California Public Utilities Commission

SGIP HPWH Staff Proposal

CPUC ENERGY DIVISION STAFF

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Acronyms & Abbreviations

AB	Assembly Bill
ACR	Assigned Commissioner Ruling
AL	Advice Letter
BPA	Bonneville Power Administration
CEC	California Energy Commission
CPUC	California Public Utilities Commission
CSE	Center for Sustainable Energy
COP	Coefficient of Performance
CO_2	Carbon dioxide
D.	Decision
HPWH	Heat Pump Water Heater
JA-13	Joint Appendix 13 Heat Pump Water Heater Demand Management Systems
IOU	Investor-Owned Utility
GHG	Greenhouse Gas
GWP	Global Warming Potential
EPA	Environmental Protection Agency
kWh	Kilowatt hour
kW	Kilowatt
M&E	Measurement and Evaluation
NEEA	Northwest Energy Efficiency Alliance
NRDC	Natural Resources Defense Council
PA	Program Administrator
PA/PI	Program Administrator and Program Implementor
PG&E	Pacific Gas and Electric Company
PNNL	Department of Energy's Pacific Northwest National Laboratory
PU Code	Public Utilities Code
PY	Program Year
SB	Senate Bill
SC	Sierra Club
SCE	Southern California Edison Company
SDG&E	San Diego Gas & Electric Company
SGIP	Self Generation Incentive Program
SJCE	San Jose Clean Energy
SMUD	Sacramento Municipal Utilities District
SoCalGas	Southern California Gas Company
Staff	Energy Division Staff
SVCE	Silicon Valley Clean Energy
TECH	Technology for Clean Heating
TOU	Time-Of-Use
TMV	Thermostatic Mixing Valve
UCM	Universal Communication Module
US	United States

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1 Executive Summary

Through Decision (D.) 19-09-027 and D.20-01-021, the California Public Utilities Commission (CPUC) designated the first budget carve-outs for heat pump water heaters (HPWHs) in the two-decade old Self-Generation Incentive Program (SGIP). Those two decisions directed Energy Division staff (Staff) to hold workshops on removing barriers to HPWH participation in SGIP and to develop a Staff Proposal on HPWH program design. This Staff Proposal is designed within the statutory mandates and program rules of SGIP to align SGIP HPWH incentives with the CPUC's broader effort to transform the HPWH marketplace through multiple other programs and proceedings.

This proposal primarily focuses on increasing the adoption of HPWHs in the single-family housing sector but also seeks to increase the uptake of HPWHs in multifamily and small commercial buildings. A brief summation of Staff's recommendations is provided below as part of the Executive Summary. Section 2 of this Staff Proposal provides the background information necessary to understand the context in which Staff make their recommendations. Section 3 of this Staff Proposal addresses the numerous challenges inherent to installing a HPWH in California and incorporating HPWHs into SGIP. Section 4 provides recommendations for allocating funding and administering HPWH incentives in the most impactful and equitable manner possible.

1.1 Appliance, Installation, and Operational Requirements

SGIP incentives should only be provided for HPWHs that can be purchased, installed, and operated in a manner that shifts load from peak to off-peak periods. This requirement will ensure that all the technology eligibility requirements codified in Public Utilities (PU) Code Section (§) 379.6 will be met regardless of the existing water heating technology and fuel source (*i.e.,* natural gas, propane, etc.). Staff recommend considering requirements in three customer class and technology categories: (1) residential unitary HPWHs, (2) residential central HPWHs, and (3) commercial unitary HPWHs. Each category has its own set of requirements based on parties' recommendations at the SGIP HPWH workshops, industry research, and existing HPWH program data. Staff do not recommend providing incentives for commercial central HPWH systems. The proposed requirements for each HPWH technology by customer class are discussed in Section 4.1 of this Staff Proposal.

1.2 Budgetary Allocations

In D.19-09-027 and D.20-01-021, the CPUC approved a combined total budget of $44.67 million for HPWHs in SGIP. Staff recommend that these funds be allocated according to the table below. The proposed SGIP HPWH budget allocation is discussed in Section 4.2 of this Staff Proposal.

SGIP HPWH Proposed Budget Allocation		
Activity:	**Percent:**	**Amount:**
Program Administration:	**5%**	**$2,233,500**
HPWH Incentives:	**95%**	**$42,436,500**
Customer Class[1]		
General Market Residential Unitary HPWHs	45%	$19,096,425
Equity Residential Unitary HPWHs only	45%	$19,096,425
General Market Residential Central HPWHs	2.5%	$1,060,912
Equity Residential Central HPWHs	2.5%	$1,060,912
Commercial Unitary HPWHs	5%	$2,121,825
Total SGIP HPWH Incentive Budget:	**100%**	**$44,670,000**

1.3 Incentive Structure for Residential Unitary HPWHs

Staff recommend that SGIP provide a single incentive for residential unitary HPWHs based on the thermal energy storage capacity of a standard 50-gallon HPWH. Staff recommend that the general market incentive be $3,100 and that the equity customer incentive be $4,185. Staff believe that this incentive structure and value achieves approximate price parity with a natural gas water heater. To enable HPWH installations where an electrical panel upgrade is required, Staff recommend a $2,800 general market customer and a $3,600 equity customer electrical panel upgrade incentive be made available. Finally, Staff recommend that a $1,500 low-global warming potential (GWP) kicker incentive be made available to help spur the marketplace adoption of HPWHs using low-GWP refrigerants. The table below summarizes Staff's recommended incentive values for both general market and equity customers.

[1] Residential includes multi-family residential properties on commercial rates.

Customer Class	Unitary HPWH Incentive	Low-GWP Kicker Incentive	Electrical Panel Upgrade Incentive	Max. SGIP HPWH Incentive
General Market Residential	$3,100	$1,500	$2,800	$7,400
Equity Residential	$4,185	$1,500	$3,600	$9,285

Staff also recommend that the electrical IOUs categorize any electrical service line upgrade costs required to complete a SGIP funded residential unitary HPWH installation as "common facility costs" rather than a cost paid by the individual customer. This common facility costs classification shifts these excess costs to all residential ratepayers when the Electrical Service Line Allowance available under Tariff Rules 15 and 16 does not cover the entire cost of an electrical service upgrade. In Section 4.3, Staff detail how the residential unitary HPWH incentives are calculated and provide recommendations on incentive layering.

1.4 Incentive Structure for Residential Central HPWHs

Staff recommend that SGIP provide a single incentive value based on the thermal energy storage capacity for residential central HPWHs. This incentive should be measured in kilowatt-hours (kWhs) and administered in a performance-based incentive structure. Staff recommend that the incentive value be $900/kWh for general market residential customers, and $1,000/kWh for equity residential customers. Staff also recommend that residential central HPWH systems utilizing low-GWP refrigerants be eligible for a $200/kWh kicker incentive. Due to the limited budget and high costs, Staff do not recommend that residential central HPWHs be eligible for an electrical panel upgrade incentive. Staff do recommend that the electrical IOUs categorize any electrical service line upgrade costs required to complete a SGIP funded residential central HPWH installation as "common facility costs" rather than a cost paid by the individual customer. In Section 4.4, Staff detail the residential central HPWH incentives and provide recommendations on incentive layering.

1.5 Incentive Structure for Commercial Unitary HPWHs

Staff recommend that SGIP provide a single incentive value based on the thermal energy storage capacity for commercial unitary HPWHs. This incentive should be measured in kWhs and administered in a performance-based incentive structure. Staff recommend that the incentive value be $700/kWh for all commercial customers and that HPWHs utilizing low-GWP refrigerants be eligible for a $200/kWh kicker incentive. Staff do not recommend that commercial unitary HPWHs be eligible for an electrical panel upgrade incentive and do not recommend a "common facility costs" classification for electrical service upgrades. In Section 4.5, Staff detail the commercial unitary HPWH incentives and provide recommendations on incentive layering.

1.6 Program Administration and Evaluation

Staff recommend a single, statewide program administrator and program implementor (PA/PI) oversee and implement SGIP HPWH incentives. The PA/PI should be competitively selected through a bidding process overseen by Southern California Edison Company and will be responsible for developing a new SGIP HPWH Handbook that details all rules and processes for obtaining SGIP HPWH incentives. The SGIP HPWH Handbook must be submitted through a tier two advice letter for Energy Division review and approval.

Staff recommend incorporating a standalone SGIP HPWH impact evaluation into the PY 2021-2025 M&E plan. In this impact evaluation report, Staff recommend that the SGIP evaluator summarize all the benefits achieved by a SGIP funded HPWH. These benefits should include, but are not limited to, the total GHG reductions achieved by the SGIP funded load shifting HPWH, which includes reductions in therms or kWhs, and the peak reduction benefits compared to a non-load shifting HPWH. When SGIP participants layer incentives from other CPUC regulated or non-regulated programs, Staff recommend the non-load shifting benefits (*i.e.,* the efficiency benefits) of SGIP funded HPWHs also be attributed to those other programs.

2 Background

In this section, we explain the history of SGIP and review the creation of a specific budget carveout for HPWHs within the program. We then explore HPWH technologies' fundamentals, including the appliance itself, how it is installed, and the different operational parameters available. Next, we explain how different customer classes' hot water demand influences HPWH electrical loads. Finally, we discuss how HPWHs can shift load through industry standards and controls.

2.1 Program History

Statutory Mandates and History of the Self Generation Incentive Program

SGIP was first established in 2001 by CPUC D.01-03-073 in response to Assembly Bill (AB) 970 (Ducheny, Stats. 2000, Ch. 329). AB 970 directed the CPUC to provide incentives on a limited term basis for distributed generation resources that could help reduce peak energy demand (*i.e.,* battery storage, fuel cells, etc.). Since 2001, the Legislature has refined and extended SGIP several times. Legislation on SGIP is codified in Public Utilities (PU) Code § 379.6 and § 379.9, which direct the CPUC to implement SGIP in accordance with specified rules, objectives, and eligibility requirements. SGIP-funded systems are required to improve the efficiency and reliability of the distribution and transmission system, reduce GHG emissions, peak demand, ratepayer costs, and provide an equitable distribution of the program's costs and benefits. All SGIP-funded technologies must: (1) help shift onsite electricity use to off-peak time periods or reduce demand from the grid by offsetting some or all of the customer's onsite energy load; (2) be commercially available; (3) safely utilize the existing transmission and distribution system; and (4) improve air quality by reducing criteria air pollutants.

The CPUC has altered and adjusted SGIP rules and processes numerous times to comply with statutory mandates and improve the program. In 2011, through D.11-09-015, the CPUC updated SGIP to allow stand-alone advanced energy storage technologies, including thermal energy storage, to be eligible for rebates.[2] In 2016, through D.16-06-055, the CPUC adopted three overarching SGIP goals: environmental benefits, grid support, and market transformation. In August 2019, the CPUC adopted D.19-08-001 creating

[2] D.11-09-015, Attachment A at p.2. See: https://docs.cpuc.ca.gov/PublishedDocs/WORD_PDF/FINAL_DECISION/143459.PDF

new operational requirements for SGIP energy storage systems to help ensure that they reduce GHG emissions, as required by PU Code § 379.6(b)(3). One of these operational requirements is that all residential SGIP energy storage customers enroll in an SGIP-compliant time of use rate.[3] As stated in D.19-08-001, "[t]he program changes approved in this decision apply to all storage systems that receive and use SGIP incentives, including thermal energy storage systems."[4] D.19-08-001 also acknowledged that certain definitions and GHG requirements may need to be altered specifically for thermal energy storage due to their differences from electrochemical storage systems.[5]

Any retail electric or gas distribution class of customer (industrial, agricultural, commercial, or residential) of Pacific Gas and Electric Company (PG&E), Southern California Edison Company (SCE), Southern California Gas Company (SoCalGas), or San Diego Gas & Electric Company (SDG&E) is currently eligible to be a "Host Customer" that receives incentives through SGIP.[6] The Host Customer is typically the utility customer of record at the site where the SGIP system is or will be located.[7] The Center for Sustainable Energy (CSE) administers SGIP on behalf of SDG&E while the other three utilities administer SGIP within their respective service territories. Thus, PG&E, SCE, SoCalGas, and CSE collectively are the SGIP program administrators (SGIP PAs).

SGIP is regularly evaluated through contracted reports. The currently approved Program Year (PY) 2016-2020 revised M&E plan for SGIP was developed by the CPUC in response to D.16-06-055 and subsequently modified in response to the passage of Senate Bill (SB) 700 (Wiener, Stats. 2018, Ch. 839). The M&E plan includes numerous different evaluation reports, which must follow the evaluation metrics established by PU Code § 379.6(i).

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[3] See: https://www.selfgenca.com/home/resources/#approved_rates
[4] D.19-08-001 at 3. https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M310/K260/310260347.PDF
[5] *Id.* at FOF 74, COL 48.
[6] D.01-03-073 authorized PG&E, SCE, SoCalGas, and SDG&E to collect ratepayers funds for SGIP (OP 2). The program has never been expanded to the smaller utilities under CPUC jurisdiction.
[7] If the Host Customer's name is not on the utility bill, a letter of explanation if required that address the relationship of the Host Customer to the named utility customer. For multi-family buildings that are installing a system of behalf of tenants, the property owner may be the host customer. See the 2021 SGIP Handbook for more details: https://www.selfgenca.com/home/resources/

HPWHs in SGIP

In April 2019, the CPUC issued an Assigned Commissioner's Ruling (ACR) that asked whether the CPUC should modify SGIP rules to increase participation of HPWHs in the program.[8] In response to the ACR, seven parties[9] filed comments in support of rule modifications that could increase HPWH participation in SGIP and called for further exploration of this topic in future workshops. Parties supporting increased HPWH participation claimed numerous benefits that load shifting HPWHs can provide (*i.e.,* GHG emission reductions, energy efficiency savings, etc.) and noted how those benefits align with SGIP's adopted goals. Supporting parties requested that the CPUC utilize SGIP funds to encourage the transformation of California's water heater marketplace from natural gas appliances to HPWHs.

In September 2019, through D.19-09-027, the CPUC established the first ever budget carve-out within the SGIP energy storage budgets for HPWHs. D.19-09-027 specifically directed the SGIP PAs to shift $4,000,000 from their large-scale energy storage budgets to an equity budget set-aside for HPWHs.[10] The decision confirmed that HPWHs "need not generate electricity to be eligible for SGIP incentives as these technologies are operated as a type of energy storing and load-shift technology. Moreover, SGIP encompasses thermal storage, which includes HPWHs."[11] D.19-09-027 further noted that HPWHs were in fact already eligible for SGIP funding "because these systems have the capacity to shift load from peak to off-peak periods and can provide California Independent Service Operator (CAISO)-integrated load drop and ramping services."[12] Noting the lack of participation in SGIP by HPWHs, however, D.19-09-027 directed Staff, in coordination with the SGIP PAs and in collaboration with Sierra Club (SC) and the Natural Resources Defense Council (NRDC) to convene a workshop on identifying and removing barriers to participation in SGIP by HPWHs.

In January 2020, the CPUC adopted D.20-01-021, which authorized ratepayer collections of $166 million annually for the years 2020 to 2024 to fund SGIP consistent with the authorization established by

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[8] ACR Seeking Comment on Implementation of Senate Bill 700 and Other Program Modifications at p.27. See: https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M281/K395/281395627.PDF.

[9] Parties that filed Opening Comments in support of modifying SGIP rules to increase participation of HPWHS included: SC/National Resource Defense Council, Sonoma Clean Power, Silicon Valley Clean Energy Authority, Peninsula Clean Energy Authority, San Jose Clean Energy and the California Energy Storage Association.

[10] D.19-09-027 at Order Paragraph (OP 5) at pp.126-127. See: https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M313/K975/313975481.PDF

[11] *Id.* at p.98.

[12] *Id.* at p.68.

SB 700. D.20-01-021 established budget allocations across eligible SGIP technology categories and directed five percent of the newly authorized funding to a general market HPWH budget. Thus, in addition to the $4,000,000 previously allocated for equity customers in D.19-09-027, the $40,670,000 allocated in D.20-01-021[13] created a combined HPWH budget within SGIP of $44,670,000. In justifying the additional funding allocation to this new, yet-to-be-utilized budget category, D.20-01-021 stated, "HPWH deployment may provide GHG reductions that significantly exceed the five-kilogram carbon dioxide (CO_2) per kWh required for storage system by this Commission in the GHG Decision. The potential grid reliability, utility customer and GHG benefits of HPWHs cannot be realized without a meaningful funding allocation, including through dedicated funding in the SGIP."[14] The decision also reiterated that Staff would hold a workshop on removing barriers to HPWH deployment in SGIP and directed that, "[i]n addition to the guidance provided in D.19-09-027, this workshop will consider whether SGIP should require use of controls to ensure HPWH re-heating off-peak."[15]

SGIP HPWH Workshops

Staff held a two-part workshop titled 'Strategies for Enabling HPWHs to Participate in SGIP' on March 19, 2020 and on May 7, 2020. [16] The workshops underscored that HPWHs have a set of unique characteristics compared to other SGIP eligible energy storage technologies. In particular, since every building in California has some degree of hot water demand, HPWHs are not an "add-on" technology designed to supplement and optimize an existing technology's standard operation. Additionally, HPWHs are relatively unusual in SGIP, as they generally represent a form of fuel substitution (*i.e.,* from natural gas to electricity). Approximately 90 percent of residential water heaters in California currently use natural gas.[17] While both workshops covered various types of HPWHs and building types, the focus of the information presented was on HPWHs in the single-family residential sector.

