings and hotels) and perceived market preferences in California for gas cooking in residential and commercial applications (primarily restaurants) that may impact the transition toward all-electric new construction. A summary of findings can be found on pages 15-16 of this report.

Background

San José's Climate Smart Goals

San José's Climate Smart San José ("Climate Smart") goals call for reducing greenhouse gas (GHG) emissions by approximately 52% below 2010 by 2030. In order to achieve these goals, the City will need to reduce its GHG emissions from each of the six emission sectors, including residential and non-residential energy, which made up 31% of GHG emissions in 2017[1]. While these GHG emissions are from existing buildings, energy choices made by new development will have a significant impact on San Jose's ability to achieve its GHG emission reduction goals given the City's development forecast[2].

In addition to reducing GHG emissions, the reach code and natural gas infrastructure prohibition ordinances are aligned with many of the key strategies under Climate Smart:

1.1 Transitioning to a renewable energy future

2.2 Making our homes energy efficient

3.1 Creating local jobs in our city to reduce Vehicle Miles Traveled

3.2 Improve our commercial building stock

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[1] "Climate Smart San Jose: A People-Centered Plan for a Low Carbon City." City of San Jose, 2018. https://www.sanjoseca.gov/home/showdocument?id=32171

[2] "Five-Year Economic Forecast and Revenue Projections, 2020-2024." City of San Jose Department of Planning, Building, and Code Enforcement, 2019. https://www.sanjoseca.gov/home/showdocument?id=45694

Adopted Reach Code and Natural Gas Infrastructure Prohibition

On 09/17/19, City Council adopted the reach code ordinance, which applies to all new construction in San José. The reach code is an overlay of the 2019 California Building Code (also known as Title 24) and provides two different compliance pathways for all-electric versus mixed fuel new construction across all building occupancy types. All-electric buildings simply need to meet Title 24's energy requirements while mixed fuel buildings are required to surpass Title 24's energy efficiency requirements, and to be "electric-ready" in the future. In addition, the reach code also requires electric vehicle charging infrastructure (EVCI) and expands solar-readiness requirements in new construction.

Following the adoption of the reach code, on 10/29/19, Council adopted the natural gas infrastructure prohibition for new detached accessory dwelling units (ADU), single-family, and low-rise (three stories or fewer) multi-family buildings. Both ordinances went into effect on 01/01/20. In addition, at the time of adoption, City Council requested that staff return to Council with an analysis as to whether the City should require electrification for all wood-frame construction up to seven stories. The purpose of this report is to provide a technical analysis on the feasibility and recommended approaches to all-electric new construction for buildings over three stories.

The Planning, Building and Code Enforcement Department (PBCE) publishes a five-year development forecast annually detailing the projected new residential and non-residential construction for San José. The table below summarizes the projected number of units for single family (375) and multifamily (roughly 2,400) homes per year and the projected square footage for commercial (1.4 million) and industrial (1 million) square feet between 2020 and 2024. Unfortunately, the City's development forecast does not distinguish between buildings based on height (i.e. number of stories), so identifying which buildings fall between 4-7 stories was not possible at the time of this report. Still, given the available forecasts, requiring all-electric new construction for buildings over three stories is expected to have a significant impact on the City's GHG emissions and will help curb future emissions. This is due largely to the assumption that San José Clean Energy's fuel mix will be 100% carbon-free by 2021; therefore, GHG emissions from all-electric buildings will be close to zero.

Five-year development forecast (2021-2025)[3]

New Construction Building Type	19/20	20/21	21/22	22/23	23/24	24/25
Single family (# of units)	580	450	375	375	375	375
Multifamily (# of units)	2,400	2,375	2,375	2,375	2,375	2,375
Commercial (sq.ft., in thousands)	2,600	1,500	1,400	1,400	1,400	1,400
Industrial (sq.ft., in thousands)	1,000	1,000	1,000	1,000	1,000	1,000

[3] "Five-Year Economic Forecast and Revenue Projections, 2020-2024." City of San Jose Department of Planning, Building, and Code Enforcement, 2019. https://www.sanjoseca.gov/home/showdocument?id=54320

Scope of this Analysis

San José's natural gas infrastructure prohibition ordinance only applies to low-rise residential buildings, which includes single-family homes, low-rise multifamily buildings (up to 3 stories), and ADUs. This report assesses the technical, economic, and market-readiness feasibility of extending that prohibition to all buildings.

This report was originally intended to only cover the feasibility of the electrification of wood-framed buildings up to seven stories. However, during the Experts' Roundtable and follow-up conversations, there was a general consensus among participants that the issues for electrification are not substantially different for mid-rise and high-rise buildings, nor for wood-framed and other structural systems. The electric equipment and technologies that are used in high-rise buildings are also used in mid-rise buildings. The main difference is that mid-rise buildings can also sometimes utilize the technologies and strategies available for use in low-rise buildings.

Structure also does not have a significant impact on the feasibility of electrification. Wood, steel, and concrete structures are all capable of accommodating electric equipment. The superior strength of steel and concrete structures may provide added flexibility for all-electric designs since they can more easily support the weight of larger volumes of hot water storage utilized in central electric heat pump designs for multifamily buildings.

This report is divided into three sections: technical, economic and market feasibility. For the purposes of this report, feasibility is considered as a combination of the following factors:

Technical:

- The feasibility of all-electric building technology and systems (e.g., HVAC, water heating), and
- The impact of all-electric building design on onsite electrical infrastructure like service sizes and onsite transformers.

Economic:

- The cost effectiveness of all-electric new construction buildings (compared with mixed fuel)

Market:

- The availability of electric equipment and technology that can be used in new construction as an alternative to gas equipment and appliances;
- The availability of the expertise to design and construct buildings that utilize that equipment and technology; and
- Market acceptance of electric alternatives to gas equipment.

