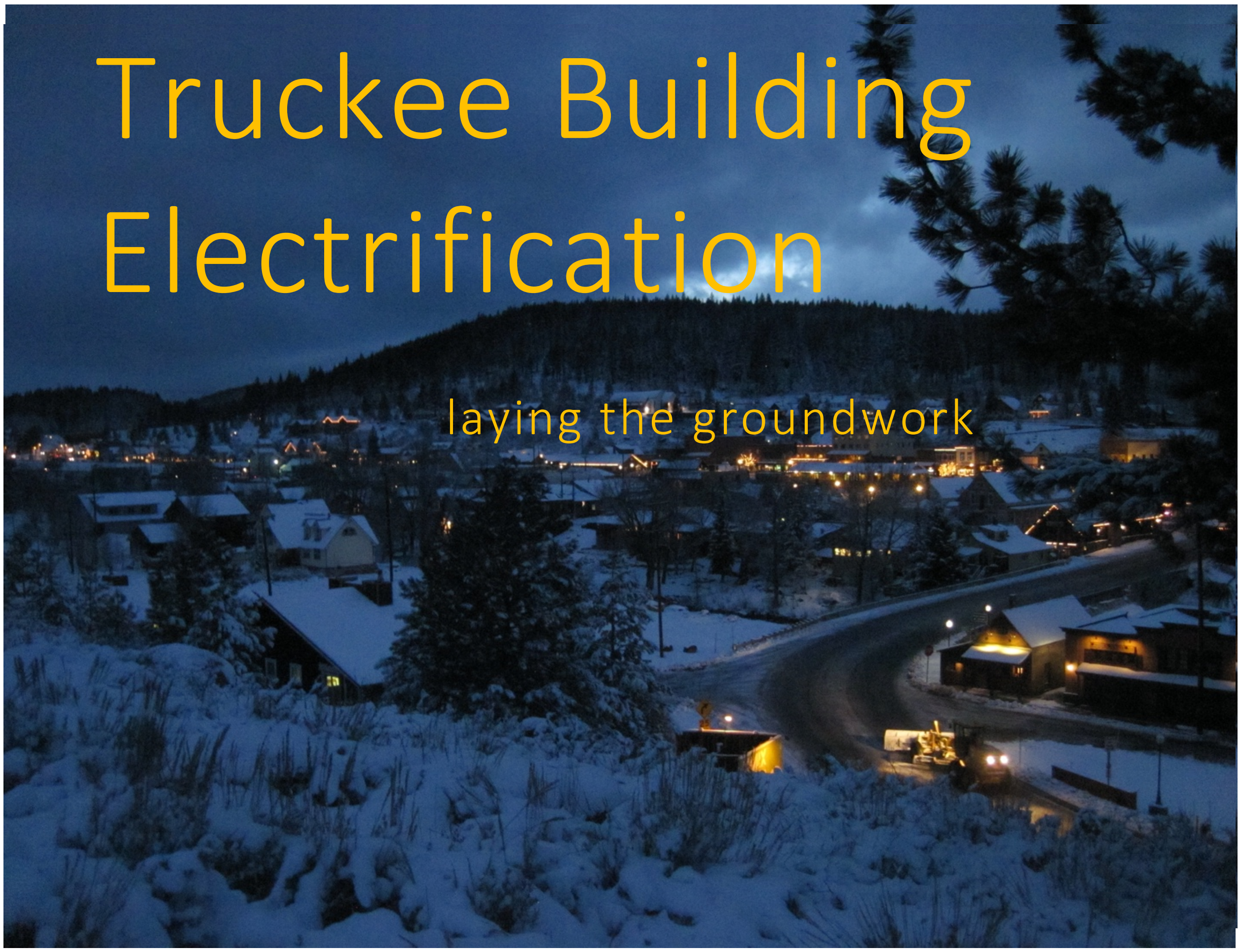

Prepared by 100% Renewable Truckee

a volunteer organization with the goal of getting Truckee to net-zero by 2050

April 2022

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Truckee Building Electrification

Introduction

In 2017, the Town of Truckee committed to reducing its greenhouse gas (GHG) emissions 80 percent below 2008 levels by 2040[1]. With the help of the Sierra Business Council, the Town of Truckee determined that building energy usage represents the largest source of GHG emissions in the community[2].

The electricity mix of the two utilities that provide power to Truckee will have very high renewable percentages in the near future. Those utilities are Truckee Donner Public Utility District (TDPUD), which provides the vast majority of electricity in Truckee, and Liberty Utilities, which provides electricity to a portion of the homes in the Glenshire subdivision[3].

TDPUD currently has an electricity mix that is 65 percent renewable, and its electricity will be 75 percent renewable sometime in 2022 when the Red Mesa Solar Plant comes online[4]. Meanwhile, 33 percent of Liberty Utilities' energy mix was generated by renewable sources in 2020[5]. Senate Bill (SB) 100, passed in 2018 by Governor Brown, requires all utilities to achieve 60 percent of generation from GHG-free sources by 2030[6]. Therefore, the majority of electricity in Truckee will be generated from clean and/or renewable sources in the near future.

The combination of high renewable electricity percentage in Truckee, along with the finding that much of Truckee's GHG emissions come from its buildings, point to the need for Truckee to focus its resources on transitioning the community's buildings from burning fossil fuels toward electrification. This will involve replacing appliances (e.g., furnaces, hot water heaters, stovetops, natural gas clothes dryers) that burn fossil fuel with appliances powered by electricity. In addition, the TDPUD will need to plan for the effects that electrification of buildings and transportation in Truckee will have on the grid: shifts in the demand profile including peak demand, impacts on integrated resource planning and challenges to maintaining adequate voltage regulation[7].