In the weeks between the two workshops, Staff informally convened an SGIP HPWH Working Group comprised of NRDC, SC/EarthJustice, AO Smith Water Heating, and the Building Decarbonization

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[13] D.20-01-021 was subsequently corrected by D.20-02-039. See: https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M327/K726/327726468.PDF
[14] D.20-01-021 at p.22. See: https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M325/K979/325979689.PDF
[15] Id.
[16] The agenda and presentations for both the March 19th and May 7th SGIP HPWH workshop can be found here: https://www.cpuc.ca.gov/sgip/
[17] 2009 California Residential Appliance Saturation Survey (RASS) Executive Summary p.11. See: https://bit.ly/3b3lEiH

Coalition (collectively "the HPWH Advocates") and the SGIP PAs. This group discussed challenges posed by trying to integrate the HPWH Advocates new upstream incentive framework proposed at the first workshop into the existing SGIP structure. The Working Group also debated the appropriate SGIP eligibility criteria for HPWHs, including whether non-load shifting HPWHs should be eligible to receive SGIP incentives and what the appropriate baseline for quantifying GHG emission reductions attributable to HPWHs might be. At the May 7, 2020, workshop, the HPWH Advocates presented a refined straw proposal that asserted that HPWHs are fundamentally different than typical SGIP energy storage systems such as batteries (*i.e.,* like other home appliances, water heaters are replaced upon failure, etc.) and suggested program modifications to increase HPWH participation in SGIP. In contrast, SoCalGas presented a program concept that utilized the existing SGIP energy storage incentive structure and proposed incentive values based on a HPWHs ability to function as load shifting thermal energy storage. The program concepts detailed at the workshop, the presentations provided by HPWH technology experts, and the discussion among stakeholders provide a strong foundation upon which we have built this Staff Proposal for removing barriers to HPWH participation in SGIP.

2.2 HPWH Appliance Fundamentals

Understanding how a HPWH operates is essential to understanding how the system can function as thermal energy storage. All HPWHs rely on a closed-loop[18] vapor compression cycle[19] and a refrigerant[20] fluid to move ambient heat from the surrounding air – or another heat source[21] – into a water storage tank to meet a desired hot water setpoint temperature and provide hot water to meet demand at a later time. During the vapor compression cycle, a refrigerant either evaporates from a liquid to a vapor gas or condenses from a vapor gas into a liquid. The HPWH's compressor and expansion valves are mechanical components powered by electricity that control the pressure and, in effect, the refrigerant's temperature.[22] If

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[18] A closed loop system is a set of mechanical and electrical devices that regulate a system's operation to achieve a desired state – or, in the case of a HPWH, a hot water setpoint – without human interaction or external input.
[19] The vapor compression cycle is the compression and expansion of a refrigerant between liquid and gaseous phases to move ambient heat from one medium (*i.e.,* the air, water, or ground) to another medium.
[20] A refrigerant is chemical compound used in all compressor systems (*i.e.,* air conditioners, refrigerators, HPWHs, etc.) that enables heat to be moved – or transferred – between two locations.
[21] Other heating sources include the ground, water, and wastewater operations.
[22] In an air sourced HPWH, the vapor compressor cycle is completed in the following order: (1) a fan pulls in air from its surrounding environment and pushes that air across the systems evaporator coil, (2) the ambient heat that is present in the air is transferred to the type of refrigerant being used, (3) the refrigerant is pumped through the compressor increasing the pressure and

refrigerant leaks during the compressor cycle, its impact on climate change is defined by the refrigerant's GWP.[23] In the United States (US) market, the dominant refrigerant used in HPWHs is R-134a, which has a GWP of 1,430[24]. HPWH models that use R-744, which has a GWP of one, are also available in the US market, but they have not been widely adopted. HPWH refrigerant leakage is minimal during installation and operation, as the units are factory-sealed at the manufacturing plant. Thus, refrigerant issues are mostly an end-of-life problem associated with improper disposal. In addition to the vapor compressor cycle process, many, but not all, HPWHs also include one or more electric resistance coils that can provide additional heating capacity when hot water demand exceeds the heat pump's ability to achieve the desired setpoint temperature and provide hot water. These coils, commonly referred to as "backup resistance heating elements," are much less efficient and use much more energy to heat the same amount of water compared to a heat pump.[25]

Most HPWHs currently available for purchase in the US are classified as "integrated" systems.[26] An integrated system is a HPWH with the compressor system, any backup resistance heating elements, a water storage tank, and any other associated components integrated into one appliance. Integrated HPWHs look like standard tank natural gas or electric resistance water heaters,[27] but they are commonly taller due to the heat pump compressor system located on top of the water storage tank. Integrated HPWHs available on the market today primarily use R-134a refrigerant, which has a GWP of 1,430. Figure 2.1 below diagrams an integrated HPWH and its various components.

the temperature, (4) the heated refrigerant is pumped through the condenser coil where the heat is transferred to water, and (5) the cooled refrigerant is then pumped back towards the evaporator coil where the process recommences.

[23] GWP measures the strength of a GHG compared to carbon dioxide over a 100-year period.

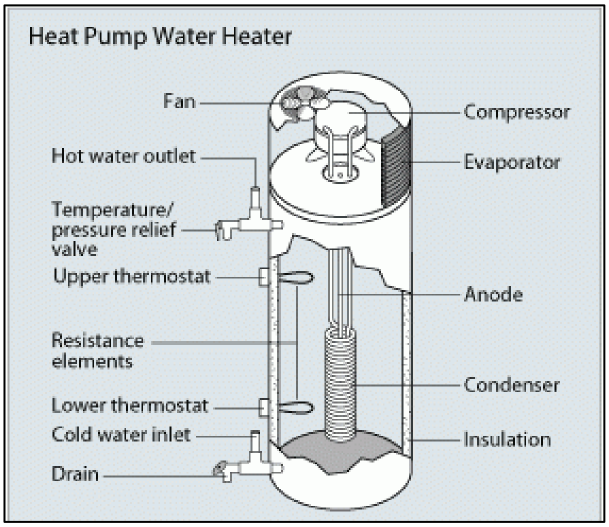
[24] Over a 100-year period one ton of leaked R-134a would trap 1,430 times more heat energy than one ton of carbon dioxide.

[25] More specifically, back-up electric resistance heating elements operate at an electrical efficiency of only 99 percent, in comparison to a heat pump vapor compressor system, which operates on average at a coefficient of performance of 300 percent or greater. Coefficient of performance is a ratio of the amount of useful heat extracted from a compressor system and the amount of electricity put into the system. For example, a heat pump with a coefficient of performance of three generates three kilowatts of heat for every one-kilowatt hour of energy consumed.

[26] Staff has collected information on 852 HPWH projects in California, of which only 15 use a split system HPWH.

[27] Electric resistance water heaters have multiple electric resistance coils that either heat water on demand or in a storage tank for use later.

Figure 2.1: Diagram of an Integrated HPWH[28]



In contrast to an integrated HPWH, a "split" system HPWH has a compressor that is separate from the water storage tank. In most split systems, water is circulated between the compressor system, where heat is transferred from the refrigerant to the water and back to the water storage tank via a cold water line and a hot water line.[29] Split systems HPWHs available on the market today primarily use R-744 refrigerant (GWP of 1). In addition to having a lower GWP, R-744 operates at a higher efficiency than R-134a refrigerant in all temperature conditions, including cold weather.[30] Figure 2.2 below diagrams an example split-system HPWH manufactured and marketed by ECO2 Systems LLC.

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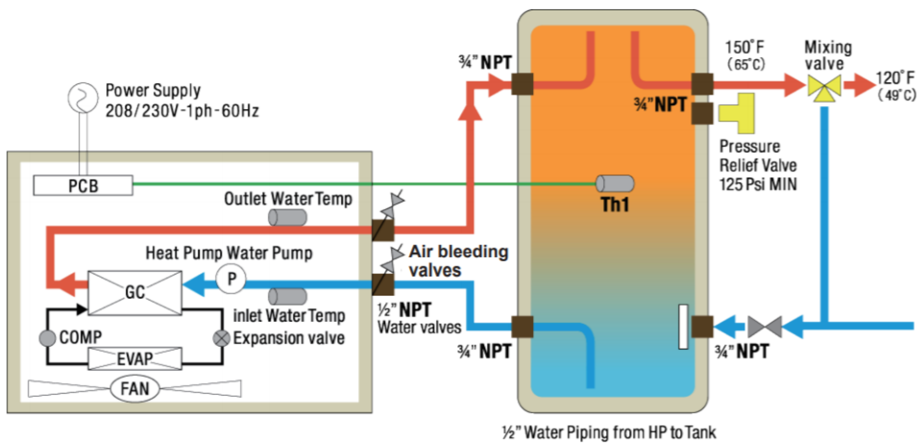
[28] US Department of Energy, See: https://bit.ly/2PfXtoE

[29] International split systems can also circulate refrigerant in between the compressor system and the storage water. This refrigerant circulation design is the exception not the norm.

[30] Field demonstrations conducted by the Washington State University Energy Program have shown that R-744 based HPWHs have the capability to operate at -15.7 F, Slide 21. See: https://www.proctoreng.com/dnld/Eklund-CO2HPWH.pdf

Figure 2.2: Diagram of a Split System HPWH[31]



Integrated and split systems can be installed in a variety of applications to meet hot water demands. In the single-family residential sector, the most common application is for one integrated HPWH to serve one household. Split HPWHs in the single-family residential sector are uncommon in the U.S., but millions of units have been sold internationally.[32] In the multi-family sector, there is no standard installation design for HPWHs. In a multi-family building, individual integrated HPWHs can be installed to serve individual households, or integrated HPWHs with larger storage tanks can be installed to serve multiple households. Alternatively, a combination of split HPWHs with large storage tanks and integrated electric resistance water heaters can be designed to meet an entire multi-family building's hot water demand. Figure 2.3 below presented by the Association for Energy Affordability during the May 7, 2020 workshop, shows the mixing and matching of HPWH technologies in multi-family properties

[31] Eco2 Systems Owner Manual, SANCO2 Heat Pump Water Heater with natural refrigerant (CO2), p.3. See: https://bit.ly/3b5oeVt
[32] Electric Power Research Institute's (EPRI's), 2015 Commercial Heat Pump Water Heaters Evaluation of Field Performance for San Diego Gas and Electric (SDG&E), P. 13. See: https://www.epri.com/research/products/3002005496

Figure 2.3: Example of How integrated HPWHs and Split HPWHs Can Be Installed in Multi-Family Buildings[33]

Central Heat Pump Water Heater Types

Units Served	HPHW Types	Example Products
2-8 apts	65-80 gal individual HPWH	Large Residential HPWH: Rheem, AO Smith, Sanden, others
10-25 apts	Central tank-type, split HPWH	AO Smith (CAHP-120), Sanden ("ganged")
25+ apts	Central HPWH w/ large tank(s)	Colmac, Nyle, Mitsubishi (2021), Rheem (Australia)

For this Staff Proposal, we refer to residential HPWHs that serve one household as "unitary" and residential HPWHs that serve more than two households as "central." Approximately 100 residential central HPWHs are installed in multi-family buildings throughout California,[34] and approximately 15 percent of these properties utilize a split system design.

The commercial sector largely mirrors the single-family and multi-family residential sectors. Commercial hot water demands can be met in a one-to-one fashion (*i.e.,* one unitary HPWH serving one business) or by a central HPWH system specifically designed to meet a commercial facility's greater hot water demand. Unlike the residential sector, it is common for multiple split systems (*i.e.,* multiple heat pumps and multiple storage tanks) to be installed, or "ganged" together to meet just one business's hot water load. As such, for the purposes of this Staff Proposal, we refer to HPWHs serving one business's hot water load as "unitary" and HPWHs serving multiple businesses' hot water load as "central."

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[33] Nick Dirr, Director of Programs, Association for Energy Affordability, presentation at the May 7, 2020 SGIP HPWH Part Two Workshop, p.59. See: https://bit.ly/3baCtIJ

[34] Nick Dirr, Director of Programs, Association for Energy Affordability, January 28, 2021.

2.3 HPWH Installation Fundamentals

HPWH installations generally require a licensed electrician to install power to the location of the HPWH. The electrical power requirements of a HPWH are based on the electrical capacity requirements of a HPWH's compressor system and the electrical capacity of the backup electric resistance coils if such coils are installed. This capacity is commonly discussed in total amperes ("amps")[35] or the amperage[36] required to operate a HPWH. Integrated and split system residential HPWHs require either a 15-amp or 30-amp electrical circuit to operate. In comparison, a commercial integrated HPWH requires an approximately 70-amp electrical circuit to operate. Central system amperage requirements vary based on the final design of the system, but a general design principle is that electrical capacity and the size of available hot water storage are inversely related.[37] Regardless of the total amperage, a HPWH's electrical capacity is powered by an electrical wire connected to a building's electrical panel[38] via a conduit.[39] From the utility's meter, electrical wires route through a main breaker switch, into the main electrical panel, through individual circuit breakers,[40] and branch circuits[41] to the various electrical loads in a building. See Figure 2.4 below.

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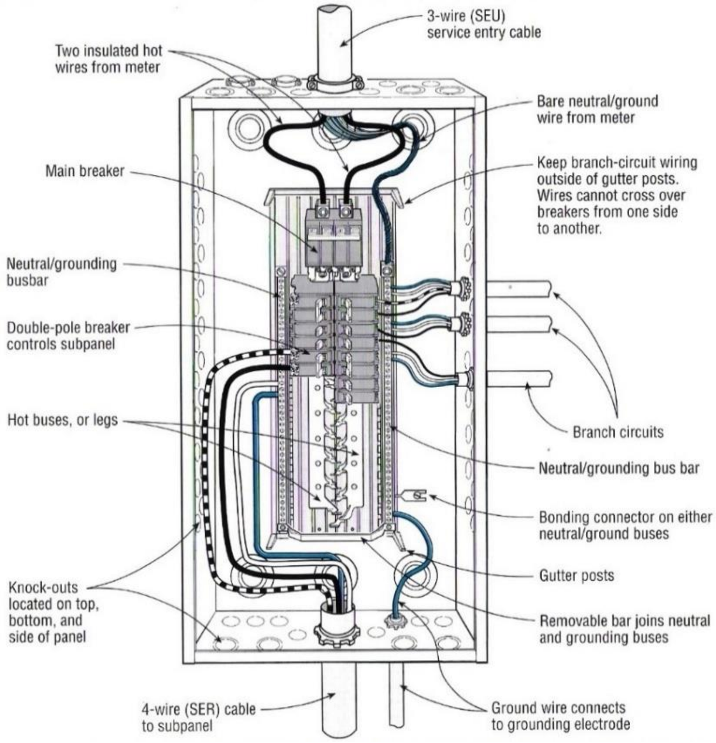
[35] Amps are a base unit of electric current.
[36] Amperage is the strength of an electric current expressed in number of amps.
[37] For example, central systems with smaller hot water storage tanks require larger capacity heat pumps to generate hot water, and inversely central systems with larger hot water storage tanks require smaller capacity heat pumps as they can store greater volumes of hot water.
[38] An electrical panel is the connection between the electrical providers external utilities wires, the electrical meter, and a building's internal electrical wiring.
[39] An electrical conduit is a rigid or flexible tube used to protect and route electrical wiring in a building or structure. Conduits are commonly made of metal or plastic.
[40] A circuit breaker is an electronic switch that automatically interrupts the electrical flow in an electrical circuit if there is an overload or short.
[41] A branch circuits is the electronic wiring, or conductor, that extends from the circuit breaker to the electrical load (*i.e.,* the HPWH).

Figure 2.4: Diagram of an Main Electrical Panel[42]



Buildings either have a single main electrical panel or a main electrical panel with multiple sub-panels.[43] In single-family residential buildings, main electrical panels are commonly rated in total amperage sizes ranging between 100 and 200 amps and have between 20 and 60 "circuit spaces" for circuit breakers to be installed. Every two circuit spaces can accommodate one circuit breaker rated between 15 and 30 amps. In multi-family and commercial buildings, the same principles apply, but the panel amperage sizes are larger, and the number of circuit spaces is greater. It is also common in multi-family and commercial buildings to see numerous subpanels installed throughout the building. Regardless of the building type, there must be sufficient amperage capacity and available circuit breaker space on the electrical panel to power a HPWH. For example, suppose an existing single-family homeowner has a 100-amp service panel with 24 circuit spaces, and they want to upgrade their existing natural gas water to a HPWH. In that case, they will likely need to complete two steps. First, they will need to work with their electrician to submit a service request to their electrical utility's planning department to increase, or upgrade, their homes' electrical service size (*i.e.,*

[42]Source: https://bacamajalah.com/26-good-electrical-panel-wiring-diagram/perfect-electrical-panel-wiring-diagram-electricalmainpanel/

[43] Electrical sub-panels are smaller panels that distribute power to a specific area of a building or home. For example, a single-family detached garage could have a sub-panel for all the circuits located in that space.

increase from 100 amps to 200 amps). The assigned service planner will assess the application, perform the necessary field inspections, process the service order request, and execute the electrical service upgrade to the electrical meter. In certain circumstances, the utilities' electrical service line to the electrical meter may already be rated for 200-amps. In that case, no major work is required in front of the meter and the homeowner just needs to upgrade to a 200-amp electrical panel. If the electrical service line to the utility's meter is rated for less than 200-amps, then the electrical service line must be upgraded. The process of upgrading a service line can cost the homeowner thousands of dollars depending on the numerous electrical capacity requirements, like the need to upgrade a distribution transformer, safety requirements, site conditions, and local ordinances, many of which require undergrounding of wires. Residential and ratepayers socialize all or a percentage of these costs through a fixed tier " Electrical Service Line Allowance" provided by each of the investor-owned utilities (IOUs) for "new and permanent" load established under two Electric Tariff Rules – Rule 15 (Distribution Line Extensions) and Rule 16 (Service Line Extensions).[44] Once the electrical utility completes the electrical service line upgrade to the meter, the electrician can finish upgrading the electrical panel and complete the necessary electrical work from the HPWH to the panel as discussed above. If the home has enough amperage on the electrical panel but not enough circuit space, the electrician can install a subpanel as discussed above.

