DNV·GL

Water Heater Technology Economic Assessment: Final Research Plan

California Public Utilities Comission

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1 INTRODUCTION AND BACKGROUND

1.1 Water heaters in California

Water heaters, sometimes referred to as the "forgotten appliance," account for roughly 25% of all household energy use in California, making them the second-largest single source of residential energy consumption[1], behind only space heating. Roughly 40% of US households use electricity to heat water[2], although the percentage is lower in California, at only 6% for single family homes and 14% for multifamily homes[3]. For homes that use natural gas to heat water, 49% of household gas use can be attributed to water heating[4]. For homes that use electricity, a significant portion of their electricity bill is attributed to water heating. PG&E estimates that gas water heaters are approximately 40% cheaper to operate than electric water heaters[5].

In California, some homes and lower-income communities throughout the state, such as the San Joaquin Valley, lack access to natural gas lines; currently the most affordable way to heat water for residential use. In 2014, California's legislature passed AB 2672, which requires the California Public Utilities Commission to analyze economically feasible options that can increase access to affordable energy in disadvantaged communities. For those options that are cost-effective, the bill requires the commission to take appropriate action and determine the appropriate funding sources.[6]

Further, some of California's multi-family water heating fleet is aging and many multi-family building owners have been slow to uptake newer technologies. While classic landlord-tenant barriers may be one reason; another reason is that replacing a gas appliance triggers additional expenses. Gas appliance replacement triggers a requirement that the building pass a Combustion Appliance Zone (CAZ test). While the costs of performing the test are known, the cost of mitigating any test failures is not and can be extremely costly. For this reason, building owners are prone to have a "if it isn't broke don't fix it" mentality when considering water heater replacements.

1.2 Emerging water heating technologies

Heat pumps are gaining popularity for both space heating and cooling and water heating applications due to their high efficiency and flexibility. Heat pump water heaters are more widely available than ever before. A key feature of the heat pump water heater is that they are hybrids. They function both as a heat pump (a reverse refrigerator) during periods of low demand, and as a traditional electric resistance water heater during period of high demand. Thus, unlike incumbent technologies, the overall efficiency of heat pump water heaters is highly dependent on hot water load profiles and ambient conditions. Also, the load shape profile of heat pump water heaters in considerable different than standard electric water heaters. Overall, the market share of heat pump water heaters is still low.

1 http://www.eia.gov/consumption/residential/reports/2009/state_briefs/pdf/ca.pdf

2 https://www.energystar.gov/ia/partners/prod_development/new_specs/downloads/water_heaters/Water_Heater_Market_Profile_2010.pdf

3 https://webtools.dnvgl.com/susc/CPUC_CLASS_2012/SUSc_CPUC_CLASS_2012.aspx

4 http://www.energy.ca.gov/2010publications/CEC-200-2010-004/CEC-200-2010-004-ES.PDF

5 https://www.pge.com/en/myhome/myaccount/usage/index.page

6 http://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201320140AB2672

Recent research has shown that to reach net-zero energy by 2050, Californians will need to run their homes, cars, and businesses off of electricity from carbon-free sources[7]. This means two things for water heaters in California:

1. The share of electric water heaters will increase dramatically in the coming years, and
2. Water heaters will be powered by intermittent energy sources like solar and wind.

Another recent study by the Brattle Group[8] found that water heaters, specifically grid-connected water heaters, offer an attractive opportunity for improving the reliability, economics, and environmental footprint of the green-powered grid. The growing adoption of intermittent generating sources increases the value of flexible loads to system operators. Grid-enabled or grid-interactive water heaters could provide flexible load in the following ways:

1. Demand response (shift water heater demand to times of low system demand),
2. Energy storage (absorb energy in times when the marginal cost is low or negative due to the high penetration of intermittent renewables),
3. Frequency regulation and other grid balancing services (water heaters controlled over very short time intervals with near instantaneous response).