There are many comprehensive, well thought out guides on building electrification that take into consideration all aspects of electrifying new buildings and retrofitting existing buildings. Appendix I contains a list of some of these resources. Rather than recreate the information provided by those guides**, this paper will focus on the aspects of building electrification specific to the Town of Truckee, in particular the challenges that Truckee's deep snow and frequent wintertime power outages pose. We will show in this paper that these challenges can be overcome with forethought and strategic planning.**

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1 Truckee Town Council Resolution 2017-58: Establishing Renewable Energy and Greenhouse Gas Emissions Reduction Goals.
[2] Sierra Business Council. 2018. *Town of Truckee Community-Wide and Municipal-Operations 2016 Greenhouse Gas Emissions Re-Inventories.* Available: https://www.townoftruckee.com/home/showpublisheddocument/17906/636730344940930000.
[3] TDPUD. Electric Service Territory. Available: www.tdpud.org/Home/ShowDocument?id=7905
[4] TDPUD. 2021, "Truckee Donner Public Utility District Strategic Plan 2021-2024", pg. 3
[5] Liberty Utilities LLC, 2020, "2020 Power Content Label Liberty Utilities CalPeco Electric LLC"), Available: https://california.libertyutilities.com/uploads/2020_LU%20CalPeco%20PCL.pdf
[6]California Legislative Info, 2018, Available: https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201720180SB100
[7]Blonsky et al, "Potential Impacts of Transportation and Building Electrification on the Grid: A Review of Electrification Projections and Their Effects on Grid Infrastructure, Operation, and Planning", Available: https://www.osti.gov/servlets/purl/1576484

Heat Pump Basics

The electrification of buildings has been made possible by a variety of technologies, including heat pumps and induction cooktops. Because heat pumps can be used to condition a building's air and to heat water, and because those two processes are by far the most energy intensive power sinks in buildings, heat pumps and how they perform in Truckee's climate will be a major focus of this paper. Therefore, before going into a discussion of building electrification implementation, it is important to define terminology and draw some distinctions between different types of heat pumps. Appendix II points to some additional useful primers on how heat pumps work.

Heat pumps can be used for heating, ventilation, and air conditioning (HVAC), water heating, and for drying clothes. In the winter, a heat pump can transfer heat from outside air or the ground into buildings. Heat pumps that exchange heat with the air are called air source heat pumps (ASHPs), while those that exchange heat with the ground are called ground source heat pumps (GSHPs). In the warm summer months, heat pumps for conditioning air reverse direction and are used to cool homes. While heat pump water heaters in the summer continue to pump heat into the water heater.

ASHPs and GSHPs work in slightly different ways. ASHPs take outside air and blow it over a network of tubes or pipes filled with liquid refrigerant. Even though the outside air is cold, it is warm relative to the liquid refrigerant, which changes the refrigerant from a liquid to a gas. The gas is then compressed through a condenser, generating additional heat. The refrigerant—and the increased heat it stores—is then used to warm the air inside the building. Condenser units for ASHPs must be installed outside of the building envelope.

GSHPs rely on a network of either horizontal or vertical underground pipes filled with a mixture of water and non-toxic antifreeze that takes advantage of the near constant temperature of ground below a depth of 15 feet. GSHPs exchange heat with this water mixture instead of with outdoor air. Unlike ASHPs, the condenser/evaporator unit that extracts the heat for a GSHP is installed within the building envelope.

Generic Building Electrification Challenges

There are several challenges to building electrification that all towns face: securing financial resources, providing effective community outreach to influence behavior, building workforce capacity necessary to implement changes, and addressing issues associated with synthetic refrigerants.

Financing

Building electrification is an expensive undertaking. The Town of Ithaca, NY is currently in the process of attempting to electrify all 6,000 of its community's buildings. Ithaca has estimated that the total cost of the building electrification portion of the project will be $500M. Ithaca is planning to implement this ambitious plan using a financing model that leverages public funding and loan guarantees to bring private equity financing to the table[8]. 100% Renewable Truckee will be monitoring Ithaca's progress and continuing a conversation with Ithaca's Director of Sustainability to assist efforts locally.

If Ithaca's building electrification effort is successful, it is possible that a similar building electrification financing mechanism could be put into place here in Truckee. However, even if Ithaca's approach is successful, Truckee policy makers will have to determine how to finance building electrification in the community. Without secure funding, Truckee's main source of GHG emissions will continue to be a major contributor to the climate crisis.

Community Outreach and Behavior Change

In addition to the cost of retrofitting existing buildings, educating the citizens of Truckee about the urgent need to make plans and begin to implement building electrification will be critical. Resolving existing issues will require pilot projects, planning, investment capital, and time. Truckee cannot wait until 2040 to get serious about building electrification. This message needs to be communicated to the community in a consistent and urgent manner.

It is also necessary to educate the public on the efficacy of current electric appliances. Earlier generations of heat pumps did not perform well in cold climates, and some residents and HVAC installers may have negative impressions as a result. Residents and businesses may have similar perceptions of induction cooktops, which look a lot like electric resistance cooktops that can have poor performance characteristics. The public needs to be brought up to speed on the superior performance of induction cooktops even when compared to gas stoves[9]. Not only is the performance of an induction cooktop superior to a gas stove, there are significant health benefits and cost savings associated with eliminating the burning of natural gas or propane in the cooking of food indoors[10].

Lastly, Truckee residents are aware of the frequency and duration of winter storm-caused power outages. If Truckee is to successfully electrify, the Town, TDPUD, and Liberty Utilities must make significant improvements to the grid to improve its resilience to winter storms. Plans to do so must be clearly communicated to the public.