In addition to electrical work, HPWH installations also require the expertise of a licensed plumber. The plumbing requirements of a HPWH depend on the type of HPWH system being installed and the volume of hot water demand that must be met. When a single residential building, multi-family household, or commercial business's hot water demand is being met by one HPWH system, the plumbing configuration is relatively simple. Essentially, separate pipes are required to move cold water into the HPWH (cold-water inlet pipe) and heated water to where it will be used in the building (hot-water outlet pipe). As discussed in Section 2.5, there are benefits from installing a HPWH that can exceed normal hot water faucet temperatures.[45] In this scenario, to avoid scalding, a thermostatic mixing valve (TMV) must also be installed in-between the cold-water inlet line and the hot-water outlet pipe, and a separate TMV setpoint temperature (*i.e., the temperature of the water coming out of the TMV)* must be set. A TMV's function is to temper the overheated hot water leaving the water heater to a safe temperature by blending hot water with cold water.

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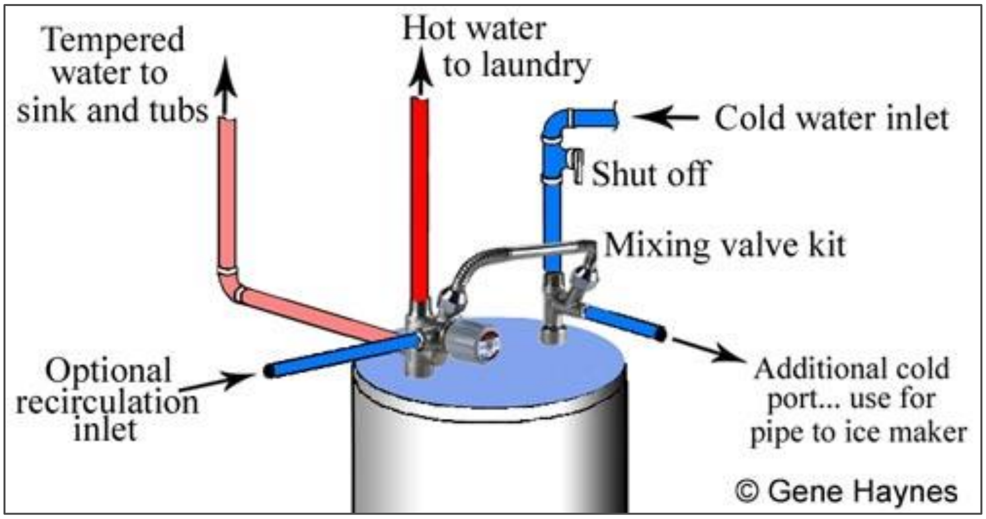
[44] For more details Rule 15 and 16 see: https://www.cpuc.ca.gov/General.aspx?id=6442465113

[45] The United States Consumer Product Safety Commission recommends faucet-delivered residential hot water temperature not to exceed 120 degrees Fahrenheit.

This tempering process ensures that the user doesn't scald themselves at the faucet when the HPWH setpoint temperature is increased above the recommended 120 degrees Fahrenheit temperature.[46] Figure 2.5 below shows an example of a TMV installation.

Figure 2.5: Example of TMV Installation[47]

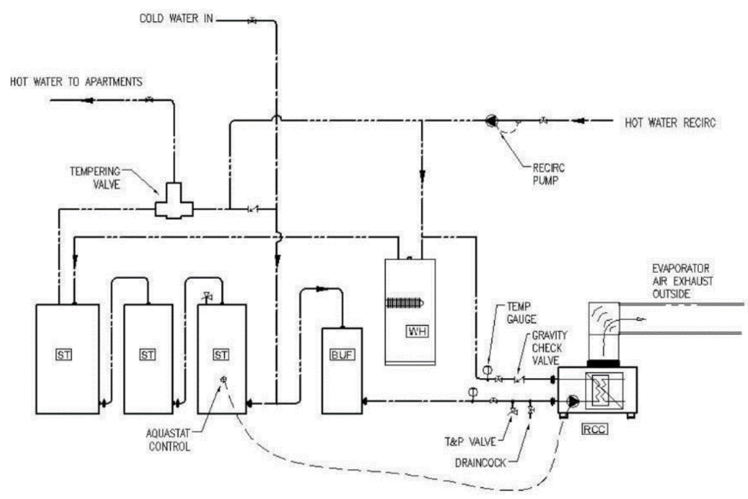


In a scenario where multiple residential households' or commercial businesses' hot water demands are met by a central HPWH design, the plumbing configuration complexity scales with the volume of hot water demand. In addition, central HPWH systems must provide enough hot water to meet "peak" hot water load and "off-peak" instantaneous demand by maintaining the temperature of the hot lines at all times. To explore these plumbing configurations, we use the three central HPWH design categories shown earlier from the HPWH Workshops (see Figure 2.3). In the two to eight-unit and 10 to 25-unit central HPWH categories described above, when one integrated HPWH with a large storage tank or multiple split system compressors are "ganged" together, the plumbing configurations will essentially mirror the plumbing configurations above.[48] TMVs will likely be installed in both scenarios to enable higher setpoint temperatures in the storage tanks to ensure building hot water demand is met. When more than 25 units are served by a central HPWH system the plumbing configuration complexity increases as the system design relies almost exclusively on split system HPWHs, requires much greater volumes of hot water storage, and

[46] All properly designed TMVs are fail-safe devices, meaning that they will prevent a scalding incident if the product fails by only providing cold water to the end user.
[47] See: http://waterheatertimer.org/Advantages-disadvantages-mixing-valve.html
[48] In the "ganged" split system, each compressor will be connected to a main cold-water supply line and a hot water return line with individual branch lines that are connected to one or multiple large storage tanks.

requires "swing" storage tanks to operate the system efficiently. Figure 2.6 below shows an example of this complexity.

Figure 2.6: Simple Schematic Design of a Residential Central HPWH system[49]



2.4 HPWH Operation Fundamentals

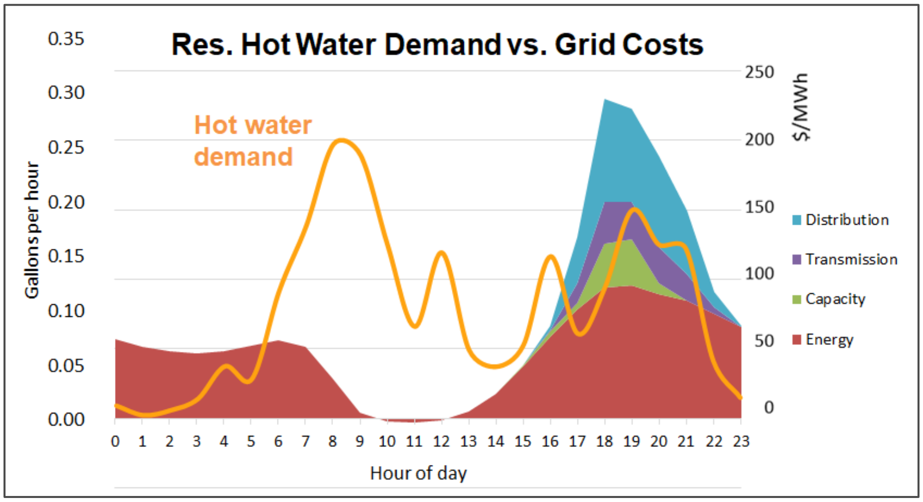
With an understanding of how a HPWH functions and how a HPWH is installed, next we review how a HPWH operates to meet hot water demands. Each original equipment manufacturer develops and manufactures their HPWHs with a proprietary control logic – or software – that determines how and when their HPWHs operate to achieve the setpoint temperature based on numerous interdependent operational variables.[50] Thus, the operational descriptions below do not represent any specific HPWH manufacturer, model, or system type, but rather the average operational characteristics of residential and commercial customers.

Single household residential hot water demand, whether in a single-family home or within individual multi-family household, follows a general demand curve as shown in Figure 2.7. Hot water demand peaks

[49] Source: Ecotope's Reverse Cycle Chiller Pilot Project: Multifamily Heat Pump Water Heaters in Below Grade Parking Garages in the Pacific Northwest, p.6. See: https://bit.ly/2NHyQkx
[50] Operational variables include the volume of hot water, the storage volume of the HPWH tank, the type of refrigerant used by the compressor system, the incoming temperature of the inlet or cold water line, the installation location of the HPWH, the ambient air temperature, etc.

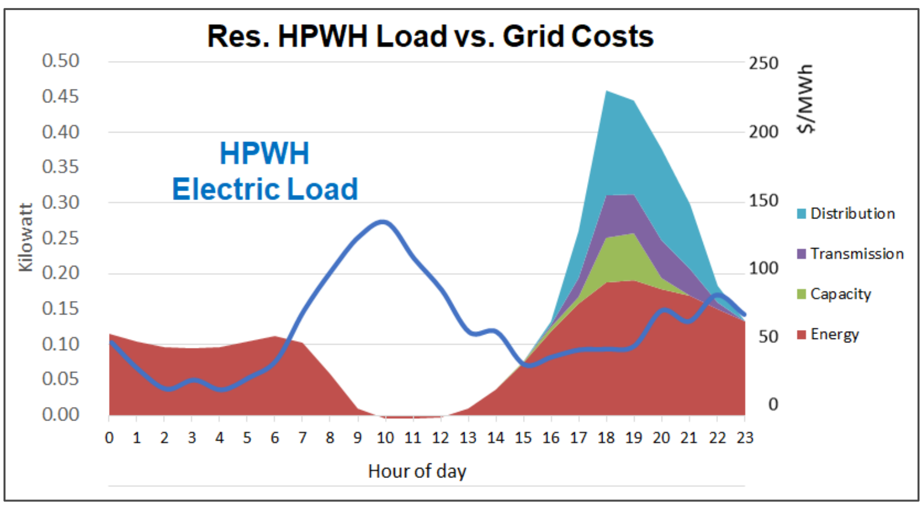
during the morning hours as people wake up, declines mid-day, and peaks again as people return home from work.

Figure 2.7: Single-Family Residential Hot Water Demand Curve[51]



As a result of this hot water demand curve, the electric usage of a residential HPWH follows the daily pattern shown in Figure 2.8.

Figure 2.8: Single-Family Residential HPWH Electric Load[52]



[51] Source: Pierre Delforge (NRDC) presentation at the March 19, 2020 Part 1 SGIP HPWH workshop. Data sources: Hot water draws: Kruis, N., Wilcox, B. Lutz, J. California Residential Domestic Hot Water Draw Profile Selection Methodology. May 18, 2016. Grid costs: PG&E GRC Phase 2, 2024 projection.
[52] Id.

By comparing the two previous figures we can identify several characteristics about the standard operation of a single household HPWH. The first is that peak electricity demand occurs within two hours of the peak hot water demand. This delayed peak for electricity highlights the ability of the HPWH to meet the demand for hot water first by using the hot water stored in the storage water tank and second over time by using the heat pump. The second characteristic is how the HPWH's electrical demand curve peaks during the middle of the day (*i.e.,* off-peak hours)[53] when renewable generation, especially utility-scale and rooftop solar are greatest. Finally, the third characteristic is that evening HPWH electricity usage occurs during peak hours to meet evening hot water demand. On average, this on-peak electricity usage accounts for 14 percent of a single-family residential HPWH's electricity consumption.[54]

In the multi-family sector where more than one household is being served, the hot water demand curve for an entire complex on average is similar in shape to that of single-family households, but the hot water demand across individual households (*i.e.,* specific apartment or condominium units) can vary greatly. As shown in Figure 2.9 below, multi-family hot water demand peaks in the morning hours as people wake up, dips during mid-day, and peaks again as people return home in the evening.[55] Each black line in Figure 2.9 represents an individual household's hot water demand, whereas the blue line represents the entire building's average hot water demand.

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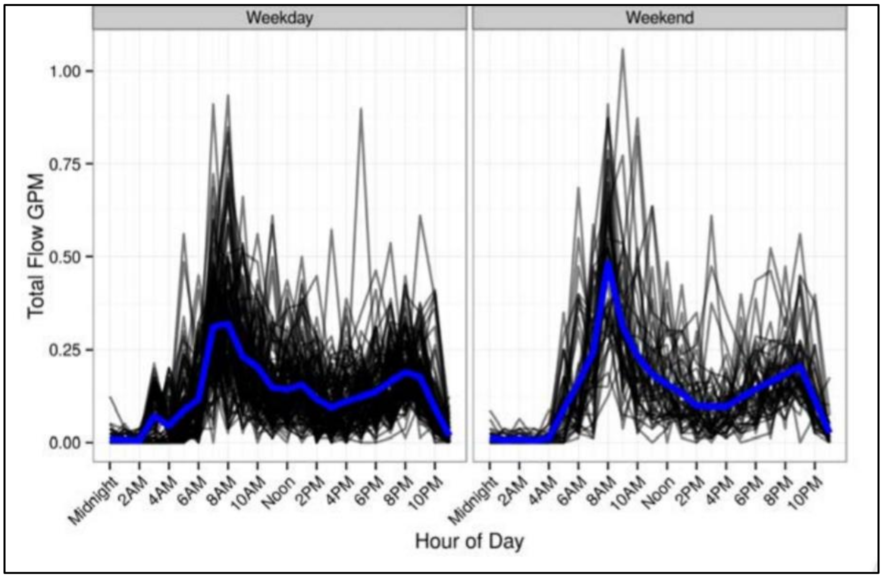
[53] Off-peak hours vary by utility, but generally occur between 8:00am and 4:00pm.

[54] Heat Pump Water Heater Electric Load Shifting: A Modeling Study at p.22. See: https://ecotope-publications-database.ecotope.com/2018_001_HPWHLoadShiftingModelingStudy.pdf

[55] The "size" of these peaks determines the peak hot water load that a residential central HPWH system must designed to achieve.

Figure 2.9: Multi-Family Hot Water Demand Curve[56]

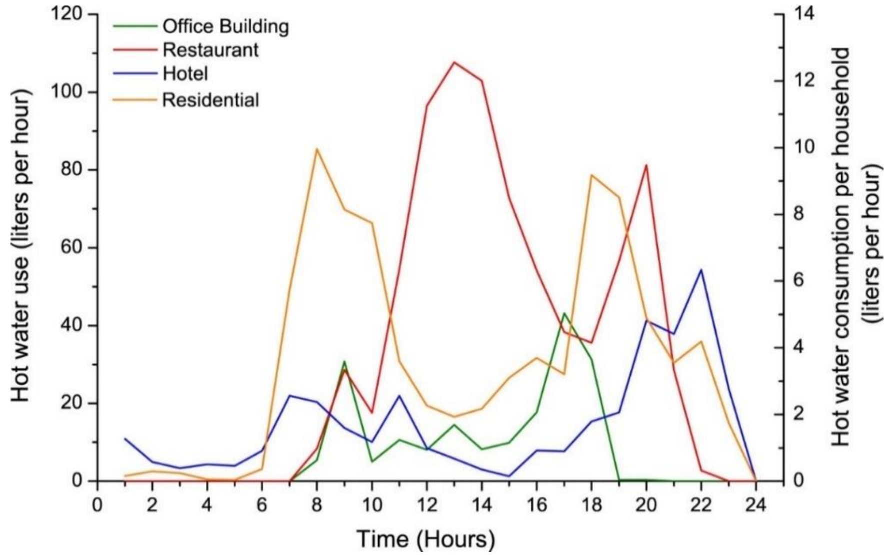


While the hot water demand profiles of single-family and multi-family residences may be similar in aggregate, the electricity load profiles are not. This difference is due to the wide variety of central system designs, as discussed previously, and the requirement that central HPWHs be designed to meet the building's peak hot water demand *and* any individual household's instantaneous hot water. Meeting the building's peak hot water demand requires both properly sized heat pumps and properly sized hot water storage tanks. Meeting any individual household's instantaneous demand requires hot water to be constantly circulated throughout the building. Also, in both existing buildings and new construction designs, physical space can be a system design constraint.

As seen in Figure 2.10 below, the commercial sector's hot water demand profiles and hot water volume vary greatly based on the business type.

[56] American Council for an Energy Efficient Economy. https://www.aceee.org/sites/default/files/pdf/conferences/hwf/2019/5c-oram.pdf.

Figure 2.10: Commercial Building Hot Water Demand Curve Comparison[57]



Note: Residential sector hot water consumption is shown on the right Y-Axis.