2 STUDY APPROACH AND STUDY TASKS

2.1 Study Goals and Objectives

This study aims to establish the total costs of ownership for selected water heating technologies in California IOU territories. The selected water heating technologies include:

a. Efficient gas tank water heater, 40 gallon
b. Efficient gas instantaneous water heater
c. Heat pump water heater, 50 gallon
d. Efficient electric tank water heater
e. Efficient electric tank water heater, grid interactive

Specifically, the CPUC seeks to understand the total cost of ownership of heat pump water heating systems and competing technologies for two customer groups:

1. Single family occupants
   a. Standard residential electric and gas rate plans
   b. TOU residential rate plan
   c. Low income residential rate plan (this group includes those with no access to natural gas for water heating purposes, such as those in the San Joaquin Valley)

7 http://www.energy.ca.gov/2014publications/CEC-500-2014-108/CEC-500-2014-108.pdf

8 http://www.brattle.com/news-and-knowledge/news/report-by-brattle-economists-finds-electric-water-heaters-can-provide-economic-and-environmental-benefits

2. Multifamily building occupants and owners
    a. Standard residential electric and gas rate plans
    b. TOU residential rate plan
    c. Low income residential rate plan

The multifamily portion of the study aims to determine if heat pump water heaters are an attractive opportunity for owners to make upgrades to their buildings without unforeseen CAZ mitigation costs.

This study also includes a back-of the-envelope style economic analysis to determine if grid-connected efficient electric storage water heater installations could be an opportunity improve the reliability and lower the environmental footprint of California's grid while providing an economic benefit as well.

The primary objectives of this study are as follows:

1. Determine the net present value (NPV) of the total cost of ownership of the above customer and water heating technology combinations.
2. Determine total CO_2 emissions for each of the customer and water heating technology combinations described above.
3. Compare the options on total cost of ownership and CO_2 emissions.
4. Provide insight on the results in the context of California's future (i.e. all net-zero buildings, increased penetration of renewables)

DNV GL also intends to:

- In the context of AB 2672, provide basis to help the commission determine whether heat pump water heaters are a cost effective option for single family homes in disadvantaged communities.
- Determine if heat pump water heaters are a cost-effective replacement for gas water heaters in multi-family buildings.
- Determine if grid-enabled water heaters are a cost effective option for both single family homes in disadvantaged communities and multifamily owners and occupants.

2.2 Study approach

Specifically, we will consider the two different customer segments for this study and three water heating technologies. The customers and water heating technology combinations are as follows:

1) Residential single family, replacing standard 40 gallon electric water heater. Potential replacement options include:
    a. Efficient gas tank water heater, 40 gallon (extension of natural gas line not included)
    b. Efficient gas instantaneous water heater (extension of natural gas line not included)
    c. Heat pump water heater, 50 gallon
    d. Efficient electric tank water heater, 40 gallon
    e. Efficient electric tank water heater, 40 gallon, grid interactive

2) Multi-family building owner who needs to replace 5 or more standard 40 gallon gas water heaters- one per residence. Potential replacement options include:
    a. Efficient gas tank water heater, 40 gallon (extension of natural gas line not included)
    b. Heat pump water heater, 50 gallon
    c. Efficient electric tank water heater, 40 gallon
    d. Efficient electric tank water heater, 40 gallon, grid interactive

For each customer and each water heating technology option we will attempt to determine the total cost of ownership including upfront costs, standard installation costs, as well as other costs such as Combustion Appliance Zone (CAZ) testing and mitigation, and non-standard installation costs, like installing condensate drains for a heat pump water heater. We will consider a number of factors that can have an impact on the overall cost of ownership including climate, utility rates, and feasibility of installation. We will also explore technical and regulatory barriers that exist for each option.

DNV GL will use life-cycle cost analysis (LCCA) over a 10-year period and assume each of the technologies has at least a 10-year lifetime. Table 1 gives key cost estimates for each of the customer and technology combinations.

Table 1: Key cost estimates for each water heating technology and customer combinations

Technology to be replaced:	Technology to be installed:	Key cost estimates
\Single Family Electric water heater	Efficient gas water heater, tank and instantaneous	Purchase price Installation costs CAZ testing CAZ mitigation costs Local natural gas line extension Gas prices
	Electric heat pump water heater	Purchase price Installation costs Drain installation Electric rates Estimated performance for CA climate zone
	Efficient electric water heater, standard and grid interactive	Purchase price Installation costs Electric rates Grid connectivity Estimated ancillary benefit
Multi-family single-unit gas water heater	Efficient gas water heater	Purchase price Installation costs CAZ testing CAZ mitigation costs Gas rates
	Electric heat pump water heater	Purchase price Installation costs Drain installation Local electrical extension Estimated performance for CA climate zone
	Efficient electric water heater, standard and grid interactive	Purchase price Installation costs

		Local electrical extension Grid connectivity Estimated ancillary benefit

Key data resources include, IOU tracking databases for purchase price and installation costs and primary data collected during interviews with market actors.

