Water Heater Technology Economic Assessment: Draft Report

California Public Utilities Comission

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1 EXECUTIVE SUMMARY

Water heaters, sometimes referred to as the "forgotten appliance," account for a significant portion of a household's energy consumption. Many households currently use gas water heaters that are typically cheaper to procure than comparable electric models. The relatively low price of natural gas also makes gas water heaters more attractive in places like California.

Recent legislation (Assembly Bill 2672) is driving the need to explore more efficient and cost effective methods of water heating in disadvantaged communities that do not have access to affordable natural gas. Also, as California's energy supply mix shifts towards cleaner electric generation sources such as wind and solar, there is greater interest in switching away from natural gas. Under this context, the California Public Utilities Commission (CPUC) contracted DNV GL to assess the cost of ownership of efficient gas and electric water heating technologies within each IOU territory.

1.1 Study goals

Study goals for this project was to conduct an economic assessment of various efficient gas and electric water heater technologies. Specific objectives were to: 1) explore impacts of emerging technologies such as heat pump water heaters and electric storage water heaters that can interact with the grid; 2) assess total costs associated with procurement, operation, societal costs of carbon as well as applicable cash inflows over the course of a water heater's lifetime; 3) research barriers to replacing gas water heaters such as combustion appliance tests through interviews with contractors.

1.2 Results

The results discussed in this report focus on both single family and multi-family households across California's investor-owned utilities (IOU), Pacific Gas and Electric (PG&E), Southern California Edison (SCE), San Diego Gas and Electric (SDG&E), and Southern California Gas Company (SCG). DNV GL analyzed results for each water heater across the following rate plans for each utility: standard, low income, and time-of-use (TOU). The impact of a recent, real time pricing, plan was also studied for electric water heaters that could be controlled by the grid.

Our findings show that gas - storage and instantaneous – water heaters are still the most cost-effective across all utilities and rate plans. Heat pump water heaters are economical at current TOU rates for single family customers and provide even greater savings for multi-family customers. However, heat pump water heaters can be impractical in many multi-family households due to sizing constraints and availability of space to maximize efficiency. Implications of combustion appliance tests on adoption of efficient water heaters remains unclear and needs further research. Lastly, DNV GL found that electric water heaters with grid interaction have the potential to be a cost-effective resource based on theoretical scenarios, however, further research is needed to fully understand their impacts.

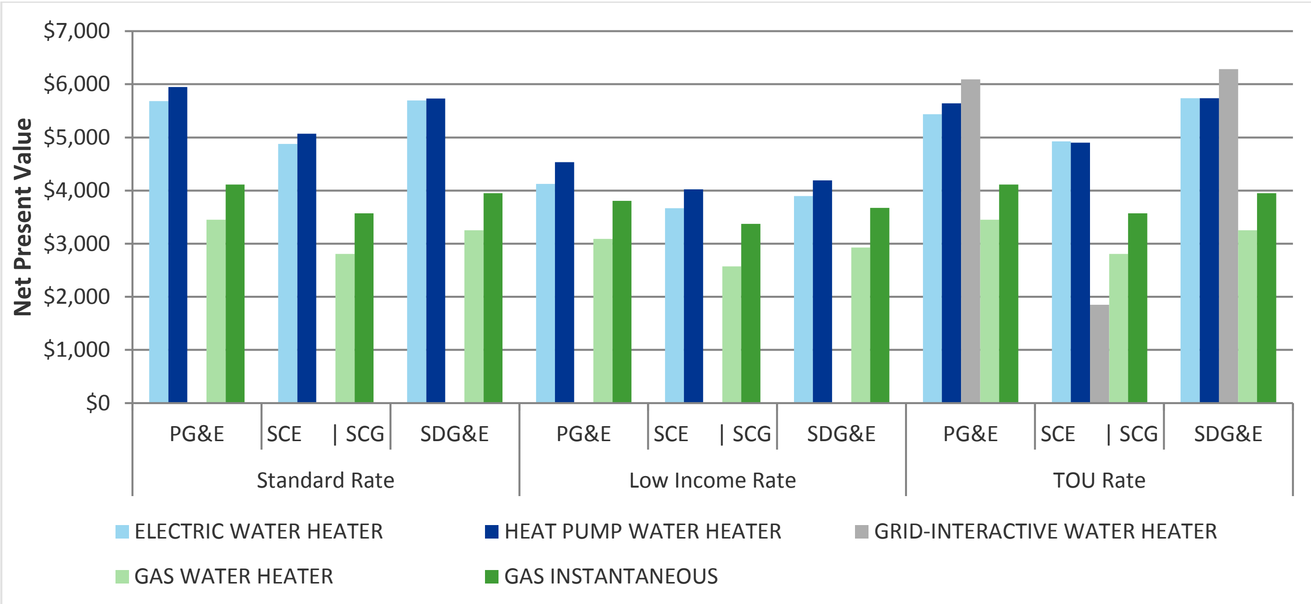

Figure 1-1: Net Present Value of Total Costs of Ownership for Water Heating Technologies for Single Family Customers across all Utilities and Rates

2 INTRODUCTION

In 2014, California's legislature passed AB 2672 requiring the California Public Utilities Commission to analyze economically feasible options that can increase access to affordable energy in disadvantaged communities. The bill requires the Commission to take appropriate action and determine the appropriate funding sources for options deemed cost effective.[1] The Commission contracted with DNV GL to explore cost-effective technology options for providing domestic water heat for residential customers in single family and multifamily dwellings. The work scope included conducting an assessment on the economics for purchasing and operating the technologies under various rate options; including standard, TOU and low-income rates for disadvantage residents.

2.1 Background

2.1.1 California Water Heater Market

Water heaters account for roughly 25% of all household energy use in California, making them the second - largest single source of residential energy consumption[2], behind space heating. Nearly half (49%) of the homes in California use natural gas as the primary fuel for water heaters.[3] Compared to only 6% of single family homes and 14% of multi-family homes using electricity for water heat.[4] For homes that use electricity, approximately 20% of their electricity bill is attributed to water heating.[5] PG&E estimates that gas water heaters are up to 75% cheaper to operate than electric water heaters.[6]

Where natural gas is the most affordable way to heat water for residential use; some homes in lower-income communities throughout the state, such as the San Joaquin Valley, lack access to natural gas lines. The San Joaquin Valley comprised of several communities across Fresno, Kern, Kings, Madera, Merced, San Joaquin, Stanislaus and Tulare counties and account for approximately 10% of all households in California.[7]

California's multi-family water heating base is also aging and many multi-family building owners have been slow to uptake newer technologies. Classic landlord-tenant barriers may be one reason for the slow upgrades. Replacing gas appliances triggers a requirement that the building also pass a Combustion Appliance Safety (CAS) test. While the costs to implement the test are known, the cost of mitigating any test failures is unknown and can be extremely costly.[8] For this reason, building owners are prone to have a "if it ain't broke don't fix it" mentality when considering water heater replacements.

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[1] California, 2014.
[2] EIA, 2009.
[3] CEC, 2010.
[4] DNV GL, 2014a.
[5] EIA, 2017.
[6] PG&E, 2017.
[7] US Census Bureau, 2015.
[8] Opinion Dynamics, 2014.

2.1.2 Available Water Heating Technologies

Recent research has shown that to reach net-zero energy by 2050, Californians will need to run their homes, cars, and businesses using electricity from carbon-free sources.[9] This raises two possibilities for water heaters in California:

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

DNV GL examined the impacts of emerging technologies such as heat pump water heaters and grid-interactive water heaters to address the issues described above.

Heat pump water heaters are hybrids and operate in two modes depending on the household's demand for hot water. They function as a heat pump (a reverse refrigerator) during periods of low demand where they draw warm air from their surroundings to heat refrigerant that is used to heat water. This functionality is combined with the traditional electric resistance water heater function during periods of high demand. Also, the load profile of heat pump water heaters is considerably different than standard electric water heaters as they reheat water over a more gradual period. Unlike standard gas storage water heaters, the overall efficiency of heat pump water heaters is highly dependent on hot water load profiles and ambient conditions. 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. Yet overall, the market share of heat pump water heaters is still low at approximately 1%.[10]

A recent study by the Brattle Group found that water heaters, specifically grid-interactive water heaters, offer an attractive opportunity for improving the reliability, economics, and environmental footprint of the green-powered grid.[11] Water heaters with grid-interactive capabilities can shift their load and consume electricity during periods that have the least impact on the grid. The growing adoption of intermittent generating sources increases the value of flexible loads to system operators. Grid-enabled or grid-interactive water heaters can provide flexible load in the following ways:

1. Demand response (cycle water heater demand to optimize periods of low/high 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 to increase or decrease load with near instantaneous response).

[9] CEC, 2013.
[10] NEEA, 2012.
[11] Brattle, 2016a.

3 STUDY APPROACH

3.1 Study Objectives

This study aims to establish the total costs of ownership for selected water heating technologies in the four California Investor-Owned-Utilities (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[12]
d. Efficient electric tank water heater, 40-gallon
e. Efficient electric tank water heater, 50-gallon[13], 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. 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)
    c. TOU residential rate plan
2. Multi-family building occupants and owners
    a. Standard residential electric and gas rate plans
    b. Low income residential rate plan
    c. TOU residential rate plan

The multi-family portion of the study aims to determine if heat pump water heaters are an attractive option for owners making upgrades to their buildings if they eliminate unforeseen costs due to combustion appliance safety (CAS) testing and mitigation. CAS tests are required whenever changes are made to a combustion appliance such as a gas water heater.

This study also includes a "back-of the-envelope" style economic analysis to determine if grid-interactive efficient electric storage water heater installations provide an opportunity to 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 water heating technology combinations. NPV represents the difference of cash outflows (such as initial and

[12] A 50-gallon heat pump water heater is an appropriate substitute for a 40-gallon gas or standard electric water heater because of its slower recovery time. Recovery time dictates how fast a water heater can reheat water to meet demand. See: http://products.geappliances.com/appliance/gea-support-search-content?contentId=16777

[13] A 50-gallon electric tank water heater size was chosen for the grid-interactive case as it is comparable to the heat pump water heater and is also the size that was used in the Brattle group study.

operational costs) and cash inflows an estimate of the overall cost of the equipment during its useful life in today's dollars.

2. Determine total CO_2 emissions for each 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).

In addition to the above objectives, DNV GL also addresses the following researchable issues;

- Provide framework to help the Commission determine whether heat pump water heaters are a cost-effective option in the context of AB 2672 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-interactive water heaters are a cost-effective option for both single family homes in disadvantaged communities and multi-family owners and occupants.

3.2 Study Approach

The primary study approach DNV GL applied was to calculate the NPV of the cost of ownership for two different customer segments and three water heating technologies. The customer 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, 50-gallon, grid-interactive
2) Multi-family building owner who needs to replace five 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, 50-gallon, grid-interactive

For each customer and each water heating technology option, we determined the NPV of the total cost of ownership including upfront costs, standard installation costs, as well as other costs such as CAS testing and mitigation, and non-standard installation costs, like installing condensate drains for a heat pump water heater. We consider several factors that can have an impact on the overall cost of ownership including climate, utility rates, and feasibility of installation. We also explored technical and regulatory barriers that exist for each option.

DNV GL used life-cycle cost analysis (LCCA) over a 10-year period and assume each of the technologies has at least a 10-year lifetime. Table 3-1 provides the key cost categories used for each customer and technology combinations.

Table 3-1: Key cost categories for each water heating technology and customer combinations

Existing Technology	Technology Replacement	Key Cost Categories
Single Family Electric Storage Water Heater	Efficient Gas Water Heater: Storage and Instantaneous	Purchase price Installation costs CAS testing CAS mitigation costs Gas prices
	Electric Heat Pump Water Storage Heater	Purchase price Installation costs Electric rates Estimated performance for CA climate zone
	Efficient Electric Storage Water Heater: Standard and Grid-interactive	Purchase price Installation costs Electric rates Grid connectivity Estimated ancillary benefit
Multi-Family Single-Unit Gas Storage Water Heater	Efficient Gas Storage Water Heater	Purchase price Installation costs CAS testing CAS mitigation costs Gas rates
	Electric Heat Pump Storage Water Heater	Purchase price Installation costs Drain installation Local electrical extension Estimated performance for CA climate zone
	Efficient Electric Storage Water Heater: Standard and Grid-interactive	Purchase price Installation costs Local electrical extension Grid connectivity Estimated ancillary benefit

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

3.3 Methodology

3.3.1 Literature and Document Review

The study team reviewed the following documents:

- Brattle Group study
- California Independent System Operator (CAISO) Annual Report on Market Issues & Performance
- California Lighting and Appliance Saturation Study (CLASS) database
- Database of Energy Efficiency Resources (DEER) and supporting CA work papers
- ENERGY STAR® Water Heater Market Profile
- Life Cycle Costs best practices
- Northwest Energy Efficiency Alliance (NEEA) Heat Pump Water Heater Field Study Report

- Residential Appliance Saturation Study (RASS)
- Utility Water Heater Rebate Program application data

3.3.2 Financial Model - Life Cycle Cost Analysis

To establish the total costs of ownership DNV GL used 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, 50-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, 50-gallon, grid-interactive

For each case, DNV GL determined the cost to purchase, install, maintain, and operate the water heaters (see Section 3.3.3). To complete the analysis, DNV GL also estimated the revenue generated by water heaters in the case of the grid-interactive water heaters, costs associated with CO_2 emissions for each scenario, and other parameters for present-value analysis including discount rate, estimated useful life, and inflation rate of operation costs.

Table 3-2: Parameters for life cycle cost analysis

Parameter	Value
Discount rate	8%[14]
Operation annual inflation rate	3%
Green-house-gas emissions cost	$13/Metric Ton[15]
Estimated useful life	10 years

After identifying all the costs (as described in the following section), DNV GL determined the NPV of each scenario. To do so, DNV GL first projected the costs and benefits, if any associated with owning and operating the water heater. The present value was determined for each year using the discount rate. DNV

[14] Based on cost of capital (rate of return) determined by CPUC Cost of Capital Proceedings for major utilities. See: http://www.cpuc.ca.gov/General.aspx?id=10458

[15] Based on the 2016 IDER avoided cost calculator (update underway pursuant to D.16-06-007 in the IDER proceeding)

GL summed the total present-value costs to determine the NPV of each of the water heater technologies and customer combinations. Table 3-3 is shows an example of one such calculation.

Table 3-3: Example NPV calculation

Single Family												
LIFE CYCLE COST OF ELECTRIC WATER HEATER												
		Today	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**	**Year 9**	**Year 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
Present Value		$1,000	$494	$485	$476	$467	$458	$449	$440	$432	$424	$416
NPV	**$5,540**											

3.3.3 Model Inputs

The core components and assumptions that were used to model NPV for each water heater technology in multiple scenarios is described in the following sections. Inputs included first costs, annual energy use, load shapes, operational costs as well as greenhouse gas related costs.

3.3.3.1 First Costs

DNV GL determined first or up-front costs by examining two primary data sources: DEER work paper and application data for IOU-rebated water heaters, obtained through CPUC data request procedures. DEER work paper included values for unit, labor and installation costs, but values did not vary between single family and multi-family households. The DEER unit and total costs shown in Table 3-4 were from a work paper from 2015, SCE13WH001.3 that cited a 2014 Itron study for the measure costs.[16] With respect to application data, DNV GL received a sample of invoices that were filed as part of the following programs:

- Home Energy Efficiency Rebate (HEER) Program
- Multifamily Energy Efficiency Rebate (MFEER) Program
- Single family and Multi-Family Home Upgrade Program as part of Energy Upgrade California

In most cases, customers are required to submit receipts with their rebate application, however the IOU application data DNV GL received proved to be a bigger challenge than expected as it was not uniform. While some files contained only receipts for water heaters purchased at home improvement stores, others contained invoices from contractors that combined the water heater unit, labor and parts costs associated with installation into one sum. This made it difficult to isolate unit costs and total costs for each installation across all IOU application data. DNV GL mined the sampled water heater projects for data indicating either the unit (equipment) costs or the total cost for equipment and installation. Table 3-4 provides a detailed comparison of the costs from both data sources.

[16] Itron and DNV GL, 2014.

Table 3-4: Comparison of Up-Front Costs between DEER work papers and IOU application data

Water Heater Technology	Single Family				Multi Family			
	DEER	Application Data		Difference	DEER	Application Data		Difference
		Average	n			Average	n	
Efficient Electric (40-gal)								
Unit Cost	$626	$352	6	-78%	$626	$357	9	-75%
Total Cost	$939	$1,147	1	18%	$939	-	0	-
Efficient Gas (40-gal)								
Unit Cost	$817	$598	21	-36%	$817	$569	14	-44%
Total Cost	$1,146	$1,054	8	-9%	$1,146	$789	7	-45%
Instantaneous Gas								
Unit Cost	$940	$845	1	-11%	$940	$842	2	-12%
Total Cost	$1,289	$3,782	7	66%	$1,289	$2,179	2	41%
Heat Pump (50-gal)								
Unit Cost	$1,565	$976	37	-60%	$1,565	$928	7	-69%
Total Cost	$2,033	$1,777	8	-14%	$2,033	$1,091	1	-86%

As seen above, single family and multi-family costs from the IOU application data were lower in most cases, sometimes up to 80% lower compared to DEER. The lower costs seem plausible given that the IOU application data reflects a more recent picture of the market compared to data in DEER that is probably outdated. To reconcile the high variability in costs between DEER and IOU application data, DNV GL assumed the up-front costs in Table 3-5 for all analyses in the report.

Table 3-5: Assumed Up-Front Costs

Water Heater Technology	Single Family	Multi-Family
Efficient Electric (40-gal)		
Unit Cost	$375	$375
Total Cost	$1,100	$850
Efficient Gas (40-gal)		
Unit Cost	$600	$600
Total Cost	$1,100	$850
Instantaneous Gas		
Unit Cost	$850	$850
Total Cost	$2,500	$2,000
Heat Pump (50-gal)		
Unit Cost	$1,000	$1,000
Total Cost	$1,800	$1,500
Efficient Electric, Grid-Interactive (50-gal)[17]		
Unit Cost	$1,200	$1,200

[17] The costs for a 50-gallon grid-interactive water heater were based off two cases in the IOU application data.