In the office building sector, hot water demand is largely contained with the workday's standard operational hours. In the hotel sector, hot water demand occurs throughout all hours of the day but is dominated by an evening peak. The restaurant sector not only consumes the largest volume of water of all the commercial sectors, but it also has two daily peaks, like residential buildings. While there is great potential for HPWHs to meet the various commercial hot water demands, the same level of lab testing and field research as has yet to be completed for commercial HPWHs. As such, there is not yet a standard electrical load curve for each sector.

2.5 Load Shifting

"Load shifting" refers to a HPWH's ability to move electricity usage that would regularly occur during peak load periods to off-peak times by storing additional thermal energy in the hot water storage tank. Utilizing residential unitary and split HPWHs for load shifting has been a research topic of interest for years in the Pacific Northwest and California due to the benefits these systems can provide to the electric grid and their ability to reduce GHG emissions.

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[57] "A review of domestic hot water consumption profiles for application in systems and buildings energy performance analysis" Figure 5, Renewable and Sustainable Energy Reviews Volume 81, Part 1, January 2018, p.1539. See: https://www.sciencedirect.com/science/article/abs/pii/S1364032117308614

Starting in 2009, a combination of organizations in the Pacific Northwest, including the Bonneville Power Administration (BPA), Ecotope, the Department of Energy's Pacific Northwest National Laboratory (PNNL), the Northwest Energy Efficiency Alliance (NEEA), and Washington State University, began research on both integrated and split system HPWHs and their ability to provide demand response resources. [58] In 2012, NEEA published an initial HPWH Model Validation Study exploring integrated HPWH behavior and energy usage.[59] In July 2015, PNNL released a Demand Response Performance of Sanden Unitary/Split System Heat Pump Waters showing that units could successfully shift hot water load between 6 and 12 hours.[60] In December 2015, BPA released an Advanced HPWH Research Final Report summarizing the multi-year lab and field-testing research on Sanden's split system. In 2018, BPA published findings from its residential demand response field study of 94 electric resistance water heaters and 133 HPWHs utilizing a communication pathway known as CTA-2045 to send peak shed, grid emergency, and energy shift demand response signals.[61] This multitude of studies affirmed that both types of HPWHs – integrated and split systems – can respond to different demand response signals throughout the calendar year and provide grid value with high participant satisfaction.[62]

Over a similar period, the California IOUs and other organizations began research into HPWH operations and demand response capabilities locally. In 2009 to understand energy savings strategies in single-family homes, PG&E completed its Energy Performance Analysis for Heat Pump Water Heaters.[63] In 2017 to better understand the potential impacts of load shifting HPWHs on the California Energy Commission's (CEC's) Building Energy Efficiency Standards in Title 24 of Part 6 of the California Code of Regulations (*i.e.,* the Energy Code) and support ongoing modeling work by Ecotope and NRDC., PG&E's

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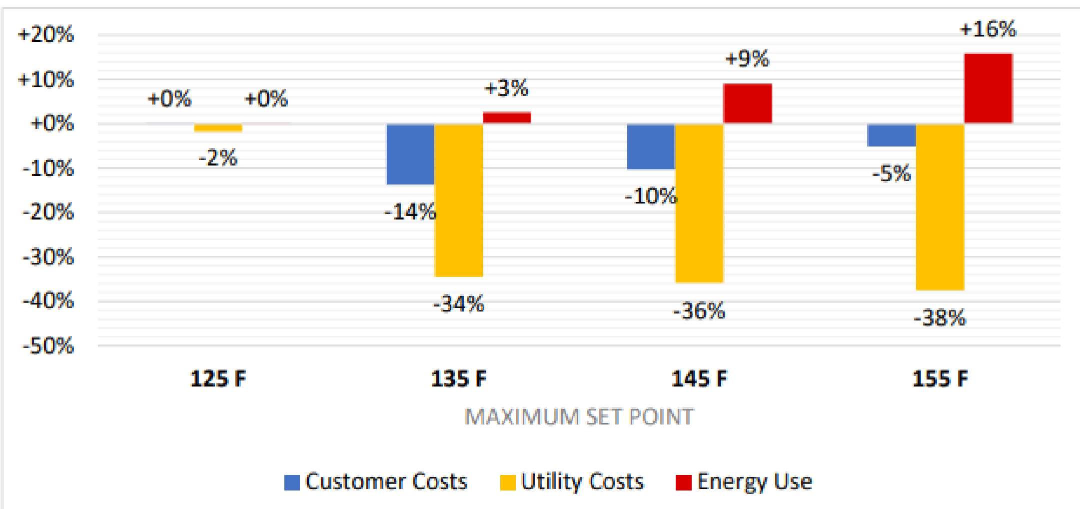
[58] Demand response is the ability of customers to change their electricity usage at certain times of a day in response to an economic incentive, utility price signal, or other conditions.
[59] Heat Pump Water Heater Model Validation Study presented by Ecotope on behalf of NEEA. See: https://neea.org/img/uploads/heat-pump-water-heater-saving-validation-study.pdf
[60] Demand-Response Performance of Sanden Unitary/Split-System Heat Pump Water Heaters. See: https://labhomes.pnnl.gov/documents/PNNL-24224_Demand-Response_Performance_of_Sanden_Unitary_and_Split-System_Heat_Pump_Water_Heaters.pdf
[61] BPA CTA-2045 Water Heater Demonstration Report, including A Business Case for CTA-2045 Market Transformation, 2018. See: https://www.bpa.gov/EE/Technology/demand-response/Documents/Demand%20Response%20-%20FINAL%20REPORT%20110918.pdf
[62] The BPA CTA-2045 Water Heater Demonstration program found that customer satisfaction was overwhelmingly high based on survey responses. Survey questions asked how often residence ran out of hot water, their overall participant experience, their likelihood of participation in future pilots, and their primary reason for participating.
[63] PG&E's Energy Performance Analysis for Heat Pump Water Heaters. See: https://www.etcc-ca.com/reports/energy-performance-analysis-heat-pump-water-heaters

Codes and Standards team funded lab testing of four different HPWH manufacturers' models.[64] In 2018, Ecotope and NRDC released a paper documenting the impact on customer costs, utility costs, and energy savings that various load shifting control strategies can have for a residential HPWH. This paper found that compared to a non-load shifting HPWH, an integrated residential HPWH implementing a "Load-Up/Shed Strategy" where the HPWH overheats, or "loads-up" on thermal energy, provides a range of customer and utility benefits.[65] As shown in Figure 2.11 below, the range of benefits varies based on the different setpoint temperature programmed into the integrated HPWH.[66]

Figure 2.11: Cost and Energy Savings by Setpoint Temperature for a TOU-Based Load-Up/Shed Strategy, TOU Price Signal[67]



The paper also found that split system HPWHs utilizing R-744 refrigerant could provide similar customer bill savings (17 percent) and much higher utility savings (65 percent) using the "Load-Up/Shed

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[64] PG&E's Lab Testing Heat Pump Water Heaters to Support Modeling Load Shifting, See: https://www.etcc-ca.com/reports/lab-testing-heat-pump-water-heaters-support-modeling-load-shifting?dl=1609879610

[65] TOU is an electricity rate plan, or tariff, which varies according to the time of day, season, and day type (weekday or weekend/holiday).

[66] The customer cost savings are compared to a non-load shifting HPWH and the utility costs is Pacific Gas and Electric Company's estimated 2024 hourly marginal energy, transmission, and distribution costs. All estimated cost savings are calculated on an annual basis.

[67] Ecotope/NRDC Heat Pump Water Heater Electric Load Shifting: A Modeling Study, 2018, p.21. See: https://ecotope-publications-database.ecotope.com/2018_001_HPWHLoadShiftingModelingStudy.pdf

Strategy."[68] R-744 split system HPWHs can provide more utility savings compared to integrated R-134a HPWHs due to their ability to generate and store hot water at a higher temperature, 150°F versus 125°F.

In July 2020, the CEC adopted Joint Appendix[69] 13 Heat Pump Water Heater Demand Management Systems (JA-13),[70] establishing a pathway for load shifting residential HPWHs to receive load management compliance credit[71] towards meeting compliance with the California Energy Code. The JA-13 documentation establishes a set of California unique appliance standards and installation requirements designed to enable HPWHs to function as thermal energy storage daily. These requirements were based mainly on the research completed by Ecotope and NRDC in 2018 and include requirements such as installing a TMV and sizing the HPWH tank based on the number of bathrooms in the home. Staff believe that the JA-13 specifications will increasingly influence the types of HPWHs available in the California market, incentive program installation requirements, and enable the deployment of technology as a form of thermal energy storage. [72] Additional details on JA-13's appliance communication requirements are discussed below.

Over the past decade, multiple states' lab testing, field demonstration, and technology specification refinements have proven that properly configured and installed unitary and split system HPWHs in the single-family sector can function as thermal energy storage. However, both integrated and split system central HPWH designs serving multi-family and commercial buildings have not received as much research and analysis. This lack of early research makes these sectors ripe for strategic market transformation.

Industry consensus on the optimal communications standards and protocols to enable HPWH load shifting is an evolving topic without a clear consensus. As such, Staff provide a brief overview of the topic, focusing on single-family residential HPWHs here.

With the CEC's adoption of JA-13 in July 2020, California took two innovative steps forward by requiring JA-13 compliant HPWHs to have the ability to download and store local utility time-of-use

[68] Id, p.24.
[69] A Joint Appendix is a Title 24 Part 6 Energy Code compliance option that has been approved by the CEC.
[70] CEC JA-13 Heat Pump Water Heater Demand Management Systems. See: https://www.energy.ca.gov/rules-and-regulations/building-energy-efficiency/manufacturer-certification-building-equipment/ja13
[71] Compliance credits are used to meet the energy efficiency requirements of the Energy Code through the performance pathway.
[72] As of January 31, 2021, two national original equipment manufacturers (AO. Smith and Rheem) are selling JA-13 compliant HPWHs in California. For a full list of models see: https://www.energy.ca.gov/media/4490.

schedules and by establishing local and remote communication methods that residential HPWHs in new construction must meet to receive compliance credit. Local communication methods are defined as "a method that can be performed from within the building that does not require the [HPWH] to have a live connection to an off-premise source. A temporary connection to a live off-premise source such as a smart phone, may be used for local setup and updates."[73] Local methods can also include a temporary connection to local WiFi internet or a Bluetooth connection. An example of a local communication method is the download and set up of TOU schedules and demand management controls at the point of installation. In contrast, a remote method is defined as "a method that is performed via a live connection to an off-premise source, such as the internet, advanced metering infrastructure (AMI), or cellular communication."[74] Remote methods mirror more traditional demand response programs where an off-premise signal is sent either by a utility or third-party to a HPWH with a set of demand management controls.

Beyond California, NEEA and the US Environmental Protection Agency (EPA) proposed separate but interrelated requirements for residential HPWHs. In its latest update to its advanced water heating specification, NEEA required all HPWHs rated Tier 3 and higher under its specifications to have a CTA-2045 or equivalent connectivity. CTA-2045 is an American National Standards Institute (ANSI) standard that defines both a connection standard and an information exchange signal between two different technologies. CTA-2045-A defines the standards and physical dimensions of the mechanical and electrical connection (*i.e.,* a port) and the physical devices' standards and physical dimensions that "plugs in" to that connection. This "plug-in" device is called a Universal Communication Module (UCM) and is akin to a computer USB thumb drive. A Universal Communication Module can be designed to receive and send signals over multiple telemetries, including WiFi, Bluetooth, a cellular phone, etc. This multiple telemetry pathway can enable greater participation of low-income customers who may not have access to WiFi in their households. CTA-2045 also defines the information exchange model (*i.e.,* demand response signal) that can be used to communicate a demand management signal through a CTA-2045 UCM.

In February 2021, the US EPA issued its Final Draft Version 4.0 Program Requirements Product Specification for Residential Water Heater, which includes an optional Connected Product Criteria for water heaters. The proposed protocols would require "connected" HPWHs to "meet the communication and

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[73] CEC's JA-13, p.1. See: https://www.energy.ca.gov/sites/default/files/2020-07/JA13_Qualification_Requirement_HPWH_DM_ADA.pdf
[74] Id.

equipment performance standards for CTA-2045-A, OpenADR 2.0b (Virtual End Node), or both."[75] The OpenADR 2.0b exchange protocol developed by the OpenADR Alliance is an information exchange model that can be executed absent a CTA-2045-A UCM.[76] In addition, the specification defined specific demand response operational modes, including a "load up" operational mode, similar to the one required by the CEC in JA-13.

75 ENERGY STAR® Program Requirements Product Specification for Residential Water Heaters Eligibility Criteria Draft 1, Version 4.0 at p.8: https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Final%20Draft%20Version%204.0%20Water%20Heaters%20Specification.pdf

76 https://www.openadr.org/assets/openadr_drprogramguide_v1.0.pdf

3 Challenges

Both non-load shifting and load shifting HPWHs face considerable cost and customer adoption challenges. These challenges are primarily because approximately 90 percent of California's water heaters utilize natural gas as their primary fuel.[77] Additionally, it is important to understand the numerous other HPWH incentive programs operating in California to send appropriate and effective cost signals to customers. This section outlines the hurdles to HPWH adoption and the current incentive landscape before, in the next section, recommending incentive structures and values for increasing the deployment of HPWHs through SGIP.

3.1 HPWHs are More Expensive than Incumbent Technologies

In a retrofit scenario, replacing an existing natural gas water heater with a HPWH is an expensive endeavor in multiple ways.[78] Staff collected data on average integrated HPWH appliance costs and average natural gas water heater appliance costs for a typical residential household, shown in Table 3.1 below. As can be seen, integrated HPWH appliance costs are approximately double the cost of a natural gas water heater.[79]

Table 3-1: Comparison of Appliance Costs - HPWH and Natural Gas Water Heaters[80]

Tank Size	Average HPWH Appliance Cost	Average Natural Gas Water Heater Appliance Cost[81]	Delta to Achieve Appliance Price Parity
50-gal Unitary	$1,300	$600-$800	**$500-$700**
65-gal Unitary	$1,750	NA	--
75-gal Unitary	NA	$1,100	--
80-gal Unitary	$2,000	$1,250	**$750**

[77] 2009 California Residential Appliance Saturation Survey (RASS) Executive Summary p.11. See: https://bit.ly/3b3lEiH
[78] Replacing a propane water heater with a HPWH has the same cost barriers to adoption as a natural gas water heater.
[79] This cost difference is driven by the higher efficiency and zero-emission features that a HPWH provide compared to a standard atmospheric natural gas water heater found in many existing California homes.
[80] HPWH and natural gas water heater appliance costs were accessed on homedepot.com on January 6, 2021.
[81] Costs for federally code compliant minimum efficiency NG water heater.

In addition to appliance cost deltas, the cost of installing an integrated HPWH is more expensive than replacing an existing natural gas water heater. Switching to a HPWH requires additional installation labor to complete the necessary electrical changes to transition a building from a natural gas water heater to an electric-powered water heater. The specific obstacles to making this transition include:

- The difficulty of separately hiring both a plumber and an electrician to complete the installation or finding a general contractor with the appropriate licenses to install both the plumbing and electrical upgrades required for a HPWH.
- Completing the necessary electrical improvements to transition a building from a natural gas water heater to an electric-powered water heater.
- The complications of installing a sub-panel if there isn't enough circuit space on the main electrical panel.
- Finding a plumber familiar with HPWHs. Plumbing contractors strongly prefer the incumbent technologies and are hesitant to recommend a HPWH due to the technology's perceived drawbacks. To address the perceived drawbacks *(i.e.,* the need for greater maintenance, higher upfront appliance costs, additional time required to heat water, location concerns, and space requirements[82]*)* and risks of installing the appliance, plumbers increase their installation costs.

To transform the HPWH market beyond natural gas, the incentive provided by SGIP must enable the net project cost of installing a new HPWH to be equivalent to or less than the cost of replacing an existing natural gas water heater. To support this analysis, Staff requested and received gross HPWH cost data from existing HPWH incentive programs being implemented by Sacramento Municipal Utility District (SMUD), Silicon Valley Clean Energy (SVCE), San Jose Clean Energy (SJCE), and Marin County. The value shown in Table 3.2 below reflects average gross project costs, including both the appliance and installation.

[82] Building Decarbonization Coalition. Contractor Needs Assessment. April 22, 2020. See: http://www.buildingdecarb.org/uploads/3/0/7/3/30734489/emi_consulting_bdc_contractor_needs_assessment_report_final_2020.04.22__1_.pdf

Table 3-2: Total HPWH Project Cost by Incentive Program[83]

Program	Number of HPWH Installations	Average HPWH Project Costs without a Panel Upgrade (includes cost of the appliance)
Northern CA HPWH Incentive Programs	715	$4,540

If we assume labor costs of approximately $700 to install a new 50-gallon natural gas water heater when one has failed, this means a total project cost of $1,300-$1,500. Thus, the data in Table 3.2 indicates that a customer's out-of-pocket cost to purchase and install a 50-gallon HPWH on average is approximately $3,100 more than replacing their existing natural gas water heater with a new model upon failure.

Many of the same cost barriers found in single-family households are also found in multi-family and commercial buildings installing HPWHs. To support this analysis, Staff requested and received gross cost data for central HPWH installations from Staff at the California Department of Community Service and Development overseeing the implementation of the Low-Income Weatherization Program. Across 15 central HPWH projects serving 1,524 households, the average cost per unit was approximately $2,500. Given the only recent availability of integrated HPWHs to the commercial sector, Staff was could not request or receive costs data from other HPWH programs or sister agencies.