2.3 Study Tasks

2.3.1 Task 1: Data gathering, Tracking Database, Literature review

Objective: The goal of this task is to review material to determine what information is available and to develop a list of characteristics to draw from IOUs databases. Outcomes from this task will include; documenting potential sources of data inputs such as costs; and determining sources for costs and other required data.

This activity includes investigating total project costs for multifamily and single family heat pump and competing technologies. Possible sources include utility databases, primary data collection, and other literature. As necessary, we will request input from water heater installers, CAZ testers, and other experts in the field. We will talk to current multi-family and other program staff to gain further insight on the costs and benefits of switching to an electric-based water heating system.

We will research the most-current information on grid-interactive water heaters and results of pilots in the field, and total costs.

Key documents we either have reviewed or will review include:

- CLASS database
- CEC EPIC funded water heating studies
- EPRI heat pump water heater studies
- Brattle group study
- Life Cycle costs best practices
- Energy Star Water Heater Market Profile
- NYSERDA Domestic Water Heater Performance for NY Homes
- DEER and supporting CA work papers
- PG&E's Emerging Technologies Program: Market-Focused Program Design to Accelerate Penetration of ENERGY STAR Water Heaters

2.3.2 Task 2: Research Plan

Objective: Document study approach, scope of work, schedule and project communications.

This document meets the draft deliverable for this Task. We will finalize the Research Plan based on feedback from the ED Project Manager, the IOUs, stakeholders, and public commenters (as appropriate).

Deliverables:

- Final Research Plan for California Residential Water Heating Technology Assessment

2.3.3 Task 3: Interviews and Data Collection

Objective: Determine values for key cost estimates

This task includes developing data requests, decipher and review data request materials, develop data collection methodology, conduct primary data collection interviews on data not accessible from IOUs.

Depending on available data sources, it may be necessary to collect primary data in the form of interviews. As listed above, possible interview subjects include water heater installers, CAZ testers, multi-family building owners, utility program staff, ED staff, and experts in the water heating field. Potential interview topics include cost of typical projects, cost of typical CAZ testing, rate of CAZ testing failures, typical mitigation requirements and associated costs, decision making process of energy upgrades, and program goals. We estimate we will complete 10 interviews. DNV GL will draft interview guides, solicit ED feedback, and complete interviews.

Deliverables:

- Data Requests
- Interview guides
- Interview target summary

2.3.4 Task 4: Research and Analysis

Objective: The purpose of this task will be to develop lifecycle cost models, determine costs and model inputs, and determine cost of ownership for each of pre-determined water heater use case.

DNV GL will use a spreadsheet based life-cycle cost analysis (LCCA) to determine the most cost effective option among the competing technologies for each of the following use cases:

1) Residential single family, replacing standard 40 gallon electric water heater. Potential replacement options include:
    a. Efficient gas tank water heater, 40 gallon (extension of natural gas line not included)
    b. Efficient gas instantaneous water heater (extension of natural gas line not included)
    c. Heat pump water heater, 50 gallon
    d. Efficient electric tank water heater, 40 gallon
    e. Efficient electric tank water heater, 40 gallon, grid interactive

2) Multi-family building owner who needs to replace 5 or more standard 40 gallon gas water heaters in his residence. Potential replacement options include:
    a. Efficient gas tank water heater, 40 gallon (extension of natural gas line not included)
    b. Heat pump water heater, 50 gallon
    c. Efficient electric tank water heater, 40 gallon
    d. Efficient electric tank water heater, 40 gallon, grid interactive

Lifecycle costs include costs to purchase, install, maintain, and dispose of water heaters. DNV GL will also estimate the revenue generated by water heaters in the case of the grid interactive water heaters.

Environmental costs will not be included; however, DNV GL will also estimate the total CO_2 impact of each of the scenarios.