Total Cost	$1,730	$1,730

3.3.3.2 Annual Energy Use

DNV GL relied on DEER and associated tools to calculate annual energy consumption. Following is a description of the methodology.

Baseline

DNV GL used DEER's Measure Analysis Software (MASControl) to create baseline energy use values for the standard gas and electric storage water heaters for each utility per housing type. The specifications for both water heater baseline types are based on the new 2015 Federal Standards which are:

- Gas Storage: 40-gallon, 75 kBtuh, 0.62 EF
- Electric Storage: 40-gallon, 12 kW, 0.94 EF

DNV GL used the MASControl software model for the above specifications to generate annual consumption data for each of the 16 building climate zones in California. We ran the model for both water heater types and housing types across all 16 climate zones. A utility specific value was developed by averaging the values from each of the climate zones in the utility. A summary of the baseline annual energy use values can be seen in Table 3-6 below.

Table 3-6: Baseline water heater annual energy use by utility and housing type

Utility	Electric Storage		Gas Storage	
	Single Family	Multi-Family	Single Family	Multi-Family
	kWh/yr	kWh/yr	therm/yr	therm/yr
PG&E	3,285	2,760	179	154
SCE	2,995	2,522	-	-
SCG	-	-	166	143
SDG&E	3,009	2,532	166	144

Savings

In the next step, we applied savings values for each efficient model of electric and gas water heater to the baseline. We used DEER's Remote Ex-Ante Database Interface (READI) versions 2011 and 2015 to research savings values for replacement water heating technologies with the following specifications:

- Electric Heat Pump Water Heater (50-gallon): 12 kW, 2.00 EF
- Gas Instantaneous Water Heater: 150 kBtuh, 0.82 EF

Table 3-7: Replacement water heater annual savings by utility and housing type

Utility	Heat Pump		Gas Instantaneous	
	Single Family	Multi-Family	Single Family	Multi-Family
	kWh/yr	kWh/yr	therm/yr	therm/yr
PG&E	635	847	37	27
SCE	715	814	-	-

SCG	-	-	34	25
SDG&E	745	824	34	26

Adjustment

The savings values listed in DEER's READI interface are based on a different, pre-2015 standard baseline. Thus, it is necessary to reduce the savings given in READI by the savings derived for the new baseline to avoid double counting. This adjusted savings value was subtracted from the baselines from Table 3-6 to create annual energy use for each replacement water heater technology. Table 3-8 provides the final values from the MASControl and READI interface.

Table 3-8: Final baseline, savings, and energy use vales for each utility

		Single Family				Multi Family			
		Baseline [18]	Savings [19]	Adjustment [20]	Energy Use[21]	Baseline	Savings	Adjustment	Energy Use
Electric	**Utility**	**Annual kWh**				**Annual kWh**			
Heat Pump (50-gal)	PG&E	3,285	635	321	2,971	2,760	847	321	2,234
	SCE	2,995	715	313	2,593	2,522	814	313	2,021
	SDG&E	3,009	745	311	2,575	2,532	824	311	2,019
Gas	**Utility**	**Annual Therms**				**Annual Therms**			
Gas Instantan -eous	PG&E	179	37	10	152	154	27	10	137
	SCG	166	34	9	141	143	25	9	127
	SDG&E	166	34	9	142	144	26	9	128

3.3.3.3 Load Shape

DNV GL developed load shapes for the efficient electric and heat pump water heaters for both weekday and weekends. The load shapes facilitated calculating hourly electricity usage that was then used to calculate annual operating costs for TOU rates. Load shapes for both technologies were derived for summer and winter seasons, however only the winter data is shown in Figure 3-1 for demonstration purposes.

The electric water heater load shape was derived from daily, average hourly load profiles and average monthly load profiles developed by the Northwest Power and Conservation Council (NW Council) for electric domestic hot water heating. We derived the load profile from the shape from the NW Council and applied DEER electric use values.

DNV GL derived the heat pump water heater curve from the 2013 NEEA Heat Pump Water Heater Field Study Report.[22] We derived the load profile from the shape published in the NEEA report and applied DEER electric use values for heat pump water heaters.

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[18] Based on MasControl runs for climate zone in IOU territory

[19] Savings listed in READI tool for the water heater used in the analysis

[20] Savings listed in READI tool for baseline water heater

[21] =Baseline - (Savings-Adjustment)

[22] NEEA, 2013.

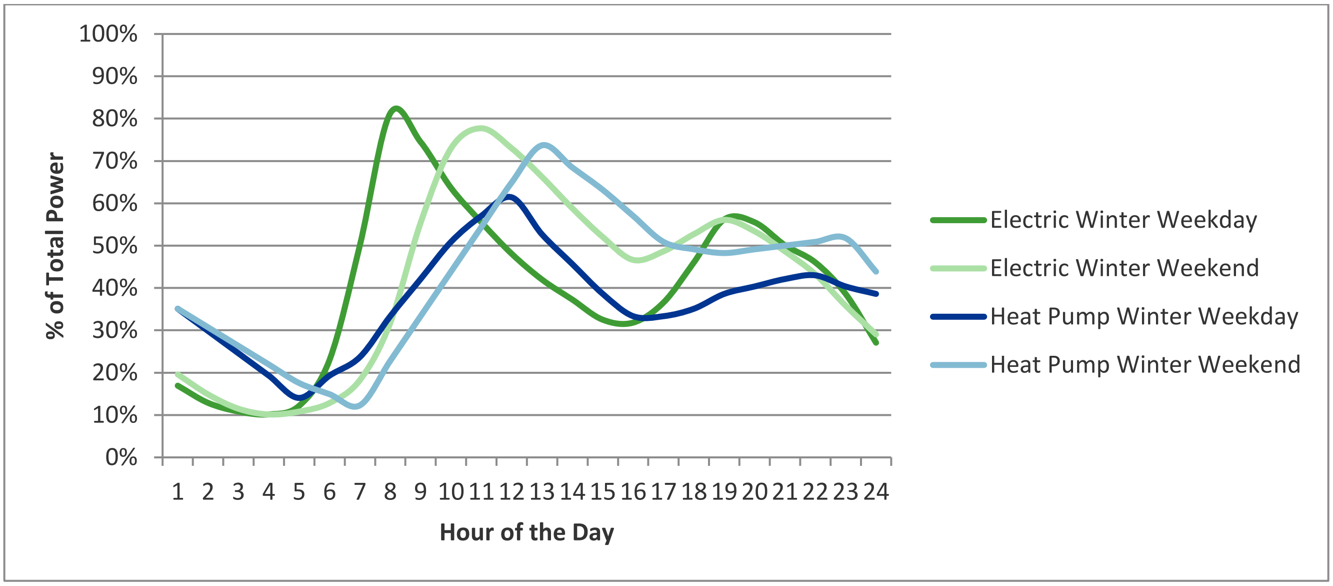

Figure 3-1: Electric and Heat Pump Water Heater Load Shapes

3.3.3.4 Grid-interactive Water Heaters

In addition to the standard efficient electric water heater, DNV GL considered a grid-interactive electric water heater under two scenarios: TOU and real-time pricing plans (described further in Section 4.7). DNV GL assumed that the advanced electric water heater or a grid-interactive water heater could provide ancillary services. These services include frequency regulation where a grid-interactive water heater serves as a generation asset that can be controlled almost instantaneously to maintain and optimize alternating current (ac) frequency on the electrical grid.

The grid-interactive water heater can serve as a valuable load resource, one that can quickly ramp up and down to meet the needs of the grid. The value of this type of resource is highly dependent on market conditions. The ability of grid-interactive water heaters to provide frequency regulation has been demonstrated by Great River Energy in Minnesota, Pacific Northwest National Laboratory, EPRI and Hawaiian Electric Company. While a single water heater currently would not be eligible for the California ancillary services program, DNV GL assumed the same market conditions and ancillary service benefits as described by Brattle.[23] The estimates include benefits of providing frequency regulation paid to the provider or consumer both for available capacity and called resources. DNV GL estimated that a grid-interactive water heater could provide $182 of ancillary benefits to the grid in the first year.[24]

3.3.3.5 Operational Costs

Operational costs for water heaters include fuel charges; either electric or gas and maintenance costs. DNV GL could not find evidence of regular maintenance cost for water heaters and therefore only included fuel costs.

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[23] Brattle, 2016a.
[24] Brattle, 2016.

DNV GL examined three types of customer rates to calculate annual electric and gas charges for each of the water heater technologies. We break down operational costs by standard, low-income and TOU rates. For standard rate plans, only Tier 1 rates are considered. The rates and resulting annual operating costs for each water heater technology and rate plan are given by IOU in Table 3-9 through Table 3-11.

Table 3-9: Standard Electric and Gas Rates and Annual Operating Costs

Standard Rate			Single Family	Multi-Family
Electric	**Utility**	**$/kWh**	**$**	**$**
Electric Storage (40-gallon)	PG&E[25]	0.18276	600	504
	SCE[26]	0.16317	489	411
	SDG&E[27]	S: 0.20452 W: 0.18867	591	498
Heat Pump (50-gallon)	PG&E	0.18276	543	408
	SCE	0.16317	423	330
	SDG&E	S: 0.20452 W: 0.18867	506	397
Gas	**Utility**	**$/therm**	**$**	**$**
Gas Storage (40-gallon)	PG&E[28]	1.34103	240	207
	SCG[29]	0.92969	154	133
	SDG&E[30]	1.27210	212	183
Gas Instantaneous	PG&E	1.34103	204	183
	SCG	0.92969	131	118
	SDG&E	1.27210	180	162

SDG&E: S = Summer, W = Winter

Low income customers across all IOUs are eligible for reduced electric rates. They can receive a discount of about 35% to 40% from the standard rate depending on the utility. Gas customers on low income plans across all IOUs can save 20% on annual operating costs compared to the standard rate. The low income rates we used are illustrated in Table 3-10.

25 PG&E (Electric): Rate from E-1 Residential Service. Accessed January 30, 2017.

26 SCE: Rate from Schedule D Domestic Service. Accessed January 30, 2017.

27 SDG&E (Electric): Rate from Schedule DR Domestic Service. Accessed January 30, 2017.

28 PG&E (Gas): Rate from G-1 Residential Service. Accessed January 30, 2017.

29 SoCalGas: Rate from GR Residential Service. Accessed January 30, 2017.

30 SDG&E (Gas): Rate from Schedule GR Natural Gas Service. Accessed January 30, 2017.

Table 3-10: Low Income Electric and Gas Rates and Annual Operating Costs

Low Income Rate			Single Family	Multi-Family
Electric	**Utility**	**$/kWh**	**$**	**$**
Electric Storage (40-gallon)	PG&E[31]	0.11929	393	331
	SCE[32]	0.10204	330	278
	SDG&E[33]	S: 0.11493 W: 0.10462	356	299
Heat Pump (50-gallon)	PG&E	0.11929	356	268
	SCE	0.10204	285	222
	SDG&E	S: 0.11493 W: 0.10462	304	239
Gas	**Utility**	**$/therm**	**$**	**$**
Gas Storage (40-gallon)	PG&E[34]	1.02158	192	165
	SCG[35]	0.77123	123	107
	SDG&E[36]	1.01563	169	146
Gas Instantaneous	PG&E	1.02158	163	146
	SCG	0.77123	105	95
	SDG&E	1.01563	144	130

SDG&E: S = Summer, W = Winter

TOU charges are applicable to electric appliances and a summary of annual operating costs for efficient electric storage, heat pump and electric storage grid-interactive water heaters can be seen in Table 3-11 below. Customers with a standard electric storage water on TOU rate plans in SCE and SDG&E can expect to see about a 1% increase in annual operating costs compared to the standard rate plans. Whereas PG&E customers can expect a decrease of about 6% when switching to a TOU plan. Customers in PG&E and SCE with heat pump water heaters can expect an 8% and 5% reduction, respectively, when switching to a TOU plan. Only baseline rates were considered, like Tier 1 usage. The TOU plan operating costs were developed using the load profiles described in Section 3.3.3.3.

31 PG&E (Electric): Rate from EL-1 Residential CARE Program Service. Accessed January 30, 2017.

32 SCE: Rate from Schedule D-CARE Service. Accessed January 30, 2017.

33 SDG&E (Electric): Rate from Schedule DR-LI. Accessed January 30, 2017.

34 PG&E (Gas): Rate from GL-1 Residential CARE Program. Accessed January 30, 2017.

35 SoCalGas: Rate from Schedule G-CARE. Accessed January 30, 2017.

36 SDG&E (Gas): Rate from Schedule G-CARE. Accessed January 30, 2017.

Table 3-11: TOU Annual Operating Costs

TOU Rate		Single Family	Multi Family
Electric	**IOU**	**$**	**$**
Electric Storage (40-gallon)	PG&E[37]	568	477
	SCE[38]	495	417
	SDG&E[39]	597	503
Heat Pump (50-gallon)	PG&E	503	378
	SCE	401	313
	SDG&E	507	398
Electric Storage Grid-interactive (50-gallon)	PG&E	750	750
	SCE	185	185
	SDG&E	764	764

3.3.3.6 Green House Gas (GHG)

The difference in energy consumption between a standard or baseline water heater compared to a more efficient replacement technology can be considerable as shown earlier in Table 3-7. However, the impact that the replacement water heaters have on GHG emission reductions can also be significant and are worth examining.

DNV GL applied the most recently available electric and natural gas GHG emission factors to each water heater technology to calculate GHG emissions and associated social costs. Social costs of carbon or GHG costs are based on cap and trade market prices and are included as outflows for each water heater technology in the overall NPV calculations. When available, we applied emissions factors specific to each IOU; otherwise we relied on the default values from EPA's Emissions & Generation Resource Integrated Database (eGRID2012) released in October of 2015. All GHG emissions are reported in metric tons of carbon dioxide-equivalent (CO_2e) which is the sum of carbon dioxide, methane (CH_4) and nitrous oxide (NO_2) emissions normalized by their respective global warming potential (GWP) factors. A summary of annual GHG emissions and costs related to each water heating technology is illustrated in

[37] PG&E (Electric): Rate from E-TOU Residential Time-Of-Use Service. Accessed January 30, 2017.

[38] SCE: Rate from TOU-D Time-Of-Use Domestic Service. Accessed January 30, 2017.

[39] SDG&E (Electric): Rate from TOU-DR Time-Of-Use Service. Accessed January 30, 2017.

Table 3-12.

Table 3-12: Annual Greenhouse Gas Emissions and costs for all water heating technologies by utility and housing type

		Single Family			Multi Family		
Electric	**Utility**	**Annual kWh**	**Metric ton CO_2e**	**GHG Costs ($)**	**Annual kWh**	**Metric ton CO_2e**	**GHG Costs ($)**
Heat Pump (50-gallon)	PG&E	2,971	0.59	7.67	2,234	0.44	5.76
	SCE	2,593	0.60	7.75	2,021	0.46	6.04
	SDG&E	2,575	0.72	9.37	2,019	0.57	7.35
Electric Storage (40-gallon)	PG&E	3,285	0.65	8.48	2,760	0.55	7.12
	SCE	2,995	0.69	8.95	2,522	0.58	7.54
	SDG&E	3,009	0.84	10.95	2,532	0.71	9.21
Electric Storage Grid-interactive (50-gallon)	PG&E	4,380	0.87	11.30	4,380	0.87	11.30
	SCE	4,380	1.01	13.10	4,380	1.01	13.10
	SDG&E	4,380	1.23	15.94	4,380	1.23	15.94
Gas	**Utility**	**Annual Therms**	**Metric ton CO_2e**	**GHG Costs ($)**	**Annual Therms**	**Metric ton CO_2e**	**GHG Costs ($)**
Gas Instantaneous	PG&E	152	0.81	10.48	137	0.73	9.43
	SCG	141	0.75	9.75	127	0.68	8.78
	SDG&E	142	0.75	9.78	128	0.68	8.80
Gas Storage (40-gallon)	PG&E	179	0.95	12.37	154	0.82	10.63
	SCG	166	0.88	11.43	143	0.76	9.89
	SDG&E	166	0.88	11.48	144	0.76	9.92

As observed in the above table, GHG emissions from heat pump and standard electric storage water heaters are lower than both gas water heater technologies. In California, natural gas consumption results in higher GHG emissions when compared to electricity consumption that includes a mix of cleaner source energy such as hydroelectric, nuclear, wind or solar.[40] The specific power mix for each IOU can also vary and helps explain why PG&E's electric emissions are lower than SCE and SDG&E. As of 2014, PG&E's power mix comprised of greater non-fossil fuel generation (solar, wind, nuclear and hydroelectric) compared to that of SCE and SDG&E.[41]

The impact of fuel switching is highlighted when comparing GHG emissions of a gas and electric water heater. For instance, a single family customer replacing a 40-gallon gas storage water heater with a 50-gallon heat pump water heater in PG&E service territory can expect to reduce 0.36 metric tons of CO_2e emissions annually. This reduction equates to CO_2 emissions from approximately 385 pounds of coal burned.[42] If the same customer switched their 40-gallon gas storage water heater to a 40-gallon electric storage water heater they could expect to reduce their annual emissions by 0.30 metric tons of CO_2e.

[40] EIA, 2016.

[41] PG&E, 2015.

[42] EPA, 2017.

3.3.4 Primary Data Collection

DNV GL conducted in-depth interviews with a utility program staff member[43] and Energy Upgrade California contractors who are listed as performing Combustion Safety Tests. The purpose of the interviews was to gain further insight on the costs and benefits of switching to an electric-based water heating system. The contractors interviewed included water heater installers, CAS testers, multi-family building contractors, and an expert in the water heating field. Interview topics included experience with CAS testing, typical failure points, cost of typical repairs, cost of typical CAS testing, and rate of CAS testing mitigation requirements and associated costs.

However, there was no convergence on what is the typical rate of failure, typical failure points or costs associated with CAS mitigation. Improper venting on gas ranges, improper installations of water heaters and air conditioning, oversize exhaust fans in bathrooms, and ducting malfunctions were all sited as common failures. Typical costs for repairs ranged from free - exhaust fan control adjustment - to more expensive equipment repair at $500-$2,000 in rare cases.