Taking into account these considerations, different loads (i.e. energy demands) will pose greater and lesser degrees of difficulty to electrify in mid- and high-rise buildings. For example, the clear consensus among the stakeholders at the Experts' Roundtable (described below) was that the load that poses the greatest technical difficulty will be electrifying central water heating systems used in many multifamily and hotel buildings to serve domestic hot water load. Likewise, the clear consensus was that the load that poses the greatest market acceptance difficulty is the elimination of gas cooking. The barriers and opportunities for electrifying these and other energy loads will be discussed in greater detail in the following sections.

Sources

This report draws on several sources for this assessment including:

- **San José Building Electrification Experts' Roundtable:** In preparation for this report, San José held an Experts' Roundtable meeting in December 2019 (see Appendix A: Building Electrification Experts' Roundtable Participants) on the issues of electrifying mid- and high-rise buildings. This Roundtable brought together stakeholders and technical and market experts. Participants were led through a series of small group and large group discussions that explored the issues. The results of the Roundtable provide substantial insight for the City into the issues involved in building all-electric mid- and high-rise buildings.
- **Electrification Cost Effectiveness Reports:** The California Utilities Codes and Standards Program produced a series of cost effectiveness reports to support the adoption of electrification reach codes like San José's. It includes the costs and savings of all-electric designs for mid- and high-rise buildings. For the mid-and high-rise buildings studied, the reports found that all-electric buildings were less costly to construct than mixed-fuel buildings due to the considerable savings in gas infrastructure.[4]
- **Other Sources:** There are also other sources for information used in this report, including additional discussions with stakeholders, other reports and conference and webinar presentations, particularly presentations given by Ecotope, Inc., market research and interviews conducted by Building Electrification Initiative (BEI), and Steven Winter Associates, Inc. at the 2020 ASHRAE Winter Conference in Orlando, Florida.

Feasibility & Approaches to All-Electric Buildings

This section assesses the feasibility of electrifying the various gas loads common in mid- and high-rise buildings.

Technical Feasibility

The following sections of this report address the natural gas loads common in mid- and high-rise buildings individually, including water heating (both domestic and service), space conditioning, cooking (both residential and commercial), clothes drying, and additional miscellaneous loads.

Water Heating

It is important to note that electric water heating equipment includes both lower-efficiency electric resistance and higher-efficiency heat pump technology. The low efficiency of electric resistance equipment makes it very difficult for a building that includes electric resistance water heating to comply with Title 24. Therefore, this section focuses on the feasibility of heat pump-based systems and the technical issues of the way that they operate. While resistance-based equipment generates its own heat, heat pump-based systems actually move heat from the surrounding air or another source into the water. As they work by moving existing heat rather than generating it, heat pump water heaters are

[4] "2019 Nonresidential New Construction Reach Code Cost Effectiveness Study." Prepared by TRC Advanced Energy and EnergySoft for California Energy Codes and Standards Statewide Utility Program. Draft – 2019.

capable of achieving levels of efficiency 3-4 times their electric resistance counterparts and 4-5 times as efficient as their gas counterparts.

There are a handful of high-level technical considerations in the use of heat pump equipment for water heating:

- For a number of reasons[5], heat pump water heating systems are most cost-effective when designed with large storage capacity and relatively slow recovery (lower heating capacity). For example, a load that could be served by a 40-gallon gas water heater would generally require a 50-gallon tank with a heat pump water heater. These larger storage volumes need to be incorporated into the building design.
- Most heat pump waters simply use ambient air as their heat source, so generally the source of heat is the air around the heat pump. The heat pump therefore needs access to a large enough volume of air to provide the heat to “pump” into the water. When heat pump water heaters are located indoors, this is an important consideration. If heat pumps are located in a traditional “boiler room”-sized or water-heater closet-sized space, they need a supply of ducted outside air to prevent over-chilling of the room, similar to how gas boilers require a large volume of combustion air and exhaust ductwork. Another option is to locate the heat pumps on the roof or in a below-ground garage where there is a sufficient air resource. Some heat pump water heaters utilize a ground source loop that pulls heat from underground, or from warm wastewater, and therefore do not need access to air.
- Since heat pump water heaters take heat from the surrounding air, they will cool and dehumidify the area where they are located. This can actually be advantageous in some circumstances.
- Heat pump water heaters generate noise with their compressor and fan, similar to air conditioners, chillers, air-handlers and other types of equipment. The level of noise varies considerably between products, and continues to drop from that of earlier generations of equipment. Additionally, water heaters are often located in locations where noise is not a significant issue. But noise can be an issue in some applications.
- Some heat pumps are far less efficient when reheating warm water compared to heating cold source water. This has an impact on the design and equipment selection in central water heating systems (discussed in greater detail below).

Hot water is delivered by two basic configurations of equipment: individual and central water heating systems. Hot water is sometimes categorized as domestic hot water and service hot water, but it is really these differences in the systems that create and deliver hot water that are important.

[5] These reasons for large storage and small heat pumps include: 1) Heat pumps use electricity, which is subject to demand (kW) charges, so smaller heat pump capacity will reduce demand charges; 2) smaller heat pump capacity will reduce wiring and electrical service requirements to the building, which reduce first cost; 3) time-of-use electricity pricing makes it beneficial to avoid using electricity during peak and partial-peak hours, and large storage capacity can potentially enable a HPWH system to ride through those periods without operating the heat pumps at all, then re-charge the tanks during off-peak hours when prices are low.