The study team will estimate the following costs:

- First costs
    - Cost to install
        - Including additional plumbing and/or electrical work for any fuel switching
        - Cost associated with Combustion Appliance Zone testing
            - Cost to complete test
            - Cost to mitigate any testing failures
- Operating costs
    - Cost of energy
        - Based on load curve
    - Additional operating costs
        - Grid connection costs, as applicable
        - Maintenance costs, as applicable

Each of the costs will be projected for a 10 year period, a present value (PV) will of the project cost will be calculated, and the costs will be summed to determine the net present value (NPV) of each of the water heater technologies and customer combinations. Table 2 is shows an example of one such calculation.

Table 2: Example NPV calculation

Single Family												
LIFE CYCLE COST OF ELECTRIC WATER HEATER												
		Today	**Year**	**Year**	**Year**	**Year**	**Year**	**Year**	**Year**	**Year**	**Year**	**Year**
			1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
First Cost		$1,000										
Operating Cost			$519	$535	$551	$567	$584	$602	$620	$638	$657	$677
Subtotal		$1,000	$519	$535	$ 551	$567	$584	$602	$620	$638	$657	$ 677
PV		$1,000	$494	$485	$ 476	$467	$458	$449	$440	$ 432	$ 424	$ 416
NPV	**$ 5,540**											

To estimate costs, the study team will use California-based previously estimated costs where available, such as those included in work papers available in the Database for Energy Efficient Resources (DEER). The study team will also use average costs from water heating tracking data, where applicable. When these data sources fail, the study team will use in-depth interviews with contractors and/or obtain representative bids to develop original costs estimated. As necessary, we will request input from water heater installers, CAZ testers, and other experts in the field. We will talk to current multi-family and other program staff to gain further insight on the costs and benefits of switching to an electric-based water heating system. We will research the most-current information on grid-interactive water heaters and results of pilots in the field, and total costs.

Deliverables:

- Develop sample frame based on available data on contacts for: water heater installers, water heater program participants, water heater experts, CAZ and HERs raters, multi-family building owners.

2.3.5 Task 5: Report on Findings

Objective: Deliver final report that summarizes the results of the water heating economic assessment.

At the conclusion of the data collection, research, and analysis, DNV GL will prepare a draft report summarizing the results from the above tasks. We will finalize the research report based on feedback from the ED Project Manager, the IOUs, stakeholders, and public commenters (as appropriate).

Deliverables:

- Draft report
- Public webinar
- Response to comments
- Final report

2.3.6 Task 6: Project Management

DNV GL will provide day-to-day management for all project activities including managing schedules, invoicing, staffing needs, etc. DNV GL will maintain regular contact with the project team via monthly meetings (can be more often if needed) and progress reports.

Deliverables:

- Monthly invoices
- Bi-weekly check-in meetings and progress reports

2.3.7 Project Timeline

DNV GL will initiate project within 2 weeks after team approval. Timeline is driven by availability of subjects for interviews. Table 3 displays the proposed project timeline and budget.

Table 3: Project Timeline and Budget

Tasks	May 2016	June 2016	July 2015	Aug 2015	Sept 2015	Oct 2016	Nov 2016
Tasks 1: Data gathering, tracking, database development, lit review							
Task 2: Research plan							
Task 3: Primary data collection interviews							
Task 4: Research and Analysis							
Task 5: Report on Findings							
Task 6: Project Management							