Further, the sample of persons interviewed was not representative of typical projects or for that matter, typical contractors. Given the lack of consensus, DNV GL opted to apply potential scenarios gleaned from the interviews. The scenarios DNV GL applied for gas water heaters for this analysis include:

1. No/low mitigation costs
2. High mitigation costs ($2,000 for replacing a water heater)

Per available information and the interviews, Scenario 1, no mitigation costs, was deemed most typical. The consensus was that a small portion of housing units fail the test (1-15%) and that older buildings are more likely to fail than new construction. For this reason, CAS mitigation costs were not included in the baseline analysis covered in the Results Sections 4.1-4.4. However, cost of CAS testing was included at a rate of $450 per single family installation and $400 per multi-family installation. This includes the cost of preliminary (test-in) and post (test-out) installation safety inspections. CAS mitigation costs are discussed further in Section 4.6.

[43] Interview was conducted with a member of the Association for Energy Affordability (AEA). AEA designs and administers multi-family energy efficiency programs on behalf of BayRen, SCE and SCG.

4 RESULTS

DNV GL examined the NPV of each water heater technology across the all IOUs, with varying rate plans and customer types. The NPV highlights the investment needed to purchase and operate each water heater technology over a span of 10 years. Note: the rate plans included in the results as described in Section 3.3.3.5 of this report are standard, low income and TOU. A summary of these results are highlighted in the sections below. Full results are available in Appendix A of this report. We calculated the NPV using the inputs and assumptions below:

- Outflows
  - First cost: total up-front cost of water heating equipment including installation and CAS testing (where applicable).
  - Operating cost: annual energy cost per IOU for standard, low-income and TOU rates.
  - Other cost: GHG emissions cost per year
- Inflows: This category only applies to the electric storage grid-interactive water heater as it can provide benefits or avoided costs through its frequency regulation services.
- Discount rate: 8% per year
- Annual inflation: 3% per year for operation and maintenance as well as ancillary services like frequency regulation.

4.1 Standard rate plans

We illustrate the difference in NPV for customers on a standard plan in single family (Figure 4-1) and multi-family (Figure 4-2) households below. NPVs for heat pump water heater are slightly higher than electric water heaters for all single family IOU customers with differences ranging from less than 1% for SDG&E customers to approximately 4% higher for both PG&E and SCE customers. Single family and multi-family customers under PG&E and SDG&E have higher NPV values across all water heater technologies compared to similar SCE and SCG customers. This is due to SCE and SCG having lower annual unit energy consumption and lower electricity and gas costs, on average, compared to PG&E and SDG&E. Both types of gas water heaters in PG&E and SDG&E had higher NPVs compared to SCG customers due to higher gas utility rates.

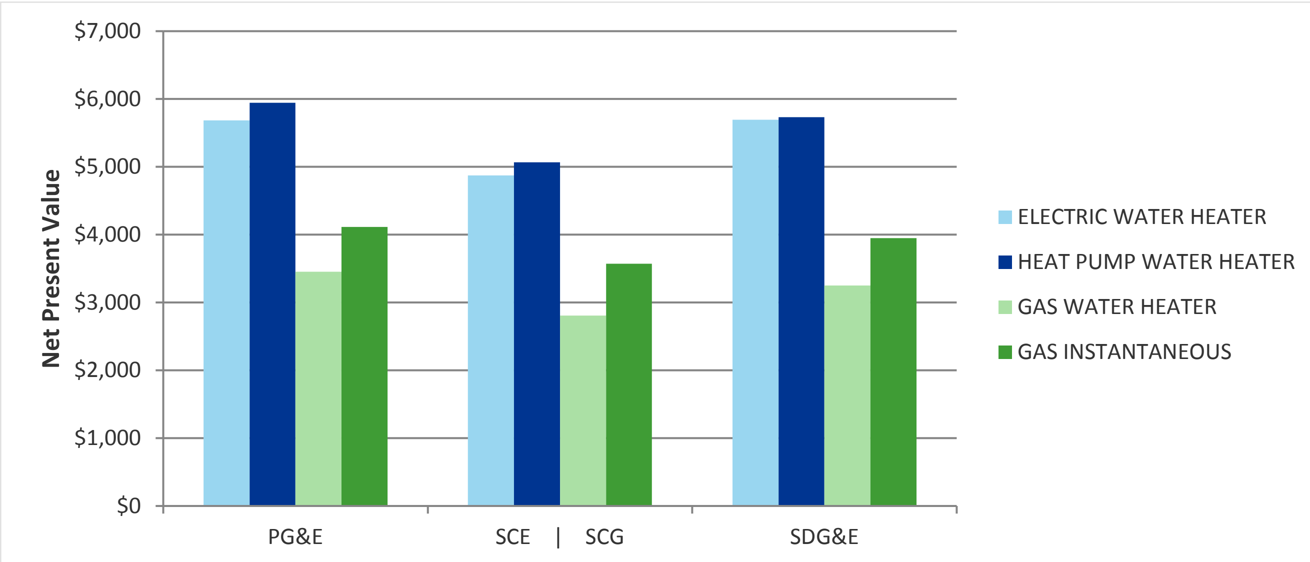

Figure 4-1: Standard Rate Net Present Values of Water Heating Technologies for Single Family Customers

These results indicate that water heater NPV for multi-family customers across all IOUs was approximately 20% less than single family households. This difference is attributed primarily to lower annual energy consumption by water heater units in multi-family dwellings as well as slightly lower first or up-front water heater costs. Specifically, electric water heaters had higher NPV compared to heat pump water heaters for PG&E and SDG&E, with almost similar NPV for SCE customers.

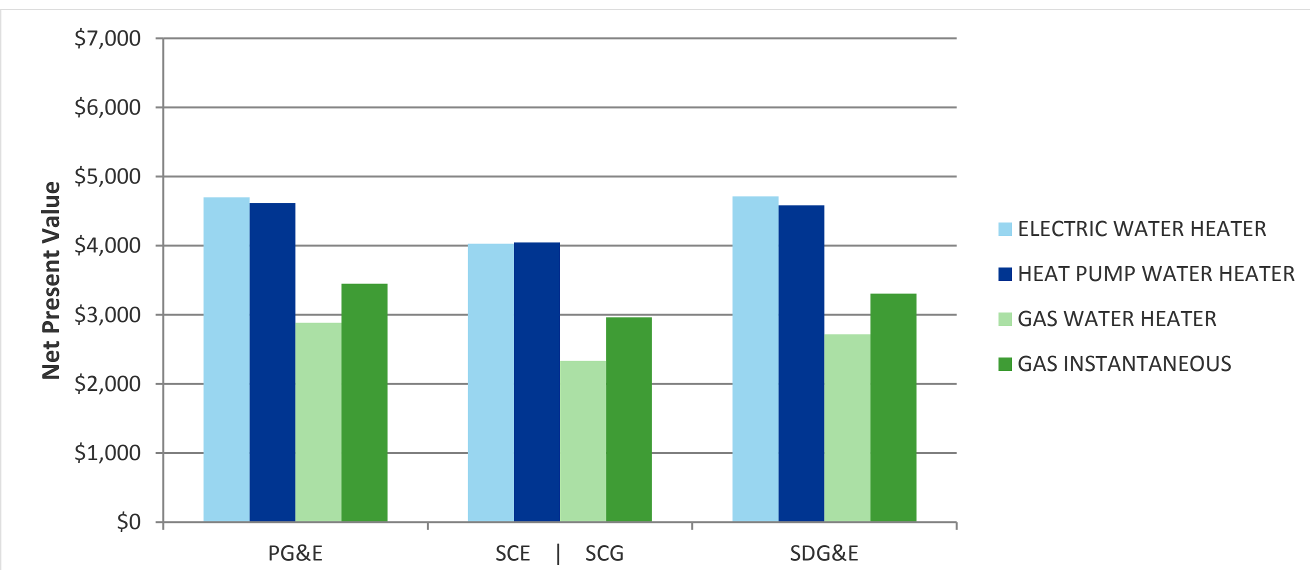

Figure 4-2: Standard Rate Net Present Values of Water Heating Technologies for Multi-Family Customers

4.2 Low Income rate plans

For all utilities, low income customers have lower annual operating costs due to discounts on their utility bills. For electric customers, households on low income plans see a reduction of approximately 35-40% in utility costs compared to households on standard rate plans. For gas customers, households on low income plans receive a 20% reduction on their utility bills compared to standard rate plans. Lower utility bills explain the difference or reduction in NPV.

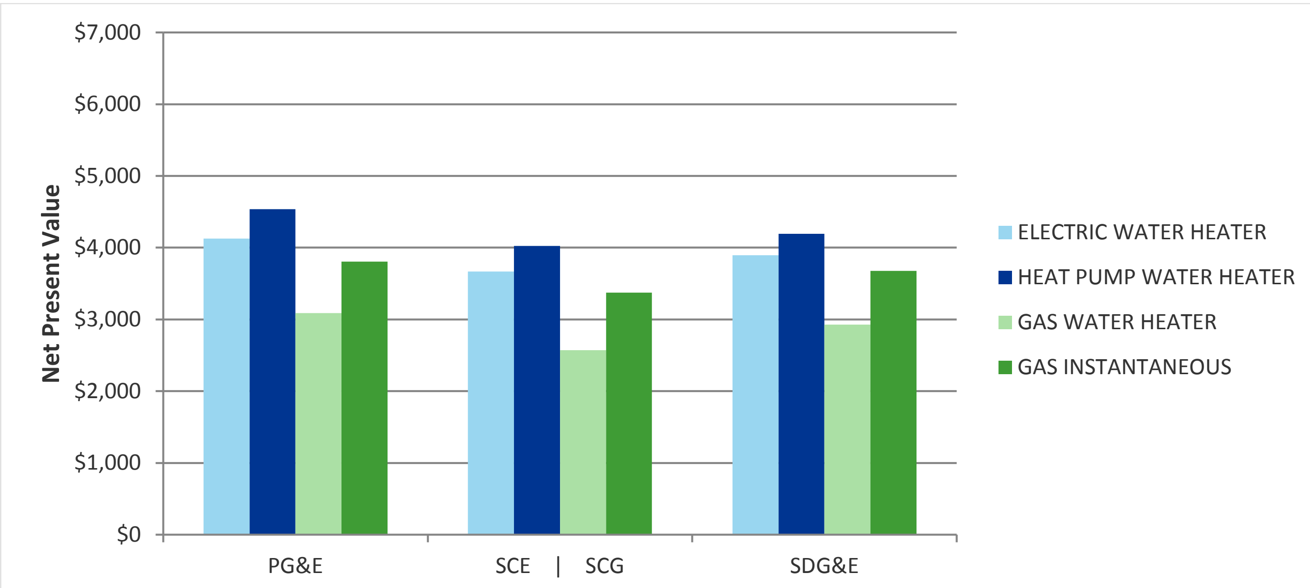

Figure 4-3: Low Income Rate Net Present Values of Water Heating Technologies for Single Family Customers

Low income multi-family households have a lower NPV due to the same reasons described in Section 4.1, lower annual energy consumption and lower up-front costs. These differences coupled with a cost reduction in utility bills result in one of the lowest NPV for all water heater technologies across the various rate plans and customers discussed in this report.

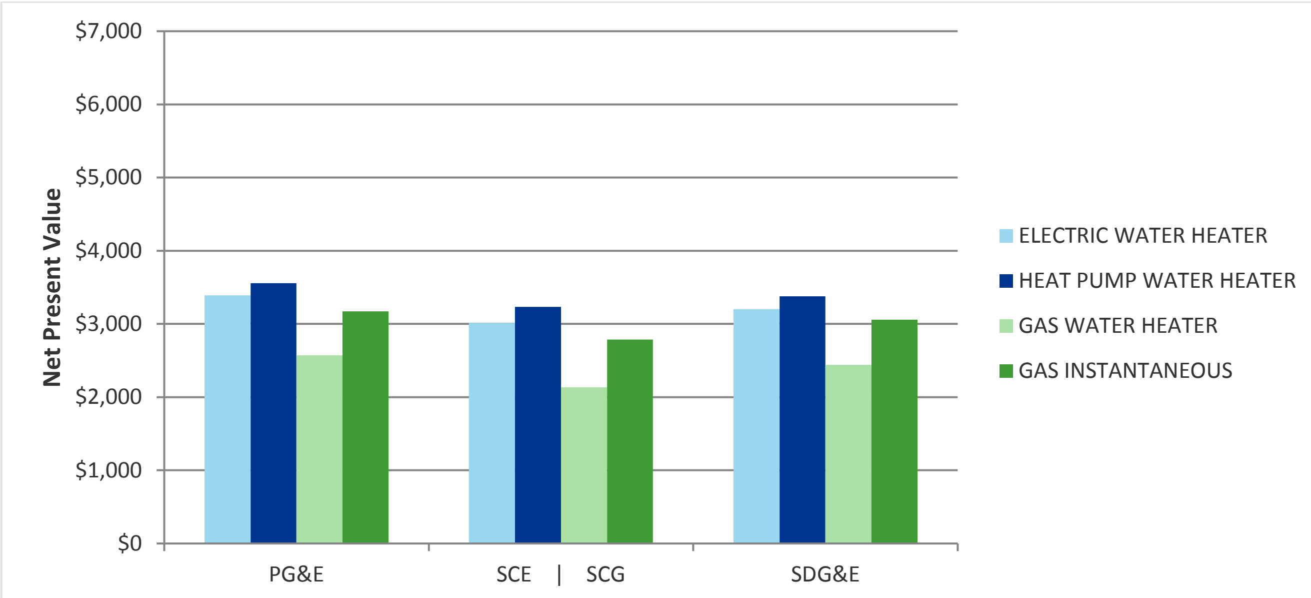

Figure 4-4: Low Income Rate Net Present Values of Water Heating Technologies for Multi-Family Customers

4.3 Time-of-use rate plans

TOU rate plans apply to electricity consumption thus they are only relevant to electric storage, heat pump and grid-interactive electric storage water heaters. While Figure 4-5 and Figure 4-6 shows all five water heater technologies, the gas storage and gas instantaneous water heaters on standard rate plans are only shown for reference. The NPVs for electric and heat pump water heaters on TOU rates only saw an increase of approximately 1% and 3%, respectively, on average, compared to standard rates. The highest of these increases can be seen in PG&E where higher TOU rates resulted in a 4.3% increase in NPV for electric water heaters and 5.1% increase for heat pump water heaters. SCE's TOU plan had the lowest impact of the three IOUs due to their relatively low rate structure. This was, in part, driven by SCE's lowest off-peak rate which was at least 12 cents lower per hour in the summer and at least 10 cents lower per hour in the winter than both PG&E and SDG&E's lowest off-peak rates.

Heat pump and standard electric water heaters had comparable NPVs among all IOUs under the TOU plan. The only exception was PG&E where the difference in NPV was highest between the two technologies. Grid-interactive water heaters would require the highest investment under PG&E and SDG&E TOU rates. However, they are the most cost-effective option among all water heater technologies, electric or gas, under SCE's TOU rates. This sharp decrease in NPV is led by the assumption that grid-interactive water heaters would only operate during the lowest rate period of a utility per day. In the case of SCE, this meant a TOU rate of $0.04/kWh compared to $0.15-$0.21/kWh in PG&E and $0.16-$0.19/kWh in SDG&E, depending on the season.

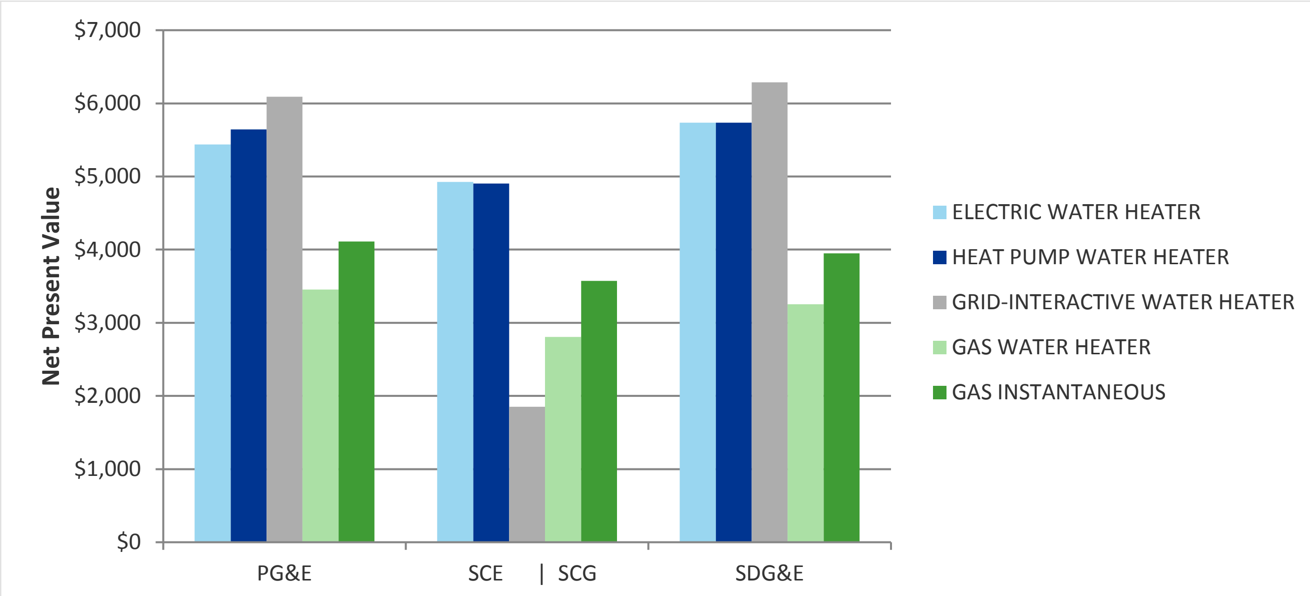

Figure 4-5: Time-of-use Rate Net Present Values of Water Heating Technologies for Single Family Customers

Multi-family households with TOU rates also show comparable NPVs between electric and heat pump water heaters compared to single family households. The primary difference, however, is that heat pump water heaters across all IOUs had lower NPVs than the standard electric water heater. This is due to lower first costs for heat pump water heaters in multi-family dwellings. Multi-family customers, just as with other rate plans, experience an 18% decrease in NPV from single family households due to more efficient unit consumption and lower up-front costs. Costs and benefits for grid-interactive water heaters in multi-family households were assumed to be the same as single family households.