In addition to the higher costs of HPWHs, over 80 percent of water heater replacements in the United States are completed on an emergency basis (*i.e.,* upon failure or when service is needed).[84] This market adoption characteristic and the prevalence of natural gas water heaters make it challenging for customers to consider or even install HPWHs given the immediate desire to have hot water. Thus, incentives will be necessary to help overcome this barrier to adoption.

[83] Data is for a variety of tank sizes but is largely 50-gallon tanks (89 percent of projects). Note that 80-gallon tanks only represent 5 percent of the data.
[84] General Electric Appliances. How to increase the market penetration of HPWH Energy Star Presentation, Slide 4., See: https://www.energystar.gov/sites/default/files/asset/document/1_Francois%20LeBrasseur_Early%20and%20Often_FINAL.pdf

3.2 A HPWH Installation May Require an Electrical Panel and Service Upgrade

As noted in Section 3.2, some, but not all, customers will require an electrical panel, and potentially an electrical service line upgrade, if there is not adequate amperage on their existing electrical panel to accommodate the additional electrical load from a HPWH. Included in the HPWH cost data received from SMUD, SVCE, SJCE, and Marin County were HPWH projects that required an electrical panel upgrade to 200-amps. As can be seen in Table 3.3, the average marginal cost of completing an electrical panel upgrade was approximately $4,000 and, in many cases, led to a doubling of total gross project costs.

Table 3-3: Total HPWH Project Cost by Incentive Program[85]

Program	# HPWH Installations	Average HPWH Project Costs without a Panel Upgrade	Average HPWH Project Costs with an Electrical Panel Upgrade
Northern CA HPWH Incentive Programs	715	$4,540	$8,381

This data did not track which projects required an electrical service line upgrade, nor did it track any out-of-pocket costs to the customers that exceeded the Electrical Service Line Allowance available under Tariff Rules 15 and 16. Fortunately, the CPUC has already considered electrical service upgrades in the context of electric vehicle charging. In D.11-07-029, the CPUC classified costs in excess of the available Electrical Service Line Allowance as "common facility costs" and ordered the IOUs to track service and distribution system upgrade costs related to electrical vehicle electricity load.[86] In effect, this "common facility costs" classification shifted all electrical service upgrade costs, when needed, from individual customers to all residential ratepayers. In D.13-06-014, the CPUC found it appropriate to extend the "common facility costs" classification until June 13, 2016, due to minimal costs involved.[87] In D.16-06-11, the CPUC extended the "common facility costs" classification again until June 30, 2019, after determining

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[85] Data is for a variety of tank sizes but is largely 50-gallon tanks (89 percent of the data). Note that 80-gallon tanks only represent 5 percent of the data.

[86] Ordering Paragraph 5 classifies all residential service facility upgrade costs in excess of the residential allowance as common facility costs and Ordering Paragraph 6 directs the IOUs to prepare a load research report plan that "Track[s] and quantif[ies] all new load and associated upgrade costs in a manner that allows PEV load and related costs to be broken out and specifically identified." D.11-07-029, p. 86-87. See: https://docs.cpuc.ca.gov/PublishedDocs/WORD_PDF/FINAL_DECISION/139969.PDF

[87] D.13-06-014, See: https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M070/K281/70281733.PDF

the classification's costs had a de minis impacts on residential ratepayers.[88] In April 2019, the IOUs filed the Joint IOU Electric Vehicle Load Research Project report showing that, of the estimated 415,272 electric vehicle customers in California, only 618 customers (or 0.15 percent) who installed electric vehicle charging from 2011 to 2019 required a service line or distribution system upgrade, and, of those 618 customers, only 72 (or 11.65 percent) would have had to pay out-of-pocket costs in excess of the allowance.[89] However, these out-of-pocket costs would have ranged from $14 to $338,274 if the CPUC in D.11-07-029, D.13-06-014, and D.16-06-011 had not adopted special interim cost treatment that permitted basic electric vehicle charging costs exceeding the allowance to be classified as "common facility costs."[90] These same cost impediments exist for HPWH adoption.

Without funding, the costs associated with a necessary electric panel upgrade and potentially an electrical service upgrade will likely deter customers from adopting a HPWH.

3.3 Ensuring HPWHs Meet SGIP Requirements May Further Increase Costs

The question of how HPWHs meet the SGIP eligibility requirements was a key topic of discussion for the HPWH working group. D.19-09-027 called for "[e]nsuring load shifting" of HPWHs to be a priority question for Staff to address in the SGIP HPWH workshop.[91] D.20-01-021 further instructed the workshop to explore "whether SGIP should require use of controls to ensure HPWH re-heating off-peak."[92] As discussed at the workshops, the HPWH Advocates represented that, because HPWHs help incorporate renewables into the grid, they should not be required to have the additional controls necessary to avoid re-heating on-peak as a condition of receiving SGIP funding. In contrast, in its opening comments on HPWHs in the SGIP rulemaking (R.20-05-012), SoCalGas asserted, "While it is possible for HPWHs to function as a

[88] D.16-06-011, see: https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M070/K281/70281733.PDF
[89] Joint IOU Electric Vehicle Load Research Report 7th Report, Filed April 2, 2019, p.8. See: https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M334/K604/334604419.PDF
[90] D.11-07-029 defined basic electric vehicle charging as Level 1 and 2 charging for at least one vehicle, p.59. See: https://docs.cpuc.ca.gov/PublishedDocs/WORD_PDF/FINAL_DECISION/139969.PDF
[91] D.19-09-027 at p.71. https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M313/K975/313975481.PDF
[92] D.20-01-021 at p.22.

[thermal energy storage] system, it will require the adoption of explicit program rules to ensure shifting the increased electric load to non-peak times."[93]

All tank water heaters, including HPWHs, by design and standard operation function as a type of thermal energy storage since the water tank stores thermal energy in the form of hot water for later use. With the adoption of D.19-08-001, D.19-09-027, and D.20-01-021, the CPUC acknowledged that HPWHs can function as a type of SGIP eligible thermal energy storage given their ability to "shift load from peak to off-peak periods"[94]and meet all five of SGIP's statutorily-required eligibility criteria identified in PU Code §§ 379.6(e) and 379.6(b)(1), as well as the environmental, grid benefits, and market transformation goals adopted by the CPUC in D.16-06-055. As stated in PU Code § 379.6(e), behind-the-meter technologies eligible for SGIP must be able to shift onsite energy use to off-peak time periods or reduce demand from the grid by offsetting some or all of the customer's onsite energy load. Suppose a HPWH is replacing a customer's existing electric resistance water heater. In that case, the HPWH will offset or reduce a portion of a customer's onsite energy load by virtue of the HPWH being a more efficient water heating technology. This reduction means that HPWHs replacing electric resistance water heaters meet the SGIP eligibility requirement to reduce onsite load. If, in contrast, a HPWH is replacing a customer's existing natural gas water heater, the HPWH will not offset a customer's onsite energy load and will *increase* demand on the electric grid. This increase means that, to be eligible for SGIP, a HPWH replacing a natural gas water heater must shift onsite energy use to off-peak time periods.

Requiring load shifting HPWHs in SGIP increases gross project costs, thus making the economics of fuel substituting from natural gas to a HPWH even more of a challenge. For example, installing a TMV to enable the safe overheating of the storage tank can increase a project's cost by two hundred dollars or more. The HPWH appliance itself may be more expensive. Additionally, the procurement and installation of equipment to enable maximal load shifting, such as a CTA-2045 UCM, increases costs.

[93] Comments of Southern California Gas Company to Order Instituting Rulemaking Regarding Policies, Procedures and Rules for the Self-Generation Incentive Program and Related Issues. June 29, 2020, p.11.See: https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M341/K393/341393484.PDF

[94] D.19-09-027, p.68. See: https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M313/K975/313975481.PDF

3.4 Accounting for GHG Emissions is Complicated

Evaluators compare the GHG emissions of SGIP-funded energy storage technologies to the emissions associated with powering the electric grid.[95] For electrochemical storage, evaluators measure GHG emissions according to when the system charges and discharges. In contrast, for thermal energy storage technologies currently funded by SGIP, evaluators must create a counter factual operational baseline to represent what would have happened in the intervention's absence. HPWHs are unique in SGIP as thermal energy storage systems, as they are not an added technology but instead a replacement technology. When a HPWH replaces an electric resistance water heater, GHG accounting follows the same operational baseline calculation currently used for other energy storage technologies because what is being measured is the GHGs of the electricity used. However, when a HPWH replaces a natural gas water heater, the GHG emissions must take into consideration the reduction of natural gas usage along with the increase in, and timing of, electricity usage.

This baseline challenge and regulatory precedent led to continual debate among the HPWH Working Group – whether the GHG emission reductions associated with HPWHs should be only based on the GHG emission reductions associated with the electrical grid (including whether or not the HPWH could load shift) or if the GHG emission reductions should also include the GHG emissions of the existing water heating technology that the HPWH was replacing. During the working group meetings, NRDC calculated and presented Figure 3.1 below, showing that regardless of the counterfactual baseline selected, both non-load shifting and load shifting residential HPWHs far exceed the five-kilogram carbon dioxide (CO_2) per kWh GHG threshold requirement established for SGIP-funded commercial energy storage projects.

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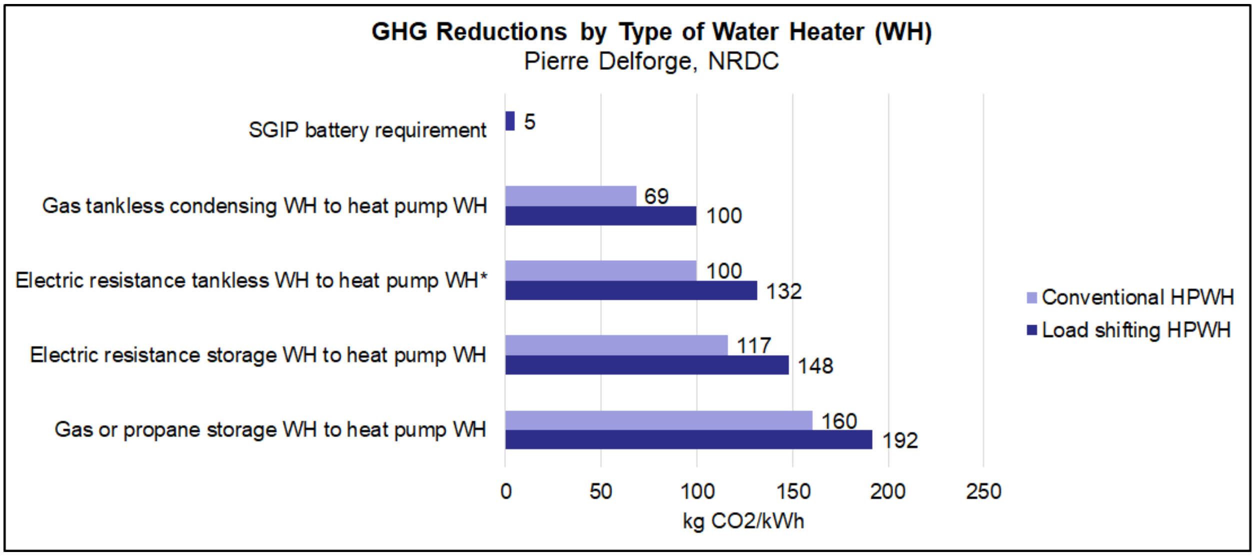
[95] This was also discussed in the December 29, 2017 ACR that directed the creation of the SGIP GHG Signal Working Group in R.12-11-005. The ACR states, "the working group should develop operational requirements for SGIP energy storage systems based on the GHG emissions of the electric grid". Assigned Commissioner's Ruling (1) Establishing an Energy Storage Greenhouse Gas Signal Working Group (2) Entering a Summary of the November 15, 2017 Energy Storage Workshop, p.3

Figure 3.1: GHG Reductions by Water Heater Type[96]



The majority of the HPWH Working Group members agreed that there is no simple solution for measuring the counterfactual emissions of water heating solely against the electric grid. Still, they accepted the use of a tankless electric resistance water heater as a proxy for baseline grid water heater emissions. The group felt that this was an appropriate representation due to the temporal match between tankless ERWH demand and electrical grid utilization.

Absent from the HPWH Working Group discussion on GHG emissions was how to incorporate any HPWH refrigerant leakage into the GHG reduction accounting. As noted in the Background section, the primary refrigerant used in the HPWH marketplace is R-134a which has a GWP of 1,430. Several parties commented that, if fully leaked during installation or operation, HPWHs using R-134a would decrease by less than 10 percent, but not eliminate, the GHG life cycle emission benefits of an SGIP-funded HPWH.[97] While Staff note that, with proper installation, the risk of refrigerant leakage is low, it is not zero. Due to

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[96] May 7, 2020, SGIP HPWH Workshop Part 2, Slide 8. See: https://www.cpuc.ca.gov/uploadedFiles/CPUC_Public_Website/Content/Utilities_and_Industries/Energy/Energy_Programs/Demand_Side_Management/Customer_Gen_and_Storage/SGIP.HPWH.Workshop.Part2.pdf.

[97] As stated in the comments of the California Environmental Justice Alliance (CEJA), NRDC, and SC on the proposed decision establishing building decarbonization pilots in R.19-11-001, "…over a 15-year life, a HPWH avoids 8.9 MT CO_2e compared to a gas water heater, not including avoided methane leakage. Therefore, refrigerant leakage offsets less than 10 percent of the lifetime emissions savings in the worst-case scenario, [full leakage] and without accounting for the climate impacts from fugitive methane from fossil gas production, processing, distribution and behind-the-meter leakage which would further increase the emissions reduction benefits of HPWHs." March 3, 2020. At p.5. See: https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M328/K691/328691031.PDF

their high upfront costs, their current split system design, and increased installation costs associated with the systems, HPWH technologies with refrigerants with a GWP of less than 1,000 are typically only available from distributors.

In the single-family market, the only HPWH that utilizes a refrigerant with a GWP of less than 1,000 is manufactured, marketed, and sold by ECO2 Systems LLC. This product currently sells for approximately $3,900 to $4,300, a nearly 100 percent premium over comparable unitary HPWH models available in the single-family market. Multiple factors drive this price premium, but it is primarily due to the compressor system's need to operate at a higher pressure to utilize R-744.[98] This demand for higher operating pressure requires more robust materials to be used in the compressor system, thus increasing the appliance's upfront costs. In addition to the HPWH appliance being more expensive, the water heating market is saturated with unitary or tankless water heaters. Thus, to install a split R-744-based refrigerant system like the SanCO2 model requires additional costs to modify the existing plumbing at the storage tank and install new plumbing to the separate compressor system.

This combination of higher appliance costs and installation costs makes the only available single-family market CO_2-based HPWH a "niche" product and not easily available to the public. Unlike other unitary HPWHs, which can be purchased directly at a national home improvement retailer like Home Deport or Lowes, CO_2-based HPWHs must be purchased directly from a distributor.

An added challenge is that since proper installation largely ensures that HPWHs will not leak refrigerants, the problem with refrigerant leakage is mostly an end-of-life appliance disposal issue. To date, the disposal and recycling of SGIP funded technologies have remained outside the scope of the program's GHG accounting.

3.5 Other HPWHs Programs are Providing Incentives Concurrently

Since the initial budget carve-out for HPWHs in SGIP was approved in September 2019, the CPUC has created, modified, or is actively reviewing a number of other regulatory programs intended to encourage the adoption of HPWHs through incentives.[99] These programs have different funding sources, design

[98] R-744 operates at approximately double the pressure of R-134a and thus requires more robust compressor system components.
[99] A fact sheet on approved CPUC HPWH incentive programs as of May 1, 2020 is available here: https://www.cpuc.ca.gov/WorkArea/DownloadAsset.aspx?id=6442465700

requirements, cost-effectiveness requirements, goals, and evaluation methodologies. To provide clarity and direction to the state's HPWH marketplace, the CPUC directed Energy Division to conduct a workshop and produce a staff proposal with a framework for how to address funding when incentives are layered.

On August 20, 2020, an Energy Division issued an incentive layering Staff Proposal in the CPUC's Building Decarbonization proceeding (R.19-01-011). That Staff Proposal outlined an incentive layering framework by which the incentive programs for heat pump technologies could be coordinated to bring market certainty for deployment and simplify the administration of incentives for program participants.[100] The Staff Proposal suggested that a heat pump program implementer could layer incentives from the multiple budgets, but receive credit for the proportion of the incentive provided vis-à-vis other incentives during program evaluation. For example, if a heat pump-funded energy efficiency program provides only 20 percent of the total incentive value, then that program implementer may only claim 20 percent of the program's evaluated ex-post benefits, which may include energy savings, demand savings, GHG emission reductions, or any other program metric. Notably, the Staff Proposal defined the total incentive value as any incentive applied to lower the cost of purchasing the appliance but did not consider any additional incentive provided to enable the installation or control of the appliance.