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[8] Civil Engineering Magazine, 2022, "New York municipality to electrify all buildings in a bid to decarbonize", Available: https://www.asce.org/publications-and-news/civil-engineering-source/civil-engineering-magazine/article/2022/01/new-york-municipality-to-electrify-all-buildings-in-bid-to-decarbonize

[9] Reviewed, 2021, "Induction Cooking – Here's Why You Should Make the Switch", Available: https://www.reviewed.com/ovens/features/induction-101-better-cooking-through-science

[10] California Air Resources Board, 2022, "Indoor Air Pollution from Cooking", Available: https://ww2.arb.ca.gov/resources/documents/indoor-air-pollution-cooking

Workforce Capacity Building

As is the case across the United States, the local workforce will need to grow significantly in order to address the workload for electrifying the community[11]. If workforce capacity development plans are not implemented in the near future, community-wide building electrification will be difficult to achieve. The Town, TDPUD, and the Contractors Association of Truckee Tahoe (CATT) should develop workforce capacity plans to meet the needs of the increasing workload. Ithaca is looking into a region-wide workforce capacity building effort because building a workforce of that size for a local, decade-long retrofit push does not make sense. The workers trained for this effort will need jobs for decades to come and that is only possible when a region's worth of building electrification jobs are in the pipeline.

Synthetic Refrigerants are Powerful Greenhouse Gasses

The electrification of buildings relies on heat pump technology. Heat pumps require refrigerants, which are chemical compounds that are used as a heat carrier and have been the cause of much environmental consternation. Synthetic, non-flammable refrigerants were invented to replace flammable natural refrigerants. Unfortunately, these synthetic refrigerants caused ozone depletion in the Earth's upper atmosphere. This led to the Montreal Protocol which banned chlorofluorocarbon (CFC) refrigerants worldwide. Unfortunately, this resulted in the replacement of CFCs with hydrofluorocarbon (HFC) synthetic refrigerants, which are safe for the ozone layer, but are also extremely powerful GHGs thousands of times more potent than carbon dioxide (CO_2).

Currently, the most prevalent HFC refrigerant used in heat pumps is R410a, which has a Global Warming Potential (GWP) of 2088, meaning that it has a heat trapping capacity that is 2088 times more than CO_2. According to the California Public Utilities Commission, an average of 12 pounds of refrigerant leaks from a heat pump over the course of its lifetime, most of that at the time of decommissioning. This is the equivalent of running a car for 5 years[12].

Europe is ahead of the United States in trying to address this. They are already in the process of phasing R410a out and replacing it with HFC-32. HFC-32 has half the GWP of R410a, and it is also more efficient at heat transfer than R410a, resulting in a net GWP of one-third of R410a. The downside of HFC-32 is that it is considered slightly flammable, although it is very difficult to ignite[13]. Europe and Australia have approved its use inside buildings.

One bright spot on the refrigerant front is that Sanden, a hot water heater manufacturer, offers an air source hot water heat pump (HWHP) in the United States that uses CO_2 as a refrigerant (GWP of 1). The Sanden HWHP can produce hot water efficiently down to an outside ambient temperatures of -25°F. While some field tests have

[11] Business Wire, 2021, "U.S. Skilled Trades Labor Shortage Heightens as In-Demand Jobs Remain Unfilled the Longest", Available: https://www.businesswire.com/news/home/20210318005265/en/U.S.-Skilled-Trades-Labor-Shortage-Heightens-as-In-Demand-Jobs-Remain-Unfilled-the-Longest

[12] California Public Utilities Commission, 2021, "Proposer Defined Study: A Roadmap for Accelerating the Adoption of Low-Global Warming Potential HVAC Refrigerants" Available: https://pda.energydataweb.com/api/downloads/2506/CPUC%20HVAC%20Refrigerants%20-%20PDS_05032021_FinalReport.pdf

[13] Air-conditioning and Refrigeration Equipment Manufacturers Association of Australia (AREMA), 2014, "R32 – Common Questions", Available: https://www.airah.org.au/Content_Files/TechnicalPublications/R32-Common-Questions-Sept-2014.pdf

been run to determine the effectiveness of using a Sanden HWHP to provide air and water heating[14], no commercial offerings are available at this time.

The potential for significantly lower GWP refrigerant based systems on the horizon suggests that preparations for heat-pump-based electrification should be made, but a rollout could benefit from a delay in anticipation of these lower GWP refrigerants being introduced to the domestic market before full Truckee-wide rollout.

Truckee Climate-Related Building Electrification Challenges

Winter weather in Truckee, including cold temperatures, heavy snowfall, and extended power outages due to severe storms, poses some electrification challenges that many communities in the United States do not face. Table 1 below summarizes these challenges by heat pump technology.

Table 1. Heat Pump Challenges in Truckee by Technology

Challenge	**Air Source Heat Pump**	**Ground Source Heat Pump**
Cold Climate	Yes	No
Snow and Ice	Yes	No
Power Outages	Yes	Yes

Cold ambient outside temperatures used to be a challenge to the efficient operation of heat pumps because there is less heat energy to extract from the outside air on cold winter days. However, that challenge has largely been surmounted due to improvements in heat pump technology. The wintertime snowpack in some areas of Truckee can get deep and stay deep for the entire winter, which creates a challenge of keeping the air flow of an ASHP unobstructed. Similarly, snow and ice shedding from roofs can damage the exterior unit of an ASHP system. Finally, Truckee experiences frequent winter storms which can bring isolated or widespread power outages lasting for days. This poses a problem for both ASHPs and GSHPs here in Truckee.