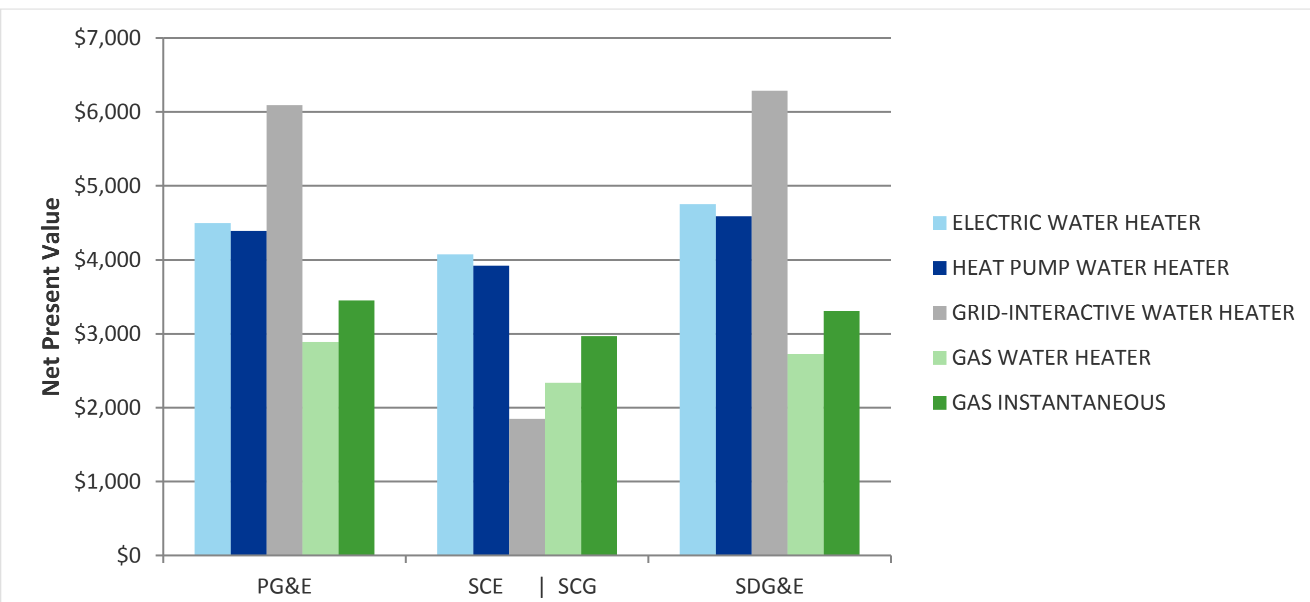

Figure 4-6: Time-of-use Rate Net Present Values of Water Heating Technologies for Multi-Family Customers

4.4 Comparison of Standard and Time-of-use rate plans

In the previous section, we described the effects of standard TOU rate plans as of January 2017. In this section, we examined the impacts that future TOU rates may have on operational costs for customers with standard electric and heat pump water heaters. Figure 4-7 compares the NPV using the two rates used in the previous section plus an adjusted (TOU-Adj) which approximates the potential impact of the upcoming rate changes to rollout in 2017. We derived the TOU-Adj, by adjusting the value of current TOU plans by a factor of 20%. This meant that the lowest of the TOU rates during the summer and winter seasons, described as "Off-Peak" (PG&E and SDG&E) and "Super-Off-Peak" (SCE), were reduced by 20%, whereas all other TOU rates were increased by 20%. The red font in the table indicates the lowest TOU rates per IOU that were further decreased by 20%.

Table 4-1: Original TOU Rates per IOU with adjustment in $/kWh[44]

IOU	Rate	Original		Adjusted	
		Summer	Winter	Summer	Winter
PG&E	Peak	$0.28	$0.17	$0.34	$0.20
	Off-Peak	$0.21	$0.15	$0.17	$0.12
SCE	On-Peak	$0.36	$0.25	$0.43	$0.30
	Off-Peak	$0.19	$0.18	$0.22	$0.22
	Super-Off-Peak	$0.04	$0.04	$0.03	$0.03
SDG&E	On-Peak	$0.26	$0.22	$0.31	$0.26
	Semi-Peak (Off-Peak)	$0.20	$0.21	$0.25	$0.25
	Off-Peak (Super-Off-Peak)	$0.16	$0.19	$0.13	$0.15

For single family customers, both electric and heat pump water heaters appear to benefit from switching from a standard electric rate to a TOU rate plan since the NPV either decreases or remain approximately the same. The affect is somewhat different using the TOU-Adj rate. While the NPV for both electric and heat pump water heaters declines under PG&E's TOU-Adj rate, it increases under SCE and SDG&E's TOU-Adj rate. This difference may be attributed to the current TOU rate structures for the IOUs as shown in Table 4-1. For instance, PG&E has two rate periods, peak and off-peak, where during a weekday a customer is only subject to five hours of peak pricing and virtually all other hours are considered off-peak. Whereas, SCE has 14 hours and SDG&E has 16 hours of what may be on-peak and semi-peak hours during a typical weekday. Increasing the rate during these hours by 20% creates an even greater impact than a similar increase during a peak hour under PG&E's TOU plan.

44 TOU Rates as of January 30, 2017.

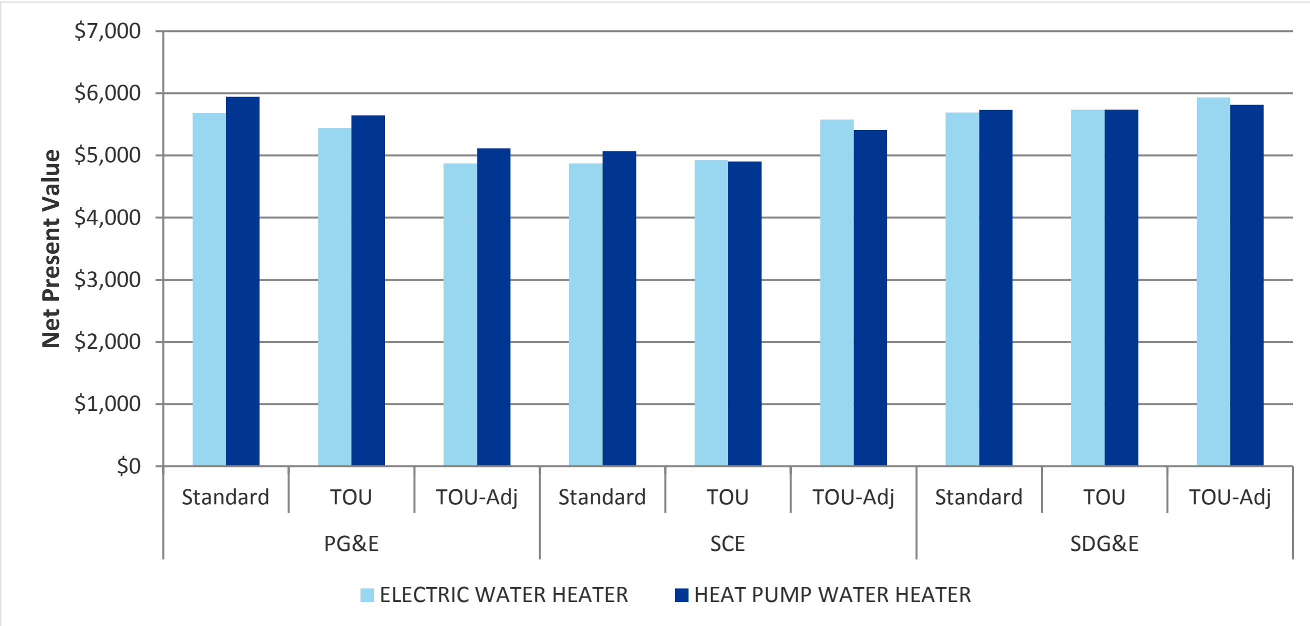

Figure 4-7: Comparison of Standard, TOU and TOU-Adj rate plans for Single Family Customers

The results are somewhat different when looking at the effect of TOU rates on multi-family customers. Heat pump water heaters under the TOU rate are more cost-effective than standard electric water heaters in all IOUs. This shift is primarily due to lower first costs as well as lower energy use (operational costs) among multi-family households. Heat pump water heaters are also more economical than standard electric water heaters under the TOU-Adj rate. However, their overall NPV increased compared to both standard and the regular TOU rates in SCE and SDG&E.

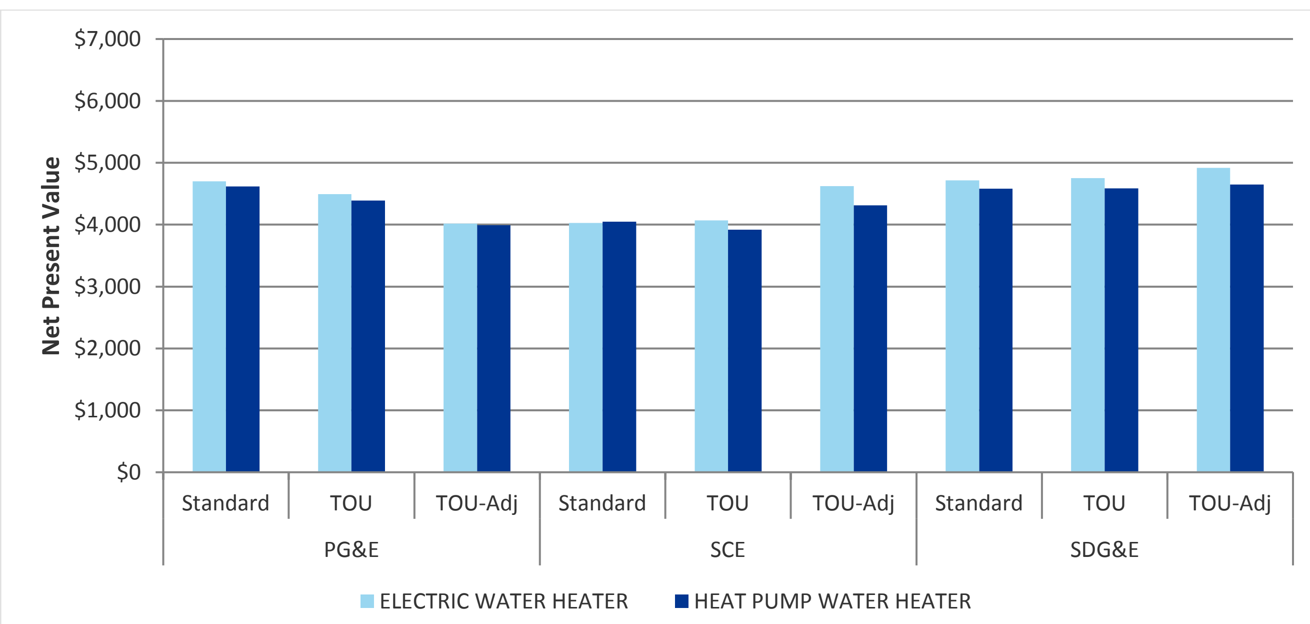

Figure 4-8: Comparison of Standard, TOU and TOU-Adj rate plans for Multi-Family Customers

4.5 First Cost Implications on Low Income Program

DNV GL also modeled scenarios where low-income customers would not be responsible for any first costs when replacing their water heater with a more efficient gas or electric model. First costs include the price of a water heater, installation and CAS testing costs, when appropriate. DNV GL performed this analysis with the assumption that first costs are theoretically covered for the customer through an IOU or another entity's program. The figures below highlight the effects on NPV after removing first costs for low income customers and where only operational and GHG costs are considered. Compared to figures in Section 4.2, there is a large decrease in NPV over the course of 10 years for all water heating technologies. The most notable reductions occur with gas instantaneous water heaters as the NPV declines by an average of 69%, followed by standard gas water heaters that declined an average 55% across all utilities. Overall, the NPV declined across all utilities by 42% for heat pump and 28% for electric water heaters.

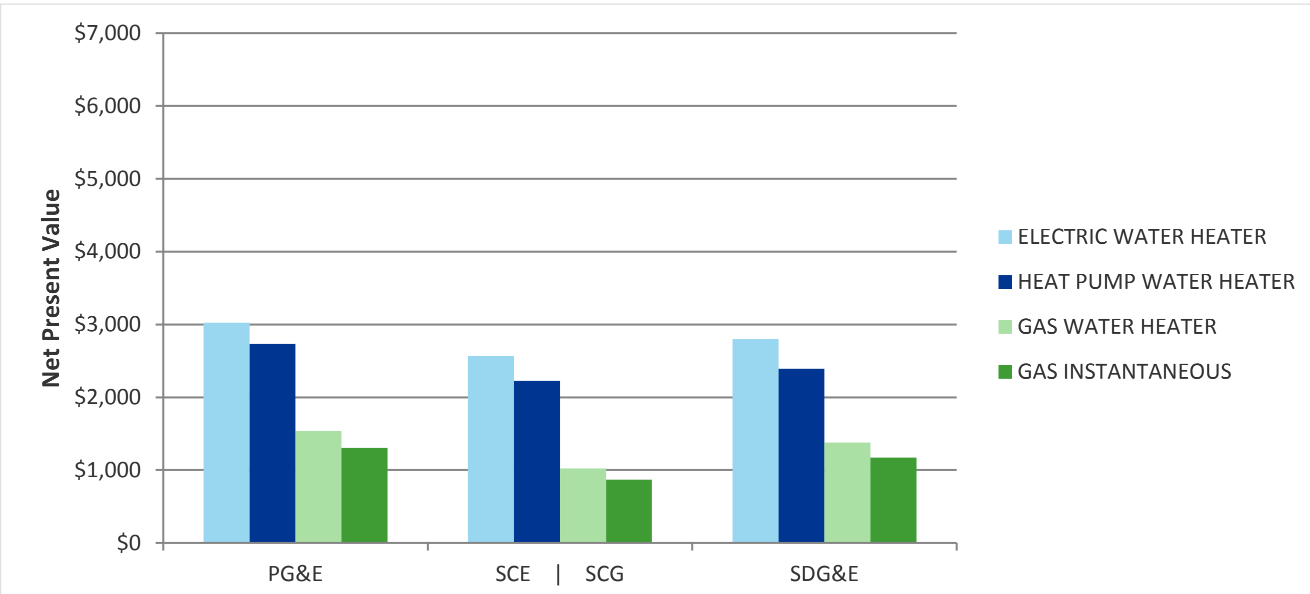

Figure 4-9: Low Income Rate Net Present Values of Water Heating Technologies for Single Family Customers - $0 First Costs

Figure 4-9 also highlights the differences in operational and GHG costs between electric and gas water heaters. Average operational costs for customers with an electric water heater are approximately $340 per year compared to $150 per year for gas water heaters. SCE and SCG had the lowest operational costs related to electric and gas water heater compared to both PG&E and SDG&E. Similarly, multi-family customers experienced the same type of reductions as described for single-family customers. The major difference is that the operational costs for multi-family customers are lower due to lower baseline energy use compared to single family customers.

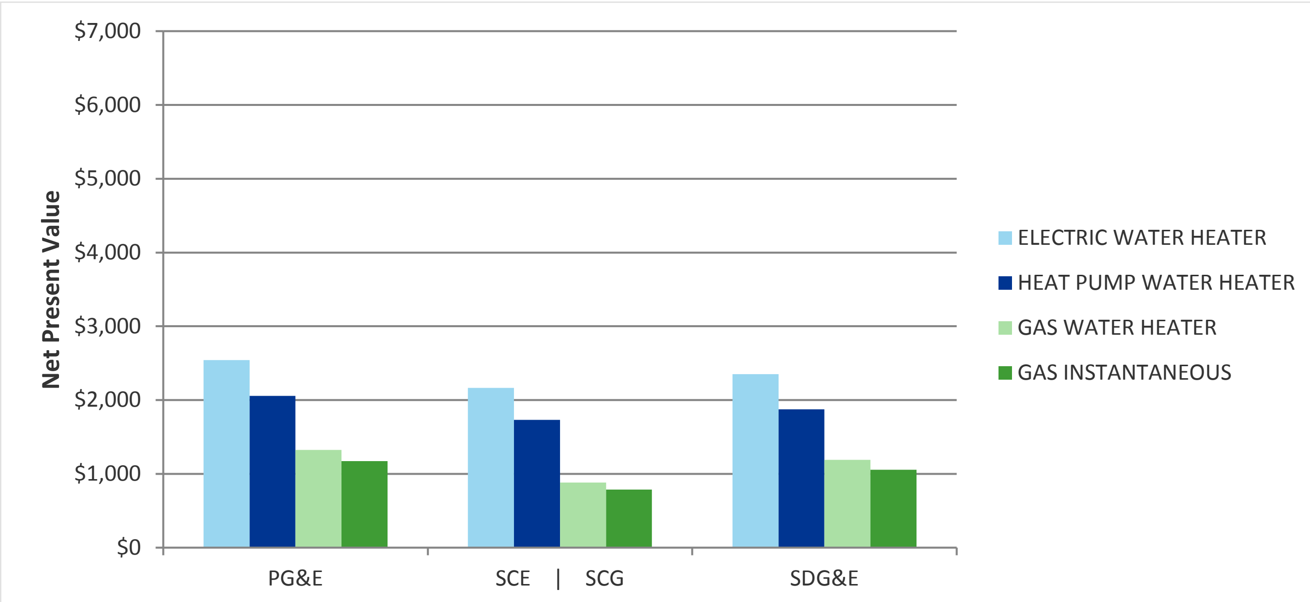

Figure 4-10: Low Income Rate Net Present Values of Water Heating Technologies for Multi-Family Customers - $0 First Costs

As noted in Section 4.2, the most cost-effective water heater for low income customers using the standard low income scenarios across all utilities was the efficient gas storage unit. This was followed by gas instantaneous, electric storage and heat pump water heaters. With the removal of first costs, outcomes shifted considerably as water heaters not only reduced the NPVs but the most cost-effective water heater technologies also changed. For instance, gas instantaneous units became the most cost-effective choice across all water heater technologies. Additionally, heat pump water heaters were more economical than electric water heaters for both single family and multi-family customers when first costs are removed.