On September 24, 2020, the Assigned Commissioner issued an ACR in the Building Decarbonization proceeding seeking feedback on the proposed incentive layering framework. In comments on the ACR, parties flagged that the statewide energy efficiency plug load and appliance program, the building decarbonization's Technology and Equipment for Clean Heating (TECH) Initiative, and SGIP could each provide incentives for a single HPWH. Parties noted that each program has a different set of goals, provides incentives at different points in the supply chain (*i.e.,* upstream, midstream, or downstream), and at different times during the installation process (*i.e.,* pre-installation and post-installation). Parties also emphasized that it is critical to consider the gross cost of HPWHs, including incentives for installation and control of the appliance. Several parties opposed the Staff Proposal's proposed attribution methodology, arguing that the potential reduction in attributable savings would negatively impact existing contracts, program cost-effectiveness, be highly disruptive to energy efficiency contracts under review, and create a future disincentive to pursue heat pump measures. Notably, incentive layering is most problematic for the energy

[100] The Building Decarbonization Phase II Staff Proposal incentive layering framework also applied to other building decarbonization technologies such as heat pump heating ventilation air conditioning (HVAC) appliances, and induction stove ranges. See: https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M345/K591/345591050.PDF

efficiency portfolio where budget and program approval depend on an ex-ante (*i.e.,* forecasted) portfolio cost-effectiveness. In contrast, program budgets for SGIP and the TECH Initiative are not dependent on a program ex-ante cost-effectiveness.

4 Recommendations

In this section, we provide Staff recommendations for "removing barriers to HPWH [participation] in SGIP."[101] As directed in D.19-09-027, this includes programmatic structures to ensure load shifting, enable coordination with other HPWH incentive programs, and achieve equity in HPWH deployment. We first propose appliance, installation, and operational requirements for all SGIP-funded HPWHs, and recommend allocating the HPWH budget by technology type and customer class. Then we recommend incentive values and structures for each technology type and customer class. Finally, we discuss the administration of SGIP incentives and make recommendations for evaluating the program.

4.1 Appliance, Installation, and Load Shifting Requirements

As discussed in Section 3.3, a HPWH replacing an electric resistance water heater meets SGIP's statutory eligibility requirements, as the HPWH "reduces demand from the grid by offsetting some or all of the customer's onsite energy load."[102] In contrast, a HPWH that replaces a natural gas water heater increases demand from the grid and thus requires controls to ensure that the HPWH "shifts onsite energy use to off-peak time periods."[103] Staff recommend that the CPUC require all SGIP-funded HPWHs to shift load from peak to off-peak periods through controls and operational parameters. This requirement is the simplest way for the CPUC to ensure that regardless of the existing water heater fuel type (*i.e.,* natural gas, electricity, propane, or wood), all HPWHs meet SGIP's statutory requirements to reduce grid demand or shift peak demand.[104]

A typical electric load curve of a load shifting HPWH installed in an individual single-family or multi-family household is shown in Figure 4.1. Importantly, Figure 4.1 shows that such households typically shift electricity use from both the morning and the evening peak into the middle of the day when solar photovoltaic generation is highest. This shifting of load from the morning and evening reduces GHG

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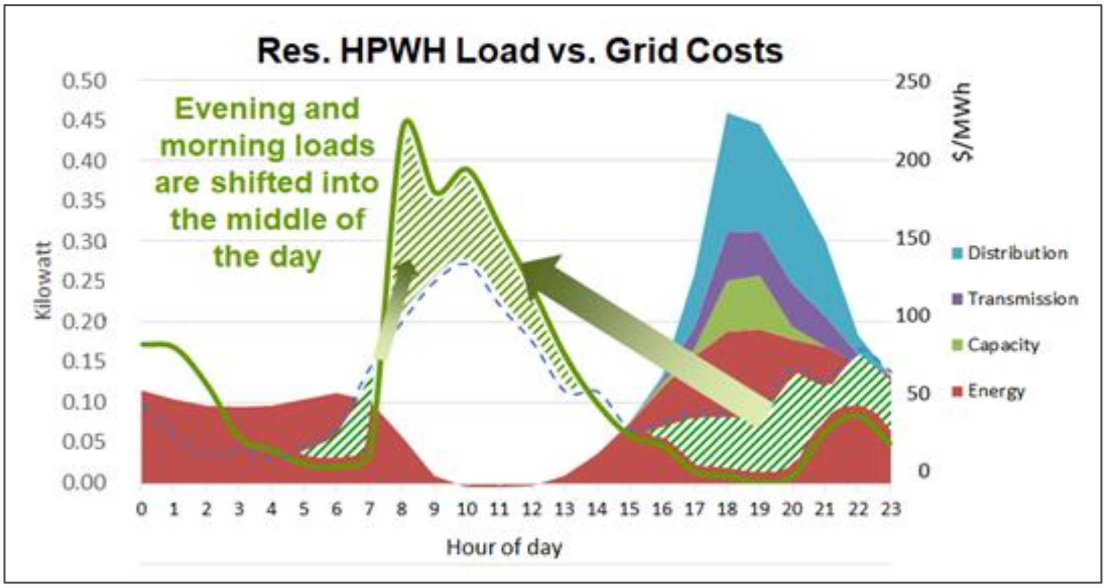
[101] D.19-09-027 at p.70.
[102] PU Code § 379.6(e)
[103] *Id.*
[104] In addition, requiring that HPWHs load shift (1) is in alignment with the load shifting suggestions and recommendations provided by the California Energy and Storage Alliance, the Joint Community Choice Aggregators, SC/NRDC, and SCE in comments on the SB 700 ACR; (2) helps achieve the state's GHG emission reductions goals by maximizing the integration of renewables; (3) lowers customer bills by shifting energy usage off peak time of use (TOU) periods; and (4) Advances California's broader demand flexibility market transformation efforts.

emissions, and the shift of load during the evening improves system reliability. These benefits align with the statutory goals of SGIP.

Figure 4.1: A Load Shifting Residential HPWH Load Curve[105]



To ensure load shifting, Staff recommend a set of appliance, installation, and operational requirements by HPWH technology[106] and customer class, as described below. These recommendations are primarily based on the HPWH Advocates' May 7, 2020 workshop recommendations.

Residential Unitary HPWHs

Staff propose that residential unitary HPWHs be defined as both "integrated" and "split" HPWHs with a total nominal compressor output power of six kilowatts (kW) or less installed to serve a single household in a single-family, duplex, or multi-family property. This definition and compressor output power designation align with the US Department of Energy definition for residential consumer water heaters.[107]

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[105] Pierre Delforge presentation at March 19, 2020 Part 1 SGIP HPWH workshop. Data sources: HPWH Load: Carew N. et. al., "Heat Pump Water Heater Electric Load Shifting: A Modeling Study," Ecotope, Jun. 2018

[106] Unitary (including both integrated and split systems) and central HPWHs that serve more than two units. The proposed HPWH technology categories are based on the categories presented by the HPWH Advocates on slide 115 at the May 7, 2020 Part 2 SGIP HPWH workshop. See: https://www.cpuc.ca.gov/uploadedFiles/CPUC_Public_Website/Content/Utilities_and_Industries/Energy/Energy_Programs/Demand_Side_Management/Customer_Gen_and_Storage/SGIP.HPWH.Workshop.Part2.pdf

[107] The Code of Federal Regulations defines a residential heat pump water heater as unit with "A maximum current rating of 24 amperes at a voltage no greater than 250 volts. See: https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=32

Appliance Requirements:

- Must be identified as a JA-13 compliant water heater by the CEC,[108]
- And be identified by NEEA's most recent qualified product list as having a CTA-2045 Compliant Communication Port.[109]

These requirements ensure that all SGIP-funded residential unitary HPWHs can store TOU rates internally in the appliance and have a CTA-2045 port. These dual requirements ensure that utilities and demand response providers can signal a SGIP funded HPWH utilizing various communication pathways.

Installation Requirements:

- Residential unitary HPWHs should be installed in compliance with the CEC's JA-13 installation specifications.
- Integrated residential unitary HPWHs should be installed at a 135°F tank setpoint and a 120°F thermostatic mixing valve setpoint temperature.
- Split system residential unitary HPWHs should be installed at a 150°F and a 120°F TMV setpoint and a 120°F thermostatic mixing valve setpoint temperature.

These requirements ensure unitary HPWHs are installed to function as thermal energy storage, achieve the load shifting benefits identified in the Ecotope/NRDC study, and safely provide hot water to households.[110]

Load Shifting Requirements:

- Residential unitary HPWHs should be programmed to execute the basic load-up and light shed demand management functionality as defined in JA-13. This demand management functionality will

[108] The Energy Commission maintains a JA-13 HPWH Certification List on their website at: https://www.energy.ca.gov/rules-and-regulations/building-energy-efficiency/manufacturer-certification-building-equipment/ja13
[109] NEEA maintains their Qualified Product List on their website at: https://neea.org/our-work/advanced-water-heating-specification
[110] To avoid water scalding US CSPC recommends faucet delivered residential hot water temperature not exceed 120 Fahrenheit. See: https://www.cpsc.gov/s3fs-public/5098-Tap-Water-Scalds.pdf?m._5xOy.uwIEj8j_PNhlzcDfcLWoPdqJ#:~:text=The%20U.S.%20Consumer%20Product%20Safety,degree%20water%20for%20two%20seconds.

signal the HPWH to store thermal energy during certain times to avoid electricity usage at different times.

- Residential unitary HPWH should execute the basic load-up and light shed demand management response based on the local utility's available SGIP-complaint TOU rates.
- SGIP funded residential unitary HPWHs are permitted to enroll in demand response programs like other energy storage resources.

These requirements ensure that load is shifted from peak to off-peak periods and that both customer and utility benefits are maximized. Given the limited number and structure of the SGIP-compliant TOU rates, Staff does not recommend requiring customers to enroll their electricity accounts in one of these rates at this time.

Residential Central HPWHs

Staff propose that residential central HPWHs be defined as larger HPWH system designs that may include integrated and split system designs that meet two or more households' hot water demands. Staff does not propose establishing a strict total nominal compressor output threshold to allow for the submission of a variety of central HPWH system designs. Given the rarity of load shifting HPWHs in the multi-family sector, and the desire to encourage innovation, Staff propose that the SGIP HPWH PA be responsible for reviewing and approving applicants' proposed installation and load shifting operational parameters to ensure they meet the requirements below.

Appliance Requirements:

- Individually installed or ganged together, HPWHs serving two more households must be identified as a JA-13 compliant water heater by the CEC or meet the US EPA's Energy Star Commercial Water Heater Specifications Version 2.0 requirements.
- Larger central HPWH system designs must be approved and included in the CEC's California Building Energy Code Compliance software.[111]

[111] The California Building Energy Code Compliance software is used by the CEC to ensure compliance with the California Energy Code.

These requirements seek to ensure that all SGIP funded HPWHs installed in multi-family buildings shift load from peak to off-peak periods.

Installation & Load Shifting Requirements:

- Residential central HPWHs must be installed and operated in a manner that shifts energy from peak to off-peak periods and annually reduces GHG emissions by five-kilogram of CO_2 per kWh, like all other non-residential SGIP energy storage technologies.
- SGIP funded residential central HPWHs are permitted to enroll in demand response programs like other energy storage resources.

These requirements ensure that load is shifted from peak to off-peak periods and that both customer and utility benefits are maximized. Given the variety of central HPWH installations, limited number, and structure of the SGIP-compliant TOU rates, Staff do not recommend requiring customers to enroll their electricity accounts in one of these rates at this time.

Commercial Unitary HPWHs

Staff propose that commercial unitary HPWHs be defined as a single or ganged together integrated or split system HPWH serving a single business's hot water demand with a total nominal compressor output power of six kW or more. This classification builds upon the US Department of Energy's definition for residential consumer water heaters and allows residential units to ganged together to meet a business's hot water demands.[112] Given the rarity of load shifting HPWHs in the commercial sector, and the desire to encourage innovation, Staff propose that the SGIP HPWH PA be responsible for reviewing and approving applicants' proposed installation and load shifting operational parameters to ensure they meet the requirements below.

[112] The Code of Federal Regulations defines a residential heat pump water heater as unit with "A maximum current rating of 24 amperes at a voltage no greater than 250 volts. See: https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=32

Appliance Requirements:

- Individually installed commercial unitary HPWHs must meet the US EPA's Energy Star Commercial Water Heater Specifications Version 2.0 requirements.[113]
- "Ganged" together commercial unitary HPWHs must be identified as JA-13 compliant water heaters by the CEC or meet the US EPA's Energy Star Commercial Water Heater Specifications Version 2.0 requirements.

These requirements seek to ensure that all SGIP funded HPWHs installed in commercial buildings can shift load from peak to off-peak periods.

Installation & Load Shifting Requirements:

- Commercial unitary HPWHs applications must be installed and operated in a manner that shifts energy from peak to off-peak periods and annually reduces GHG emissions by five-kilogram of CO_2 per kWh, like all other non-residential SGIP energy storage technologies.
- SGIP funded commercial unitary HPWHs are permitted to enroll in demand response programs like other energy storage resources.

These requirements ensure that load is shifted from peak to off-peak periods and that both customer and utility benefits are maximized.

Commercial Central HPWHs

Given the uncertain ability of this commercial central HPWHs configuration to shift load and the administrative complexity required to establish rules for the technology's participation, Staff propose that commercial central HPWHs not be eligible for SGIP incentives

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[113] See: https://www.energystar.gov/sites/default/files/Program%20Requirements_Commercial%20Water%20Heaters_Final%20Version%202.0_12%2029%2017.pdf

4.2 Budgetary Allocations

As discussed in the Background section, D.19-09-027 allocated $4,000,000 to equity HPWHs while D.20-01-021 allocated $40,670,000 to general market HPWHs, thus creating a total SGIP HPWH budget of $44,670,000.[114] Neither decision allocated any funding for the administration of HPWHs in SGIP. We turn to this component of the SGIP HPWH budget allocation first.

Funding for Program Administration of HPWHs in SGIP

D.20-01-021 provided new program administration funding to CSE and SoCalGas, but directed that PG&E and SCE use existing, unspent funds.[115] These new and existing program administration funds are intended to enable each of the four SGIP PAs to "cover administrative costs incurred for up to eight years past the date the last SGIP application will be accepted – January 1, 2026."[116] Staff note that the recommended modifications to SGIP for HPWHs in this Staff Proposal are extensive and would require extra SGIP PA staff time, above and beyond their current capacity.[117] Additionally, as discussed in Section 4.6, Staff recommend that the CPUC select a single statewide entity to administer and implement HPWH incentives under SGIP. If the CPUC adopts this recommendation, funding would have to be set aside for this new entity. Thus, Staff recommend that five percent of the total SGIP HPWH budget, or $2,233,500, be allocated to program administration.[118] Staff believes this funding level is sufficient for a new entity to develop and implement a HPWH subprogram under SGIP. This funding level also reserves 95 percent of program funding for HPWH Incentives, as shown in Table 4.1 below and discussed next.

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[114] D.20-01-021 was subsequently corrected by D.20-02-039.
[115] D.20-01-021 at p.25.
[116] D.20-01-021 at p.23.
[117] CSE's statement in their comments on the August 17, 2020 SGIP scoping memo regarding the challenges of integrating electric vehicle charging into SGIP is informative of the effort required to incorporate any new technology into SGIP. CSE state that the CPUC should "carefully consider the unique administrative challenges that integrating a new technology and use cases would entail and ensure that the PAs have adequate administrative budgets to develop a new suite of rules, processes, and program database upgrades to accommodate its inclusion." Comments of the Center for Sustainable Energy in Response to the Assigned Commissioner's Scoping Memo and Ruling. Filed in R.20-05-012. September 16, 2020, p.9. See: https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M347/K199/347199108.PDF
[118] Historically in SGIP, seven percent of the SGIP budget for each PA was set aside for program administration, including general administration, marketing, education and outreach and evaluation, monitoring and verification costs. As noted above, these allocations were modified in D.20-01-021 with CSE now receiving an 11 percent allocation, SoCalGas continuing to receive a seven percent allocation, and PG&E and SCE being required to use unspent program administration funding rather than receiving new funds. Given that there should be economies of scale from having one statewide PA for SGIP HPWHs, staff believe that a five percent allocation for program administration should be sufficient.

Table 4-1: SGIP HPWH Budget Allocation by Activity

Activity	Amount
Program Administration	$2,233,500
HPWH Incentives	$42,436,500
Total SGIP HPWH Budget	**$44,670,000**

HPWH Budget Allocation by Customer Class and HPWH Technology

Staff recommend that 90 percent, or $38,192,850, of the HPWH incentive budget be allocated to residential customers installing unitary HPWHs in existing properties. The residential customer classification includes single-family homes, duplexes, and any multi-family property where an individual household's hot water demand is being served by one load shifting HPWH, as discussed in Section 2.4.[119] Staff believe this budget allocation is appropriate due to the high degree of certainty that this customer class can successfully shift energy from peak to off-peak periods utilizing a residential unitary HPWH. In addition, Staff recommend increasing the allocation for equity customers from the $4 million initially ordered in D.19-09-027 to 45 percent, $19,096,425, of the total HPWH Incentive budget. D.19-09-027 stated, "[w]e are interested in the opportunities that HPWHs may provide for increased participation of equity budget customers in the SGIP and the related provision of grid services and bill reduction benefits because HPWHs are lower cost than most residential battery technologies."[120] This equity customer allocation leaves 45 percent, or $19,096,425, of the HPWH Incentive budget to residential general market customers.

