Pacific Gas and Electric Company

Emerging Technologies Program

Application Assessment Report # 0412

Residential Feasibility Assessment of Gas Tankless Water Heaters in PG&E Service Territory (2007 Update of Original 2004 Report)

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Executive Summary

Storage gas water heaters are the predominant residential water heating appliance used in Pacific Gas and Electric Company (PG&E) service territory and throughout California. Gas storage water heaters are characterized by low first cost, hot water delivery characteristics compatible with the cultural expectations of most U.S. homeowners, and lower than average seasonal efficiency compared to other gas heating appliances. Instantaneous or tankless gas water heaters have been available on a small scale for many years in this country, but have not yet achieved the widespread acceptance common to Europe and Japan. The current generation of tankless water heaters offers significant technology improvements over their predecessors. Variable burner capacity, higher heating capacities, and sophisticated controls have significantly improved delivery temperature characteristics under a range of flow rates. Elimination of standing pilots has also significantly improved the standby performance of tankless units; tankless Energy Factors are more than 35% higher than typical storage gas water heaters.

PG&E commissioned this study to update a 2004 PG&E tankless water heater market assessment study. During the past three years there has been considerable market interest and increased research into tankless water heater performance. In the last five years an estimated 140,000 tankless units have been installed in California. Utility new construction incentives of $200 (PG&E, Southern California Gas, and San Diego Gas & Electric) and a Federal tax credit of $300 enacted in 2006 have improved the economics of these systems.

Interviewing contractors, manufacturers, and building officials identified installation challenges and market barriers. High cost was identified as the predominant market barrier, since installed tankless costs are typically two to three times the cost of tank-type heaters. Increased installation costs result from higher equipment costs, larger gas line requirements, more costly venting, and the need for an electrical outlet required for the ignition controls and combustion air blower. Incremental costs are much lower for new construction because gas line upsizing and venting issues are more easily handled when a home or apartment is being built. Typical new construction incremental costs are estimated to be $950. Average retrofit incremental costs of $1450 were estimated in this study, but will vary greatly depending upon site features including water heater location, gas line and gas meter sizing, availability of electrical power, and venting requirements. The most expensive retrofit cost adder, a larger gas line, will be required in majority of retrofit applications.

Additional significant challenges and barriers were identified:

1. Most tankless water heaters will not operate during a power outage.
2. Tankless water heater manufacturers recommend periodic flushing to reduce the buildup of scale deposits, adding to the cost of ownership.
3. Specialized training is required for proper installation and servicing of tankless heaters.
4. Lack of homeowner and contractor experience with tankless water heaters diminishes confidence, and some building officials may resist approval. This is slowly changing as market penetration is increasing.

5. Tankless water heaters increase hot water waiting times, typically by less than 15 seconds, until the unit fully comes up to temperature. In addition, system controls require minimum hot water flow rates of 0.5 – 0.75 gpm before the burner will fire.
6. Sizing is more critical than for storage type water heaters, and the use of tankless heaters with some hot water recirculation systems may be problematic.
7. Long term reliability needs to be proven in the field. Anecdotal data suggests good reliability to date, but five more years of field experience is needed to better assess tankless reliability and maintenance issues. A particular concern relates to how well maintenance is carried out in areas with hard water where heat exchanger fouling is of concern.

Energy savings for tankless vs. tank-type heaters were calculated by accounting for differences in "load-dependent" performance of both system types, and by applying typical hot water load estimates. Whereas storage water heater efficiency[1] is largely dependent on the daily hot water load magnitude, tankless performance is more dependent on the characteristics of the hot water use pattern (principally average draw volume, number of small volume draws, and time interval between draws). Using typical estimated California hot water use of 63.6 gallons per household per day, we have projected annual tankless gas savings of 47 therms per year relative to a 0.60 Energy Factor storage water heater. Annual cost savings of $55 per year are projected at typical PG&E rates after accounting for gas savings and increased electrical consumption of 57 kWh/year (combustion air blower and standby energy). If tax credit and utility incentives reach the homeowner, the annual cash flow will be positive for new construction applications where the added cost can be amortized. Retrofit applications are more tenuous from an economic perspective with typical simple paybacks on the order of twenty years.

The market potential is significant for gas tankless water heaters. Statewide we estimate the technical potential market of about 250,000 (~25% of the market) units per year (137,000 new construction, 113,000 retrofit) with statewide savings impact of 11.9 million therms per year. Within PG&E service territory, we estimate the technical potential at about 96,000 units per year, with associated projected savings of 4.5 million therms per year.

[1] energy delivered in the form of hot water divided by gas energy consumed

Project Background

Residential gas storage water heaters have seasonal operating efficiencies considerably lower than other combustion heating appliances such as boilers and furnaces, primarily due to losses associated with keeping the tank volume hot. Tankless gas water heaters represent one approach to improving the installed efficiency of residential water heaters. Although the more efficient tankless gas water heater technology is more than 20 years old and dominates European and Japanese markets, market share in the U.S. has been insignificant until the last few years.

In recent years tankless water heater manufacturers have introduced products with pilot-less ignition, and with efficiencies that are comparable to furnaces and boilers. In addition to higher efficiency, the high capacity, rapid response, and precise temperature control of these newer products make these units suitable for replacing gas storage water heaters. Other benefits of these products include nearly unlimited hot water supply, and reduced space requirements.

In 2004, Davis Energy Group completed a market study for Pacific Gas and Electric PG&E with the objective of assessing a possible incentive program for tankless heaters. The scope of the study included identifying the energy savings potential, installation challenges, and market barriers; evaluating market size and economics in both new construction and retrofit markets, completing a market segmentation analysis for early adopters, and researching existing government or utility-sponsored incentive programs. Since 2004, more information has come out on issues related to tankless performance, hot water usage estimates, and maintenance issues. With these considerations, PG&E decided to update the 2004 study to incorporate new information.

Prior Research

In the last several years gas tankless water heaters have received increased attention from utilities, energy efficiency groups, builders, consumers, and regulatory agencies. Several recent studies are briefly described below and discussed further in the body of the report.

<u>"Literature Review of Tankless Water Heaters", Gas Technology Institute (Jan 2007)</u>

This California Energy Commission PIER-sponsored study was conducted to establish the current knowledge base for tankless gas water heaters. The study looked at market issues and barriers, prior research on tankless water heater performance and hot water end use studies, and codes and standards implications.

<u>E-Source Tech Memo "Innovation in the Residential Water Heating Sector Bubbles Over – Gas Tankless and Condensing Units Improving but Still Costly", (Nov 2006)</u>

This "members-only" report provides an assessment of advanced water heating technologies and further documents the growing interest in tankless water heaters.