4.6 Implications of CAS testing

Combustion appliance safety (CAS) testing or combustion appliance zone (CAZ) testing is required by the National Fuel Gas Code (NFGC) 54 for natural draft appliances.[45] This testing procedure requires both a preliminary (test-in) and post (test-out) installation safety inspection of all combustion appliances whenever changes to the building envelope or combustion appliances are made. The test includes carbon monoxide measurements, draft and spillage measurements for appliances vented at atmosphere, worst-case negative pressure measurements, and gas supply safety tests. The combustion safety test is a series of pass/fail results. For a unit to test in and out successfully, it must pass each of the tests. If a failure is recorded at any point in the process, the system must be serviced, the problem corrected, and tested again.

The Multifamily Market Whole Building Approach pilot evaluation identified CAS testing as a considerable pain point for multi-family building owners resulting in a barrier to energy efficiency adoption.[46] The building owners felt that the testing was onerous for properties with in-unit combustion appliances (too many on-site

[45] NFPA, 2016.

[46] Opinion Dynamics, 2014.

visits and disruption for tenants) and any retrofit that requires this type of testing is risky as the costs associated with remediation is an unknown and unbounded in expense.

DNV GL interviewed 10 contractors with CAS testing experience and found that in general, only a small proportion of housing units tested fail, and any necessary remediation is relatively small in cost. Estimates given for the rate of failure ranged from 1%-14%, with most estimates in the 1-5% range. One CAS tester noted that failures were more common in older buildings. Some common failure points were bathroom exhaust fans, and leaking ducts. In many cases, however, a repair can be made quickly and at little to no cost. Other times, more extensive work is required such as equipment or ventilation system repair or replacement.

For the purposes of this study DNV GL compared two scenarios drawing from the anecdotal information from the interviews. The scenarios include: high replacement CAS remediation and no CAS remediation. The high CAS remediation scenario assumed a cost of $2,000 per heater and the no CAS remediation scenario assumed zero additional costs per heater. Figure 4-11 shows the NPV results using the two scenarios including electric, heat pump and gas instantaneous water heaters for reference using standard rates.

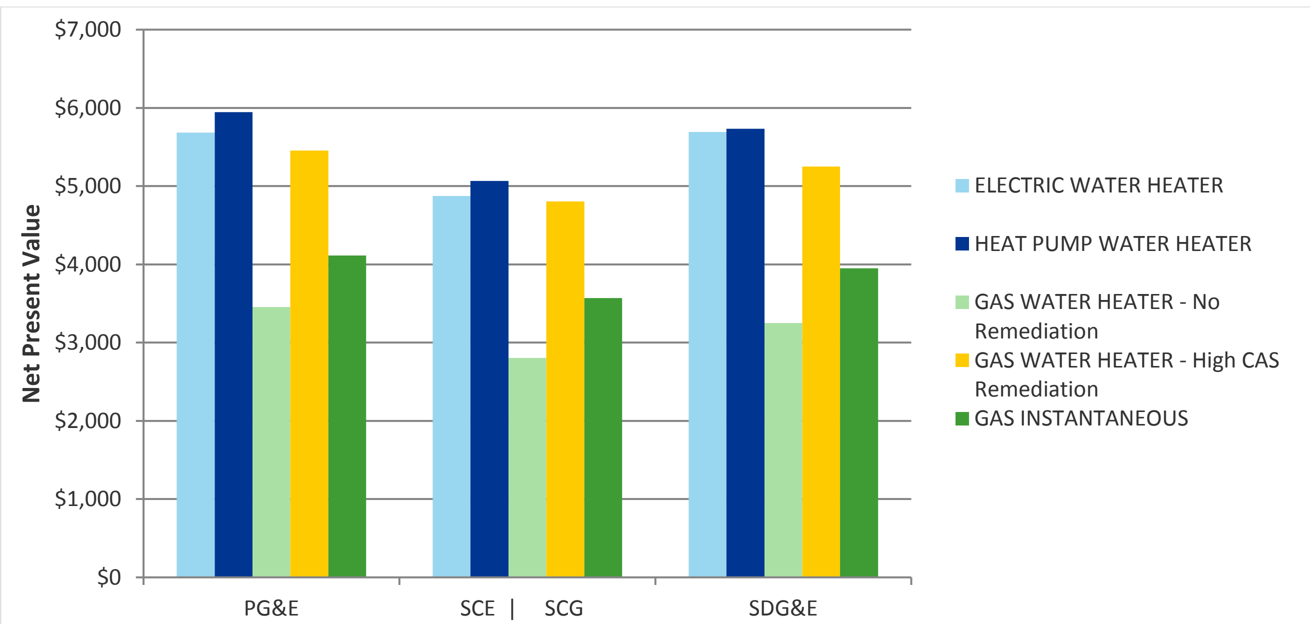

Figure 4-11: CAS High and No Remediation Scenarios (Single Family, Standard Rates)

As Figure 4-11 shows, even assuming high CAS mitigation costs, the total cost of ownership of a gas water heater is similar to or even less than electric or heat pump water heaters, assuming Tier 1 standard electric rates. The scenario with no CAS mitigation had similar NPV compared to a standard gas water heater and was the most cost-effective scenario across all IOUs.

4.7 Energy Storage and Real time pricing

In California, the frequency of negative real time pricing (indicating over-generation) increased in 2015. Negative real time pricing tends to occur in about 2% of 15 minute intervals, much of it due to the dramatic increase of solar production during the middle parts of the day.[47] Electric water heaters are perhaps the most flexible residential load on the grid. Large-scale adoption of grid-interactive electric water heaters presents an opportunity to provide ancillary services, i.e. smoothing of intermittent renewable loads, and support to frequency stability. Water heaters can absorb excess electricity whenever excess exists, in the middle of the day or night, and can store hot water to reduce the load at peak times.

To address the potential outcome of water heater storage with real time pricing, DNV GL considered a second grid-interactive water heating scenario. This case is done through back-of-the envelope calculations where DNV GL assumed the following:

1. 50-gallon water heater
2. 4 kW rating
3. Average use per day is 12 kWh (3 hours of operation)
4. Rate equal to the three lowest available real time pricing hours

SCE has a real-time pricing program designed for businesses with flexible loads that can shift or reduce electrical usage; businesses can take advantage of hourly rate changes to reduce their bills. SCE's pricing is based on time of day, season and temperature. There are nine total rates: five in summer, two in the winter, and two different pricing schedules for weekends that are unrelated to the season. While this plan is only available to commercial customers, a utility could develop a similar rate program for residential customers with grid-interactive devices.

While this rate is not currently available for residential customers nor does it give utilities control of load, DNV GL used this as a proxy rate for the scenario. The hourly rates for each season and temperature are given in Table 4-2. DNV GL assumed the hours of operation for a grid-interactive water heater to coincide with the three cheapest hours per day. Table 4-2 shows how the estimated cost of operating the gird interactive water heater was calculated.

[47] CAISO, 2016.

Table 4-2: SCE Real Time Pricing

Hour	Temperature / Season								
	Summer Weekday					Winter Weekday		Weekend	
	>=95	91-94	85-90	81-84	<=80	>90	<=90	>=78	<78
Estimated number of days (based on 2016 temperature data)	5	4	19	5	55	4	171	46	57
Average rate ($/kWh)	$0.03	$0.03	$0.02	$0.02	$0.02	$0.04	$0.03	$0.03	$0.03
Total cost by day type	$1.95	$1.26	$5.17	$1.26	$14.16	$2.14	$66.79	$16.63	$18.18
Total Annual Operating Cost									$127.54

Figure 4-12 depicts the load shape that results from a grid-interactive water heater that is set to run for three hours per day. The hours were determined to be the most advantageous for the electric system based on the price set by the real-time pricing rate schedule.

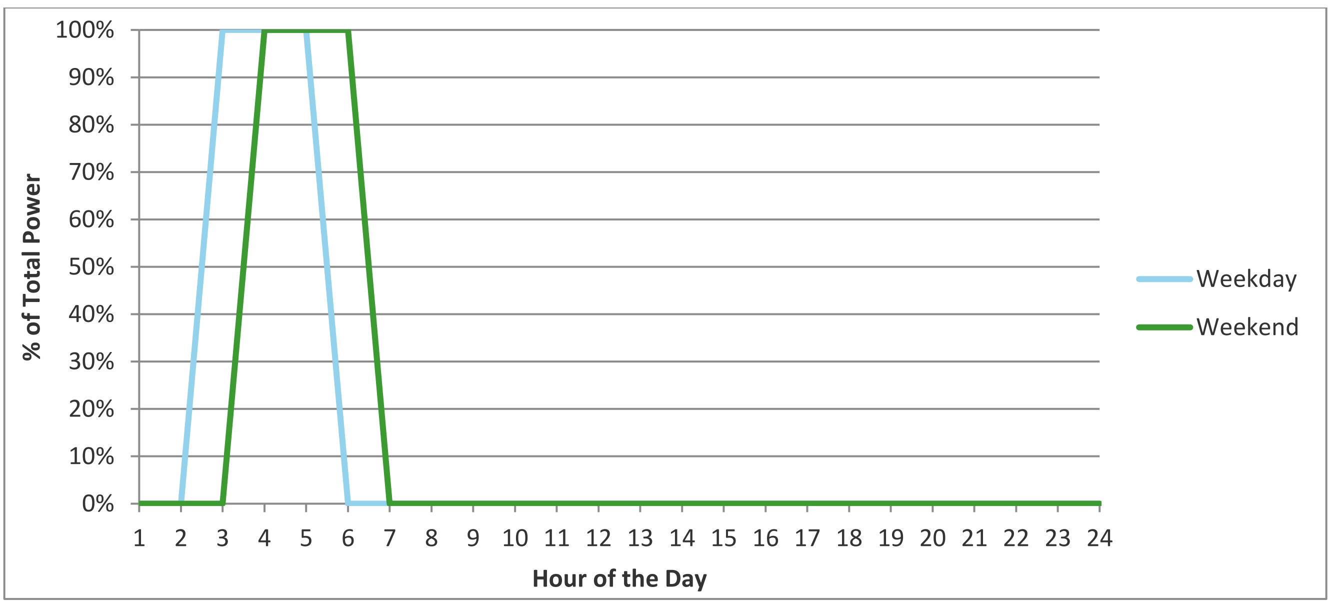

Figure 4-12: Load shape assumed for grid-interactive water heaters

It is important to note a few things:

- The load shape can and will shift with seasonal variations in renewable loads and as the load and supply mix evolves. The actual shape does not affect the analysis as efficient water heaters can store hot water for more than 24 hours with minimal temperature degradation.
- For this exercise, the overall energy use is higher than the assumed energy use in the rest of this analysis. This is to reflect some inefficiencies that could be introduced to the system due to the

potential to increase the temperature of the water after it has met the set point (leading to higher losses), and potential additional losses due to uncontrolled scheduling.[48]

- This analysis assumes 12 kWh use per day while the average baseline for PG&E is 9 kWh per day. For the purposes of the back of the envelope estimate, DNV GL assumed the same annual electric use for all utilities. DNV GL does not believe the additional system inefficiencies will result in usage that is this high, but is using this case to be conservative in the estimate.

Figure 4-13 shows the NPV for standard electric rates for three grid-interactive water heater scenarios in addition to the electric and gas water heaters. Non-grid-interactive scenarios display values under standard electric and gas rates. The three grid-interactive scenarios are:

1. A fast response grid-interactive water heater that can provide ancillary benefits to the grid. Per the Brattle group study, these benefits are assumed to be approximately $182 annually. Standard TOU rates apply (Section 4.3).
2. A grid-interactive water heater on real time pricing. In this scenario, it is assumed that the utility "pays" for the ancillary benefits that the water heater provides with real time pricing. There is no additional payment for providing this benefit.
3. A grid-interactive water heater that is enrolled in real time pricing and receives payment for providing ancillary services.

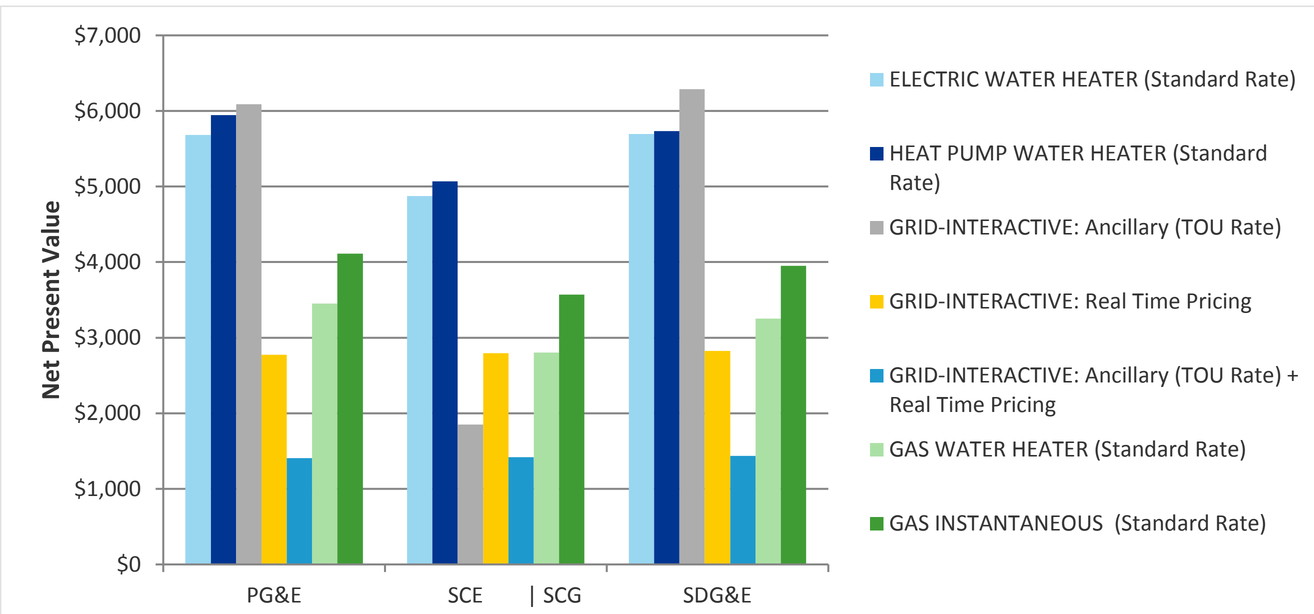

Figure 4-13: Real Time pricing and ancillary services for grid-interactive water heaters

As shown in Figure 4-13, grid-interactive water heaters that are not on the standard TOU rate are less expensive to operate over their lifetime than other electric water heaters. The exception occurs with SCE,

48 Uncontrolled scheduling: For example, a water heater that is typically scheduled to heat in the early morning hours for use between 6 AM to 10 AM may be rescheduled to heat in the afternoon when there is excess solar generation on the grid. This scheduling change could lead to a longer time difference between when the water is heated to when it is consumed and possibly requiring additional energy from the water heater to meet demand.

where the appropriate TOU rate was considerably lower than PG&E and SDG&E as described in Section 4.3 earlier. Access to real time pricing reduces cost as shown in the yellow bars, dropping the lifetime cost below the cost of gas water heaters. Furthermore, combining the grid-interactive water heater's ancillary services with real time pricing results in the lowest costs among the technologies described in the figure.

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Gas water heaters remain the most economical choice for utility customers

Standard storage gas water heaters continued to be the most cost-effective option for both single family and multi-family customers across all utilities and rate plans. This trend was primarily driven by relatively low operating or gas utility costs. Instantaneous gas water heaters were the second most cost-effective option for both customer types across utilities. While instantaneous gas water heaters had the highest first costs of all water heater technologies, their operating costs were the lowest due to efficient use paired with low gas prices.

There were a couple of exceptions to these findings. Instantaneous gas water heater was the most cost-effective water heater technology in the scenario where low income customers did not have any first costs as described in Section 4.5. The average reduction in NPV for these water heaters without first costs was approximately 70% in all utilities. Similarly, standard gas water heaters had about a 50% reduction in NPV when first costs were eliminated for low income customers. The only other scenario where gas water heaters were not the most cost-effective was when they were compared to grid-interactive water heaters on SCE's TOU rate.

5.2 TOU pricing makes heat pump water heaters more economical

Heat pump water heaters are more economical when subjected to TOU rates compared to standard rates. This was true for two of the three IOUs as NPV for single family customers dropped by 5% and 3% for PG&E and SCE, respectively. No changes were observed in heat pump water heater NPV between SDG&E's standard rate and TOU rate plans. The effect of TOU rates differed among multi-family customers as heat pump water heaters were more cost-effective than standard electric water heaters for all IOUs.

While heat pump water heaters appear attractive in multi-family households, there are a few limitations that make them less practical in such settings. Heat pump water heaters are typically sized larger than standard gas or electric storage water heaters to meet the same demand. This indicates they may not physically fit in most multi-family water heater closets. Heat pump water heaters also rely on a heat exchanger that sits on top of the unit adding a greater vertical footprint. They require ample air flow to be most efficient that may not be suitable in multi-family closets where water heaters are typically installed.

Lastly, it should be noted that since heat pump water heaters are on for more hours during the day, they may become more uneconomical if TOU rates vary widely throughout the day. More examination into the trends of future TOU rates is needed to evaluate their impacts on heat pump water heaters.

5.3 Collect better data on CAS testing and remediation and Measure Costs

DNV GL interviewed a small sample of contractors who performed CAS testing and remediation for CAS failures. We found that there was little consensus among contractors around what common failures and remediation implications were. A variety of common failures were provided ranging from improper installation of water heaters and air conditioning to ducting malfunctions. Costs related to remediation also varied greatly and ranged from free (exhaust fan control adjustment) to more expensive equipment repair at $500-$2,000 in rare cases. There is not enough evidence from the interviews and our attempts to collect data on the cost of remediation to indicate that it is a significant barrier to adoption. More targeted research that includes contractors and property owners is needed to assess this as a potential barrier and to identify ways to overcome it.

Additionally, measure costs including the cost of equipment and installation or labor costs should be collected in a uniform manner. Measure costs served as an important factor in our analysis which had significant implications on a water heater's cost-effectiveness over its useful life. Relying on outdated sources such as DEER work papers and highly variable utility application data made it difficult to accurately reflect measure costs. DNV GL recommends uniformity in collecting data as part of any Californian rate payer rebate program and updated to a central database frequently.