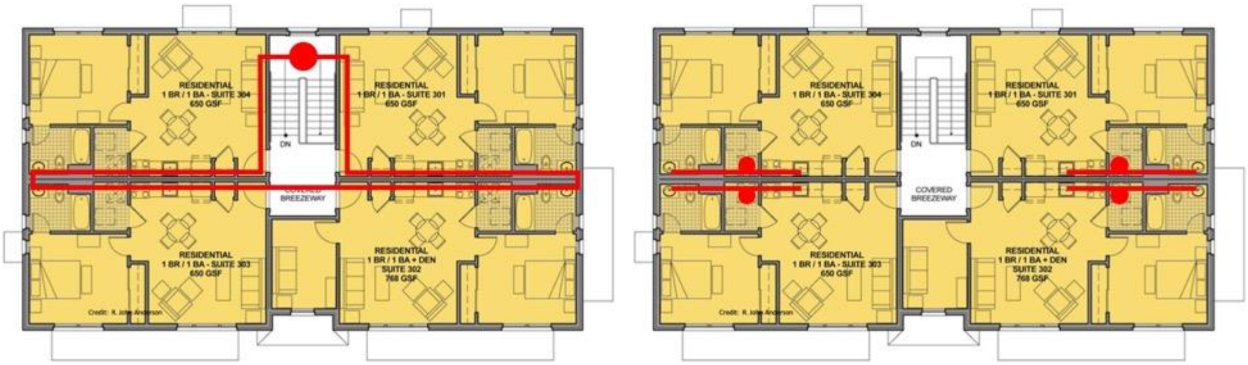


Figure 1: Central water heating with recirculation loop (left) versus individual water heaters (right) connected directly to the hot water points of use.

In individual water heating systems, the water heating equipment and the points of use for hot water are located close together and hot water flows directly from the equipment to the point of use. They cannot be located too far apart or else it will take too long to get hot water from the equipment to where it is needed. These systems are generally smaller (like the water heater in a single-family residence), but can be quite large in applications like restaurants or laundries.

In a central system, there is greater distance between the water heating equipment and the points of use and the points of use are not connected directly to the equipment. Instead, both the equipment and the points of use are connected to a recirculation loop that distributes hot water around the building. The recirculation loop ensures that there is always hot water near the points of use even though they may not be near the water heating equipment. The recirculation loop has to be kept hot when hot water draws are needed, which can be most of the day in buildings like apartments. The heat losses from a recirculation system can be substantial. Anecdotally, in systems with very efficient water heating equipment, heat losses from the distribution system can account for half of the total energy use of the entire water heating system.

The decision of whether to use an individual or central system is generally driven by the cost and/or value of square footage in the building. As buildings get taller, the higher value of space tends to incentivize the use of central systems with their lower total space requirements.

Individual Systems

Individual systems are used in both residential and commercial occupancies in mid-rise and high-rise buildings. Individual systems are generally 50- to 120-gallon integrated heat pump water heaters, where the heat pump and the water storage tank are integrated in a single piece of equipment. Split-systems can also be used, and allow for larger storage tanks for larger loads.

In mid-rise buildings the 50- to 80-gallon tanks may be found in closets within the apartment, or in closets off the central hallway. Individual tanks vented to the interior of an apartment should be selected for their acoustic ratings—some brands have not invested in sound attenuation as much as others, and 49 decibels (e.g. Rheem brand) is experienced as half as loud as 55 decibels (AO Smith, Bradford White). Acoustic treatments can buffer the sound of louder products. When heat pump water heaters are located in a water heater closet, access to sufficient air is a significant issue. Louvred doors may not provide sufficient airflow into the closet, and ducting may be required. Venting water heater closets to the hallway is an option to address concerns about noise, but could have an impact on the space conditioning of the hallway.

Individual systems are frequently used in commercial buildings for individual lavatories or kitchenettes. These are often smaller integrated units. Larger equipment is also used for commercial kitchens and laundries and are therefore more likely to be split-systems.

One kind of individual system resembles a central system. In a clustered system, a larger piece of equipment is used to serve multiple points of use, but without the use of a recirculation loop. Wait times for hot water are minimized through minimizing the volume of water between the water heating equipment and the furthest end use. This can be done through the use of a manifold connected to narrow pipe (such as 3/8") or a central supply line that has been reduced to the minimum size necessary. This is most frequently seen in multifamily buildings where the hot water points of uses in multiple units are clustered closely together.

Central Systems

Central systems are also used in both residential and commercial occupancies in mid-rise and high-rise buildings. In central systems, the water heating equipment is located in a single central location or distributed central locations. In larger buildings, it can make sense to break the building into multiple water heating zones, but this is not unique to heat pump water heater systems.

Central systems are far more common than individual systems in buildings with larger, but distributed, water heating loads, especially mid- and high-rise multifamily buildings and hotels. If the loads are smaller and distributed – like bathrooms and kitchenettes in a large office building – multiple individual water heating systems are typically used. Central systems also will sometimes utilize multiple larger integrated heat pump water heaters ganged together, but this is less common than split systems in central systems.

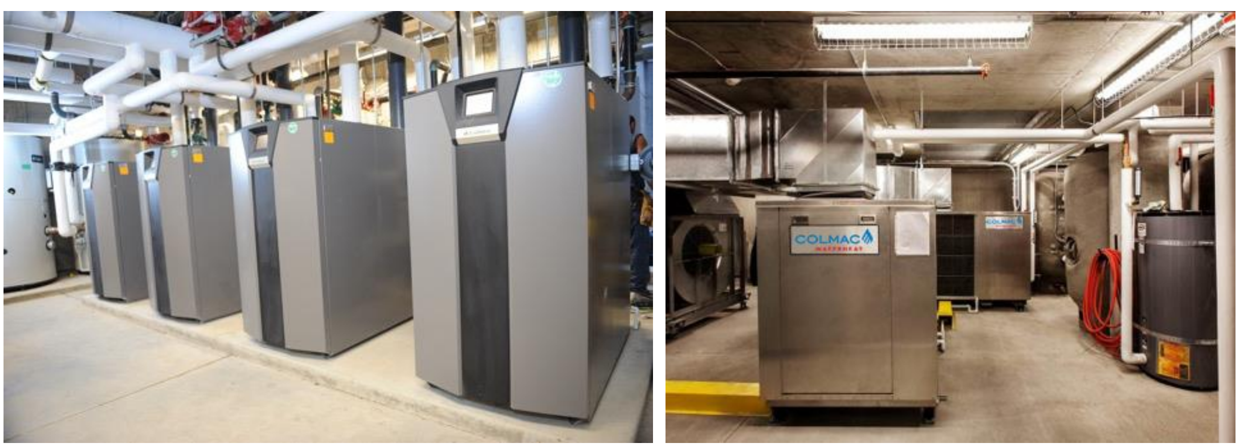


Figure 2: Central gas water heating system (left) and central heat pump water heating system (right).