<u>"Field and Laboratory Testing of Tankless Gas Water Heater Performance", Davis Energy Group, Inc. (April 2006)</u>

This California Energy Commission PIER-sponsored study reported on field and lab performance of tankless gas water heater performance. Testing was completed to assess how performance varies under different operating conditions (flow rate, draw volume, and time interval between draws) and how these factors may affect rated performance.

"Tankless Gas Water Heaters: Oregon Market Status", Prepared for the Energy Trust of Oregon (Dec 2005)

This report looked at prior tankless studies as well as a more detailed assessment of the current status of tankless water heaters in Oregon (builder/contractor perceptions, market share, and cost).

Residential Gas Water Heating Technology Status

Conventional Gas Storage Water Heaters

Storage gas water heaters (as shown in Figure 1) are heated by a gas burner located at the bottom of the vertically oriented storage tank that contains 30 to 50 gallons of hot water, usually maintained at 120°F to 140°F. Heat from the burner is conducted to the water through the concave tank bottom and the walls of a center flue that extends upward through the center of the tank. A standing pilot ignites the burner when the tank thermostat indicates the tank has fallen below the temperature setting. The gas input rating typically ranges from 34,000 to 40,000 Btuh, with high capacity models (up to 75,000 Btu per hour) available. Most storage gas water heaters are naturally vented, though some employ fans to assist venting. Gas valves are powered by a thermopile that is heated by the pilot, eliminating the need to connect the water heater to a power source.

Two factors, standby loss and recovery efficiency, contribute to overall storage gas water heater efficiency. Standby loss includes losses from the tank outside surface, flue, fittings, and pilot energy use. Heat from the pilot, which typically amounts to ~ 450 Btu/hour, often balances tank and fitting losses. Recovery efficiency is the efficiency of the water heater while the burner is operating continuously, and typically ranges from about 76-80%, although a few models report higher recovery efficiencies[2]. Overall water heater efficiency is represented by the "Energy Factor", which is based on a 24-hour test performed at a recovery load of 64.3 gallons per day[3], as prescribed by DOE test procedures adopted under the National Appliance Efficiency Act (NAECA). Equation 1 defines the current Energy Factor standard (effective January 1, 2004) for storage gas water heaters with input capacities less than 75,000 Btu per hour:

Equation 1: ***Energy Factor (EF) = 0.67 - 0.0019 x Volume (in gallons)***

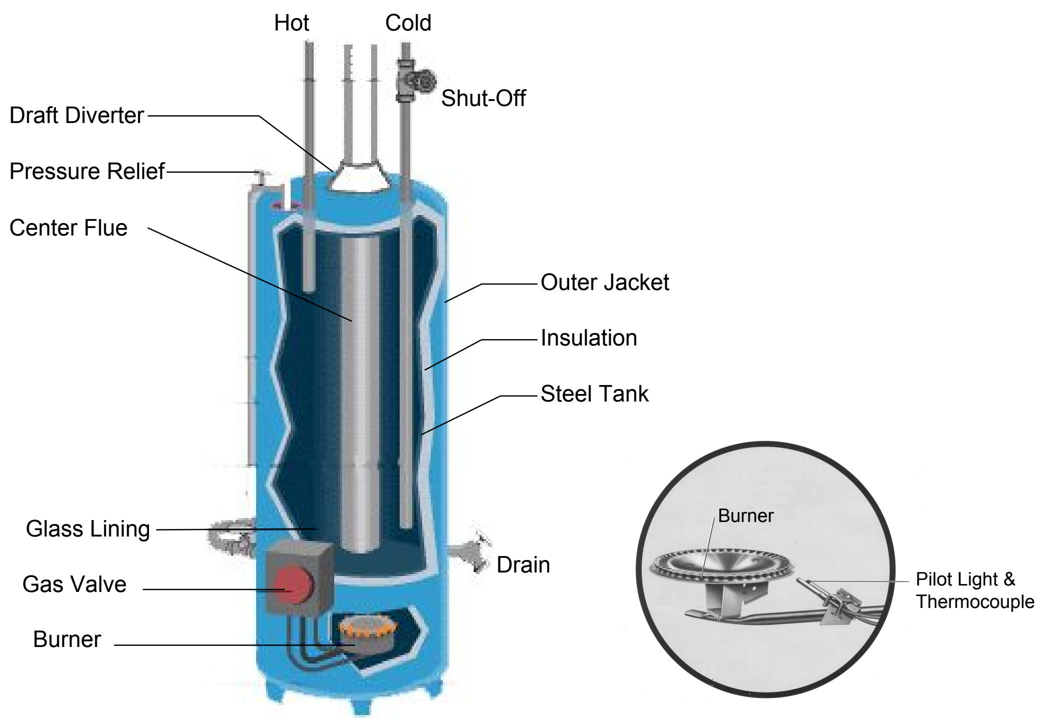
Forty and fifty gallon gas storage water heaters are therefore required to have a minimum EF's of 0.594 and 0.575, respectively.

[2] http://www.gamanet.org/gama/inforesources.nsf/vAttachmentLaunch/889576C61E16540585256E9000608247/$FILE/10-06-gas-irwh.pdf

[3] Six draws of equal volume (~10.7 gallons each) spaced one hour apart, followed by standby operation for the remaining 19 hours.

Several manufacturers produce premium high efficiency "condensing" gas storage water heaters that use a hot surface igniter or spark ignition instead of a pilot, have a closed combustion chamber, and use a blower to draw in combustion air, cycle hot combustion gases through a heat exchanger in the tank, and vent them to outdoors. Because of their high cost (over $2,500) they are used predominantly in large residential or commercial buildings, or in combined hydronic systems that provide both water heating and space heating.

Figure 1: Storage Water Heater Components



In 2004, Arthur D. Little (now TIAX) completed a report for the Gas Research Institute, DOE, and American Water Heater Co. documenting the design, prototyping, and testing of an advanced storage water heater. This unit now marketed by A.O. Smith as the Vertex, is designed for residential combined hydronic or small commercial applications. It has a 50-gallon unit and provides condensing water heating performance with a 90% thermal efficiency, 76,000 Btu/hour input capacity, powered combustion air venting, and hot surface electronic ignition[4]. Since the unit exceeds the 75,000 Btu/hour threshold it is exempt from Federal Energy Factor reporting requirements. With current contractor pricing of ~$1,500, the Vertex offers a much lower price point relative to other condensing storage water heaters on the market.

Water heaters that exceed minimum Federal Standards are available, and many builders use them to earn Title 24 energy compliance credits. California production builders typically install water heaters with Energy Factors of 0.60 to 0.62. Energy Factors above 0.63 are difficult to achieve

[4] http://www.hotwater.com/lit/spec/res_gas/ARG-SS01306.pdf

with pilot-operated non-condensing storage gas water heaters because the standby losses represent significant efficiency degradation. More advanced storage water heaters being promoted by the Super Efficient Gas Water Heating Appliance Initiative (SEGWHAI)[5] project would offer efficiencies ranging from 0.70 EF (non-condensing) to 0.82 (condensing).