ABOUT DNV GL

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Response ID	Comment #	Commenter	Page (as shown in Word document footer)	Comment	Response
1	1	SCE	1	This study proposal is not really studying technologies. It is really more of a cost benefit case study given a specific water heating implementation options for certain population (i.e., lower income) or geographic location (i.e., lack of access to gas). While it is good to conduct some cases analyses (with limited generalization) to look at economic pay-back of certain implementation scenarios. For the technology and market characterization, it would be beneficial to provide a broader characterization of the overall water heating options for residential customers. This analysis should take a comprehensive review of at all available water heating options including standalone resistance water heating options that is not grid-enabled as well as grid-enabled options.	We will update to include adding electric water heaters.
2	1	SCE	1	For the cost benefit economic analysis, since the study will be more like a case analysis, why not make it more target-population specific.	It is target population specific. It's Multifamily units with 5+ individual units, and communities with electric-
3	1	SCE	1	The water heating choices and time-of-use may be increasingly important as California moves forward to dynamic rate implementation. This economic analysis should not be static. It makes sense to present the findings as scenario analysis give the variables under evaluation (i.e., usage behavior, purchase behavior, electric/gas rate scenario, etc.)	We agree and have planned to provide scenario analysis. Electric/gas rates, and load shapes
4	1	SCE	1	Also, we need to make it clear that this study is aimed to look at implementation and adoption scenario for 1-2 years or 3-4 or 5 or beyond years. The answers from this study, timing and applicability may vary. It may be a good idea to clearly identify the timing of possible implementation to support AB2672.	This study is looking at current costs and options available on the market.
5	2	SCE	2	Let's make this more explicit. Can we say that this is ESAP qualified communities? By making this clear, we can focus our research in the 80% income qualified geographic locations. Otherwise, you will need to carefully breakdown the various responses by different demographic and income levels.	This study is not ESAP-exclusive. We are assessing economic impact under 3 rates: Standard, Standard TOU, and Standard Low-Income
6	3	SCE	3	In the multi-family apartment, there may be two scenarios for water heating: (1) central water heating for the whole apartment is the typical arrangement for smaller apartments (i.e., 8-12 units), (2) individual apartment water heater for others (i.e., multi-family condo, where the ownership of the asset resides with the condo owners). The analysis may vary based on the ownership arrangement and apartment size. Let's make sure we are addressing specific scenario rather than over-generalizing the results but specific answers are needed.	For this study we are only considering building under number (2) in your comment; units with individual water heaters.
7	4	SCE	3	Why does the water heater need to be grid-enabled? Perhaps, we need to look at grid-independent and grid-enable as two different options. We can leave it to the homeowners to decide.	Grid-enabled water heaters are revenue generating. We will consider the economics of both standard storage water heaters and grid-enabled heaters
8	5	SCE	3	We should look at the full range of NPV for grid-independent and grid-enable technologies and options. We should look at gas vs electric powered units separately.	We will consider electric storage, electric HPWH, electirc storage-grid enabled, and gas storage water heaters. They will all be compared to one another on economics and emissions
9	5	SCE	3	We should also look at simple resistance heating (i.e., run water through black coil during day time to get heating) as a low-tech and low-cost option? This may be used a hot water heating option for the summer-month. In this notion, you may have grid-enable and grid-independent water heating options side-by-side. The homeowners can make a decision on which one to select and pay for their choice.	This does not describe simple resistance heating. This describes solar water heating. Solar water heating is out of scope of this study.
10	5	SCE	3	We also need to consider the tankless water heaters. Many households have switched over to tankless water heating to get ride of the water tank.	We will add tankless water heaters
11	5	SCE	3	I recommend we identify the full range of options, then decide on which one to focus. Otherwise, this study may look not balance and incomplete.	We will consider electric storage, electric HPWH, electirc storage-grid enabled, gas tankless, and gas storage water heaters. They will all be compared to one another on economics and emissions
12	6	SCE	3	You should consider labeling this as a case study, since you are narrowing your view to specific cases and situations.	We will consider the economics under 3 rates: Standard, Standard TOU, and Standard Low-Income; Thus, they are not case studies, these situations cover numerous customers.
13	7	SCE	4	Since electricity and gas rates and costs may be very dynamic, especially in light of upcoming dynamic rate implementation in California.	We will set up the model so the rates can chage.
14	7	SCE	4	This analysis should not be static. You should show a range of NPV situation, given different rate and usage assumptions.	We agree; this is what we are planning on doing.