Cold Climate Air Source Heat Pumps

With respect to cold climate performance, heat pump technology has come a long way in a short time. There are now cold climate air source heat pumps (ccASHP) that perform effectively and efficiently in outside temperatures of 0°F and below [15] [16] [17]. The most convincing direct evidence that ccASHPs perform well in cold temperatures is that other locales with wintertime temps even colder than Truckee have installed heat pumps in large numbers. Homes and businesses in the state of Maine have installed over 100,000 heat pumps in the last 10 years. Figure 1 below shows adoption of heat pumps in Maine over time.

[14] Eklund et al, 2016, "What Does the Future of Space and Water Heating Look Like?", Available: https://www.aceee.org/files/proceedings/2016/data/papers/1_401.pdf

[15] Mitsubishi Electric, "Mitsubishi Hyper Heat Wall Mount Ductless Mini Split Air Conditioner Heat Pump User Manual", Pg. En-14, Available: https://manuals.plus/mitsubishi/mitsubishi-electric-split-type-air-conditioners-manual

[16] Fujitsu General, "Halcyon™ MINI-SPLIT TECHNOLOGY XLTH Low Temp Heating", Available: https://www.fujitsugeneral.com/us/residential/technology/xlth-low-temp-heating.html

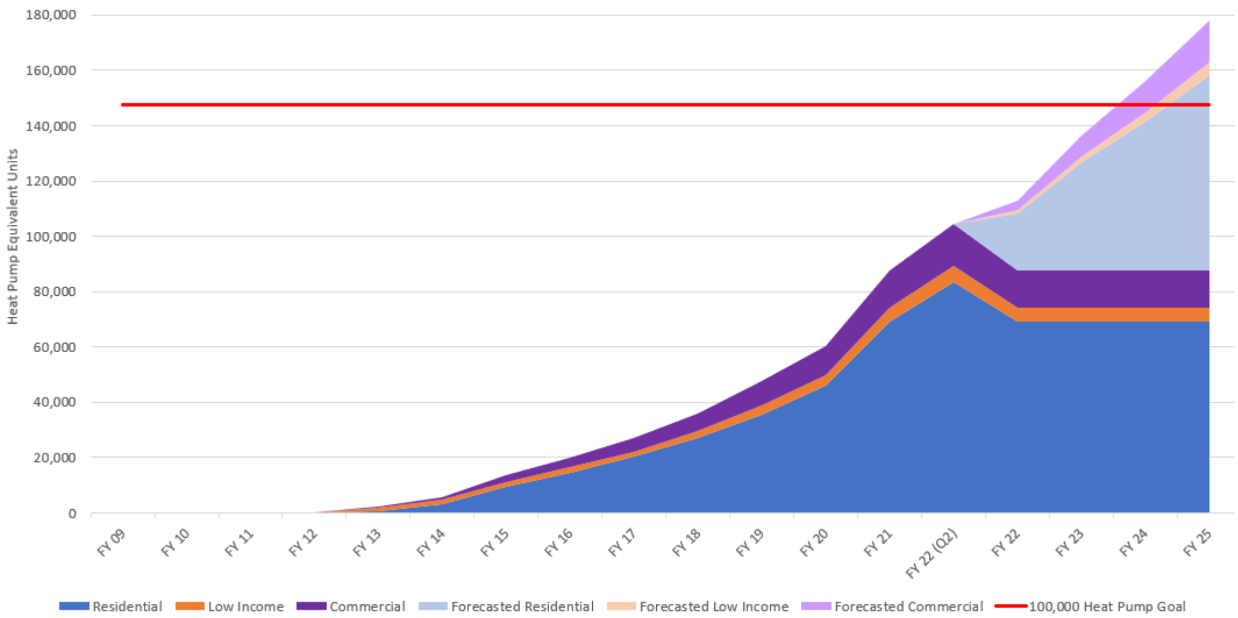

FIGURE 1 HEAT PUMP INSTALLATIONS IN MAINE
SOURCE: EFFICIENCY MAINE

Similarly, Norway has an installed 1.3 million heat pumps in recent years, with 600,000 of those being ccASHPs[18]. As of 2016, Canada had installed over 750,000 heat pumps[19].

While widespread adoption of ccASHPs in areas with a winter climate similar to Truckee is a strong indication that the technology works well, some challenges still exist. As the outside temperature decreases, the frequency of ccASHP defrost cycles goes up. When a defrost cycle occurs, the heat pump runs in reverse, effectively turning into an air conditioner while in defrost mode. This can occur for roughly 10 minutes out of every hour[20] when the outside temperature is less than 10°F This can result in an unpleasant sensation for building occupants when the system does not have backup heat.

Backup heat in the form of electrical resistance heat strips is more common in ducted HVAC systems, whereas ductless mini-split ccASHPs generally do not provide these backup heat strips. While heat strips are effective at countering this periodic flow of cold air, they are relatively low in efficiency compared to a heat pump, so incorporating them into the building HVAC system decreases the overall efficiency of the system, and since they are only available with ducted systems, the heat strip solution is not applicable to all retrofit and new build situations.

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[18]European Heat Pump Association, 2022, Available: http://www.stats.ehpa.org/hp_sales/story_sales/
[19] Canada Energy Regulator, 2019, “Market Snapshot: Growing heat pump adoption – how does the technology work?”, Available: https://www.cer-rec.gc.ca/en/data-analysis/energy-markets/market-snapshots/2019/market-snapshot-growing-heat-pump-adoption-how-does-technology-work.html
[20] NY Engineers, 2021, “How Does the Defrost Cycle Work in VRF Systems During Winter?”, Available: https://www.ny-engineers.com/blog/how-does-the-defrost-cycle-work-in-vrf-systems-during-winter

Snow and Ice

ASHP compressors sit outside the building envelope, which presents a challenge in our snowy climate. The compressor requires unobstructed air flow to perform efficiently, so if snow piles up around the unit, the air flow is significantly impeded.