Rated efficiency may exceed actual efficiency under conditions typically found in California residences. Since standby loss occurs independent of hot water use, efficiency (defined as useful energy output divided by energy input) approaches zero as hot water use decreases. At hot water loads less than 64.3 gallons per day, performance is degraded from the reported Energy Factor. The California Title-24 Residential Building Standards have accounted for the “load dependent energy factor” (LDEF) since 1992. The LDEF approach recognizes that as daily hot water loads decrease, standby losses represent an increasingly larger fraction of total hot water energy use.

Reliability of storage gas water heaters is very high. Most do not require service until they have reached the end of their useful life. Since they generally receive little or no maintenance, the typical failure mode is usually a result of tank corrosion[6].

Although storage gas water heaters represent the norm in California, their moderate heating capacity is insufficient to meet hot water requirements for filling large jetted tubs, and large families may experience hot water shortages during coincident hot water events (e.g. baths, showers, laundry, etc). In larger custom homes these shortcomings are often remedied by adding a second storage water heater. Although this increases the availability of hot water, it doubles the associated standby losses.

On a statewide basis, approximately 83% of California’s twelve million households have gas storage water heaters[7]. In PG&E territory, 82% of households utilize gas storage water heaters. Table 1 lists estimates of gas water heaters in existing housing stock by service area.

Table 1: California Gas Storage Water Heater Inventory

Utility Service Area	Existing Housing Stock	Number of Gas Water Heaters	Gas Water Heater Saturation
Pacific Gas and Electric Co.	4,628,766	3,813,231	82%
Sacramento Municipal Utility	487,468	366,493	75%
Southern California Edison	4,247,004	3,550,431	84%
LA Dept of Water & Power	1,300,720	1,142,707	88%
San Diego Gas and Electric	1,156,391	955,586	83%
Burbank, Glendale, Pasadena	169,700	147,743	87%
Statewide Total	11,990,049	9,976,191	83%

Source: CEC “California Energy Demand 2003-2013 Forecast”, 2003.

[5] see http://www.segwhai.org/
[6] Replacement of the anode rod and tank sediment flushing would extend the life of many storage water heaters, but this is rarely done.
[7] 2005 U.S. Census Bureau data shows 12,989,254 housing units in California with an estimated 12,097,894 occupied.

<u>Tankless Gas Water Heaters</u>

Tankless gas water heaters employ a burner and a heat exchanger that contains a small volume of water (typically less than one gallon). Water is heated in a single pass through the heat exchanger. By varying burner output in proportion to the water flow rate, hot water temperature is fairly precisely controlled[8]. Newer models include electronic (spark) ignition and intelligent controls, features that represent a significant improvement over products from 10-20 years ago. Virtually all of the newer models utilize combustion air blowers to achieve higher output and efficiency, and to allow horizontal "direct" venting. Lower cost models use a pushbutton piezo-electric igniter to start the pilot, use the pilot to ignite the main burner, and are naturally vented. Gas input ranges from about 60,000 Btuh to 200,000 Btuh. Smaller capacity units are intended for point-of-use, or small load applications. Most manufacturers supply both natural gas and propane fueled units.

Higher capacity models are capturing a larger market share because of their ability to respond quickly to changing loads (with little or no change in output temperature) and to meet the hot water needs of most single family homes. They provide hot water of a similar quality as storage gas heaters, yet their high capacity insures that homeowners will not run out of hot water except under conditions with very high coincident hot water loads. Figure 1 shows a garage installation of a tankless unit. Units can also be located in exterior water heater closets, interior closets (with proper ventilation), and mechanical rooms.

Figure 1: Garage Sidewall Tankless Installation

[8] Most models allow the user to set a supply hot water setpoint temperature.

Table 2 summarizes performance characteristics of some of the gas tankless water heater models currently on the market. The units with maximum input ratings of less than 120,000 Btu/hour are marginal for whole-house applications with simultaneous hot water draws (e.g. two showers or a shower coincident with clothes washer). Models with capacities higher than 160,000 Btuh are better suited for whole-house applications and replacement or substitution for tank-type units. All of the models listed in Table 2 have the capability to modulate burner firing rate down to 30% or less of their maximum heating capacity. Although tankless water heaters do not technically have standby loss, the energy required to bring the heat exchanger to temperature for each draw does reduce overall efficiency. Maximum efficiency is achieved when hot water use is concentrated into a small number of high volume draws, such as the Energy Factor test procedure.

Table 2: Characteristics of a Sampling of Available Tankless Units

Manufacturer	Model Number	EF	Btuh Max Input	Btuh Min Input	gpm Min Flow	gpm Max Flow*
A.O. Smith	XT19400L	0.78	194,000	25,000	0.75	6.4
Bosch/Aquaster	AQ125FX	0.78	130,000	35,000	0.5	4.2
Bosch/Aquaster	AQ250SX	0.85	177,000	25,000	0.8	6.2
Bradford-White	Ever-Hot	0.82	180,000	15,000	0.6	6.0
Noritz America	N-042	0.82	119,000	19,000	0.75	4.0
Noritz America	N-063	0.81	179,000	19,000	0.75	5.9
Paloma**	PH-28R1FSN	0.82	199,900	19,000	0.66	6.8
Rinnai	R53i (2520FFU)	0.82	180,000	15,000	0.5	6.0
Rinnai	R85e (2532W)	0.82	199,000	15,000	0.5	6.6
Takagi	T-KJr.	0.81	140,000	19,500	0.75	4.6
Takagi	T-H1	0.92	199,000	15,000	0.75	6.6

*At 50 deg. F temperature rise
**Also sold as Rheem, Richmond, Ruud, WaiWela

Federal Efficiency Requirements

Currently, the United States Department of Energy (DOE) applies the same basic Energy Factor test procedure to both storage and tankless water heaters. However the minimum EF relationship defined in Equation 1 was not updated for tankless water heaters in 2004, therefore the current minimum Energy Factor for tankless heaters is 0.62. The 0.62 level is a higher standard than that required for storage-type heaters but lower than the Energy Factor of every tankless product currently on the market.

On January 16, 2007, DOE held a public meeting to gather stakeholder input concerning standards for water heaters. Tankless gas water heaters will be part of the rulemaking. A framework document, distributed prior to the meeting, was discussed in detail with the aid of a PowerPoint presentation[9]. The schedule DOE proposes to maintain is as follows:

[9] http://www.eere.energy.gov/buildings/appliance_standards/residential/waterheaters.html

- Workshop Comments Due – January 30, 2007
- Data Collection Complete – June 2007
- Advanced Notice of Proposed Rulemaking (ANOPR) – September 2008
- Notice of Proposed Rulemaking (NOPR) – July 2009
- Final Rule – March 2010 (to become effective three years later)

DOE proposes to consider tankless units with an input capacity of 190,000 Btuh at various EF levels. Commenters have expressed concern that other capacity levels need to be considered given that that the tankless market is still developing and may come to favor lower capacity levels. DOE's analysis will consider the efficiency levels shown in Table 3.