5.4 Grid-interactive water heaters are an opportunity for lower costs and program innovation

With the growing concern with negative pricing due to the increased presence of solar, CA utilities (at the direction of the CPUC) are actively looking for storage solutions. In Sept 2016, AB 2868 directed the IOUs to acquire distributed energy storage capacity and explore investing in an additional 500 MW of energy storage.

DNV GL's back-of-the-envelope methodology found that grid-interactive electric water heaters have the potential to be a cost-effective resource to providing flexible load and value to the California energy mix. However, this study only considered the costs and benefits of a single participant in a few theoretical scenarios. If the 6.5%[49] of households that currently have electric water heaters (estimated to be 800,000 households)[50] were converted to grid-interactive water heaters, it could represent a flexible load of over 9,500 MWh. Going forward, DNV GL recommends a more detailed exploration of potential impacts and techniques for optimizing water heater management and "dispatch" on a utility, grid, and local level.

[49] DNV GL, 2014.
[50] US Census Bureau, 2012.

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APPENDIX A: NET PRESENT VALUE RESULTS BY UTILITY

A.1 PG&E

A.1.1 Single Family PG&E

Single Family – STANDARD RATE												
		Today	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**	**Year 9**	**Year 10**
ELECTRIC WATER HEATER												
First Cost		$ 1,100										
Operating Cost	$ 600		$ 600	$ 618	$ 637	$ 656	$ 676	$ 696	$ 717	$ 738	$ 761	$ 783
Other Outflows	$ 8		$ 8	$ 9	$ 9	$ 9	$ 10	$ 10	$ 10	$ 10	$ 11	$ 11
Inflows												
Subtotal		$ 1,100	$ 609	$ 627	$ 646	$ 665	$ 685	$ 706	$ 727	$ 749	$ 771	$ 794
PV		$ 1,100	$ 563	$ 537	$ 512	$ 488	$ 465	$ 443	$ 423	$ 403	$ 384	$ 366
NPV	**$ 5,684**											
HEAT PUMP WATER HEATER												
First Cost		$ 1,800										
Operating Cost	$ 543		$ 543	$ 559	$ 576	$ 593	$ 611	$ 630	$ 648	$ 668	$ 688	$ 709
Other Outflows	$ 8		$ 8	$ 8	$ 8	$ 8	$ 9	$ 9	$ 9	$ 9	$ 10	$ 10
Inflows												
Subtotal		$ 1,800	$ 551	$ 567	$ 584	$ 602	$ 620	$ 638	$ 658	$ 677	$ 698	$ 719
PV		$ 1,800	$ 510	$ 486	$ 463	$ 441	$ 421	$ 401	$ 382	$ 364	$ 347	$ 331
NPV	**$ 5,946**											
GAS WATER HEATER												
First Cost		$ 1,550										
Operating Cost	$ 240		$ 240	$ 248	$ 255	$ 263	$ 271	$ 279	$ 287	$ 296	$ 305	$ 314
Other Outflows	$ 12		$ 12	$ 13	$ 13	$ 14	$ 14	$ 14	$ 15	$ 15	$ 16	$ 16
Inflows												
Subtotal		$ 1,550	$ 253	$ 260	$ 268	$ 276	$ 285	$ 293	$ 302	$ 311	$ 320	$ 330
PV		$ 1,550	$ 234	$ 223	$ 213	$ 203	$ 193	$ 184	$ 175	$ 167	$ 159	$ 152
NPV	**$ 3,453**											
GAS INSTANTANEOUS												
First Cost		$ 2,500										
Operating Cost	$ 204		$ 204	$ 210	$ 216	$ 223	$ 229	$ 236	$ 243	$ 251	$ 258	$ 266
Other Outflows	$ 10		$ 10	$ 11	$ 11	$ 11	$ 12	$ 12	$ 13	$ 13	$ 13	$ 14
Inflows												
Subtotal		$ 2,500	$ 214	$ 221	$ 227	$ 234	$ 241	$ 248	$ 256	$ 263	$ 271	$ 279
PV		$ 2,500	$ 198	$ 189	$ 180	$ 172	$ 164	$ 156	$ 149	$ 142	$ 135	$ 129
NPV	**$ 4,113**											

Single Family – LOW INCOME RATE												
		Today	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**	**Year 9**	**Year 10**
ELECTRIC WATER HEATER												
First Cost		$ 1,100										
Operating Cost	$ 393		$ 393	$ 405	$ 417	$ 430	$ 443	$ 456	$ 470	$ 484	$ 498	$ 513
Other Outflows	$ 8		$ 8	$ 9	$ 9	$ 9	$ 10	$ 10	$ 10	$ 10	$ 11	$ 11
Inflows												
Subtotal		$ 1,100	$ 402	$ 414	$ 426	$ 439	$ 452	$ 466	$ 480	$ 494	$ 509	$ 524
PV		$ 1,100	$ 372	$ 355	$ 338	$ 322	$ 307	$ 293	$ 279	$ 266	$ 253	$ 242
NPV	**$ 4,126**											
HEAT PUMP WATER HEATER												
First Cost		$ 1,800										
Operating Cost	$ 356		$ 356	$ 367	$ 377	$ 389	$ 400	$ 413	$ 425	$ 438	$ 451	$ 464
Other Outflows	$ 8		$ 8	$ 8	$ 8	$ 8	$ 9	$ 9	$ 9	$ 9	$ 10	$ 10
Inflows												
Subtotal		$ 1,800	$ 363	$ 374	$ 386	$ 397	$ 409	$ 421	$ 434	$ 447	$ 460	$ 474
PV		$ 1,800	$ 336	$ 321	$ 306	$ 291	$ 278	$ 265	$ 252	$ 240	$ 229	$ 218
NPV	**$ 4,537**											
GAS WATER HEATER												
First Cost		$ 1,550										
Operating Cost	$ 192		$ 192	$ 198	$ 204	$ 210	$ 216	$ 223	$ 229	$ 236	$ 243	$ 250
Other Outflows	$ 12		$ 12	$ 13	$ 13	$ 14	$ 14	$ 14	$ 15	$ 15	$ 16	$ 16
Inflows												
Subtotal		$ 1,550	$ 204	$ 210	$ 217	$ 223	$ 230	$ 237	$ 244	$ 251	$ 259	$ 267
PV		$ 1,550	$ 189	$ 180	$ 172	$ 164	$ 156	$ 149	$ 142	$ 135	$ 129	$ 123
NPV	**$ 3,089**											
GAS INSTANTANEOUS												
First Cost		$ 2,500										
Operating Cost	$ 163		$ 163	$ 168	$ 173	$ 178	$ 183	$ 189	$ 194	$ 200	$ 206	$ 212
Other Outflows	$ 10		$ 10	$ 11	$ 11	$ 11	$ 12	$ 12	$ 13	$ 13	$ 13	$ 14
Inflows												
Subtotal		$ 2,500	$ 173	$ 178	$ 184	$ 189	$ 195	$ 201	$ 207	$ 213	$ 219	$ 226
PV		$ 2,500	$ 160	$ 153	$ 146	$ 139	$ 132	$ 126	$ 120	$ 115	$ 109	$ 104
NPV	**$ 3,804**											

Single Family – TOU RATE												
		Today	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
ELECTRIC WATER HEATER												
First Cost		$ 1,100										
Operating Cost	$ 568		$ 568	$ 585	$ 602	$ 620	$ 639	$ 658	$ 678	$ 698	$ 719	$ 741
Other Outflows	$ 8		$ 8	$ 9	$ 9	$ 9	$ 10	$ 10	$ 10	$ 10	$ 11	$ 11
Inflows												
Subtotal		$ 1,100	$ 576	$ 593	$ 611	$ 630	$ 649	$ 668	$ 688	$ 709	$ 730	$ 752
PV		$ 1,100	$ 533	$ 508	$ 484	$ 462	$ 440	$ 420	$ 400	$ 381	$ 363	$ 346
NPV	**$ 5,438**											
HEAT PUMP WATER HEATER												
First Cost		$ 1,800										
Operating Cost	$ 503		$ 503	$ 518	$ 533	$ 549	$ 566	$ 583	$ 600	$ 618	$ 637	$ 656
Other Outflows	$ 8		$ 8	$ 8	$ 8	$ 8	$ 9	$ 9	$ 9	$ 9	$ 10	$ 10
Inflows												
Subtotal		$ 1,800	$ 511	$ 526	$ 542	$ 558	$ 575	$ 592	$ 610	$ 628	$ 647	$ 666
PV		$ 1,800	$ 472	$ 450	$ 429	$ 409	$ 390	$ 372	$ 354	$ 338	$ 322	$ 307
NPV	**$ 5,644**											
GRID-INTERACTIVE WATER HEATER												
First Cost		$ 1,730										
Operating Cost	$ 750		$ 750	$ 772	$ 795	$ 819	$ 844	$ 869	$ 895	$ 922	$ 950	$ 978
Other Outflows	$ 11		$ 11	$ 12	$ 12	$ 12	$ 13	$ 13	$ 13	$ 14	$ 14	$ 15
Inflows	$ (182)		$ (182)	$ (187)	$ (193)	$ (199)	$ (205)	$ (211)	$ (217)	$ (224)	$ (230)	$ (237)
Subtotal		$ 1,730	$ 579	$ 596	$ 614	$ 633	$ 652	$ 671	$ 691	$ 712	$ 734	$ 756
PV		$ 1,730	$ 536	$ 511	$ 487	$ 464	$ 442	$ 422	$ 402	$ 383	$ 365	$ 348
NPV	**$ 6,090**											

A.1.2 Multi-Family PG&E

Multi-Family – STANDARD RATE												
		Today	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**	**Year 9**	**Year 10**
ELECTRIC WATER HEATER												
First Cost		$ 850										
Operating Cost	$ 504		$ 504	$ 520	$ 535	$ 551	$ 568	$ 585	$ 602	$ 620	$ 639	$ 658
Other Outflows	$ 7		$ 7	$ 7	$ 8	$ 8	$ 8	$ 8	$ 9	$ 9	$ 9	$ 9
Inflows												
Subtotal		$ 850	$ 512	$ 527	$ 543	$ 559	$ 576	$ 593	$ 611	$ 629	$ 648	$ 667
PV		$ 850	$ 473	$ 451	$ 430	$ 410	$ 391	$ 372	$ 355	$ 338	$ 323	$ 307
NPV	**$ 4,701**											
HEAT PUMP WATER HEATER												
First Cost		$ 1,500										
Operating Cost	$ 408		$ 408	$ 421	$ 433	$ 446	$ 460	$ 473	$ 488	$ 502	$ 517	$ 533
Other Outflows	$ 6		$ 6	$ 6	$ 6	$ 6	$ 6	$ 7	$ 7	$ 7	$ 7	$ 8
Inflows												
Subtotal		$ 1,500	$ 414	$ 427	$ 439	$ 452	$ 466	$ 480	$ 494	$ 509	$ 525	$ 540
PV		$ 1,500	$ 383	$ 365	$ 348	$ 332	$ 316	$ 301	$ 287	$ 274	$ 261	$ 249
NPV	**$ 4,618**											
GAS WATER HEATER												
First Cost		$ 1,250										
Operating Cost	$ 207		$ 207	$ 213	$ 219	$ 226	$ 233	$ 240	$ 247	$ 254	$ 262	$ 270
Other Outflows	$ 11		$ 11	$ 11	$ 11	$ 12	$ 12	$ 12	$ 13	$ 13	$ 13	$ 14
Inflows												
Subtotal		$ 1,250	$ 217	$ 224	$ 231	$ 237	$ 245	$ 252	$ 260	$ 267	$ 275	$ 284
PV		$ 1,250	$ 201	$ 192	$ 183	$ 174	$ 166	$ 158	$ 151	$ 144	$ 137	$ 131
NPV	**$ 2,886**											
GAS INSTANTANEOUS												
First Cost		$ 2,000										
Operating Cost	$ 183		$ 183	$ 189	$ 194	$ 200	$ 206	$ 212	$ 219	$ 225	$ 232	$ 239
Other Outflows	$ 9		$ 9	$ 10	$ 10	$ 10	$ 11	$ 11	$ 11	$ 12	$ 12	$ 12
Inflows												
Subtotal		$ 2,000	$ 193	$ 199	$ 204	$ 211	$ 217	$ 223	$ 230	$ 237	$ 244	$ 251
PV		$ 2,000	$ 178	$ 170	$ 162	$ 154	$ 147	$ 140	$ 134	$ 127	$ 122	$ 116
NPV	**$ 3,451**											

Multi-Family – LOW INCOME RATE												
		Today	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
ELECTRIC WATER HEATER												
First Cost		$ 850										
Operating Cost	$ 331		$ 331	$ 340	$ 351	$ 361	$ 372	$ 383	$ 395	$ 407	$ 419	$ 431
Other Outflows	$ 7		$ 7	$ 7	$ 8	$ 8	$ 8	$ 8	$ 9	$ 9	$ 9	$ 9
Inflows												
Subtotal		$ 850	$ 338	$ 348	$ 358	$ 369	$ 380	$ 391	$ 403	$ 415	$ 428	$ 441
PV		$ 850	$ 312	$ 298	$ 284	$ 271	$ 258	$ 246	$ 234	$ 223	$ 213	$ 203
NPV	**$ 3,392**											
HEAT PUMP WATER HEATER												
First Cost		$ 1,500										
Operating Cost	$ 268		$ 268	$ 276	$ 284	$ 292	$ 301	$ 310	$ 319	$ 329	$ 339	$ 349
Other Outflows	$ 6		$ 6	$ 6	$ 6	$ 6	$ 6	$ 7	$ 7	$ 7	$ 7	$ 8
Inflows												
Subtotal		$ 1,500	$ 273	$ 282	$ 290	$ 299	$ 308	$ 317	$ 326	$ 336	$ 346	$ 357
PV		$ 1,500	$ 253	$ 241	$ 230	$ 219	$ 209	$ 199	$ 190	$ 181	$ 172	$ 164
NPV	**$ 3,558**											
GAS WATER HEATER												
First Cost		$ 1,250										
Operating Cost	$ 165		$ 165	$ 170	$ 175	$ 180	$ 186	$ 191	$ 197	$ 203	$ 209	$ 215
Other Outflows	$ 11		$ 11	$ 11	$ 11	$ 12	$ 12	$ 12	$ 13	$ 13	$ 13	$ 14
Inflows												
Subtotal		$ 1,250	$ 176	$ 181	$ 186	$ 192	$ 198	$ 204	$ 210	$ 216	$ 223	$ 229
PV		$ 1,250	$ 163	$ 155	$ 148	$ 141	$ 134	$ 128	$ 122	$ 116	$ 111	$ 106
NPV	**$ 2,573**											
GAS INSTANTANEOUS												
First Cost		$ 2,000										
Operating Cost	$ 146		$ 146	$ 151	$ 155	$ 160	$ 165	$ 170	$ 175	$ 180	$ 185	$ 191
Other Outflows	$ 9		$ 9	$ 10	$ 10	$ 10	$ 11	$ 11	$ 11	$ 12	$ 12	$ 12
Inflows												
Subtotal		$ 2,000	$ 156	$ 160	$ 165	$ 170	$ 175	$ 181	$ 186	$ 192	$ 197	$ 203
PV		$ 2,000	$ 144	$ 137	$ 131	$ 125	$ 119	$ 113	$ 108	$ 103	$ 98	$ 94
NPV	**$ 3,173**											

Multi-Family – TOU RATE												
		Today	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**	**Year 9**	**Year 10**
ELECTRIC WATER HEATER												
First Cost		$ 850										
Operating Cost	$ 477		$ 477	$ 491	$ 506	$ 521	$ 537	$ 553	$ 570	$ 587	$ 604	$ 622
Other Outflows	$ 7		$ 7	$ 7	$ 8	$ 8	$ 8	$ 8	$ 9	$ 9	$ 9	$ 9
Inflows												
Subtotal		$ 850	$ 484	$ 499	$ 514	$ 529	$ 545	$ 561	$ 578	$ 595	$ 613	$ 632
PV		$ 850	$ 448	$ 427	$ 407	$ 388	$ 370	$ 352	$ 336	$ 320	$ 305	$ 291
NPV	**$ 4,495**											
HEAT PUMP WATER HEATER												
First Cost		$ 1,500										
Operating Cost	$ 378		$ 378	$ 389	$ 401	$ 413	$ 426	$ 438	$ 451	$ 465	$ 479	$ 493
Other Outflows	$ 6		$ 6	$ 6	$ 6	$ 6	$ 6	$ 7	$ 7	$ 7	$ 7	$ 8
Inflows												
Subtotal		$ 1,500	$ 384	$ 395	$ 407	$ 419	$ 432	$ 445	$ 458	$ 472	$ 486	$ 501
PV		$ 1,500	$ 355	$ 339	$ 323	$ 308	$ 293	$ 279	$ 266	$ 254	$ 242	$ 231
NPV	**$ 4,390**											
GRID-INTERACTIVE WATER HEATER												
First Cost		$ 1,730										
Operating Cost	$ 750		$ 750	$ 772	$ 795	$ 819	$ 844	$ 869	$ 895	$ 922	$ 950	$ 978
Other Outflows	$ 11		$ 11	$ 12	$ 12	$ 12	$ 13	$ 13	$ 13	$ 14	$ 14	$ 15
Inflows	$ (182)		$ (182)	$ (187)	$ (193)	$ (199)	$ (205)	$ (211)	$ (217)	$ (224)	$ (230)	$ (237)
Subtotal		$ 1,730	$ 579	$ 596	$ 614	$ 633	$ 652	$ 671	$ 691	$ 712	$ 734	$ 756
PV		$ 1,730	$ 536	$ 511	$ 487	$ 464	$ 442	$ 422	$ 402	$ 383	$ 365	$ 348
NPV	**$ 6,090**											