FIGURE 2 HEAT PUMP BURIED IN SNOW

The solution is to either mount the compressor on the side of the building above the snowline or secure the compressor to a stand built tall enough that the compressor will be above the peak height of the snowpack. In some areas of Truckee, that can be 10 feet.

FIGURE 3 HEAT PUMP MOUNTED ON SIDE OF BUILDING

Compressors mounted on the side of the building can impart vibrations to the building interior. While vibration dampeners and careful balancing of the compressor can mitigate vibration, most installers prefer to mount compressors on the ground to avoid the vibration issue.

Commercially available stands for ground mounted compressors currently only reach up to 24 inches in height, which would be far from adequate for some areas of Truckee with higher snow loads. Custom frames can be built from wood or from commercially available steel framing.

FIGURE 4 HEAT PUMP ON STAND

It should be noted that snow load varies significantly throughout Truckee. In areas with lower average snow load, the off-the-shelf solutions noted above to keep air source heat pumps above the height of the snowpack would be sufficient. In other areas, such as higher elevations of Tahoe Donner and the west end of Donner Lake may present challenges not easily remedied by standard off the shelf solutions. In which case, a contractor might have to fashion a customized site-specific solution. This could result in a significantly higher cost of implementation.

FIGURE 5 HEAT PUMP WITH ROOF

Another challenge for locating ccASHP compressors in Truckee is snow and ice shedding from roofs. Avoiding roof shed lines is critical, but during or after large snowstorms, snow can shed from rooflines that do not regularly shed. To ensure that the compressor unit is not damaged, it is advisable to build a roof structure as shown in Figure 5.

Snow piling up around ccASHP compressors and snow and ice shedding from roofs are not the only winter storm threats. Wind-driven snow can accumulate on the intake side of the compressor. A ccASHP manufacturer published a white paper that showed how to make custom, sheet metal baffles and snow hoods to provide protection from wind and snow[21].

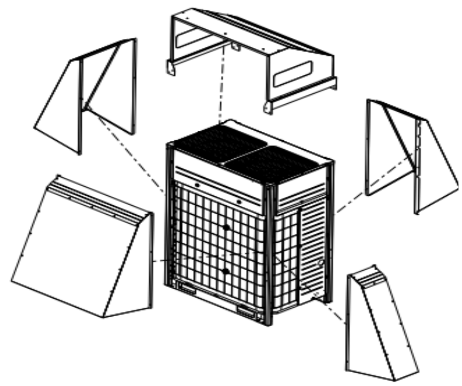

FIGURE 6 SNOW HOOD SCHEMATIC – SOURCE DAIKIN

The fact that the manufacturer designed these hoods but chose not to manufacture them shows that they believe there is need a need for his equipment in extreme winter environments, and yet the market is too limited to be commercially viable. If Truckee has a large, community-wide rollout of ccASHPs, TDPUD could contract with a local sheet metal fabricator to manufacture several versions of snow hoods for the most popular ccASHP models with an eye towards lowering the per unit cost through bulk purchasing.

There are several challenges facing widespread adoption of ccASHP technology in Truckee. None of them appear to be insurmountable, but GSHP technology may be a better fit for Truckee, as we will explore in the next section.

The Potential for Ground Source Heat Pumps

GSHPs offer several advantages over ccASHPs in Truckee's climate: they are more efficient than ccASHPs[22]; they do not have a defrost cycle; they do not have an outside unit that is subject to the snow and ice; and the system lasts longer (in part due to the fact that the heat pump unit is within the building envelope, which prolongs its life, and also because the underground pipe system can last up to 50 years).

Another consideration in GSHP's favor is that GSHPs do not split the compressor from the evaporator. This means that the refrigerant lines are factory sealed within the combined compressor/evaporator unit, resulting in a much lower likelihood of refrigerant leaks. In the case of an ASHP mini-split system, the refrigerant lines are installed by a technician on-site and charged on-site. Many joints are required to make all the connections in that system, providing many opportunities for refrigerant leaks. Also, because the distance between the compressor/evaporator is very short in the GSHP, a much smaller quantity of refrigerant is required compared to a mini-split ASHP that may have 50 feet of refrigerant lines between inside and outside units.

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[21] Daikin North America, 2017, "Applications in Extreme Climate Conditions", Available: https://www.daikinac.com/content/assets/DOC/White-papers-/BPG-EXTAMB.pdf

[22] HPAC Engineering, 2014, "Study: Geothermal Heat Pumps Outperform VRF at ASHRAE Headquarters", Available: https://www.hpac.com/heating/article/20927858/study-geothermal-heat-pumps-outperform-vrf-at-ashrae-headquarters

The major downside to GSHPs compared to ASHPs is their cost. They can be twice as expensive to install, mostly because of the cost of digging trenches and/or drilling bore holes for the ground closed loop system[23]. However, when the higher energy efficiency of a GSHP system and longer system lifespan compared to an ASHP system is accounted for, the lifetime cost of a GSHP system in cold climates could be less than that of an ASHP system[24].

How Geo-Micro-Districts Could Benefit Truckee's Electrification Efforts

A new white paper produced by an advocacy group in Massachusetts, HEET[25], along with three project pilots conducted by gas utilities[26], have recently garnered a lot attention. These efforts focus on exploring the feasibility of geo micro districts (GMD), which are utility-owned geothermal loops that connect multiple buildings to a loop installed beneath the public right-of-way (i.e., buried below the street). Building owners are only responsible for connecting their building to the GMD and installing the heat pump.