Table 3: Proposed Tankless Efficiency Levels

Efficiency Level	Energy Factor	Recovery Efficiency
Baseline	0.62	0.78
Efficiency Level 1	0.75	0.80
Efficiency Level 2	0.82	0.85
Efficiency Level 3	0.85	0.85
Efficiency Level 4	0.92	0.93

Commenters have recommended that one of the efficiency levels be 0.80, the current minimum efficiency level for the Federal 2006-2007 $300 tax credit. The technical options DOE will consider are: increased heat exchanger surface area, force draft (only if baseline is natural draft), condensing, lower power electronics, and heat exchanger insulation. Commenters express concern about the technical feasibility of insulating a heat exchanger that is exposed to the burner flames.

Reliability of Tankless Units

Long-term reliability of tankless water heaters is uncertain, but would logically be dependent upon local water conditions, use characteristics, and maintenance. At the DOE's Energy Efficiency and Renewable Energy website[10], an estimated 20 year life expectancy is offered as "typical" for tankless units. To assure continued performance, manufacturers recommend periodic flushing of the heat exchanger with a mild acid solution to prevent occlusion of the heat exchanger by water deposits. Since periodic maintenance is required (unlike storage water heaters where maintenance is non-existent), one would expect lifetimes exceeding that of storage water heaters. In addition, major components can often be replaced extending the effective service life of the unit. Clearly more field data is needed to better understand reliability, service intervals and cost, and equipment lifetimes.

[10] http://www.eere.energy.gov/consumer/your_home/water_heating/index.cfm/mytopic=12820

Product Warranties

Typical manufacturer warranties on tankless units range from 7 to 12 years on the heat exchanger and 2 to 5 years on other parts when the unit is installed by licensed and/or qualified[11] contractors in a single family residential application. Most manufacturers provide a reduced warranty period if the unit is used in conjunction with a recirculating hot water system or if used as part of a radiant heating system. Table 4 summarizes warranty characteristics from three leading manufacturers.

Table 4: Sample Tankless Water Heater Warranties (in years)

Mfg	Heat Exchanger	Other	Labor	Comments
A	10*	5*	1	* 3 years when operating as a circulating water heater
B	12**	2	0	** 2 years when not installed in a single family residence or if operated as a circulating water heater
C	10***	5***	0	*** 3 years when not installed in a single family residence or if operated as a circulating water heater

Performance Issues

Tankless heaters impose an increase in hot water waiting time at the fixture because they require a few seconds before firing and then an additional 10-30 seconds before they supply hot water close to the user-selected setpoint. Figure 3 shows lab test data of one unit with a 122° factory default temperature setting beginning with both a hot heat exchanger (recent hot water draw) and a cold heat exchanger. At a flow rate of 1.9 gpm, it took ~13 seconds to reach 110°F supply water temperature with a hot heat exchanger and 23 seconds with a cold heat exchanger, as measured at the exit of the tankless unit. Whether the homeowner notices the time delay depends on the hot water distribution system (whether it magnifies the time delay) and on the homeowner's prior hot water delivery expectations.

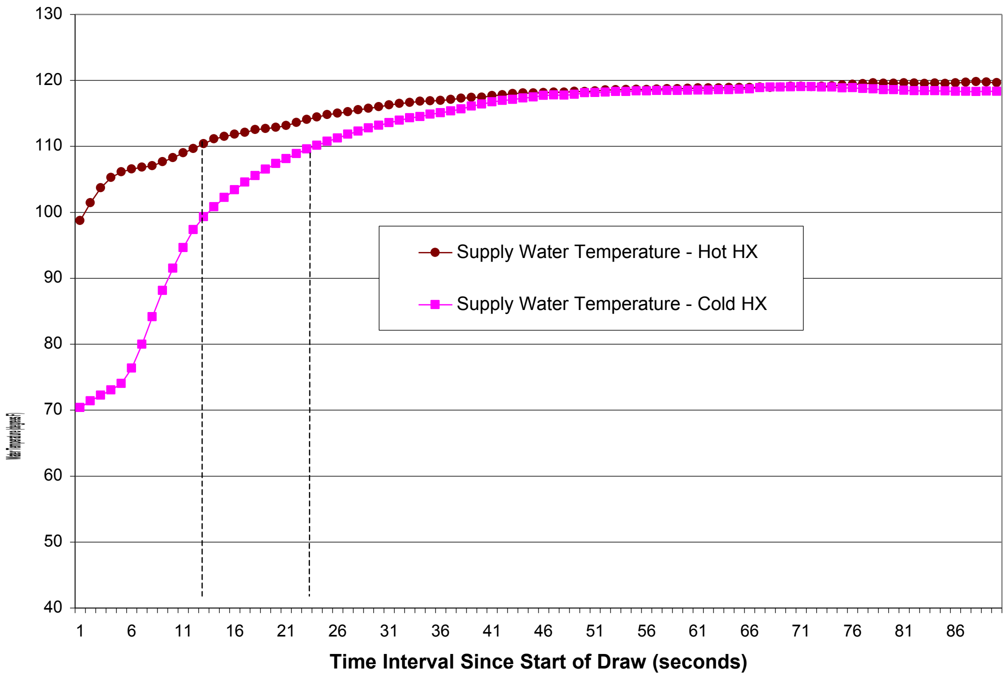
In addition to the time delay issue (and associated water waste), tankless units require a certain minimum water flow rate to fire, usually about 0.5 to 0.8 gallons per minute. This may be a hindrance depending upon how consumers use hot water. Detailed two-second interval monitoring at new home near Sacramento from October 2003 to August 2004 suggests that for this household only 2.25% of all hot water consumed was at a flow rate less than 0.8 gpm (0.3% was less than the 0.5 gpm threshold). Lack of burner firing at low flow rates may beneficially save water heater energy during inadvertent hot water draws, such as may occur with single lever faucets in the (normal) vertical position.

Many tankless water heater manufacturers promote the "endless hot water" benefit of their units. Although this might be attractive some homeowners, it certainly raises the concerns of energy and water efficiency advocates.

[11] "Qualified" may mean the contractor has undergone manufacturer-sponsored training.

The three performance issues identified here may impact acceptance and/or savings estimates of tankless units. More field data is needed provide a better understanding on these issues.