Staff also recommend basing the eligibility for the SGIP residential equity HPWH on the existing SGIP equity eligibility rules, except Staff propose eliminating the requirement that single-family homes be subject to resale restrictions or presumed resale restrictions. Staff are concerned that retaining this requirement will unduly limit the participation of lower-income single-family households. Removing this requirement is justifiable due to the somewhat larger dollar investment required for electrochemical energy storage when compared to HPWHs[121]. While HPWHs are still a fixed asset and there is some risk that

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[119] Residential customers include all multi-family properties, including those that are partially or wholly on a commercial rate.
[120] D.19-09-027 at p. 71.
[121] D.20-01-021 found that the electrochemical energy storage had a median cost of $13,500, p.21. See: https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M325/K979/325979689.PDF

ratepayers may provide a higher-level incentive to a low-income customer only to have them subsequently move, the implications of this risk are lower.

Staff recommend that five percent of the total HPWH budget, or $2,121,825, be allocated to residential central HPWH systems installed in existing residential buildings or on multi-family residential properties. Staff recommend reserving 50 percent of the multi-family residential HPWH budget, or $1,060,912 for affordable housing properties that meet SGIP's existing equity budget requirements, and the other 50 percent, or $1,060,912, be available to general market customers.[122] Central HPWHs have not received the same level of lab testing and field research as residential unitary HPWHs, and the degree to which these systems will be able to shift load from peak to off-peak periods is uncertain. Thus, Staff recommend a small budget allocation for central HPWHs, and that projects subject to a per-project incentive cap of $300,000. [123] This budget allocation and incentive cap will enable the execution and analysis of several residential central HPWHs projects.

Staff recommend that five percent of the HPWH Incentive budget, $2,121,825, be allocated to commercial businesses installing unitary HPWHs. Staff are uncertain whether any specific commercial subsector can successfully shift load from peak to off-peak periods, given that commercial hot water demand profiles vary from sector to sector, as discussed in Section 2.4. Thus, there is a need to collect and validate unitary commercial HPWHs to shift load across a variety of commercial installations. To achieve this end goal, Staff recommend a small budget allocation for unitary commercial HPWHs, and that projects be subject to a per-project incentive cap of $50,000. Staff find these values reasonable given the current lack of project cost data, research on load shifting and the recommendation that unitary commercial HPWHs only serve a single business's hot water demand.

[122] A multi-family project eligible for the SGIP equity budget are defined as a multi-family residential building of at least five rental housing units that is operated to provide deed-restricted low-income residential housing, as described in clause (i) of subparagraph (A) of paragraph (3) of subdivision (a) of PU Code § 2852, and is either: (1) in a disadvantaged community or (2) a building where at least 80 percent of the households have incomes at or below 60 percent of the area median income, as defined in subdivision (f) of Health and Safety Code § 50052.5. SGIP 2021 Handbook at 120 (Definitions and Glossary).

[123] A $5 million maximum incentive amount per project cap exists in SGIP per Section 3.2.1 of the SGIP Handbook, "Maximum Incentive Amount."

Table 4-2: SGIP HPWH Incentive Budget Allocation by Customer Class

Customer Class (Residential includes multi-family residential properties on commercial rates)	**Percent**	**Amount**
General Market Residential Unitary HPWHs	45%	$19,096,425
Equity Residential Unitary HPWHs	45%	$19,096,425
General Market Residential Central HPWHs	2.5%	$1,060,912
Equity Residential Central HPWHs	2.5%	$1,060,912
Commercial Unitary HPWHs	5%	$2,121,825
Total SGIP HPWH Incentive Budget	**100**	**$42,436,500**

4.3 Incentive Amounts for Residential Unitary HPWHs

Staff recommend three incentives to increase the adoption of residential unitary HPWHs to meet individual household hot water demands. These three incentives are designed to achieve price parity with a replacement natural gas water heater purchase and installation, cover the incremental costs associated with load shifting HPWH installations, and encourage the market adoption of HPWHs utilizing low-GWP refrigerants. Discussed below are each incentive structure and value.

Incentive Structure

Staff propose basing the residential unitary HPWH on the energy storage capacity of a 50-gallon tank volume and a setpoint temperature of 135°F. Staff find this incentive structure appropriate because 50-gallon tanks account for the majority of the installed HPWH units in the California marketplace. Furthermore, as noted in the Ecotope/NRDC study discussed in Section 2.5, at 135°F setpoint, customers see a 14 percent annual reduction in bill costs, and utilities see a 34 percent reduction in annual costs compared to non-load shifting HPWHs.[124] Above this setpoint temperature, customer bill savings decrease and utility savings only marginally increase. Additionally, a single unitary energy storage capacity value that

[124] Ecotope/NRDC Heat Pump Water Heater Electric Load Shifting: A Modeling Study, 2018 p.21. See: https://ecotope-publications-database.ecotope.com/2018_001_HPWHLoadShiftingModelingStudy.pdf

does not vary by size or refrigerant type reduces administrative complexity and avoids creating an incentive to purchase an oversized HPWH simply to receive a larger incentive.

To determine the energy storage capacity value Staff recommend utilizing the estimated electric storage capacity of a unitary HPWH provided by NRDC.[125] This approach utilizes a HPWH's tank volume and a selected tank setpoint temperature to convert gallons of stored hot water into kWhs (see Figure 4.2). At a 50-gallon tank volume and 135°F setpoint, Staff calculate an energy storage capacity of 3.1 kWh.[126]

Figure 4.2: Calculated Electric Storage Capacity of Unitary HPWHs[127]

Electric Storage Capacity (Gallons to kWh)

NRDC calculation based on 60 F inlet temperature and average COP of 3

		Tank volume		
		50 gal	65 gal	80 gal
Set point	120 F	2.4	3.2	3.9
	130 F	2.9	3.7	4.6
	140 F	3.3	4.2	5.2
	150 F	3.7	4.8	5.9

125 See NRDC presentation for the March 19, 2020 SGIP HPWH Part One Workshop, available as of March 2021 here: https://www.cpuc.ca.gov/uploadedFiles/CPUC_Public_Website/Content/Utilities_and_Industries/Energy/Energy_Programs/Demand_Side_Management/Customer_Gen_and_Storage/SGIP_HPWH_Webinar.pdf

126 The calculation is as follows:

(1) Multiply the tank volume (in gallons) by the tank setpoint temperature minus the tank inlet temperature (assume 60 degrees Fahrenheit for the inlet temperature).

(2) Multiply the result of the first step by the conversion factor to derive total British thermal units (BTUs) (8.34 pounds per gallon).

(3) Divide the result of the second step by the conversion factor to derive kWh (3,412 BTUs per kWh); and

(4) Divide the result of the third step by the Coefficient of Performance (COP) of the HPWH to derive the storage capacity (assume COP of 3).

This yields the kWh storage capacity of the HPWH.

127 Chart created by NRDC and presented at March 19, 2020 SGIP HPWH Part 1 Workshop. Slides available at: https://www.cpuc.ca.gov/uploadedFiles/CPUC_Public_Website/Content/Utilities_and_Industries/Energy/Energy_Programs/Demand_Side_Management/Customer_Gen_and_Storage/SGIP_HPWH_Webinar.pdf

Incentive Value

Based on an estimated $1,400 cost for replacing a natural gas water, Staff recommend setting the initial residential unitary HPWH incentive value for residential general market customers at $1,000/kWh. This $1000/kWh incentive value would provide a general rate market customer with a $3,100 incentive.[128] Staff find it appropriate to essentially eliminate the cost of a HPWH upgrade for equity customers. We believe this is necessary because low-income customers can access partially or fully subsidized natural gas water heaters as an alternative in other programs. As such, Staff recommend setting the initial residential unitary HPWH incentive value residential equity customers at $1,350/kWh. This incentive value would provide a residential equity customer with a $4,185 incentive and cover between 96 percent and 100 percent of the total project costs.[129] The recommended unitary HPWH incentive values by customer class are summarized in Table 4.3 below

Table 4-3: Recommended SGIP Residential Unitary HPWH Incentives by Customer Class

	General Market Residential Customers	Equity Residential Customers
Residential Unitary HPWH Incentive	$3,100 (3.1kWh * $1,000/kWh)	$4,185 (3.1kWh * $1,350kWh)

Low-GWP Kicker Incentive

Staff propose a low-GWP Appliance "Kicker" Incentive of $1,500 across all tank sizes and customer classes for residential unitary HPWHs that use refrigerants with a GWP below 150.[130] Staff propose this generous incentive value for four reasons. First, the kicker incentive is meant to meaningfully lower the upfront cost of purchasing a unitary low-GWP HPWH as the currently available appliance models are

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128 $1,000/kWh * 3.1 kWh = $3,100

129 As stated in the SGIP 2021 Handbook, at Section 3.2.2, "No project can receive total incentives . . . that exceed the Total Eligible Project Costs. Submittal of Project cost details is required to report Total Eligible Project Costs and to ensure incentive limits are not exceeded." This rule should be maintained for all HPWHs funded by SGIP.

130 A GWP below 150 is what constitutes "low" under Section 100.1 of the California Energy Code and is the same value adopted by the CPUC in D.20-03-027. See: https://efiling.energy.ca.gov/GetDocument.aspx?tn=223246-1.

approximately three times the cost of higher GWP HPWHs.[131] Second, as noted in Section 2.5, low-GWP HPWHs, such as R-744 based HPWHs, operate at higher temperatures and thus can shift load for extended periods of time compared to other HPWHs. Third, the kicker incentive provides a signal to HPWH original equipment manufacturers to develop HPWHs that utilize other low-GWP refrigerants.[132] Fourth, the kicker incentive encourages original equipment manufacturers that market and sell R-744 HPWHs on the international market to bring their products to California.[133]

Electrical Panel Upgrade and Electrical Service Incentives

In addition to the residential unitary HPWH and the low-GWP kicker incentives, Staff also recommend that electrical panel upgrade costs be eligible for residential customers.[134] As explained in Section 2.3, due to California's aging building stock and climate zones differences, an unknown portion of residential unitary HPWH customers will not have the electrical panel capacity necessary to install a HPWH. As such, Staff recommend that residential customers with an electrical panel of 200-amps or less be eligible for an additional Electrical Panel Upgrade Incentive. Based on the data in Table 3.3, the average cost of a single-family residential electrical panel upgrade is approximately $4,000.

Staff recommend setting the SGIP HPWH Electrical Panel Upgrade Incentive at 70 percent, or $2,800, whichever is less for general market residential unitary customers, and at 90 percent of the upgrade costs, or $3,600, whichever is less, for residential equity customers. By capping the Electrical Panel Upgrade Incentive as a percent of actual costs, the SGIP HPWH PA can reduce the incentive if the maximum dollar figure is not warranted in light of actual panel upgrade costs. Furthermore, to prevent these costs from dominating the SGIP HPWH incentive budget, Staff propose capping the Electrical Panel Upgrade Incentive costs at no more than 30 percent of both general market and equity residential budgets ($5,728,927 each). Staff acknowledge that these incentives (either $2,800 or $3,600) are quite high but also believe that removing this barrier for a portion of customers is valuable for transforming the marketplace.

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131 For example, as highlighted previously, Sanden's 43-gallon low-GWP HPWH systems currently costs $3,900-$4,300. See: https://worldclasssupply.com/store/Sanden-Generation-3-Heat-Pump-Water-Heater.html and https://foursevenfive.com/sanco2/

132 It will be the responsibility of the HPWH PA to establish appropriate incentive values for HPWHs using refrigerants besides R-744 based on their incremental appliance costs and operational characteristics.

133 Since 2001, R-744 based HPWHs have been marketed and sold by multiple original equipment manufacturers under the brand name Eco-Cute.

134 Eligible project costs under SGIP include electrical and critical loads panels and wiring upgrades in the SGIP equity resiliency and equity energy storage budgets, per D.20-01-021.

In addition to enabling a HPWH to be installed, a 200-amp electrical panel also enables customers to adopt additional behind-the-meter distributed energy resources more readily, such as energy storage, electric vehicle charging, and other heat pump technologies. Furthermore, providing an Electrical Panel Upgrade Incentive will provide the CPUC with data on the costs of upgrading electrical panels, upgrading the electrical service line to the utility meter, and the length of time it takes to complete the process. To enable this data collection, Staff recommend requiring Electrical Panel Upgrade Incentive applicants to document their electrical panel upgrade costs and any electrical service line upgrade costs completed by the electrical utility separate from the HPWH gross costs. This data will help inform future policies on the topic beyond SGIP. Table 4.4 below summarizes all three SGIP residential unitary HPWH incentives available to general market and equity residential customers.

Table 4-4: Maximum Unitary HPWH Incentives for a HPWH by Customer Class

Customer Class	Unitary HPWH Incentive	Low-GWP Kicker Incentive	Electrical Panel Upgrade Incentive	Max. SGIP HPWH Incentive
General Market Residential	$3,100	$1,500	$2,800	$7,400
Equity Residential	$4,185	$1,500	$3,600	$9,285

Given these incentive values, Staff estimate that between 5,250 and 10,723 households would be able to participate in SGIP. In the context of California's water heating appliance marketplace, these numbers are small; however, they would represent a 634 percent to 1400 percent growth in market adoption compared to the 715 units utilized for this analysis. Table 4.5 below summarizes the number of households by customer class.

Table 4-5: Number of Participating Households

Customer Class	Minimum number of participating households	Maximum number of participating households
General Market Residential	2,905[135]	6,160[136]
Equity Residential	2,351[137]	4,563[138]
Total	5,250	10,723

In addition to the incentives identified in Table 4.4, Staff also recommend that the CPUC direct the electrical IOUs to categorize any electrical service line upgrade costs required to complete a SGIP funded HPWH installation as "common facility costs" rather than a cost paid by the individual customer. As noted in the background and challenges section, electrical service line costs above the electrical service allowance available under Tariff Rules 15 and 16 can be significant and impede HPWH adoption. Thus, Staff find it appropriate to eliminate these costs for SGIP funded HPWHs given the small number of eligible households and the de minis cost of the classification has imposed on residential ratepayers in the past.

Incentive Layering

Having described the recommended values for residential unitary HPWH Incentives, next we recommend how residential unitary HPWH incentives should layer with other HPWH programs and how incentive values can adjust to account for market adoption signals.

Staff reviewed party comments filed in response to the incentive layering proposal presented in the R.19-01-011 Phase 2 Staff Proposal and have carefully considered how best to coordinate the SGIP HPWH program with other programs to ensure market certainty and customer and contractor clarity. With the

[135] The minimum number of participating general market households assumes, that 70 percent of the general market residential budget ($13,367,498) is utilized to provide a $3,100 unitary HPWH incentive, and $1,500 low-GWP kicker-incentive to 2,905 households. The remaining 30 percent of the general market residential budget ($5,728,928) is utilized to provide 2,046 of the 2,905 participating households with a $2,800 electrical service panel incentive.

[136] The maximum number of participating general market households assumes, that 100 percent of the general market residential budget ($19,096,425) is utilized to provide a $3,100 unitary HPWH incentive to 6,160 households.

[137] The minimum number of participating equity residential households assumes, that 70 percent of the equity residential budget ($13,367,498) is utilized to provide a $4,185 unitary HPWH incentive, and a $1,500 low-GWP kicker-incentive to 2,351 households. The remaining 30 percent of the equity residential budget ($5,728,928) is utilized to provide 1,591 of the 2,351 participating households with a $3,600 electrical service panel incentive.

[138] The maximum number of participating equity residential households assumes that 100 percent of the general market residential budget ($19,096,425) is utilized to provide a $4,185 unitary HPWH incentive to 4,563 households.

many incentive programs that include HPWHs now operating or pending final approval throughout the state, customers will want to layer incentives to reduce the cost of purchasing a new HPWH to the maximum extent possible. SGIP already has policies that cap the incentive amount at the total eligible project costs, rules on accounting for "incentives from other sources," and a disclosure requirement for when an applicant receives multiple incentives from multiple sources. Staff recommend that the total eligible project costs and multiple incentive disclosure requirement rules remain unchanged but recommend that the following rules be modified when incentive layering occurs.

First, Staff recommend reducing general market residential incentives by 100 percent of the value of other incentives for both ratepayer and non-ratepayer funded programs. This incentive reduction is a departure from the existing program rules, which only reduces the non-IOU ratepayer incentive by 50 percent of their value. Staff believes this appropriate given the generous incentives being proposed in this Staff Proposal and will simplify program administration given the number and variety of HPWHs throughout the state. Second, Staff recommend reducing equity residential customer incentives only when the total available incentive exceeds the total eligible project costs. When this occurs, the incentive should be reduced by 100 percent for both ratepayer and non-ratepayer funded programs until the sum of the SGIP and other incentives equal the total eligible project costs. Staff finds this modification in alignment with the existing SGIP Handbook and allows local equity program providers to design their programs to supplement SGIP funds.

Table 4.6 and Table 4.7 illustrate how incentive layering would occur for general market and equity residential customers under different scenarios. Staff lowered the HPWH project costs in "Incentive Layering Scenario 2" to convey how customer out-of-pocket costs lower when total project costs lower.