15	1	PG&E	1	Does this take into account new 2015 Federal Code for units over 55 gallons that mandates HP technology for electric WHs and condensing technology for gas storage WHs?	No, we are considering only 40 gallon water heaters
16	2	PG&E	2	Will this focus on central systems or individual in-unit equipment intended to serve single apartments?	This study will focus on MF with individual in-unit equipment intended to serve single apartments.
17	3	PG&E	3	Again, need to distinguish between central vs. in-unit configurations for MF buildings.	This study will focus on MF with individual in-unit equipment intended to serve single apartments.
18	4	PG&E	3	This seems to point at the study only reviewing in-unit WH equipment, however many CA MF properties use central systems and we may want to also review these scenarios within the study.	This study will focus on MF with individual in-unit equipment intended to serve single apartments. The size and situation of larger systems is too varied to include.
19	5	PG&E	4	This should not only account for upcoming TOU rate requirements, but also the possibility that a customer does/doesn't have solar PV.	The study will include current TOU rates.
20	1	SCG	3	Recommend adding (d) tankless water heater as an option. Also, recommend adding option (d) tankless water heater.	We will add tankless water heaters
21	2	SCG	3	In the below chart this says gas – assuming this should be gas.	Will correct
22	3	SCG	3	Will square footage be included?	This study does not include square footage.
23	4	SCG	3	Will cost be separated /include owner and tenant costs if tenant pays electric and gas bills?	We will consider the total cost of operation for all the NPV calcuations, including the MF. We are not planning on doing the analysis from the customer point of view for MF at this time.
24	5	SCG	4	Costs should include the additional electricity generation and emissions from that generation.	Costs are considered form the point of view of the customer only. However, we will also present the
25	1	Cal Broomhead	2	On residential systems, I would like to see a caution in terms of implementation, in that the sizing of the system is really dependent on analysis that many installers are not trained to perform. There is an opportunity for right sizing the system. Tightened and insulated homes can eliminate the furnace and use the water heater via a heat exchanger, meaning the Heat Pumps will need upsizing from only the water heating function to also handle space heating. Only replacing water heaters would orphan the furnace replacement or cause a re-investment in additional capacity.	This analysis focuses on water heater replacements, furnance replacements are out of scope and not included at this time.
26	2	Cal Broomhead		Also, given that the study as proposed mentions that heat pumps are hybrids that switch to electric resistance to meet peak loads, this will certainly affect bills via TOU rates, meaning systems will be demanding more during the peak period, exacerbating the peak….so will this be part of the economic analysis? Will we see the impact on the peak load and the peak cost? Will the analysis include looking at increasing heat pump size, or oversizing, to avoid a peak crunch on the system, beyond the impact on the bills of individuals?	This is correct, heat pumps will affect bills via TOU rates, so systems demanding more during peak time will impact peak load and costs. Impact of operating will be included.
27	1	Kelly Murphy	8	Scott Baker, Senior Business Solutions Analyst for PJM directed comments on PNNL # 23527 "Evaluation of Demand Response Performance of Large Capacity Electric Water Heaters," in FERC Submittal 20150810-5224 FERC Docket RA15-1-000 DATED 8/10/15 Mr. Baker describes the Report's shortcomings. The reason I point to this is that as we grow a greater share of ERWH (particularly in California) those devices will be asked to do a lot more duties (DR - being the very simplest tasks). Certain ERWH will become integral with the spread of Solar PV of all types – particularly residential rooftop and community solar. The term "Solar plus Storage" will become widespread incorporating the heavy deployment of Grid-Interactive Water Heaters (GIWH) – some of which can duplicate nearly all the fast-ramp grid-services as batteries. As Distributive Energy Resources (DER's) become monetized (and rewarded) portions of that revenue will flow directly to purchasers of GIWH and Solar plus GIWH Systems – greatly influencing the Present Value calculations. Consideration in the final days of research should also involve larger "Grid-Enabled" ERWH as these tanks better handle the volatility of day-to-day end-user hot water usage (similar to	Large systems are out of scope of this study. Can recommend for future studies. Further, all large systems (above 55 gallon) are mandated to include HP water technology per federal standard.
28	1	Rachel Golden		The proposed study covers a very important scope of analysis and a current research gap. Our questions and comments seek to ensure the results of the study inform decision-making around a broad range regulatory and utility strategies to achieve EE and climate goals in CA. 1) The study only looks at the economics of fuel-switching for multi-family homes. It should also include fuel-switching for single-family homes. Only 6% of single-family homes currently use electricity for water heating, so very few single-family homes will consider electric heating upgrades; the vast majority of single family homes though may be good	This study will compare the costs of both gas and electric systems in both MF and SF homes.