Figure 3: Hot and Cold Start-up Performance of a Tankless Water Heater



Hot Water Energy Usage Quantification

Household hot water usage has not been satisfactorily quantified, largely because of the expense associated with obtaining accurate hot water flow and and fixture end use data. An additional factor is that household hot water usage can't be easily quantified based solely on dwelling unit size or even number of occupants. Young families with infants will typically have more (high volume) baths and laundry loads than retired couples. Smaller houses are more likely to be occupied by lower or middle-income homeowners and therefore typically have higher occupant densities than some of the new large homes that may be occupied only by a working couple. A countering trend is greater penetration of water efficient appliances. All of these factors complicate understanding how hot water is used and what is representative in terms of usage quantity and pattern. Development of an improved understanding of hot water usage characteristics will require a significant effort to collect the high-resolution monitoring data necessary to develop statistically valid draw patterns and usage quantities.

Table 5 summarizes residential per capita hot water end use assumptions. The first two datapoints are based on DOE sources: the Building Energy Data Book (BEDB)[12] and the Code of Federal Regulations (10CFR430, Subpart B, Appendix E) describing the test procedure for

[12] The BEDB contains construction statistics and energy use estimates for residential and commercial buildings.

residential scale water heaters. The EF test results in an estimated per capita usage of 24.7 gallons per day, based on 2005 U.S. Census data[13] reporting average household size of 2.6 persons. The three following references are based on monitoring studies with the 2006 LBNL report representing a compilation of several end use studies. A simple numerical average results in per capita consumption of 21.8 gallons per day. In the absence of more robust data, this value is probably reasonable. 2005 U.S. Census data[14] suggest an average 2.92 person California household size, resulting in a 63.6 gallon/day usage level.

Table 5: Characterization of per Capita Hot Water Consumption

Description	Data Source	Hot Water Use (gal/cap-day)	Comments
Household Hot Water Estimate	2005 DOE Building Energy Data Book	16.0	BEDB estimates energy usage based on 2 and 4 person sized households
Energy Factor test assumptions	DOE water heater test usage values	24.7	64.3 gal/day divided by 2.6 persons per household (US Census Bureau)
EBMUD study	2003 Aquacraft	21.1	Based on 10 CA monitored homes
CEC PIER Hot Water Draw Patterns Study	2006 LBNL	26.1	Based on 41 homes monitored; 26 CA, 10 OR, 2 CT, 3 OH. Average of 46 daily hot water draws for all sites
Building America Site	DEG 2003	20.9	Single Sacramento area household monitored over 11 month period

Table 6 summarizes annual California gas water heater energy use estimates from four sources:

- The Database for Energy Efficiency Resources (DEER)
- DOE's Residential Energy Consumption Survey (RECS) for the years 1997 and 2001
- CEC's 2004 Residential Appliance Saturation Survey (RASS), and
- PG&E's 1997 Residential Energy Survey Report

The DEER water heating energy summary specifically excludes dishwasher and clothes washing associated energy consumption, as it is tabulated elsewhere in the database. (Since DEER provides only savings estimates for efficient dishwasher and clothes washer measures, baseline usage for these appliances was calculated based on information provided at EPA[15], Consortium for Energy Efficiency[16], and California Energy Commission[17] websites. From these sources, 11

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13 http://factfinder.census.gov/servlet/ACSSAFFFacts?_submenuId=factsheet_0&_sse=on

14 http://factfinder.census.gov/servlet/ACSSAFFFacts?_event=Search&geo_id=&_geoContext=&_street=&_county=&_cityTown=&_state=04000US06&_zip=&_lang=en&_sse=on&pctxt=fph&pgsl=010

15 http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/CalculatorConsumerDishwasher.xls

16 http://www.cee1.org/resid/seha/rwsh/res_wash_prog_des02.pdf

and 21 therms were determined for typical dishwasher and clothes washing end uses, respectively.)

Table 6: Projected Annual California Residential Water Heating Fuel Consumption

Description	Data Source	Gas Usage (therms/year)	Comments
PG&E (SF) Single Family	DEER	111 (143)	Value in "()" incl 32 therms for clothes washer (CW) and dishwasher (DW)
PG&E (MF) Multi-Family	DEER	104	
SCE & SDG&E Single Family	DEER	115 (147) 103 (135)	SCE "()" includes CW + DW SDG&E "()" includes CW + DW
SCE & SDG&E Multi-Family	DEER	104 97	SCE SDG&E
California	2001 RECS	181	All households
California	1997 RECS	229	All households
California Households	2004 RASS	183 (PG&E) 201 (All CA)	All households (single family, multi-family, mobile home)
California (SF)	2004 RASS	206	All utilities
California (MF)	2004 RASS	188	All utilities
PG&E (CA) All Households	1997 Residential Energy Survey Report	208	All households; based on 1995 energy bills and 1994 Residential Energy Survey

A quick review of the table shows the DEER estimates to be roughly 30% lower than the other sources. The DEER estimates appear unreasonably low based given a calculated 116 therms for heating 63.6 gallons per day through a 60°F temperature rise at 100% combustion efficiency. This simplified calculation does not take into account the actual combustion efficiency of typical gas storage water heaters (~76-80%), tank standby losses (~40-50 therms per years), and hot water distribution system losses (typically 15-30 therms per year[18]). The remaining sources demonstrate usage ranging from 181 to 229 therms per year[19]. A reasonable average usage based on the data presented here would be ~200 therms, suggesting that the RASS data (206 therms single family and 188 multi-family) may be representative of "typical" California usage.

[17] http://www.energy.ca.gov/appliances/2003rulemaking/clothes_washers/documents/2005-09-05_CASE_STUDY_CLOTHES_WASHERS.PDF
[18] Depending upon house size, water heater location, distribution system type&layout, and hot water usage pattern.
[19] The large change in the RECS data from 1997 to 2001 is surprising and worthy of further research.

Since newer water heaters are slightly more efficient than the existing stock, an adjustment must be made for new construction baseline consumption to account for higher EF's on currently available models. Average new single family water heater energy use is estimated at 185 therms per year based on a 65/35 mix of 40 and 50 gallon storage water heaters[20].

Objectives

The primary goal of this project was to update the 2004 PG&E study based on improved information that has become available with ongoing research and additional market data now available on gas tankless units.

The following approach was applied to accomplish this objective:

- Evaluate energy savings potential of tankless water heaters in typical California single and multi-family residential applications based on representative usage assumptions and available performance data
- Estimate potential market share in both PG&E territory and statewide
- Investigate new construction and retrofit installation challenges in single and multi-family applications
- Collect information on existing state or utility sponsored incentive programs targeting tankless water heaters
- Contact plumbers to determine representative installed costs for tankless water heaters, maintenance issues, market barriers

Experimental Procedure and Results

The focus of this project was assessment of existing data and resources and therefore did not directly result in monitoring. However two prior Davis Energy Group monitoring projects did play a key role in the savings estimation methodology presented here and are therefore briefly summarized here.