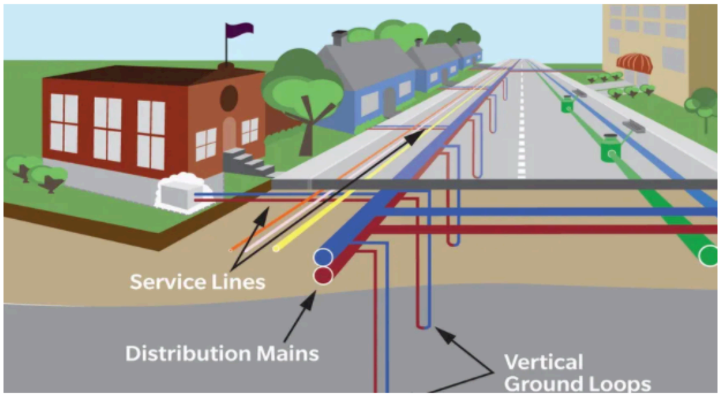

FIGURE 7 GEO MICRO DISTRICT
SOURCE EVERSOURCE

There are several benefits to implementing town-wide GMDs. First and foremost, the cost and risk in drilling bore wells can be spread amongst many buildings. The amount of time it takes to drill a bore well can vary significantly depending on the strata that the drill must penetrate, and drilling many wells can allow the utility to spread the drilling risk out over hundreds of wells. It is also likely that if many bore wells are dug at the same time, costs can be significantly reduced; digging trenches, drilling wells, installing pipes, and repaving—if done on a continual basis—significantly reduces the costs associated with the setup, breakdown, and transportation of heavy machinery. This is not the case if individual ground loops are installed for individual buildings at the building owner's expense. Another benefit is that if natural gas utilities can be convinced to switch from supplying natural gas to supplying geothermal heating and cooling, it provides a pathway to transition gas company employees to the clean energy future. Lastly, a town-wide GMD network would result in thousands of orders for GSHPs. If coordinated by the utility, these purchases could be done in bulk, reducing their cost significantly.

While the potential benefits of GMDs are significant, the HEET white paper also identifies challenges that will need to be addressed[27]. For example, State and local setback requirements for geothermal bore wells can make

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[23] Energy Sage, 2019, "Air source heat pumps vs. geothermal heat pumps", Available: https://news.energysage.com/compare-air-source-geothermal-heat-pumps

[24] Kegel et al, 2012, "Life Cycle Cost Comparison and Optimization of Different Heat Pump Systems in the Canadian Climate", Available: https://www.researchgate.net/publication/264416574_Life_Cycle_Cost_Comparison_and_Optimisation_of_Different_Heat_Pump_Systems_in_the_Canadian_Climate

[25] HEET, 2021, "Geo Micro District Feasibility Study", Available: https://heet.org/energy-shift/geomicrodistrict-feasibility-study/

[26] Canary Media, "A net-zero future for gas utilities? Switching to underground thermal networks", Available: https://www.canarymedia.com/articles/utilities/a-net-zero-future-for-gas-utilities-switching-to-underground-thermal-networks

[27] HEET, 2021, "Geo Micro District Feasibility Study", Available: https://heet.org/energy-shift/geomicrodistrict-feasibility-study

GMD systems difficult or even impossible to implement. The State of California is currently in the process of rewriting setback requirements, so this may not be as much an issue in the future. However, this supports the idea that now is the time to encourage the development of rules that would make GMD systems possible.

In addition to setback issues, researchers have identified the challenge of "thermal balance," which can result in declining performance of a GMD system over time. The ground can fall out of thermal balance if the amount of heat extracted from the ground in the winter is not replenished fully with heat in the summer so that over successive years, the ground around the bore holes becomes progressively colder. This results in a lack of heat availability during the winter. However, it is possible to restore thermal balance with the use of borehole thermal storage, which stores the heat of the summer sun within the earth for use during the winter[28] [29] [30]. Borehole thermal storage could be adapted to restore thermal balance to GSHP closed loop wells. Further investigation and development and implementation of pilot projects would be necessary to determine the feasibility of this approach. In Massachusetts, where gas utilities are implementing pilot projects, they are proposing gas boilers shared among many bore wells to restore thermal balance if necessary.

Power Outages and Backup Heat – the Status Quo

Wintertime power outages are a fact of life in Truckee. The question of how a fully electrified home will manage during these power outages is a serious one. Depending on how well-insulated and how much direct sun a home gets, an unheated home can become uninhabitable within hours without some form of emergency backup heat; in these cases, occupants need to winterize their homes and evacuate. The "winterize and evacuate" strategy is currently recommended by TD PUD for homes without backup heat in the case of prolonged power outages.

Most homes in Truckee rely on gas or propane furnaces for their primary source of heat. Generally, these systems will not function in a power outage because they rely on electricity to operate their thermostats and fans. Many homeowners have multiple heating systems in their homes, such as a wood stoves or gas fireplaces, both for aesthetics as well as a source of emergency backup heat.

Some Truckee homeowners have purchased gas generators or batteries, such as the Tesla Powerwall, to provide electricity during a power outage. These supplemental sources of electricity can potentially allow furnaces or gas-powered hydronic systems to continue to function in a power outage, but these systems burn fossil fuels. In order to truly decarbonize the community, additional plans for heating homes during winter power outages are needed.