29	1	Rachel Golden		2) The study should include 80-gallon HPWHs (not just 50 gallon) and also grid-interactive HPWHs (not just grid-interactive electric tank WHs). 80 gallon HPWHs are likely to be more efficient than 50 gallon water heaters as they will operate more in heat pump mode and less in electric resistance mode. They also have thermal storage benefits. HPWHs can be grid-interactive similar to electric tank water heaters. This	Agreeed, but this research is out of scope of our study. The Brattle study considered this options, please see: http://www.nreca.coop/wp-content/uploads/2016/02/The-Hidden-Battery-01-25-2016.pdf
30	2	Rachel Golden		3) In order to inform what rate structures are needed for electric water heating to be economical for the consumer, the study should include economic analysis of a broader variety of tariffs. The study should include the electric heating tariff and the EV-charging TOU tariff. Preliminary analysis suggests that both the current TOU rates and standard tiered rates do not have a large enough baseline to make electric heating economical as households get bumped into higher tiers. Tariffs that incentive heating in off-peak periods (with a large peak and off-peak rate differential) and with adequate allowance for heating may be needed. Analysis of a larger variety of rate structures could inform next steps in terms of rate design.	This study will consider the three rates as described to lay ground work that could include additional rate structures. Will recommend as a topic for future study.
31	2	Rachel Golden		4) What are the energy factors of the water heaters in the study? Given that electrifying water heating is a potential future EE and climate strategy that may be considered and phased in over the coming decades, we recommend the study analyze products with energy factors that are the top of the current market, not the minimum EE standard. The technology should reflect the future since this is a long-term potential	The EFs for the water heaters in this study will meet MEPS for California. Will recommend higher efficiency water heaters are evaluated in future studies.
32	3	Rachel Golden		4) Will study take into account the impact of ambient temperature by climate zone on HPWH performance and economics? HPWHs may perform better than rated energy factors in very warm climates, and less well in colder areas of the state. It may be useful to know where the savings are the greatest.	Heat pump water heaters perform better in warmer climates. This study will use DEER average values for the unit energy consumption. Regional differences in performance are out of scope.
33	3	Rachel Golden		5) Will study take into account interactive effects of HPWH and cooling/heating loads? Or is it assumed HPWHs are installed in unconditioned/outdoor spaces and have no impact on a household's heating and cooling loads.	This study will not consider interactive effects. This study will use DEER average values for the unit energy consumption. Interactive effects are out of scope.
34	3	Rachel Golden		6) Will the study factor in the cost of providing gas infrastructure in development areas that are not already served by gas? This should be included to make the results more relevant to the San Joaquin Valley Energy Access proceeding.	This study considers cost from the customer point of view. Will recommend that future study consider the cost of providing gas infastructure.
35	3	Rachel Golden		7) Will the study also factor in the cost of piping gas within the home and to the home from the main, i.e., apportioning the gas piping costs among the appliances as appropriate? The following should be compared: (a) an all-electric project, (b) a project that is all-electric except for a gas water heater, and, (c) a project that has gas water heater, cooking appliances, and space heating.	This study considers cost from the customer point of view. Will recommend that future study consider the cost of providing gas infastructure.
36	1	Solar City		Account for additional revenue streams from grid interactive water heaters providing wholesale and distribution grid services which will impact cost of ownership.	This study will consider the additional revenue stream to the customer from the grid interactive water heater.
37	2	Solar City		Consider the costs and benefits of a larger grid interactive water heater such as 50 gallon or 80 gallon.	Large systems are out of scope of this study. Can recommend for future studies. Further, all large systems (above 55 gallon) are mandated to include HP water technology per federal standard.
38	3	Solar City		Model grid interactive water heaters as a fully flexible and dynamically controlled resource with both scheduled and real-time response capability.	This study consders grid interactive water heaters with real-time response capability.
39	4	Solar City		Consider the costs and benefits when combining electric water heaters of every technology type with on-site rooftop solar power.	Considering costs and benefits of combining on-site rooftop solar is out of scope of this study.
40	5	Solar City		The greenhouse gas emissions should consider both energy consumption at the end source as well as the generation source. The generation source may vary widely from 100% on-site solar power to traditional generation resource mix with non-typical loading due to high penetration renewables and aggregated flexible distributed energy resources.	Green house gas emissions will be considered by utility for electric cases.
41	6	Solar City		Evaluate costs and benefits across a range of customer load profiles beyond just the average consumer	Evaluation beyond the average customer load profiles for electric storage water heaters and HPWH is out of scope due to budget constraints.