A 2003 field test completed with the support of the Building America program was used to develop relationships between load and efficiency for both a conventional gas storage water heater and a gas tankless unit. In this test, Davis Energy group monitored a storage water heater in a single family residence (working couple household) for 29 days, and then replaced it with a tankless water heater which was monitored for an additional 19 days. The storage water heater was ten years old at the time with an estimated 0.55 Energy Factor. The replacement tankless unit had an Energy Factor of 0.82. Detailed monitoring was installed to measure temperatures, hot water flow rates, and gas consumption of the water heater. Figure 4 depicts the monitoring installation. Solar hot water and fan coil heating operation were disabled during the Fall 2003 monitoring period.

[20] Personal communication with SEGWHAI project director Marshall Hunt.

Figure 4: Field Site Monitoring Installation Schematic

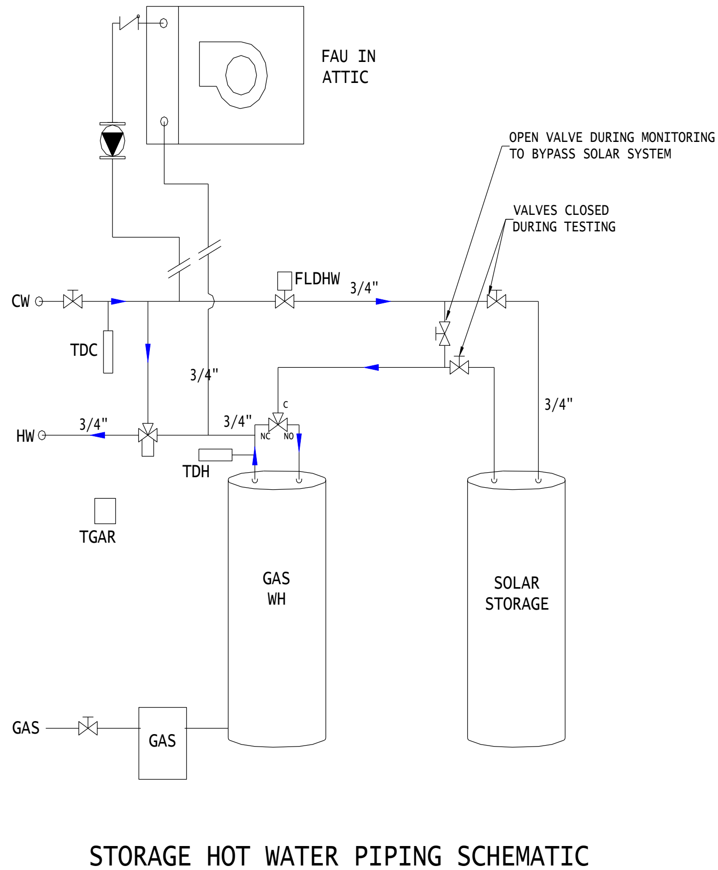
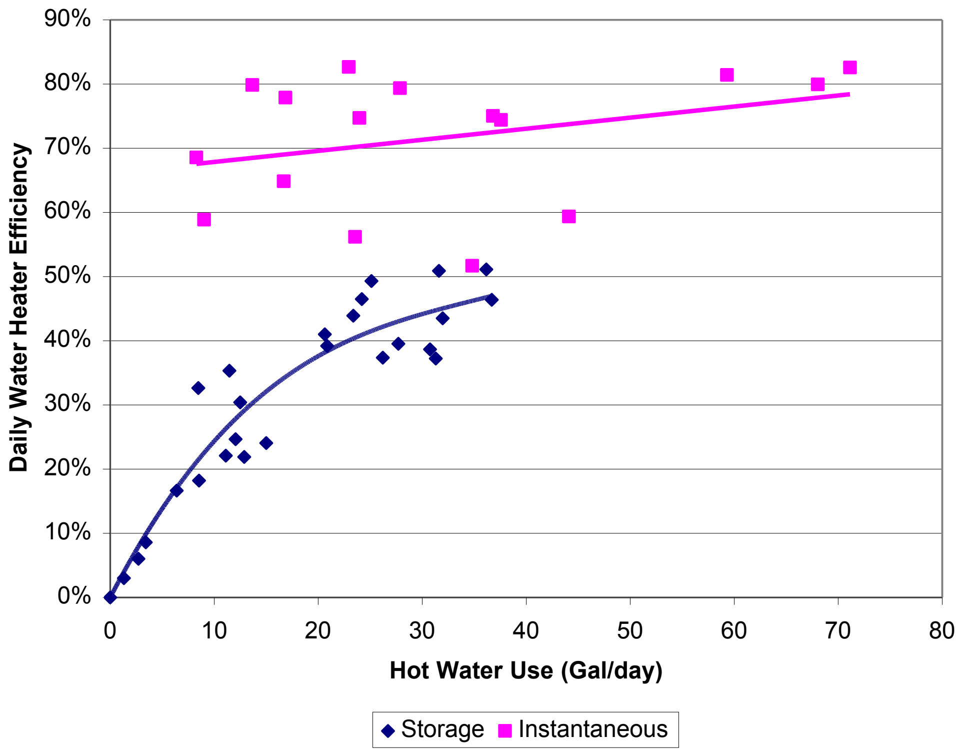


Figure 5 plots measured daily efficiency (heat delivered from the water heater divided by gas energy consumption) vs. the daily quantity of hot water drawn. The solid lines in Figure 5 are regression fits to the measured data points. The relationship between hot water use and efficiency (as a result of standby loss) is clearly demonstrated by the storage water heater curve. Extrapolation of this curve to the 64.3 gallon per day rating point yields an efficiency that appears to approach the ~0.55 Energy Factor. The wider scatter of points for the tankless heater shows there is not as direct a correlation between efficiency and daily hot water use as for the storage water heater. The upward trend of the tankless efficiency curve is due to the fact that as daily hot water use increases, individual draws are likely to be larger, and larger draws correlate with improved efficiency due to less cycling.

In 2006 Davis Energy Group participated in a PIER-sponsored hot water research project in support of the 2008 Title 24 Building Standards. DEG completed various tasks in that project including lab monitoring of a tankless unit using a monitoring configuration similar to that shown in Figure 4. The goal of this monitoring was to determine how variations in flow rate, draw volume size, and time interval between draws affects the performance of a tankless unit. Unlike storage water heaters whose efficiency is impacted by the daily draw volume, tankless water heaters are impacted by how many times the heat exchanger is cycled, the average draw volume, and how fully the heat exchanger has cooled off between draws. Figure 6 plots test results taking these variables into account. "Hot start" draws (occurring 5 minutes after the prior draw) demonstrate higher efficiencies at low draw volumes than "cold start" draws. We applied a performance envelope based on best "hot start" and worst "cold start" performance. For example at a typical bathroom sink draw volume of 1.5 gallons, a minimum "cold start" efficiency of 49% was determined, relative to a maximum "hot start" efficiency of 70%. This efficiency disparity diminishes as the draw volume increases and effectively disappears at volumes greater than 5 gallons.