The defining feature of most central systems is the recirculation loop. Hot water is pumped through the recirculation loop to bring hot water closer to the points of use. The water in the recirculation loop needs to be kept hot when hot water draws are expected. In effect, there are two hot water loads: heating cold water for use in the building and maintaining the temperature in the recirculation loop. In a gas boiler system, these two loads are typically served simultaneously by the boiler with only minimal storage. The warm return water from the recirculation loop is simply routed back through the boiler to be reheated.

However, the strategy of piping recirculation return back to the main hot water plant can create an issue for some heat pump water heaters, most notably those that use CO2 refrigerant. These heat pump water heaters are extremely efficient when heating water in a "single pass" from very cold to very hot, but are not as effective at reheating warm water. Therefore, if warm water is recirculated to a single-pass heat pump, the efficiency of the system can drop dramatically to near levels delivered by electric resistance equipment. The recommended approach for addressing this issue with single-pass heat pump water heaters is to separate the water heating and recirculation loop temperature maintenance loads and serve them with separate equipment. With this strategy, a heat pump water heater that is more effective at heating cold water can be selected to heat incoming cold water, while a heat pump water heater that is more effective at heating warm water can be used to keep the recirculation loop hot. Some practitioners have developed some highly effective and sophisticated strategies to maximize the efficiency of the single-pass approach with separate recirculation. These approaches are more complex, but maximizes efficiency.[6]

Some heat pump water heating equipment is more effective at re-heating warm water. These systems use what is known "multi-pass" operation, in which water from the tank is brought through the heat pump multiple times, each time adding 6-10 degrees of heat before being sent back to the storage tank. Multi-pass HPWH systems can be connected directly to the recirculation loop like a traditional gas boiler system, which simplifies design. This strategy can be used for many central heat pump water heating systems on the market that use traditional refrigerants like R134a, including products from AO Smith, Colmac, and Nyle, all of which can heat warm recirculation return water with less efficiency loss.

The large hot water storage tank used in central heat pump water heating systems can also pose a design challenge. Gas systems typically use large-capacity gas boilers with smaller tanks – with an overall smaller system footprint – to meet hot water demand. Designers will need to accommodate these larger tanks, which could contain thousands of gallons of water in some buildings, in their designs, ideally very early on. This will result in a change in the layout of the mechanical rooms in some buildings. However, there are numerous examples of this approach on mid-and high-rise housing in the San Francisco Bay Area. One potential source of additional space for these large HPWH storage tanks is the area vacated by deleting solar thermal (and the associated large storage tanks) in favor of additional solar PV (recommended for HPWH).

Access to air can also be an issue for large central systems. The heat pumps cannot be located in the same kind of small rooms typically used for boilers without ducting or dedicated ventilation. The ambient air in an enclosed room simply won't have sufficient heat for the larger water heating loads. Mechanical rooms can be vented to bring in outside air through louvers on the wall or an areaway to a basement. The heat pumps themselves can be vented to the outside, and most split system units are designed to accommodate this venting if needed. Heat pumps can even be ducted to the exhaust air of

[6] In fact, most of the more challenging technical issues in central water heating systems in taller buildings are not due to electric vs gas equipment at all, especially the issues with pressure that result from piping water vertically in a tall building.

the building and recover the waste heat and improve efficiency, or use the garage exhaust system as a source of outside air.

Modeling and Code Compliance

Until recently there has been a modeling barrier in Title 24 for central heat pump water heating system in mid-rise and high-rise buildings. In February of 2020, this problem was resolved with the release of Title 24 functionality for high-rise central heat pump water heaters. The initial software functionality is for a single product that has been extensively installed and field tested in California since 2017, made by Sanden. For heat pump water heaters not yet field tested, the CEC has allowed central heat pump water heater systems comply with Title 24 Prescriptively, even when code compliance for the rest of the building is being demonstrated with the Performance path.[7] This makes it possible to demonstrate compliance with products by other manufacturers (e.g. Colmac, Nyle) without waiting for field testing, or seeking an extraordinary design approval which could add considerable time to the approval process.

Transforming the Market for Central Heat Pump Water Heating

Based on our research and conversations with practitioners at the Expert's Roundtable, the technology for individual water heaters is already widely available. Most of the barriers to the electrification of individual water heaters can be solved with thoughtful design. Water heaters need to be located so that they have access to sufficient heat for the load when they are located indoors. Where heat pumps are located indoors, the issue of noise will need to be addressed, but this can be addressed with careful selection of location. San José's climate allows the heat pump to be located outside, which can solve both issues. Alternately, the issues of noise and access to heat can be addressed with vented heat pumps that allow heat pumps to be located in smaller and/or acoustically isolated spaces.

The biggest barrier to the electrification of central water heating systems in new construction is that the gas equipment cannot just be replaced with a heat pump water heater. A central heat pump water heater system has different design requirements that, while not especially complicated, are different from the standard designs for gas systems that have prevailed for years. According to interviews with some practitioners, the learning curve for central heat pump systems is much less than other high-performance systems like chilled beams and ground source heat pumps.