Power Outages and Backup Heat - the Electrified Home

A growing number of homes in mild climates have enough solar and battery power to get through power outages[31]. However, when a home is fully electrified in a cold climate, the added load of heat pumps for space and water heating will quickly drain a home battery. A recent study on GSHPs in the northwestern United States showed that GSHPs providing water and space heating could draw up to 40kWh per day, while a Tesla

[28] EnergyLink, 2020, "Borehole Thermal Energy Storage: Everything You Need to Know", Available: https://goenergylink.com/blog/borehole-thermal-energy-storage-need-to-know/
[29] ICAX, 2022, "Thermal Bank installation store heat between seasons and save carbon emissions by re-cycling Renewable Heat through Inter-seasonal Heat Stores", Available: https://www.icax.co.uk/ThermalBanks.html
[30] Ruess, 2021, Advances in Thermal Energy Storage Systems, Available: https://www.sciencedirect.com/book/9780128198858/advances-in-thermal-energy-storage-systems
[31] FastCompany, 2019, "To keep the lights on during California's blackouts, people are using solar power", Available: https://www.fastcompany.com/90415303/to-keep-the-lights-on-during-californias-blackouts-people-are-using-solar-power

Powerwall holds only 13kWh[32]. Also, as an equity issue, low- and middle-income families will find it difficult to pay for a bank of home batteries capable of powering heat pumps during a power outage. Therefore, even if it becomes technically feasible to power a fully electrified home in a cold climate with batteries through a power outage, this may not be a practical policy solution.

Many Truckee homes that are already using pellet stoves or wood stoves for backup heat are using a net-zero form of fuel. Official carbon accounting may not view these sources of energy as net-zero, but nevertheless a fuel coming from a plant or a tree that captures carbon from the air as it grows is not adding additional carbon to the atmosphere when it is combusted. This is a complex issue in that most wood pellets are currently manufactured in a carbon-intensive process, and if the source wood used to make pellets is harvested unsustainably and transported over long distances for manufacturing, the wood pellets are not a net-zero fuel. However, in Truckee, we face significant threats from wildfires, and this risk can be mitigated by mechanical forest thinning resulting in thousands of slash piles. If some portion of forest slash were converted to wood pellets without using a fossil fuel-dependent process, wood pellets could be an environmentally sound option for emergency backup heat here in Truckee. Pellet stoves require small amounts of electricity to run their thermostats and fans, so a home battery or gas generator (running on renewable net-zero fuel) would be needed to keep them running.

Wood stoves on the other hand are less problematic in that wood does not require fossil fuel-intensive processing, and if the source wood is locally and sustainably harvested, it is also an environmentally sound form of backup heat. Wood stoves have the advantage over pellet stoves of not requiring any electricity to operate.

However, many homes in Truckee rely on natural gas or propane fireplaces to provide backup heat. As these burn fossil fuels, the question is whether it will be feasible to replace these fireplaces or retrofit them to use renewable, net-zero fuels. Renewable propane[33], if it becomes commercially available, will be significantly more expensive than today's fossil fuels because of the large amount of energy needed to produce them and the high capital cost of the equipment needed to manufacture them. In addition to the issue of cost, there are other issues related to renewable fossil fuels including their carbon intensity and availability[34].

Power Outages – Building a More Resilient Grid

Solving the problem of how to provide backup heat in the case of a power outage does not address all power outage concerns. For instance, homeowners that replace their gas ranges with induction cooktops will not be able to cook during a power outage. Due to recent record breaking, intense winter storms, Truckee residents are aware of the fragility of the existing grid. Getting community support for town-wide building electrification will require credible assurances that improvements to grid reliability are planned and will be implemented.

Undergrounding our local distribution system would significantly increase the resilience of our local grid to power outages. However, the Tahoe Donner Homeowner's Association conducted a survey of its homeowners and found that members opposed the project by a margin of three to one due to the high costs of the project,

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[32] Eklund et al, 2019, "What Does the Future of Space and Water Heating Look Like?", Available: https://www.aceee.org/files/proceedings/2016/data/papers/1_401.pdf

[33]Rouch Cleantech, 2022,"Renewable Propane: The Near-Zero Solution", Available: https://www.roushcleantech.com/renewable-propane-the-near-zero-solution

[34] Sightline Institute, 2021, "The Four Fatal Flaws of Renewable Natural Gas", Available: https://www.sightline.org/2021/03/09/the-four-fatal-flaws-of-renewable-natural-gas

which were estimated to be $30,000-35,000 per property[35], and promptly dropped the project. However, if TDPUD implemented a GMD project, construction costs to dig up the streets could potentially be shared with the undergrounding project. It is also possible that if we could commit to a town-wide building electrification plan similar to that of Ithaca's, Truckee could roll undergrounding of utilities into the overall cost of the project by making the case that grid reliability is crucial to the success of the electrification program. Furthermore, if the undergrounding project was rolled into a GMD project, there is potential for overall project savings.

However, our distribution system is not the only source of power outages in Truckee. TDPUD and Liberty Utilities rely on NV Energy's transmission line network, which is a frequent source of local power outages. To address this source of power disruptions, a utility-scale long duration storage project could be installed at the Truckee Tahoe Airport. This long duration storage could provide power during winter storm-caused outages and outages from Public Safety Outage Management events during wildfire season. Simultaneously, this would increase the percentage of renewables in TDPUD's energy generation portfolio. A feasibility study for long duration storage in Truckee is needed to determine specifics such as projected load, whether what combination of distributed and utility scale consolidated storage facilities make sense, and determining where long duration storage could be implemented, and what per kWh cost and density of available long duration storage technology should trigger initiating a long term duration storage project in Truckee.

Efforts are underway to create incentives to bring the cost of long duration storage down[36], and costs of long duration storage are projected to fall rapidly as more systems are deployed. This technology is in its infancy, and there are several varieties of long duration storage technologies with no clear front-runner. Technology advancements will also be required before costs decline significantly[37]. Even so, setting aside land at the airport and including a long duration storage facility in the Airport Board's planning process when considering other projects at the airport will be important to ensure that when the time comes to implement a long duration storage facility, there is land available to implement it.