Figure 5: Field Measurements of Gas Storage and Tankless Water Heater Performance

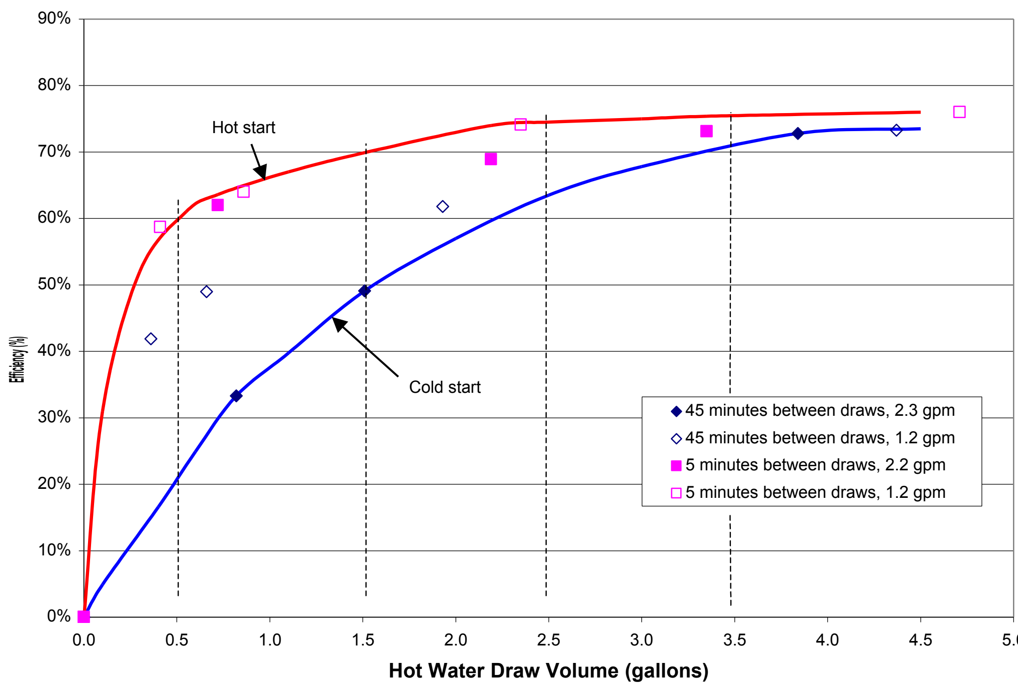


The performance data shown in Figure 6 further raises the issue of how and when hot water is consumed in a household. Although knowledge is improving in this area, typical usage profiles are not well documented. To estimate full season performance impacts a "representative" hot water load profile was developed. Table 6 disaggregates assumed daily hot water events into one gallon bins to account for draw volume size. In addition, thermal efficiencies are calculated for both "cold" and "hot" heat exchangers. Estimated efficiencies for draws of four gallons or less are based on Figure 6. From five through ten gallons, a linear interpolation is assumed. The assumption is also made that at an eleven gallon hot water draw, the efficiency of a tankless unit is equal to the rated recovery efficiency[21], in this case an assumed 81.6%. As shown in Table 7, much of the performance degradation occurs at draw volumes less than four gallons. The

[21] Eleven gallons corresponds to the approximate draw volume in the Energy Factor test (one sixth of 64.3 gallons).

difference between the cumulative "hot" and "cold" efficiency (77.3% and 70.3%, respectively) is significant when compared to the assumed nominal 81.6% efficiency. In reality, expected degradation will lie somewhere between these two points. In absence of a robust usage pattern data, we applied a 40% weighting factor to "cold start" and a 60% weighting to "hot start". The resulting seasonal efficiency is calculated to be 74.5%, or 8.8% below the nominal 81.6% efficiency. This proposed 8.8% degradation has been recommended to the California Energy Commission for derating tankless water heater Energy Factors for the 2008 Standards[22]. Derating of tankless water heaters would mitigate an added performance advantage over storage water heaters whose rated performance (Energy Factor) has been adjusted within Title 24 since 1992.

Figure 6: Tankless Efficiency Variations with Volume and Time Interval Between Draws



[22] http://www.energy.ca.gov/title24/2008standards/documents/2006-05-18_workshop/2006-05-11_GAS_WATER.PDF

Table 7: Projected Typical Tankless Performance (Cold and Hot Start)

		"Cold Start"		"Hot Start"	
Hot Water Draw Vol (gallons)	% of Total Load	Estimated Thermal Efficiency	Weighted Efficiency	Estimated Thermal Efficiency	Weighted Efficiency
1	9.0%	***21.0%***	1.9%	***60.0%***	5.4%
2	10.0%	***49.0%***	4.9%	***70.0%***	7.0%
3	7.0%	***63.0%***	4.4%	***74.0%***	5.2%
4	5.0%	***71.0%***	3.6%	***76.0%***	3.8%
5	2.0%	72.5%	1.5%	76.8%	1.5%
6	2.0%	74.0%	1.5%	77.6%	1.6%
7	1.0%	75.5%	0.8%	78.4%	0.8%
8	4.0%	77.1%	3.1%	79.2%	3.2%
9	5.0%	78.6%	3.9%	80.0%	4.0%
10	5.0%	80.1%	4.0%	80.8%	4.0%
11	6.0%	81.6%	4.9%	81.6%	4.9%
12	8.0%	81.6%	6.5%	81.6%	6.5%
13	8.0%	81.6%	6.5%	81.6%	6.5%
14	8.0%	81.6%	6.5%	81.6%	6.5%
15	5.0%	81.6%	4.1%	81.6%	4.1%
16	4.0%	81.6%	3.3%	81.6%	3.3%
17	3.0%	81.6%	2.4%	81.6%	2.4%
18	3.0%	81.6%	2.4%	81.6%	2.4%
19	3.0%	81.6%	2.4%	81.6%	2.4%
20	2.0%	81.6%	1.6%	81.6%	1.6%
Overall Efficiency			70.3%		77.3%

Project Results

Energy Savings Potential

As previously discussed, conventional storage water heater performance is strongly dependent upon daily recovery load and tankless performance is more dependent on the characteristics of the household usage profile (volumetric size of the individual draws and the time interval between draws). Davis Energy Group used a version of the Water Heater Analysis Method (WHAM) model to better understand how storage water heater performance is affected by load. The WHAM model (Lutz et al, 1999), based on the DOE water heater test procedure, allows the user to vary key parameters that affect seasonal water heater performance. These parameters include daily draw volume; inlet, ambient, and tank setpoint temperature; and key water heater performance characteristics (recovery efficiency, tank volume, standby heat loss coefficient, and rated input). Tankless performance was estimated using the proposed 8.8% EF degradation proposed for the 2008 Title 24 Standards. Figure 7 plots projected annual energy use (left axis) for a 0.60 EF fifty gallon storage water heater and a 0.82 EF tankless water heater as a function of daily recovery load. Tankless savings, both in terms of annual therms and percentage savings, are shown on the right hand axis.