The consensus of the Roundtable participants was that the technology for these systems is widely available, even though finding it through distributers can occasionally be an issue. They identified the primary barrier as the need for more practitioners with experience and expertise with these systems. Right now, there are a small number of firms successfully designing these systems, so there is a need to transfer the knowledge and lessons learned by those pioneers to the broader market. The Roundtable participants suggested a handful of strategies that the City might employ to address this issue:

- **Design workshops:** The City could host professional development workshops where more experienced practitioners can train their peers how to effectively design central heat pump water heater systems. These workshops would preferably come with professional education credits since practitioners already have a need for continuing education. There is also a robust professional education infrastructure in the Bay Area to keep professionals informed of the

[7] "Executive Director Determination Pursuant to Section 1501(c)8C for Central Heat Pump Water Heating System." efiling.energy.ca.gov/GetDocument.aspx?tn=231318&DocumentContentId=63067.

regular code updates and the constantly changing market. The City could partner with other South Bay jurisdictions that have passed electric reach codes to host trainings.

- **Technical support from the City:** The City could contract some of the more experienced practitioners to assist and mentor project teams with less experience. In this way, the experience of the small number of experienced practitioners is spread out more broadly. Practitioners who are new to the design approaches would learn from more experienced practitioners and would have greater success in their early projects.
- **Guidance Documents:** A technical guide on how to design central heat pump water heating systems could be used by practitioners unfamiliar with the systems. There is a broader need for this kind of guidance, so San José may be able to partner with other organizations in its creation.
- **Equipment Manufacturers:** Many manufacturers of equipment hold regular education and training sessions at their distributors or in the offices of design engineers. Two such trainings have been held in the Bay Area in the past year. The City could host similar training sessions open to the profession.
- **Utility Continuing Education Programs:** PG&E also provides education and training series, as shown here: https://pge.docebosaas.com/learn**.**

Space Heating

Air conditioning and ventilation are already almost universally provided by electric equipment for cooling, so the only real consideration for the electrification of HVAC loads is space heating. One fundamental consideration for the electrification of buildings is that electric heat does not necessarily mean electric resistance heat. Just as heat pump water heater can produce hot water far more efficiently than resistance water heaters, heat pump space conditioners can produce warm air far more efficiently than resistance heat systems. It can be difficult, if not impossible, to meet the energy requirements in Title 24 with electric resistance equipment unless they are serving small loads. There are some concerns about the performance of heat pumps in cold climates, but this is not a significant concern in San José's relatively mild climate.

The consensus of the Roundtable participants was that electric heating technologies mid- and high-rise buildings are already widely used and generally understood. Some mid-rise buildings can use the same technologies and equipment used in low-rise buildings. For example, some multifamily buildings use split-system heat pumps where each unit has its own outdoor heat pump located on the roof. Many buildings can also use Variable Refrigerant Flow (VRF) systems where multiple indoor units are connected to a single outdoor heat pump. There are limits on how long the refrigerant line that connects the indoor and outdoor units (these vary by equipment), so they are more common in mid-rise buildings (although they can be used in high-rises with careful design). The through-the-wall packaged heat pumps that are common in hotels can be used in taller buildings, and only become less common when buildings start to use curtain wall systems.

As buildings get taller, they have fewer system options in general, not just in all-electric buildings. Mixed-fuel high-rise buildings generally use a chiller and boiler to provide cooling and heating respectively to equipment inside the building. Heat pumps and "reverse chillers" can be used in place of boilers. It is important to note that as buildings get taller, they become more and more dominated by cooling loads and less by heating loads. This means that a tall building can be providing air conditioning to the spaces even during the winter when people's homes would be providing heat. As a result, as buildings get taller, the cooling equipment becomes more dominant and the heating equipment becomes smaller. This makes it easier to electrify the heating equipment.

The equipment and expertise are already readily available to electrify HVAC equipment, so this does not present a significant barrier to all-electric mid- and high-rise buildings.

Cooking

The issues for the electrification of cooking loads are very different for residential and commercial kitchens. While cooking ranges and cooktops are the primary issue for residential cooking, commercial kitchens have a much wider array of gas equipment that includes equipment like gas fryers. However, electric equipment already exists for both residential and commercial kitchens. Large portions of the U.S. do not use gas but rely primarily on electricity for their energy needs, yet they still cook food, so equipment is not the primary issue for electrifying cooking loads. In commercial kitchens, there are electric alternatives to all major appliances.

The technical feasibility issues for cooking have considerable overlap with market perception (discussed later in this report), but there is a genuine technical difference between cooking on gas ranges and traditional electric ranges. With gas ranges, the temperature can be changed more quickly and more minutely than traditional electric stoves. Electric resistance coil and ceramic cooktops tend to have a significant lag when changing temperatures and this has an impact on cooking. However, electric induction ranges offer a solution to this issue. These use an electromagnet field to “induce” heat in ferrous cooking vessels like pots and pans. They allow the temperature to be changed as quickly and minutely as gas. Therefore, even for cooking ranges, adequate electric equipment alternatives exist.

Clothes drying

Electric clothes dryers are widely available at the residential scale. Comments made at the Roundtable indicate that the market does not seem to have a preference for either gas or electric dryers. Larger “commercial” electric dryers are also widely available. However, as commercial dryers approach the very large sizes sometimes used in commercial laundries and hotels, electric models become less common. All-electric buildings with very large laundry loads, such as hotels, may need to alter their designs to accommodate different equipment layouts that utilize different dryer models. Heat pump dryers can also be an effective alternative to gas dryers.

Other Gas Loads

Mid- and high-rise buildings can also have other, less common gas loads. These have their own considerations and are addressed briefly below:

Gas Fireplaces: There are electric alternatives to indoor gas fireplaces. One technology utilizes LED lighting to create a fairly convincing approximation of flames. It is worth noting that gas fireplaces were introduced as an alternative to wood fireplaces, and they too were only an approximation of the wood fires they replaced.