A.2 SCE and SCG

A.2.1 Single Family SCE and SCG

Single Family – STANDARD RATE												
		Today	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**	**Year 9**	**Year 10**
ELECTRIC WATER HEATER (SCE)												
First Cost		$ 1,100										
Operating Cost	$ 489		$ 489	$ 503	$ 518	$ 534	$ 550	$ 566	$ 583	$ 601	$ 619	$ 638
Other Outflows	$ 9		$ 9	$ 9	$ 9	$ 10	$ 10	$ 10	$ 11	$ 11	$ 11	$ 12
Inflows												
Subtotal		$ 1,100	$ 498	$ 513	$ 528	$ 544	$ 560	$ 577	$ 594	$ 612	$ 630	$ 649
PV		$ 1,100	$ 461	$ 440	$ 420	$ 401	$ 383	$ 366	$ 349	$ 333	$ 318	$ 304
NPV	**$ 4,875**											
HEAT PUMP WATER HEATER (SCE)												
First Cost		$ 1,800										
Operating Cost	$ 423		$ 423	$ 436	$ 449	$ 462	$ 476	$ 490	$ 505	$ 520	$ 536	$ 552
Other Outflows	$ 8		$ 8	$ 8	$ 8	$ 8	$ 9	$ 9	$ 9	$ 10	$ 10	$ 10
Inflows												
Subtotal		$ 1,800	$ 431	$ 444	$ 457	$ 471	$ 485	$ 499	$ 514	$ 530	$ 546	$ 562
PV		$ 1,800	$ 399	$ 381	$ 364	$ 347	$ 332	$ 316	$ 302	$ 288	$ 275	$ 263
NPV	**$ 5,068**											
GAS WATER HEATER (SCG)												
First Cost		$ 1,550										
Operating Cost	$ 154		$ 154	$ 159	$ 163	$ 168	$ 173	$ 179	$ 184	$ 189	$ 195	$ 201
Other Outflows	$ 11		$ 11	$ 12	$ 12	$ 12	$ 13	$ 13	$ 14	$ 14	$ 14	$ 15
Inflows												
Subtotal		$ 1,550	$ 165	$ 170	$ 176	$ 181	$ 186	$ 192	$ 198	$ 203	$ 210	$ 216
PV		$ 1,550	$ 153	$ 146	$ 140	$ 133	$ 127	$ 122	$ 116	$ 111	$ 106	$ 101
NPV	**$ 2,805**											
GAS INSTANTANEOUS (SCG)												
First Cost		$ 2,500										
Operating Cost	$ 131		$ 131	$ 135	$ 139	$ 144	$ 148	$ 152	$ 157	$ 162	$ 166	$ 171
Other Outflows	$ 10		$ 10	$ 10	$ 10	$ 11	$ 11	$ 11	$ 12	$ 12	$ 12	$ 13
Inflows												
Subtotal		$ 2,500	$ 141	$ 145	$ 150	$ 154	$ 159	$ 164	$ 169	$ 174	$ 179	$ 184
PV		$ 2,500	$ 131	$ 125	$ 119	$ 114	$ 109	$ 104	$ 99	$ 95	$ 90	$ 86
NPV	**$ 3,571**											

Single Family – LOW INCOME RATE												
		Today	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**	**Year 9**	**Year 10**
ELECTRIC WATER HEATER (SCE)												
First Cost		$ 1,100										
Operating Cost	$ 330		$ 330	$ 340	$ 350	$ 360	$ 371	$ 382	$ 394	$ 406	$ 418	$ 430
Other Outflows	$ 9		$ 9	$ 9	$ 9	$ 10	$ 10	$ 10	$ 11	$ 11	$ 11	$ 12
Inflows												
Subtotal		$ 1,100	$ 339	$ 349	$ 359	$ 370	$ 381	$ 393	$ 404	$ 417	$ 429	$ 442
PV		$ 1,100	$ 314	$ 300	$ 286	$ 273	$ 261	$ 249	$ 237	$ 227	$ 216	$ 207
NPV	**$ 3,669**											
HEAT PUMP WATER HEATER (SCE)												
First Cost		$ 1,800										
Operating Cost	$ 285		$ 285	$ 294	$ 303	$ 312	$ 321	$ 331	$ 341	$ 351	$ 362	$ 372
Other Outflows	$ 8		$ 8	$ 8	$ 8	$ 8	$ 9	$ 9	$ 9	$ 10	$ 10	$ 10
Inflows												
Subtotal		$ 1,800	$ 293	$ 302	$ 311	$ 320	$ 330	$ 340	$ 350	$ 361	$ 371	$ 383
PV		$ 1,800	$ 272	$ 259	$ 248	$ 236	$ 226	$ 215	$ 206	$ 196	$ 187	$ 179
NPV	**$ 4,024**											
GAS WATER HEATER (SCG)												
First Cost		$ 1,550										
Operating Cost	$ 123		$ 123	$ 127	$ 131	$ 135	$ 139	$ 143	$ 147	$ 152	$ 156	$ 161
Other Outflows	$ 11		$ 11	$ 12	$ 12	$ 12	$ 13	$ 13	$ 14	$ 14	$ 14	$ 15
Inflows												
Subtotal		$ 1,550	$ 135	$ 139	$ 143	$ 147	$ 152	$ 156	$ 161	$ 166	$ 171	$ 176
PV		$ 1,550	$ 125	$ 119	$ 114	$ 109	$ 104	$ 99	$ 94	$ 90	$ 86	$ 82
NPV	**$ 2,571**											
GAS INSTANTANEOUS (SCG)												
First Cost		$ 2,500										
Operating Cost	$ 105		$ 105	$ 108	$ 112	$ 115	$ 118	$ 122	$ 126	$ 129	$ 133	$ 137
Other Outflows	$ 10		$ 10	$ 10	$ 10	$ 11	$ 11	$ 11	$ 12	$ 12	$ 12	$ 13
Inflows												
Subtotal		$ 2,500	$ 115	$ 118	$ 122	$ 126	$ 129	$ 133	$ 137	$ 141	$ 146	$ 150
PV		$ 2,500	$ 106	$ 102	$ 97	$ 93	$ 88	$ 84	$ 81	$ 77	$ 73	$ 70
NPV	**$ 3,372**											

Single Family – TOU RATE												
		Today	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**	**Year 9**	**Year 10**
ELECTRIC WATER HEATER												
First Cost		$ 1,100										
Operating Cost	$ 495		$ 495	$ 510	$ 525	$ 541	$ 557	$ 574	$ 591	$ 609	$ 627	$ 646
Other Outflows	$ 9		$ 9	$ 9	$ 9	$ 10	$ 10	$ 10	$ 11	$ 11	$ 11	$ 12
Inflows												
Subtotal		$ 1,100	$ 504	$ 519	$ 535	$ 551	$ 567	$ 584	$ 602	$ 620	$ 639	$ 658
PV		$ 1,100	$ 467	$ 446	$ 426	$ 406	$ 388	$ 370	$ 354	$ 337	$ 322	$ 308
NPV	**$ 4,924**											
HEAT PUMP WATER HEATER												
First Cost		$ 1,800										
Operating Cost	$ 401		$ 401	$ 413	$ 426	$ 438	$ 452	$ 465	$ 479	$ 494	$ 508	$ 524
Other Outflows	$ 8		$ 8	$ 8	$ 8	$ 8	$ 9	$ 9	$ 9	$ 10	$ 10	$ 10
Inflows												
Subtotal		$ 1,800	$ 409	$ 421	$ 434	$ 447	$ 460	$ 474	$ 488	$ 503	$ 518	$ 534
PV		$ 1,800	$ 379	$ 362	$ 345	$ 330	$ 315	$ 300	$ 287	$ 274	$ 261	$ 250
NPV	**$ 4,903**											
GRID-INTERACTIVE WATER HEATER												
First Cost		$ 1,730										
Operating Cost	$ 185		$ 185	$ 190	$ 196	$ 202	$ 208	$ 214	$ 220	$ 227	$ 234	$ 241
Other Outflows	$ 13		$ 13	$ 13	$ 14	$ 14	$ 15	$ 15	$ 16	$ 16	$ 17	$ 17
Inflows	$ (182)		$ (182)	$ (187)	$ (193)	$ (199)	$ (205)	$ (211)	$ (217)	$ (224)	$ (230)	$ (237)
Subtotal		$ 1,730	$ 16	$ 16	$ 17	$ 17	$ 18	$ 18	$ 19	$ 19	$ 20	$ 21
PV		$ 1,730	$ 15	$ 14	$ 13	$ 13	$ 12	$ 12	$ 11	$ 11	$ 10	$ 10
NPV	**$ 1,850**											

A.2.2 Multi-Family SCE and SCG

Multi-Family – STANDARD RATE												
		Today	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**	**Year 9**	**Year 10**
ELECTRIC WATER HEATER (SCE)												
First Cost		$ 850										
Operating Cost	$ 411		$ 411	$ 424	$ 437	$ 450	$ 463	$ 477	$ 491	$ 506	$ 521	$ 537
Other Outflows	$ 8		$ 8	$ 8	$ 8	$ 8	$ 8	$ 9	$ 9	$ 9	$ 10	$ 10
Inflows												
Subtotal		$ 850	$ 419	$ 432	$ 445	$ 458	$ 472	$ 486	$ 500	$ 515	$ 531	$ 547
PV		$ 850	$ 388	$ 371	$ 354	$ 338	$ 322	$ 308	$ 294	$ 280	$ 268	$ 256
NPV	**$ 4,029**											
HEAT PUMP WATER HEATER (SCE)												
First Cost		$ 1,500										
Operating Cost	$ 330		$ 330	$ 340	$ 350	$ 360	$ 371	$ 382	$ 394	$ 406	$ 418	$ 430
Other Outflows	$ 6		$ 6	$ 6	$ 6	$ 7	$ 7	$ 7	$ 7	$ 7	$ 8	$ 8
Inflows												
Subtotal		$ 1,500	$ 336	$ 346	$ 356	$ 367	$ 378	$ 389	$ 401	$ 413	$ 425	$ 438
PV		$ 1,500	$ 311	$ 297	$ 284	$ 271	$ 258	$ 247	$ 235	$ 225	$ 215	$ 205
NPV	**$ 4,047**											
GAS WATER HEATER (SCG)												
First Cost		$ 1,250										
Operating Cost	$ 133		$ 133	$ 137	$ 141	$ 146	$ 150	$ 155	$ 159	$ 164	$ 169	$ 174
Other Outflows	$ 10		$ 10	$ 10	$ 11	$ 11	$ 11	$ 11	$ 12	$ 12	$ 13	$ 13
Inflows												
Subtotal		$ 1,250	$ 143	$ 148	$ 152	$ 156	$ 161	$ 166	$ 171	$ 176	$ 181	$ 187
PV		$ 1,250	$ 133	$ 127	$ 121	$ 115	$ 110	$ 105	$ 100	$ 96	$ 92	$ 87
NPV	**$ 2,336**											
GAS INSTANTANEOUS (SCG)												
First Cost		$ 2,000										
Operating Cost	$ 118		$ 118	$ 122	$ 126	$ 129	$ 133	$ 137	$ 141	$ 146	$ 150	$ 154
Other Outflows	$ 9		$ 9	$ 9	$ 9	$ 10	$ 10	$ 10	$ 10	$ 11	$ 11	$ 11
Inflows												
Subtotal		$ 2,000	$ 127	$ 131	$ 135	$ 139	$ 143	$ 147	$ 152	$ 156	$ 161	$ 166
PV		$ 2,000	$ 118	$ 113	$ 107	$ 103	$ 98	$ 93	$ 89	$ 85	$ 81	$ 78
NPV	**$ 2,965**											

Multi-Family – LOW INCOME RATE		Today	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
ELECTRIC WATER HEATER (SCE)												
First Cost		$ 850										
Operating Cost	$ 278		$ 278	$ 286	$ 295	$ 303	$ 312	$ 322	$ 332	$ 341	$ 352	$ 362
Other Outflows	$ 8		$ 8	$ 8	$ 8	$ 8	$ 8	$ 9	$ 9	$ 9	$ 10	$ 10
Inflows												
Subtotal		$ 850	$ 285	$ 294	$ 303	$ 312	$ 321	$ 331	$ 341	$ 351	$ 361	$ 372
PV		$ 850	$ 264	$ 252	$ 241	$ 230	$ 219	$ 209	$ 200	$ 191	$ 182	$ 174
NPV	**$ 3,013**											
HEAT PUMP WATER HEATER (SCE)												
First Cost		$ 1,500										
Operating Cost	$ 222		$ 222	$ 229	$ 236	$ 243	$ 250	$ 258	$ 266	$ 274	$ 282	$ 290
Other Outflows	$ 6		$ 6	$ 6	$ 6	$ 7	$ 7	$ 7	$ 7	$ 7	$ 8	$ 8
Inflows												
Subtotal		$ 1,500	$ 229	$ 235	$ 242	$ 250	$ 257	$ 265	$ 273	$ 281	$ 289	$ 298
PV		$ 1,500	$ 212	$ 202	$ 193	$ 184	$ 176	$ 168	$ 160	$ 153	$ 146	$ 139
NPV	**$ 3,234**											
GAS WATER HEATER (SCG)												
First Cost		$ 1,250										
Operating Cost	$ 107		$ 107	$ 110	$ 113	$ 117	$ 120	$ 124	$ 127	$ 131	$ 135	$ 139
Other Outflows	$ 10		$ 10	$ 10	$ 11	$ 11	$ 11	$ 11	$ 12	$ 12	$ 13	$ 13
Inflows												
Subtotal		$ 1,250	$ 117	$ 120	$ 124	$ 127	$ 131	$ 135	$ 139	$ 143	$ 148	$ 152
PV		$ 1,250	$ 108	$ 103	$ 98	$ 94	$ 90	$ 86	$ 82	$ 78	$ 74	$ 71
NPV	**$ 2,134**											
GAS INSTANTANEOUS (SCG)												
First Cost		$ 2,000										
Operating Cost	$ 95		$ 95	$ 98	$ 100	$ 103	$ 107	$ 110	$ 113	$ 116	$ 120	$ 124
Other Outflows	$ 9		$ 9	$ 9	$ 9	$ 10	$ 10	$ 10	$ 10	$ 11	$ 11	$ 11
Inflows												
Subtotal		$ 2,000	$ 103	$ 107	$ 110	$ 113	$ 116	$ 120	$ 124	$ 127	$ 131	$ 135
PV		$ 2,000	$ 96	$ 92	$ 87	$ 83	$ 80	$ 76	$ 73	$ 69	$ 66	$ 63
NPV	**$ 2,785**											

Multi-Family – TOU RATE												
		Today	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
ELECTRIC WATER HEATER												
First Cost		$ 850										
Operating Cost	$ 417		$ 417	$ 429	$ 442	$ 456	$ 469	$ 483	$ 498	$ 513	$ 528	$ 544
Other Outflows	$ 8		$ 8	$ 8	$ 8	$ 8	$ 8	$ 9	$ 9	$ 9	$ 10	$ 10
Inflows												
Subtotal		$ 850	$ 424	$ 437	$ 450	$ 464	$ 478	$ 492	$ 507	$ 522	$ 538	$ 554
PV		$ 850	$ 393	$ 376	$ 358	$ 342	$ 327	$ 312	$ 298	$ 284	$ 271	$ 259
NPV	**$ 4,070**											
HEAT PUMP WATER HEATER												
First Cost		$ 1,500										
Operating Cost	$ 313		$ 313	$ 322	$ 332	$ 342	$ 352	$ 363	$ 373	$ 385	$ 396	$ 408
Other Outflows	$ 6		$ 6	$ 6	$ 6	$ 7	$ 7	$ 7	$ 7	$ 7	$ 8	$ 8
Inflows												
Subtotal		$ 1,500	$ 319	$ 328	$ 338	$ 348	$ 359	$ 370	$ 381	$ 392	$ 404	$ 416
PV		$ 1,500	$ 295	$ 282	$ 269	$ 257	$ 245	$ 234	$ 224	$ 213	$ 204	$ 194
NPV	**$ 3,918**											
GRID-INTERACTIVE WATER HEATER												
First Cost		$ 1,730										
Operating Cost	$ 185		$ 185	$ 190	$ 196	$ 202	$ 208	$ 214	$ 220	$ 227	$ 234	$ 241
Other Outflows	$ 13		$ 13	$ 13	$ 14	$ 14	$ 15	$ 15	$ 16	$ 16	$ 17	$ 17
Inflows	$ (182)		$ (182)	$ (187)	$ (193)	$ (199)	$ (205)	$ (211)	$ (217)	$ (224)	$ (230)	$ (237)
Subtotal		$ 1,730	$ 16	$ 16	$ 17	$ 17	$ 18	$ 18	$ 19	$ 19	$ 20	$ 21
PV		$ 1,730	$ 15	$ 14	$ 13	$ 13	$ 12	$ 12	$ 11	$ 11	$ 10	$ 10
NPV	**$ 1,850**											

A.3 SDG&E

A.3.1 Single Family SDG&E

Single Family – STANDARD RATE		Today	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
ELECTRIC WATER HEATER												
First Cost		$ 1,100										
Operating Cost	$ 591		$ 591	$ 609	$ 627	$ 646	$ 666	$ 686	$ 706	$ 727	$ 749	$ 772
Other Outflows	$ 11		$ 11	$ 11	$ 12	$ 12	$ 12	$ 13	$ 13	$ 13	$ 14	$ 14
Inflows												
Subtotal		$ 1,100	$ 602	$ 620	$ 639	$ 658	$ 678	$ 698	$ 719	$ 741	$ 763	$ 786
PV		$ 1,100	$ 559	$ 534	$ 510	$ 488	$ 466	$ 445	$ 425	$ 407	$ 388	$ 371
NPV	**$ 5,694**											
HEAT PUMP WATER HEATER												
First Cost		$ 1,800										
Operating Cost	$ 506		$ 506	$ 521	$ 537	$ 553	$ 570	$ 587	$ 604	$ 622	$ 641	$ 660
Other Outflows	$ 9		$ 9	$ 10	$ 10	$ 10	$ 11	$ 11	$ 11	$ 12	$ 12	$ 12
Inflows												
Subtotal		$ 1,800	$ 516	$ 531	$ 547	$ 563	$ 580	$ 598	$ 616	$ 634	$ 653	$ 673
PV		$ 1,800	$ 478	$ 457	$ 437	$ 417	$ 399	$ 381	$ 364	$ 348	$ 332	$ 318
NPV	**$ 5,731**											
GAS WATER HEATER												
First Cost		$ 1,550										
Operating Cost	$ 212		$ 212	$ 218	$ 225	$ 231	$ 238	$ 245	$ 253	$ 260	$ 268	$ 276
Other Outflows	$ 11		$ 11	$ 12	$ 12	$ 13	$ 13	$ 13	$ 14	$ 14	$ 15	$ 15
Inflows												
Subtotal		$ 1,550	$ 223	$ 230	$ 237	$ 244	$ 251	$ 259	$ 266	$ 274	$ 283	$ 291
PV		$ 1,550	$ 207	$ 198	$ 189	$ 181	$ 173	$ 165	$ 158	$ 151	$ 144	$ 137
NPV	**$ 3,251**											
GAS INSTANTANEOUS												
First Cost		$ 2,500										
Operating Cost	$ 180		$ 180	$ 186	$ 191	$ 197	$ 203	$ 209	$ 215	$ 222	$ 228	$ 235
Other Outflows	$ 10		$ 10	$ 10	$ 10	$ 11	$ 11	$ 11	$ 12	$ 12	$ 12	$ 13
Inflows												
Subtotal		$ 2,500	$ 190	$ 196	$ 202	$ 208	$ 214	$ 220	$ 227	$ 234	$ 241	$ 248
PV		$ 2,500	$ 176	$ 169	$ 161	$ 154	$ 147	$ 140	$ 134	$ 128	$ 123	$ 117
NPV	**$ 3,950**											