Table 4-6: Net Cost to a General Market Residential Customer When Incentive Layering Occurs

Incentive Layering Scenario	HPWH Project Cost (A)	Other HPWH Program Incentives (B)	SGIP Incentive Paid (C)	Total Incentive Paid (D)=(B+C)	Out-of-Pocket Customer Costs (E)=A-D
SGIP Only	$4,540[139]	--	$3,100	$3,100	**$1,250**
Incentive Layering Scenario 1	$4,540	$1,000	$2,100	$3,100	**$1,250**
Incentive Layering Scenario 2	$3,600[140]	$1,000	$2,100	$3,100	**$500**

Table 4-7: Net Cost to an Equity Residential Customer When Incentive Layering Occurs

Incentive Layering Scenario	Average HPWH Project Cost (A)	Other HPWH Program Incentives (B)	SGIP Incentive Paid (C)	Total Incentive Paid (D)=(B+C)	Net Cost (E)=A-D
SGIP Only	$4,350[141]	--	$4,185	$4,185	**$165**
Incentive Layering Scenario 1	$4,350	$1,000	$3,350	$4,350	**$0**
Incentive Layering Scenario 2	$3,600	$1,000	$2,600	$3,600	**$0**

[139] Using the statewide HPWH costs data discussed in Table 3.2, Staff estimate that a 50-gallon HPWH has an approximate gross project cost of $4,540. Notably, Table 3.2 includes some 65-gallon and larger gallon tanks, as well as a mix of load shifting and non-load shifting HPWHs. The load shifting HPWHs that will be eligible under SGIP will have higher total project costs than standard HPWHs because of the need to install a TMV, download TOU rates to the appliance, and program demand management controls.

[141] Using the statewide HPWH costs data discussed in Table 3.2, Staff estimate that a 50-gallon HPWH has an approximate gross project cost of $4,350. Notably, Table 3.2 includes some 65-gallon and larger gallon tanks, as well as a mix of load shifting and non-load shifting HPWHs. The load shifting HPWHs that will be eligible under SGIP will have higher total project costs than standard HPWHs because of the need to install a TMV, download TOU rates to the appliance, and program demand management controls.

Staff recommend that the SGIP HPWH PAs, in coordination with TECH Initiative, be responsible for adjusting the value of SGIP incentive based on incentive information disclosed by the applicant and verified using the incentive database being developed by the TECH Initiative.[142] Staff also propose that the CPUC require the SGIP HPWH PA to ensure the SGIP application is compatible with the TECH Initiative incentive tracking database.

Finally, Staff recommend that in lieu of prescriptive incentive step down, the SGIP HPWH PA be required to file a tier two advice letter annually on June 1st that summarizes the program data, highlights the impact on the load shifting HPWH marketplace, and, if recommended, proposes a new incentive value for general market residential customers. Energy Division will have the authority to approve or deny the incentive value modifications. Any modifications would go into effect on January 1st of the upcoming calendar year. This structure provides greater market certainty to contractors and enables the CPUC to adjust incentive values based on market conditions. Due to the subsidization of natural gas water heating appliances by other CPUC programs and the proposed incentive layering structure, Staff do not recommend adjusting equity customer incentive values.

4.4 Incentive Structure for Residential Central HPWHs

There is limited data available on the gross cost of residential central HPWHs,[143] and the data available to Staff from existing HPWH incentive programs active in California do not delineate between appliance and installation costs. Based on data that Staff have received, residential central HPWH systems cost approximately $3,000 per unit. Thus, a residential central HPWH system at a 100-unit multi-family building could have gross project costs of approximately $300,000. Central HPWH systems must be custom-designed and built for the hot water demand of a specific multi-family building. The system design must consider available space for hot water storage tanks within a building's footprint and the electrical panels'

[142] TECH Implementer will be building an incentive tracking database that will be available to other PAs overseeing HPWH incentive programs, for the purpose of aligning rules and funding to the greatest extent possible. Staff propose that the CPUC require the SGIP HPWH PA discussed in Section 4.6 to utilize this database to confirm any non-SGIP appliance incentives received prior to installation.
[143] As of January 2021, Staff estimate that there are likely less than 100 central HPWHs operating in multi-family buildings in California.

existing electrical capacity. Examples of these tradeoffs and the customization needed depending on the number of units and occupancy of each unit can be explored using Ecotope's "Ecosizer" tool.[144]

Incentive Structure

Staff propose a single incentive based on the system's thermal energy storage capacity, like residential unitary residential HPWHs. Unlike residential unitary HPWHs, Staff does not propose establishing a set value energy storage capacity for residential central HPWHs due to the complexity and design differences. Instead, we recommend that a project's applicant be responsible for calculating and proposing a capacity in the application process. The SGIP HPWH PA will be responsible for reviewing, approving, or proposing modifications back to the applicant.

Staff also recommend that residential central HPWH systems be subject to performance-based incentive payments. Requiring performance-based incentive payments will allow the CPUC to validate the estimated energy storage potential, measure peak demand reduction, and subsequently, the GHG emission reductions of these systems. Staff recommend that the SGIP HPWH PA reduce performance-based incentive payments for residential central HPWH projects by one dollar per kilogram of GHG emissions under the five-kilogram of CO_2 per kWh SGIP GHG reduction threshold, in alignment with rules established D.19-08-001. Staff also recommend that the winning SGIP HPWH PA propose a methodology for establishing a project's non-load shifting baseline, a standard set of normalization factors (*i.e.,* outdoor temperature, etc.), and a methodology for calculating GHG emission reductions. These methodologies should be submitted to Energy Division via a tier two advice letter no later than 30 business days after the contractual notice to proceed.

Incentive Value

Staff recommend setting the residential central HPWH Incentive Value at $900/kWh for general market residential and $1,000/kWh for equity residential customers. For the same reasons noted in Section 4.3, Staff also recommend a $200/kWh kicker incentive be available for heat pumps using low-GWP refrigerants. These proposed incentive values would cover approximately 80 percent of a general market customer's project cost and 100 percent of equity residential customer project cost for a 100-unit building,

[144] The "Ecosizer" tool is available at https://ecosizer.ecotope.com/sizer/

$300,000 project. As discussed in Section 4.2, Staff recommend a $300,000 per project cap for central HPWH system incentives.

Electrical Panel Upgrade and Electrical Service Incentives

Staff recommend that common area or "whole building" electrical panel upgrades for residential central projects occurring in multi-family buildings be ineligible for an Electrical Panel Upgrade Incentives. Electrical panel upgrade costs in multi-family buildings are significant and would dramatically reduce the residential central incentive budget. Staff is hopeful that other ratepayer or non-ratepayer funded programs can help support the cost of any necessary electrical panel upgrades. In circumstances where a SGIP funded central residential HPWH project requires an electrical service upgrade, Staff recommend that the CPUC direct the electrical IOUs to categorize any electrical service line upgrade costs as "common facility costs." As noted in the background and challenges section, electrical service line costs above the electrical service allowance available under Tariff Rules 15 and 16 can be significant and impede HPWH adoption. Thus, Staff find it appropriate to eliminate these costs for SGIP funded HPWHs given the small number of eligible multi-family properties.

Incentive Layering

Staff recommend that the same incentive layering structure proposed for residential unitary HPWHs in Section 4.3 apply to residential central HPWHs as well. Those recommendations, without explanation, are repeated here.

- Staff recommend reducing general market residential incentives by 100 percent of the value of other incentives for both ratepayer and non-ratepayer funded programs.
- Staff recommend reducing equity residential customer incentives only when the total available incentive exceeds the total eligible project costs. When this occurs, the incentive should be reduced by 100 percent for both ratepayer and non-ratepayer funded programs until the sum of the SGIP and other incentives equal the total eligible project costs.

4.5 Incentive Structure for Commercial Unitary HPWHs

As noted in Section 4.2, there is limited data available on both the ability of commercial unitary HPWHs to shift load from peak to off-peak periods and on the gross cost of installing such units. Based on data Staff did receive, a commercial unitary HPWH designed for installation in a small business commercial application, such as AO Smith's CHP-120 model,[145] has an approximate total project cost ranging from $12,500 to $16,000 per unit installed.

Incentive Structure

Staff propose a single incentive based on the system's thermal energy storage capacity and that the project's applicant be responsible for calculating and proposing a capacity in the application process. It is inappropriate to set a value for the storage capacity due to the noted differences compared to residential unitary HPWHs. The SGIP HPWH PA will be responsible for reviewing, approving, or proposing modifications back to the applicant.

Staff also recommend that commercial unitary HPWH systems be subject to performance-based incentive payments. Requiring performance-based incentive payments will allow the CPUC to validate the estimated energy storage potential, measure peak demand reduction, and subsequently the GHG emission reductions of these systems. Staff recommend that the SGIP HPWH PA reduce performance-based incentive payments for commercial unitary HPWH projects by one dollar per kilogram of GHG emissions under the five-kilogram of CO_2 per kilowatt hour SGIP GHG reduction threshold, in alignment with rules established D.19-08-001. Staff also recommend that the winning SGIP HPWH PA propose a methodology for establishing a project's non-load shifting baseline, a standard set of normalization factors (*i.e.,* outdoor temperature, etc.), and a methodology for calculating GHG emission reductions. These methodologies should be submitted to Energy Division via a tier two advice letter no later than 30 business days after the contractual notice to proceed.

Incentive Value

Staff recommend setting the commercial unitary HPWH incentive value at $700/kWh and providing a $200/kWh kicker incentive for systems using low-GWP refrigerants. Staff find it appropriate to set a slightly lower incentive vis-à-vis general market residential customers due to commercial customers' greater access to capital and additional financing. Finally, given the small budget allocation, Staff recommend

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145 https://www.hotwater.com/Water-Heaters/Commercial/Water-Heaters/Heat-Pump/CHP-120-Fully-Integrated-Heat-Pump/

keeping the incentive value flat rather than reducing it over time. As discussed in Section 4.2, Staff recommend a $50,000 per project cap for commercial unitary HPWH incentives.

Electrical Panel Upgrade Incentives

Staff recommend that commercial customers not be eligible for the electrical panel upgrade available to residential unitary customers under SGIP. Staff believe these electrical upgrades should be less of a barrier for this customer segment in terms of both existing onsite load and ability to pay. Furthermore, Staff does not recommend that commercial electrical service upgrade costs be classified as "common facility costs." This is in alignment with past CPUC precedent.

Incentive Layering

Staff is only aware of one other CPUC statewide program, the energy efficiency statewide midstream commercial water heating program, that could provide incentives for commercial unitary HPWHs.[146] Staff recommends reducing the SGIP unitary commercial incentives by 100 percent of the value for both ratepayer and non-ratepayer funded programs when incentive layering occurs.

4.6 Program Administration and Evaluation

The SGIP HPWH workshop and the August 2020 Assigned Commissioner's Scoping Memo asked parties whether the existing SGIP PAs or another entity is best positioned to oversee the implementation of SGIP HPWH incentives. Because the SGIP PAs are currently inundated with applications given the recent increase in demand for SGIP incentives,[147] and because of the new programmatic structure proposed here, Staff recommend that the CPUC select a single statewide program administrator and program implementor (PA/PI) to oversee SGIP HPWH incentives. As previously discussed, HPWHs are a distinct and unique technology compared to all existing energy storage technologies in SGIP. The rules, processes, and structures recommended in this Staff Proposal are similarly unique and lend themselves to a new entity acting as the PA/PI for HPWHs in SGIP.

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[146] Commercial customers are ineligible for TECH program incentives.

[147] The 2020 Q4 SGIP Workshop presentation at slide 6 demonstrated the substantial increase in volume of applications received in 2020. Available as of March 2021 under SGIP Workshop Material at: https://www.selfgenca.com/home/resources/

Staff believe a statewide PA/PI organizational structure through a single entity will simplify program execution, enable better coordination with other HPWH incentive programs, reduce administrative costs, maximize ratepayer benefits, and catalyze market transformation. Having a single, separate entity be responsible for the SGIP HPWH subprogram will also avoid putting additional burden on the SGIP PAs to implement new, highly detailed technology rules, given existing Staff and database development constraints. Staff recognize that selecting and contracting with a new PA/PI entity requires time to execute but believe that the benefits of this streamlined program oversight structure outweigh the additional time required.

Staff propose the following organizational structure for the administration of SGIP HPWH incentives, which consists of three main actors:

1. PA Contract Holder: Staff propose that the CPUC direct SCE to issue a Request for Proposal (RFP) to select a statewide PA/PI for SGIP HPWHs through a competitive bidding process and to contract with the winning entity. SCE would be responsible for providing ongoing fiscal support through the collection, disbursal, and monitoring of SGIP HPWH funds.
2. PA/PI: Staff recommend that a statewide PA/PI be responsible for the execution, coordination, and implementation of the SGIP HPWH budget and program in accordance with the adopted HPWH decision. The CPUC should require this entity to develop a program handbook for SGIP-funded HPWHs that articulates the program rules ultimately adopted by the CPUC and details the specific application processes. Per existing processes, Staff recommend that the CPUC require the SGIP HPWH PA/PI to submit advice letters for all SGIP HPWH Program Handbook changes. The CPUC should also direct the SGIP HPWH PA/PI to consult with all four existing SGIP PAs to understand existing SGIP processes and recommend which programmatic rules should be retained for HPWHs.
3. CPUC: Staff propose that Energy Division Staff lead the confidential evaluation of PA/PI bids and select the winning bidder. Staff would also be responsible for managing the PA/PI and coordinating with the TECH Initiative's quarterly meetings to enable continuous program coordination and transformation of California's HPWH marketplace.

SGIP HPWH PA/PI Selection Criteria

To enable the successful selection of an SGIP HPWH PA, Staff propose the following guidelines for the Request for Proposal:

- Bidders must demonstrate substantial experience overseeing the implementation of statewide programs. Bidders must identify key personnel to be involved in the implementation and describe their relevant experience.
- Bidders must demonstrate that their organization can successfully implement the SGIP HPWH subprogram and properly distribute funding.
- Bidders should explain their familiarity with SGIP and any experience working with the existing SGIP PAs.
- Bidders should explain how they intend to implement a simple, streamlined program application process for each HPWH category. This explanation should include how performance-based incentive HPWH installations will be evaluated, approved, and incentives administered.
- Bidders should explain how they intend to coordinate the SGIP HPWH incentive application with TECH initiatives' application and other HPWH incentive applications to enable incentive layering.
- Bidders should explain how they intend to reach residential equity customers to support and enhance this customer segment's participation.
- Bidders should explain how they intend to issue incentive payments and communicate the status of these payments to applicants.
- Bidders should explain how they can assist customers with understanding and completing any required electrical panel upgrades.
- Bidders should explain how they will develop a comprehensive SGIP HPWH Program Handbook and integrate stakeholder feedback.
- Bidders should provide a sample of HPWH load shifting signage that can be installed on all residential unitary HPWHs.
- Bidders should provide a program budget that details how program administration funds will be spent.
- Bidders should demonstrate familiarity with the TECH Initiative and any energy efficiency HPWH incentives.

- Bidders should explain how project cost data will be tracked and made available to Staff.
- Bidders should explain how incentive data will be shared with the forthcoming TECH Initiative project database.

Evaluation

Staff recommend the SGIP evaluator summarize all the benefits achieved by a SGIP funded HPWH. These benefits should include, but are not limited to, the total GHG reductions achieved by the SGIP funded load shifting HPWH, which includes reductions in therms or kWhs, and the peak reduction benefits compared to a non-load shifting HPWH. As proposed in Sections 4.3, 4.4, and 4.5, SGIP participants are eligible to layer incentives from multiple sources, including CPUC regulated and non-regulated programs. Even though all the HPWH benefits are included in the SGIP evaluation, Staff recommend that when incentive layering does occur the non-load shifting benefits (*i.e.,* the efficiency benefits) of SGIP funded HPWHs also be attributed to those other programs, (further guidance specific to incentive layering is anticipated to be developed in Phase 2 of R.19-01-011.) Furthermore, Staff recommend that the load shifting benefits achieved by SGIP funded HPWHs not be attributed to other incentive programs. Finally, due to the fundamental differences between HPWHs and other forms of energy storage Staff recommend that the PY 2021-2025 M&E plan include a dedicated HPWH impact evaluation report. Staff is coordinating with the SGIP PAs to develop an M&E plan for PYs 2021-2025, where this separate impact evaluation report should be incorporated.

5 Conclusion

The CPUC has taken numerous actions to facilitate the rapid transformation of California's water heating marketplace using HPWHs as an essential strategy to achieve the state's ambitious climate change goals in recent years. The incorporation of load-shifting HPWHs into SGIP – one of California's oldest and most successful behind-the-meter incentive programs – further affirms the importance of these appliances and further defines the role they will play in achieving California's climate and energy goals. It also comes at a time when the value of behind-the-meter load shifting resources like HPWHs cannot be overstated. California's famous "duck curve," which represents the net load, or difference between forecasted load and expected electricity generation from utility-scale variable generation resources, is flying high in 2021 and setting new records. The CPUC is taking swift action in Emergency Reliability Rulemaking (R.20-11-003) to ensure enough generation and demand flexibility resources are available to avoid blackouts in the event of another high temperature and sustained heat storm in 2021. While the thousands of HPWHs proposed to be installed by SGIP won't solve the 2021 duck curve or summer reliability concerns, when deployed at scale load shifting HPWHs, will help integrate hundreds of megawatts and eventually gigawatts of renewable energy into the grid. This integration will help reduce GHG emissions and be a valuable grid reliability asset.

To achieve this long-term load shifting vision, Staff recommend that the CPUC use the data gathered from all CPUC-funded HPWH programs to design a single consolidated HPWH market transformation program in Phase IV of the Building Decarbonization proceeding (R.19-01-01). Developing a single consolidated HPWH market transformation program will allow the CPUC to minimize administrative costs, streamline customer adoption, and, when paired with appropriate market signals, maximize the technology's load shifting potential to benefit all Californians.