Gas barbeques: There are electric alternatives to free-standing gas barbeques. Additionally, while it is less than ideal considering San José’s Climate Smart goals, most free-standing barbeques are fueled by propane, which would not be impacted by a gas infrastructure prohibition.

Swimming Pools: Swimming pools often use gas boilers or water heaters to maintain pool temperature. Heat pump boilers are capable of filling this purpose. Additionally, many pools make use of solar thermal systems that use solar energy to heat water, so it is possible to eliminate this gas load without adding any electric load or equipment. The lower water temperatures needed for pools makes solar thermal heating particularly well-suited to pool water heating.

Impact on Electrical Infrastructure

The increased electrical load that results from electrification can have an impact on the electrical infrastructure that serves all-electric buildings. These considerations include the impact on electrical service and transformer size and subsequently to the utility grid infrastructure and on back-up power requirements. Impacts to the utility grid infrastructure are outside of the scope of this analysis and should be evaluated by the utility or entity responsible for maintaining the grid infrastructure.

Electrical Service and Transformer Capacity

Utilizing electric equipment instead of gas equipment does add electric load to those buildings. In mid- and high-rise buildings, this can have an impact on the electrical service size and/or the size of any onsite transformers that might be needed for the building. However, there are several important considerations that can mitigate the impact of electrification on the electrical capacity of the building:

- California's energy code is the most stringent state energy code in the U.S. California buildings are considerably more efficient than buildings in other jurisdictions and the impact of electrifying gas loads is therefore less than other jurisdictions with less efficient buildings.
- Mid- and high-rise buildings since taller buildings tend to be more dominated by cooling loads than low-rise buildings. Therefore, when heating can be provided by the same equipment that provides cooling, electrifying the heating load should not require any additional electrical capacity.
- The heating capacity (the size of the equipment) required for heat pump water heater systems is considerably less than their gas counterparts. According to stakeholders, the capacity of heat pump systems can be one quarter to one third the capacity required by gas water heating systems.
- Electrical service and transformer sizes are not very granular. There can be large steps between one transformer and the next size larger transformer and one electrical service size and the next size larger. As a result, some buildings have capacity to spare and some do not. According to participants at the Roundtable, it is very possible that some buildings will not need any additional capacity to accommodate the additional load, while others may trigger an increase in transformer service size. As a result, the impact of electrification on electrical service infrastructure costs are difficult to predict.
- Any costs that result from increases in electrical capacity would be mitigated by the savings from not installing gas infrastructure to the site. In all of the buildings analyzed by the 2019 Nonresidential New Construction Reach Code Cost Effectiveness Study, all-electric versions cost less to construct than their mixed-use counterparts.
- The biggest potential impact in the reach code on building electrical capacity is from the EVCI requirements. These will be the same regardless of whether the building is all-electric or mixed fuels.

- The electrical code allows the required capacity to be reduced when load management equipment is installed in the building. This equipment could be leveraged to reduce or avoid the need for increased electrical infrastructure in buildings due to the electrification of loads or addition of EVCI.

Back-up Power Supply

Although some buildings include back-up power for all or most loads, in most buildings back-up power is only for emergencies and only serves essential systems. Few, if any, of the loads that would be electrified in an all-electric building would be necessary during an emergency. Space heating, water heating, cooking, and accessory loads like fireplaces and pools are generally not necessary in an emergency. Therefore, electrification is not likely to have any impact on emergency back-up systems. For buildings with full backup systems, electrification would increase the size of the system needed. However, this impact can be mitigated. One of the biggest loads, water heating in multifamily buildings and hotels, already essentially has an energy storage system built in. The larger storage tank required by heat pump water heaters means that they will have a larger store of hot water to serve the building in a power outage.

Economic Feasibility

The California Energy Codes and Standards Statewide Utility program is currently working on cost effectiveness reports for the electrification of mid-rise and high-rise multifamily buildings. Both of these reports are still under development, but the mid-rise report is nearing completion and preliminary results are available. These preliminary findings show that all-electric mid-rise multifamily buildings can be less costly to construct than their mixed-fuel counterparts.

Figure 3Figure 1 shows the construction cost difference between a central gas system and two different HPWH systems. The first system is a clustered HPWH system and the second is a central HPWH system with a recirculation loop. For San Jose's Climate Zone 4, the clustered system is less costly to construct than the central gas boiler, but the central system is more costly to construct than the central gas boiler. The market for central HPWH systems is still nascent, costs are expected come down as market adoption increases, manufacturers and installers achieve economies of scale, and innovation brings new technology to market. In the meantime, the clustered approach provides a cost-competitive pathway for electric water heating in mid-rise new construction.

Figure 4 shows the cost effectiveness of the clustered HPWH system. A benefit to cost ratio greater than one implies cost effectiveness is positive, a number less than one is not considered cost effective. In order to show cost differences for all-electric mid-rise buildings, two different benefit to cost ratios are used: time dependent valuation (TDV) and utility bill impacts (on-bill). The main difference between these two is that TDV considers the cost of electricity and natural gas during different times of the day and year whereas on-bill method applies IOU rates to estimated annual electricity and natural gas consumption. When considered on an on-bill basis, the clustered HPWH system has higher annual utility costs than the gas system. On a lifecycle basis, the increased annual utility costs outweigh the first cost savings. However, these projections do not take into account two key factors: 1) State incentives that are being developed under SB1477 and SGIP programs; 2) natural gas rates are expected to increase faster than electric rates as gas output declines due to several factors. These two factors would improve the cost effectiveness of central HPWH systems.

On a TDV (Time Dependent Valuation) basis, the clustered HPWH system has lower annual costs and lower lifecycle costs. TDV takes into account the long-term projected costs of providing power during peak periods, and therefore values savings during those peak periods more.