Single Family – LOW INCOME RATE												
		Today	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**	**Year 9**	**Year 10**
ELECTRIC WATER HEATER												
First Cost		$1,100										
Operating Cost	$ 356		$ 356	$ 366	$ 377	$ 389	$ 400	$ 412	$ 425	$ 437	$ 450	$ 464
Other Outflows	$ 11		$ 11	$ 11	$ 12	$ 12	$ 12	$ 13	$ 13	$ 13	$ 14	$ 14
Inflows												
Subtotal		$1,100	$ 367	$ 378	$ 389	$ 401	$ 413	$ 425	$ 438	$ 451	$ 464	$ 478
PV		$1,100	$ 340	$ 325	$ 311	$ 297	$ 284	$ 271	$ 259	$ 247	$ 236	$ 226
NPV	**$3,895**											
HEAT PUMP WATER HEATER												
First Cost		$1,800										
Operating Cost	$ 304		$ 304	$ 313	$ 323	$ 333	$ 342	$ 353	$ 363	$ 374	$ 385	$ 397
Other Outflows	$ 9		$ 9	$ 10	$ 10	$ 10	$ 11	$ 11	$ 11	$ 12	$ 12	$ 12
Inflows												
Subtotal		$1,800	$ 314	$ 323	$ 333	$ 343	$ 353	$ 364	$ 375	$ 386	$ 397	$ 409
PV		$1,800	$ 291	$ 278	$ 266	$ 254	$ 243	$ 232	$ 222	$ 212	$ 202	$ 193
NPV	**$4,192**											
GAS WATER HEATER												
First Cost		$1,550										
Operating Cost	$ 169		$ 169	$ 174	$ 180	$ 185	$ 191	$ 196	$ 202	$ 208	$ 214	$ 221
Other Outflows	$ 11		$ 11	$ 12	$ 12	$ 13	$ 13	$ 13	$ 14	$ 14	$ 15	$ 15
Inflows												
Subtotal		$1,550	$ 181	$ 186	$ 192	$ 198	$ 203	$ 210	$ 216	$ 222	$ 229	$ 236
PV		$1,550	$ 168	$ 160	$ 153	$ 146	$ 140	$ 134	$ 128	$ 122	$ 117	$ 111
NPV	**$2,929**											
GAS INSTANTANEOUS												
First Cost		$2,500										
Operating Cost	$ 144		$ 144	$ 149	$ 153	$ 158	$ 162	$ 167	$ 172	$ 177	$ 183	$ 188
Other Outflows	$ 10		$ 10	$ 10	$ 10	$ 11	$ 11	$ 11	$ 12	$ 12	$ 12	$ 13
Inflows												
Subtotal		$2,500	$ 154	$ 159	$ 163	$ 168	$ 173	$ 179	$ 184	$ 189	$ 195	$ 201
PV		$2,500	$ 143	$ 137	$ 130	$ 125	$ 119	$ 114	$ 109	$ 104	$ 99	$ 95
NPV	**$3,675**											

Single Family – TOU RATE												
		Today	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**	**Year 9**	**Year 10**
ELECTRIC WATER HEATER												
First Cost		$ 1,100										
Operating Cost	$ 597		$ 597	$ 615	$ 634	$ 653	$ 672	$ 692	$ 713	$ 734	$ 756	$ 779
Other Outflows	$ 11		$ 11	$ 11	$ 12	$ 12	$ 12	$ 13	$ 13	$ 13	$ 14	$ 14
Inflows												
Subtotal		$ 1,100	$ 608	$ 626	$ 645	$ 665	$ 684	$ 705	$ 726	$ 748	$ 770	$ 793
PV		$ 1,100	$ 564	$ 539	$ 515	$ 492	$ 470	$ 449	$ 430	$ 410	$ 392	$ 375
NPV	**$ 5,737**											
HEAT PUMP WATER HEATER												
First Cost		$ 1,800										
Operating Cost	$ 507		$ 507	$ 522	$ 538	$ 554	$ 571	$ 588	$ 605	$ 624	$ 642	$ 661
Other Outflows	$ 9		$ 9	$ 10	$ 10	$ 10	$ 11	$ 11	$ 11	$ 12	$ 12	$ 12
Inflows												
Subtotal		$ 1,800	$ 516	$ 532	$ 548	$ 564	$ 581	$ 599	$ 617	$ 635	$ 654	$ 674
PV		$ 1,800	$ 479	$ 458	$ 437	$ 418	$ 399	$ 382	$ 365	$ 348	$ 333	$ 318
NPV	**$ 5,738**											
GRID-INTERACTIVE WATER HEATER												
First Cost		$ 1,730										
Operating Cost	$ 764		$ 764	$ 787	$ 810	$ 834	$ 859	$ 885	$ 912	$ 939	$ 967	$ 996
Other Outflows	$ 16		$ 16	$ 16	$ 17	$ 17	$ 18	$ 18	$ 19	$ 20	$ 20	$ 21
Inflows	$ (182)		$ (182)	$ (187)	$ (193)	$ (199)	$ (205)	$ (211)	$ (217)	$ (224)	$ (230)	$ (237)
Subtotal		$ 1,730	$ 598	$ 616	$ 634	$ 653	$ 673	$ 693	$ 714	$ 735	$ 757	$ 780
PV		$ 1,730	$ 554	$ 530	$ 506	$ 484	$ 462	$ 442	$ 422	$ 403	$ 385	$ 368
NPV	**$ 6,288**											

A.3.2 Multi-Family SDG&E

Multi-Family – STANDARD RATE												
		Today	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**	**Year 9**	**Year 10**
ELECTRIC WATER HEATER												
First Cost		$ 850										
Operating Cost	$ 498		$ 498	$ 513	$ 528	$ 544	$ 560	$ 577	$ 594	$ 612	$ 631	$ 649
Other Outflows	$ 9		$ 9	$ 9	$ 10	$ 10	$ 10	$ 11	$ 11	$ 11	$ 12	$ 12
Inflows												
Subtotal		$ 850	$ 507	$ 522	$ 538	$ 554	$ 571	$ 588	$ 605	$ 624	$ 642	$ 661
PV		$ 850	$ 470	$ 449	$ 429	$ 410	$ 392	$ 375	$ 358	$ 342	$ 327	$ 312
NPV	**$ 4,716**											
HEAT PUMP WATER HEATER												
First Cost		$ 1,500										
Operating Cost	$ 397		$ 397	$ 409	$ 421	$ 434	$ 447	$ 460	$ 474	$ 488	$ 503	$ 518
Other Outflows	$ 7		$ 7	$ 8	$ 8	$ 8	$ 8	$ 9	$ 9	$ 9	$ 9	$ 10
Inflows												
Subtotal		$ 1,500	$ 404	$ 416	$ 429	$ 442	$ 455	$ 469	$ 483	$ 497	$ 512	$ 527
PV		$ 1,500	$ 375	$ 358	$ 342	$ 327	$ 313	$ 299	$ 286	$ 273	$ 261	$ 249
NPV	**$ 4,583**											
GAS WATER HEATER												
First Cost		$ 1,250										
Operating Cost	$ 183		$ 183	$ 188	$ 194	$ 200	$ 206	$ 212	$ 218	$ 225	$ 232	$ 239
Other Outflows	$ 10		$ 10	$ 10	$ 11	$ 11	$ 11	$ 12	$ 12	$ 12	$ 13	$ 13
Inflows												
Subtotal		$ 1,250	$ 193	$ 199	$ 205	$ 211	$ 217	$ 224	$ 230	$ 237	$ 244	$ 252
PV		$ 1,250	$ 179	$ 171	$ 163	$ 156	$ 149	$ 143	$ 136	$ 130	$ 124	$ 119
NPV	**$ 2,720**											
GAS INSTANTANEOUS												
First Cost		$ 2,000										
Operating Cost	$ 162		$ 162	$ 167	$ 172	$ 177	$ 183	$ 188	$ 194	$ 200	$ 206	$ 212
Other Outflows	$ 9		$ 9	$ 9	$ 9	$ 10	$ 10	$ 10	$ 11	$ 11	$ 11	$ 11
Inflows												
Subtotal		$ 2,000	$ 171	$ 176	$ 181	$ 187	$ 193	$ 198	$ 204	$ 210	$ 217	$ 223
PV		$ 2,000	$ 159	$ 152	$ 145	$ 138	$ 132	$ 126	$ 121	$ 115	$ 110	$ 105
NPV	**$ 3,304**											

Multi-Family – LOW INCOME RATE												
		Today	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
ELECTRIC WATER HEATER												
First Cost		$ 850										
Operating Cost	$ 299		$ 299	$ 308	$ 317	$ 327	$ 337	$ 347	$ 357	$ 368	$ 379	$ 390
Other Outflows	$ 9		$ 9	$ 9	$ 10	$ 10	$ 10	$ 11	$ 11	$ 11	$ 12	$ 12
Inflows												
Subtotal		$ 850	$ 308	$ 318	$ 327	$ 337	$ 347	$ 358	$ 368	$ 379	$ 391	$ 402
PV		$ 850	$ 286	$ 273	$ 261	$ 250	$ 239	$ 228	$ 218	$ 208	$ 199	$ 190
NPV	**$ 3,202**											
HEAT PUMP WATER HEATER												
First Cost		$ 1,500										
Operating Cost	$ 239		$ 239	$ 246	$ 253	$ 261	$ 269	$ 277	$ 285	$ 293	$ 302	$ 311
Other Outflows	$ 7		$ 7	$ 8	$ 8	$ 8	$ 8	$ 9	$ 9	$ 9	$ 9	$ 10
Inflows												
Subtotal		$ 1,500	$ 246	$ 253	$ 261	$ 269	$ 277	$ 285	$ 294	$ 303	$ 312	$ 321
PV		$ 1,500	$ 228	$ 218	$ 208	$ 199	$ 190	$ 182	$ 174	$ 166	$ 159	$ 152
NPV	**$ 3,376**											
GAS WATER HEATER												
First Cost		$ 1,250										
Operating Cost	$ 146		$ 146	$ 151	$ 155	$ 160	$ 165	$ 170	$ 175	$ 180	$ 185	$ 191
Other Outflows	$ 10		$ 10	$ 10	$ 11	$ 11	$ 11	$ 12	$ 12	$ 12	$ 13	$ 13
Inflows												
Subtotal		$ 1,250	$ 156	$ 161	$ 166	$ 171	$ 176	$ 181	$ 187	$ 192	$ 198	$ 204
PV		$ 1,250	$ 145	$ 139	$ 132	$ 126	$ 121	$ 115	$ 110	$ 105	$ 101	$ 96
NPV	**$ 2,441**											
GAS INSTANTANEOUS												
First Cost		$ 2,000										
Operating Cost	$ 130		$ 130	$ 134	$ 138	$ 142	$ 146	$ 150	$ 155	$ 160	$ 164	$ 169
Other Outflows	$ 9		$ 9	$ 9	$ 9	$ 10	$ 10	$ 10	$ 11	$ 11	$ 11	$ 11
Inflows												
Subtotal		$ 2,000	$ 139	$ 143	$ 147	$ 151	$ 156	$ 161	$ 166	$ 170	$ 176	$ 181
PV		$ 2,000	$ 129	$ 123	$ 117	$ 112	$ 107	$ 102	$ 98	$ 94	$ 89	$ 85
NPV	**$ 3,057**											

Multi-Family – TOU RATE												
		Today	**Year 1**	**Year 1**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**	**Year 9**	**Year 10**
ELECTRIC WATER HEATER												
First Cost		$ 850										
Operating Cost	$ 503		$ 503	$ 518	$ 533	$ 549	$ 566	$ 583	$ 600	$ 618	$ 637	$ 656
Other Outflows	$ 9		$ 9	$ 9	$ 10	$ 10	$ 10	$ 11	$ 11	$ 11	$ 12	$ 12
Inflows												
Subtotal		$ 850	$ 512	$ 527	$ 543	$ 559	$ 576	$ 593	$ 611	$ 629	$ 648	$ 668
PV		$ 850	$ 475	$ 454	$ 434	$ 414	$ 396	$ 378	$ 361	$ 345	$ 330	$ 315
NPV	**$ 4,753**											
HEAT PUMP WATER HEATER												
First Cost		$ 1,500										
Operating Cost	$ 398		$ 398	$ 409	$ 422	$ 434	$ 447	$ 461	$ 475	$ 489	$ 504	$ 519
Other Outflows	$ 7		$ 7	$ 8	$ 8	$ 8	$ 8	$ 9	$ 9	$ 9	$ 9	$ 10
Inflows												
Subtotal		$ 1,500	$ 405	$ 417	$ 430	$ 442	$ 456	$ 469	$ 483	$ 498	$ 513	$ 528
PV		$ 1,500	$ 376	$ 359	$ 343	$ 328	$ 313	$ 299	$ 286	$ 273	$ 261	$ 250
NPV	**$ 4,588**											
GRID-INTERACTIVE WATER HEATER												
First Cost		$ 1,730										
Operating Cost	$ 764		$ 764	$ 787	$ 810	$ 834	$ 859	$ 885	$ 912	$ 939	$ 967	$ 996
Other Outflows	$ 16		$ 16	$ 16	$ 17	$ 17	$ 18	$ 18	$ 19	$ 20	$ 20	$ 21
Inflows	$ (182)		$ (182)	$ (187)	$ (193)	$ (199)	$ (205)	$ (211)	$ (217)	$ (224)	$ (230)	$ (237)
Subtotal		$ 1,730	$ 598	$ 616	$ 634	$ 653	$ 673	$ 693	$ 714	$ 735	$ 757	$ 780
PV		$ 1,730	$ 554	$ 530	$ 506	$ 484	$ 462	$ 442	$ 422	$ 403	$ 385	$ 368
NPV	**$ 6,288**											

APPENDIX B: GRID-INTERACTIVE REAL TIME RATE PLAN

The following table was gathered from SCE's small commercial real time pricing schedule "General Service – Small" (TOU-GS-1-RTP).[51] The cells highlighted in blue represent the three lowest cost hours of operation per day type.

Table B-1: SCE Real Time Pricing Rate Structure

Hour	Temperature / Season								
	Summer Weekday					Winter Weekday		Weekend	
	>=95	91-94	85-90	81-84	<=80	>90	<=90	>=78	<78
1:00 AM	0.047	0.038	0.033	0.031	0.030	0.052	0.038	0.040	0.036
2:00 AM	0.041	0.032	0.028	0.026	0.026	0.048	0.034	0.035	0.031
3:00 AM	0.035	0.027	0.023	0.022	0.022	0.041	0.032	0.031	0.029
4:00 AM	0.031	0.025	0.021	0.020	0.020	0.045	0.032	0.030	0.026
5:00 AM	0.032	0.027	0.024	0.022	0.022	0.048	0.034	0.029	0.026
6:00 AM	0.043	0.035	0.030	0.028	0.028	0.060	0.043	0.031	0.028
7:00 AM	0.045	0.037	0.033	0.030	0.030	0.069	0.049	0.030	0.026
8:00 AM	0.048	0.042	0.038	0.035	0.035	0.072	0.053	0.033	0.028
9:00 AM	0.055	0.059	0.042	0.040	0.040	0.069	0.053	0.039	0.035
10:00 AM	0.101	0.089	0.047	0.047	0.046	0.078	0.054	0.044	0.039
11:00 AM	0.233	0.191	0.063	0.051	0.050	0.112	0.056	0.048	0.044
12:00 PM	0.512	0.304	0.071	0.054	0.052	0.143	0.056	0.051	0.045
1:00 PM	0.836	0.443	0.096	0.056	0.054	0.174	0.055	0.052	0.044
2:00 PM	1.457	0.717	0.238	0.063	0.057	0.240	0.055	0.053	0.042
3:00 PM	2.109	0.927	0.384	0.081	0.062	0.300	0.055	0.056	0.042
4:00 PM	2.962	1.197	0.499	0.104	0.068	0.343	0.054	0.058	0.043
5:00 PM	2.964	1.099	0.507	0.095	0.066	0.292	0.055	0.063	0.045
6:00 PM	2.190	0.832	0.320	0.072	0.057	0.190	0.059	0.067	0.048
7:00 PM	1.371	0.423	0.177	0.065	0.054	0.163	0.062	0.065	0.049
8:00 PM	0.966	0.285	0.121	0.055	0.051	0.167	0.062	0.064	0.052
9:00 PM	1.065	0.463	0.121	0.057	0.054	0.170	0.059	0.070	0.054
10:00 PM	0.213	0.179	0.063	0.052	0.050	0.088	0.055	0.057	0.050
11:00 PM	0.059	0.075	0.047	0.046	0.046	0.062	0.050	0.049	0.043
12:00 AM	0.052	0.044	0.040	0.038	0.037	0.057	0.042	0.042	0.036
Estimated number of days	5	4	19	5	55	4	171	46	57
Average rate ($/kWh)	$0.03	$0.03	$0.02	$0.02	$0.02	$0.04	$0.03	$0.03	$0.03
Total cost by day type	$1.95	$1.26	$5.17	$1.26	$14.16	$2.14	$66.79	$16.63	$18.18
								Total Annual Operating Cost	$127.54

[51] Accessed January 31, 2017.

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