Recommended Next Steps

Now is the time to initiate studies and pilot projects that will help the Town of Truckee and the other Truckee districts (e.g., TDPUD, Truckee Tahoe Airport, Tahoe Truckee Unified School District) strategically plan our future electrification efforts. These efforts will undoubtedly require collaboration between the various districts in Truckee. We suggest the following next steps:

- **[Town of Truckee, TDPUD]** The City of Boulder, Colorado commissioned a white paper on building electrification (Renewable Heating and Cooling in Boulder: Strategies for Electrification of Residential Heating & Cooling). A comprehensive study along these lines, specific to Truckee, would be a crucial document to help Truckee plan an electrification strategy. Some key pieces of information to be included

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[35] Sierra Sun, 2006, "Tahoe Donner buries underground utility plan", Available: https://www.sierrasun.com/news/tahoe-donner-buries-underground-utility-plan/

[36] U.S. Department of Energy, 2021, "Long Duration Storage Shot", Available: https://www.energy.gov/sites/default/files/2021-07/Storage%20shot%20fact%20sheet_071321_%20final.pdf

[37] Energy Sage, 2021, "Long duration storage: what you need to know 2021", https://news.energysage.com/long-duration-storage-what-you-need-to-know/

in the report are a survey of the existing building stock, a comprehensive analysis of possible funding sources and financing mechanisms.

- **[Truckee Tahoe Airport, TDPUD, Town of Truckee]** Study setting aside land at the airport for long duration storage (possibly paired with utility-scale solar) to improve grid resilience and increase of TDPUD's renewable energy generation sources. A feasibility study for such a project is also needed to determine the amount of energy required and a plan for distribution of back-up electricity. An overall plan for back-up electricity and grid resilience should also consider subsidization of distributed batteries to be located in homes and businesses.
- **[TDPUD]** Study how a utility undergrounding effort could be subsidized by State and federal dollars, making the case that grid resilience in Truckee is a requirement for a community-wide building electrification plan, and secondarily as a wildfire mitigation measure. These sources of funding could be critical to making undergrounding affordable.
- **[TDPUD, Town of Truckee]** Study GMD implementation in Truckee. Drill test bore wells in various locations around Truckee to determine thermal transfer characteristics and gain a better understanding of the required number of wells and depth of the wells to support Truckee's building heating needs. Study State and local setback requirements for geothermal bore wells to determine whether these requirements would make GMD implementation difficult or impossible. Determine whether Southwest Gas or the TDPUD would be the better utility to implement GMD. Implement a pilot project, perhaps on a below-market rate housing project that includes some form of thermal energy replacement during the summer using the bore well thermal storage concept.
- **[Tahoe Truckee Unified School District, TDPUD]** Study how Tahoe Truckee Unified School District could convert its bus fleet to electric buses and how these buses could be used to provide power to the grid when school is not in session. This vehicle-to-grid study could look at the power provided to the grid as a mechanism for lowering peak demand and for mobile battery power for localized power outages.
- **[Town of Truckee, TDPUD, CATT]** Collaborate on a workforce capacity building plan.
- **[Town of Truckee]** Consider a mandate for new construction to be all electric.

Appendix I – Primers on Home Electrification

There are a variety of public-facing comprehensive guides and informational resources for home electrification that have already been developed. We at 100% Renewable Truckee recommend the following home electrification guide:

- Electrify Everything in Your Home – A Guide to Comfy, Healthy, Carbon-Free Living

Follow that up with reading one of the applicable guides from the following list. It is not necessary to read these guides cover to cover, but a quick skim will give you some idea of some of the considerations involved in an electrification retrofit or all-electric new construction:

- A Pocket Guide to All-Electric Retrofits of Single-Family Homes
- Zero Emissions All Electric Multifamily Construction

Truckee Building Electrification

- Zero Carbon Commercial Construction Guide 2nd Edition
- Zero Emissions All Electric Single-Family Construction
- Consumers Energy All-Electric Multifamily Design Guide October 2021

Appendix II – How Heat Pumps Work

Because the greatest source of GHG emissions associated with buildings is from the air and water heating and cooling[38], the technology most critical to achieving electrification in Truckee is the heat pump. Most existing air and water heating and cooling systems in Truckee are powered by fossil fuels, and in both cases, these can be replaced with electric heat pumps. Heat pump technology is two to four times more energy efficient than the existing legacy technologies[39]. Further, because the local electricity mix is dominated by renewables, heat pumps are the cleanest technology with respect to GHG emissions.

Heat pumps utilize the same fundamental technology as a refrigerator. However, refinements to the technology allow heat pumps to operate effectively and efficiently in cold climates. Rather than generate heat directly, heat pumps use refrigerants to transfer heat from outside air to inside the home in the winter; in the summer, this process is reversed, and heat pumps provide air conditioning using warm outside air.

There are many informational and reader-friendly primers on heat pump technology available online. Here are a select few:

- How Stuff Works – How Heat Pumps Work
- EnergyStar – How Does a Heat Pump Work
- The Engineering Mindset – Heat Pumps Explained

Questions

If you have questions about this 100% Renewable Truckee report, please feel free to reach out to us:

Matt Tucker
415.699.9223
matt.alex.tucker@gmail.com

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[38] Rocky Mountain Institute, 2018, "The Economics of Electrifying Buildings", Available: https://rmi.org/insight/the-economics-of-electrifying-buildings/

[39] Rocky Mountain Institute, 2020, "It's Time to Incentivize Residential Heat Pumps", Available: https://rmi.org/its-time-to-incentivize-residential-heat-pumps/