	Central Gas Boiler DHW	Clustered HPWH DHW	Central HPWH & PV
Total Cost Per HP or Boiler	$106,105	$3,962	$14,224
Number of HPs / Boilers Reqd	1	32	15
Total Equipment Cost	$106,105	$126,778	$213,364
Year of Replacement	15	15	15
Reduction in Cost	0%	15%	15%
Replacement Cost	$68,105	$69,168	$116,408
20% Solar Thermal (npv)	$73,735		
35% Solar Thermal (npv)	$109,705		
PV Requirement (npv)			$27,855
TOTAL - CZ1-9	$247,944	$195,946	$357,627
TOTAL - CZ10-16	$283,914	$195,946	$357,627
Inc Cost - CZ1-9		($51,998)	$109,682
Inc Cost - CZ10-16		($87,968)	$73,712

Figure 3: Costs for Gas versus Electric Water Heating Equipment

WITHOUT PV											WITH 1kW-DC PER APARTMENT		
Climate Zone	Elec Utility	Gas Utility	Total Gas (therms)	Total Electric (kWh)	NPV Utility Cost Savings	NPV TDV Savings	Incremental Cost	TDV B/C Ratio	On-Bill B/C Ratio	Comp. Margin	NPV TDV Savings	Incremental Cost	TDV B/C Ratio
CZ01	PGE	PGE	97.6	-649	-$1,487	-$291	-$443	1.52	0.30	-7.2%	$4,637	$2,722	1.70
CZ02	PGE	PGE	97.9	-758	-$838	$266	-$122	>1	0.15	0.1%	$6,184	$3,044	2.03
CZ03	PGE	PGE	94.3	-606	-$940	$35	-$443	>1	0.47	-0.2%	$5,894	$2,722	2.17
CZ04	PGE	PGE	99.8	-686	-$920	$168	-$122	>1	0.13	1.6%	$6,323	$3,044	2.08

Figure 4: Cost Effectiveness of mid-rise all-electric buildings

Market Feasibility

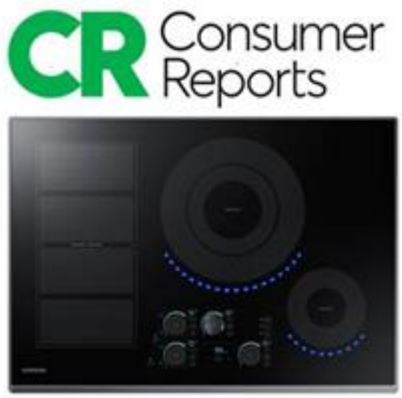
The market for all-electric new construction in the Bay Area is still at an early stage, and while it is already at cost-parity or lower than mixed fuel construction in most cases, it is reasonable to expect that all-electric new construction has significant cost reduction potential as equipment becomes more common and the workforce more familiar and more competitive on all-electric new construction. Market acceptance is not a technical feasibility issue, but it is an important consideration. Consumer perception and preferences can create a non-technical barrier to electrification that the City can help to address. According to participants at the Roundtable, the market is generally open to electric equipment and the only major market preference that could pose a barrier is the elimination of natural gas cooking.

Residential Cooking

In residential cooking, the primary barrier is a market preference for gas cooking by some consumers, and developer perception of market preferences. Gas cooking is seen as an amenity, and sometimes an essential amenity in higher-end projects. While using natural gas for cooking is more prevalent in the Northeast and West, electricity is still the most common fuel source for cooking in the U.S., particularly in the South. According to a survey conducted by the U.S. Energy Information Administration, 75% of households in the South reported having a cooking appliance that uses electricity[8]. Furthermore, there are recent studies indicating that customer perception may change with increased exposure to induction cooking. A recent customer research study conducted by the Sacramento Municipal Utility District (SMUD) found that 79% of customers had a negative impression of induction cooking prior to trying it, but a 91% positive impression afterwards. Additionally, many people believe that "gourmet" stoves are gas models, but Consumer Reports rate induction cooktops far ahead of gas in terms of performance.

2018 – 10 Top Rated Cooktops

	Score	Cooktop
1.	100	Induction - Samsung $2,000
2.	100	Induction – Dacor $3,100
3.	99	Induction – GE $1,800
4.	99	Induction – GE $1,440
5.	99	Induction – GE $2,600
6.	99	Induction – Kenmore $1,600
7.	99	Induction – Bosch $1,700
8.	97	Induction – Kenmore $1,200
9.	97	Induction – Frigidaire $700
10.	97	Induction – Frigidaire $820
...	94	top rated Electric cooktop $900
...	94	top rated Electric cooktop $1,400
...	89	top rated Gas cooktop $1,350



Residential gas cooking actually comes at a considerable cost in mid- and high-rise multifamily projects. The gas infrastructure required for gas cooking is substantial. Gas cooking also creates the need for more indoor ventilation, which increases the size and cost of the ventilation system. Because of these challenges, many mid- and high-rise residential projects already use electric cooking. Gas cooking is also very inefficient, with only about 30% of the energy consumed making it into the food, while electric cooking equipment can approach 90% efficiency.[9] Perhaps most significantly, gas cooking has a tremendous impact on indoor air quality. Gas cooking can release levels of pollutants that, if they were measured outside, would violate the Clean Air Act.[10] As a result, households with gas cooking have nearly three times that rate of treatment for asthma.[11]

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[8] Woodward, M., & McNary, B. (2018, November 19). U.S. Energy Information Administration - EIA - Independent Statistics and Analysis. Retrieved from https://www.eia.gov/todayinenergy/detail.php?id=37552

[9] Frontier Energy. "Residential Cooktop Performance and Energy Comparison Study." Prepared for Sacramento Municipal Utility District, July 2019.

[10] Gillis, J. and Nilles, B. (2019). "Your Gas Stove Is Bad for You and the Planet" The New York Times. www.nytimes.com/2019/05/01/opinion/climate-change-gas-electricity.html

[11] Jarvis et al. (1996) "Evaluation of asthma prescription measures and health system performance based on emergency department utilization." https://www.ncbi.nlm.nih.gov/pubmed/8618483

Participants of the Roundtable suggested outreach programs to address these issues. San José already has an induction check-out program where residents can check out an induction countertop unit to give it a try and has hosted induction cooking workshops. The participants suggested going beyond that program with a public service style outreach program highlighting the indoor air quality issues of gas cooking in order to counteract any market preference for gas cooking.

Commercial Cooking

Restaurants are a common occupancy on the ground floor of mid-rise and high-rise buildings and can be found in upper floors as well. Like residential cooking, the electric equipment for commercial kitchens is available. National food restaurants, for example, have both gas and electric options for their restaurants depending on what utilities are available. However, in many commercial kitchens, the use of gas is more than just a market preference. Commercial cooking is a production process and comprises part of the business model of restaurants. Professional chefs are often trained on gas equipment and the cooking processes in kitchens have often been built around the specifics of gas equipment. Therefore, electrification requires a change to production and business practices, not just market perception.

However, induction cooking is making inroads in commercial kitchens.[12] Since it only heats the pots and pans, induction cooking is safer than gas or electric resistance cooking. There is less chance of a fire, and less risk of burns from cooking staff. Induction ranges also put less heat into the kitchen, making them more comfortable and more likely to meet the new OSHA indoor occupational heat standards while also reducing cooling loads in kitchens. Many of the commercial kitchens in Silicon Valley tech office buildings are all-electric, and some global tech firms are now working to transition all of their kitchens from gas to electric.

Market Feasibility Summary

All-electric equipment exists and is readily available for both residential and commercial kitchens, so there really is not a technical barrier. The main barrier is a market preference for gas cooking. A campaign based on the negative indoor air quality impact of gas cooking may be the best approach to address this barrier in the residential market. For commercial kitchens, Roundtable participants suggested high-profile all-electric kitchen pilots to help show professionals that induction cooking is not just a viable option to gas cooking but is preferable in many ways.

Summary of Findings

All-electric mid-rise and high-rise buildings are possible in the San Jose market today. While there are obstacles to the universal adoption of all-electric buildings in San Jose, they are feasible:

- Electric equipment that can replace gas equipment is generally available. There may be some challenges with local distributers having ready access or stocking some electric equipment, but that will decrease as more and more all-electric buildings are built in San José.
- The load that poses the greatest difficulty for electrification is central water heating systems in multifamily buildings and hotels. The equipment is available, and the design approaches are

[12] Kostuch Media Ltd. (2017). Why Induction Cooking is the Hottest Trend to Hit Restaurant Kitchens. Food Service and Hospitality. www.foodserviceandhospitality.com/why-induction-cooking-is-the-hottest-trend-to-hit-restaurant-kitchens/

well established. The issue with these systems that there is a need for more practitioners who have the experience and expertise to effectively design these systems. The Roundtable participants identified a handful of possible solutions to this issue including training workshops, technical resources, and technical assistance.

- The other load that presents barriers to electrification is cooking, especially in restaurant settings. For residential cooking, there is a perceived market preference for gas cooking. For commercial cooking, restaurant staff in California have frequently been trained on gas equipment and cooking processes have been developed around gas equipment. However, there are some restaurants in California already using all-electric kitchens. Addressing both of these issues may require public outreach and pilot programs that demonstrate the advantages of all-electric cooking over gas cooking and help overcome the business practice hurdle.
- There is the possibility that electrification of mid- and high-rise buildings could have an impact on the electrical infrastructure needed both on-site (service size and onsite transformers) and the grid. This impact can be unpredictable from building to building and can be mitigated through the use of load management equipment.
- A corollary benefit is the elimination of the gas service and the additional service request and time that several workshop participants mentioned a gas service often entails.

Appendix A: Building Electrification Experts' Roundtable Participants

Participating Organization	Organization type	# of attendees
Alameda Municipal Power	Utility	1
Association for Energy Affordability	Engineering	1
Bayview Development Group	Real Estate Development and Investment Group	1
BCCI Construction	Developer/ Contractor	1
Charities Housing	Affordable Housing Development Nonprofit	1
City of San Jose	Municipality	12
Delivery Associates	Other	1
EDesignC Inc.	Engineering	1
EHDD	Architect	1
Fairfield Residential	Property Management Services	1
First Community Housing	Affordable Housing Development Nonprofit	1
Gensler	Architecture Firm	1
Guttmann & Blavoet	Engineering	1
Hawley Peterson Snyder	Architecture Firm	1
HDS Construction Corp	Other	1
IBEW 332	Union	1
Integral Group	Electrical and Mechanical Engineering Firm	1
Joint Venture Silicon Valley	Environmental Non-Profit (General)	1
KTGY Architecture and Planning	Architecture Firm	1
Menlo Spark	Other	1
MidPen Housing	Affordable Housing Development Nonprofit	3
Natural Resources Defense Council	Environmental Non-Profit (General)	4
New Buildings Institute	Technical Expert	1
Norman S. Wright Mechanical	Manufacturer (HVAC)	2
NRG Engineering	Engineering	1

Panasonic	Manufacturer (heat pump AC units)	1
Santa Clara County Housing Authority	Other	1
Silicon Valley Clean Energy	Community Choice Energy	1
Smith Group	Design Firm	2
South Main Plaza LLC	Other	1
Stanford University	Educational Institution	1
SummerHill Apartment Communities	Other	1
Tommy Siu and Associates	Other	1
Urban Catalyst Fund	Other	1
Western Allied Mechanical Inc	Manufacturer	1
Total		53