Figure 7: Project Water Heater Performance as a Function of Daily Recovery Load

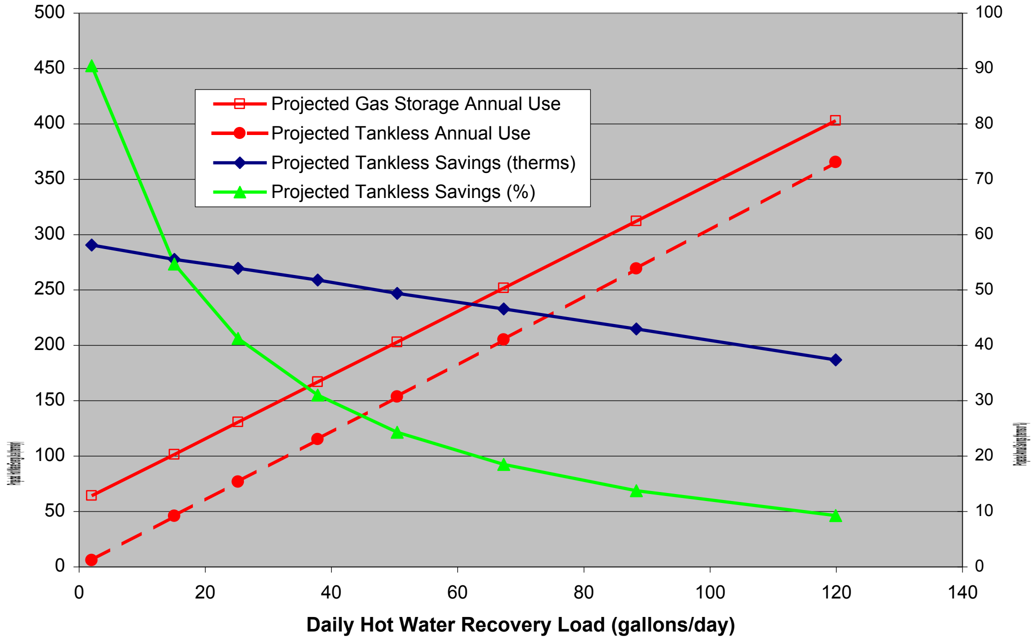


Figure 7 clearly shows the impact of standby inefficiencies at low recovery loads. In contrast to tankless water heater that shows negligible gas consumption at a 2 gal/day recovery load, the storage unit is projected to consume ~ 60 therms per year. As recovery load is added, the additional load is met at the recovery efficiency of the water heater (~78%) for the storage case and at the derated efficiency of 74.7% [23] for the tankless unit. Tankless savings diminish with increasing recovery load since the recovery efficiency of the storage water heater is greater than the degraded efficiency of the 0.82 EF tankless unit. Through the 40-70 gal/day recovery load range annual energy savings range from 45-50 therms/year and percentage savings range from 18-30%. These savings projections will vary based on the characteristics of the water heater and household use pattern effects.

Tankless units do consume small amounts of electrical energy both in standby mode (~5 Watts continuous) and in firing mode where a combustion air blower draws ~75 Watts. On an annual basis the electrical energy consumption typically amounts to 50-70 kWh. In addition, outdoor tankless units have anti-freeze controls that will add additional electrical energy use. Limited monitoring at sites in Borrego Springs, CA found anti-freeze usage totaling 2-4 kWh/week during a cold January 2007 weather spell (lows close to freezing) suggesting that further monitoring is needed to assess this impact in colder regions of California.

Table 8 summarizes projected energy impacts as a function of recovery load. Homeowner cost savings are calculated based on current PG&E residential gas and electric rates (G-1 and E-1). Gas savings were assumed to accrue at the monthly average second tier gas rate over the past twelve months ($1.33 per therm) and added electric consumption was factored at the second tier rate level ($.13 per kWh). For the typical California household, annual therm savings of 47.0

[23] 74.7% = 0.82 EF times 0.912 to account for 8.8% derating for cycling effects.

therms are projected with an increased electrical usage of 57 kWh. Combined annual cost savings of $55 are projected.

Table 8: Projected Household Annual Energy and Cost Impacts

Number in Household	Assumed Recovery Load (gal/day)	Gas Savings (therms/year)	Increased Electrical Use (kWh/year)	Annual $ Savings
1	21.8	54.5	50	$66
2	43.6	50.7	56	$60
3	65.4	46.9	62	$54
4	87.2	43.1	69	$48
2.92*	**63.6**	**47.0**	**57**	**$55**

* average CA household size according to U.S. Census Bureau 2005 American Community Survey

DEER presents tankless ("point of use water heater") savings of 28.1 and 25.3 therm/year for PG&E single and multi-family applications. Presuming this is based on the total water heating energy use (including clothes washer and dishwashing), annual tankless savings are ~20%. These savings are slightly lower than the Davis Energy Group estimates and when combined with the lower baseline usage result in only about 60% of our projected savings.

Limitations in Applicability

Tankless gas water heater performance is more strongly affected by household usage characteristics (number of draws, draw volume, and draw pattern) than a storage water heater. The 8.8% performance degradation assumed in the tankless savings estimation covers the first order effects of cycling and use pattern. We expect that site-by-site variations may affect the overall efficiency by a few percentage points, resulting in slightly higher or lower savings. Further field testing and operational testing at PG&E's San Ramon test facility will provide additional results to refine this estimate.

Incremental Costs

Typical incremental new construction and retrofit costs are estimated at $950 and $1450, respectively. For new construction, these costs will vary slightly with the make and model of the unit to be installed. Retrofit costs are much more variable as issues with gas line sizing could easily add $500 or more to the $1450 installed cost estimate. Additional site uncertainties could raise venting and electrical costs, complicate the installation process (need for a larger gas meter), and in some extreme cases require upsizing the gas line to the house. A careful assessment by a licensed plumber is necessary to evaluate installation details.

Product Service Life

The lack of extended field experience with the new generation tankless units precludes an accurate assessment of service life. The EERE website suggests a 20 year service life for tankless units. Primary failure modes would appear to be maintaining the heat exchanger (removing scale deposits) and electronic controls. Limited anecdotal data from plumbers and builders suggest limited problems to date. Several more years of field experience will be useful in determining how tankless units perform over time.

Discussion

Installation Challenges and Market Barriers

The primary market barriers faced by tankless water heaters are higher first cost and market unfamiliarity. A number of installation challenges also affect market acceptability. Market players, including manufacturers, building officials, and plumbing contractors were contacted to identify these challenges. Each of these groups had a different perspective on issues confronting the market for tankless systems.

The new construction market offers more favorable cost situation than retrofits since the key cost factors affecting tankless economics (gas line sizing, venting, and electrical accessibility) have minimal cost impacts in new construction. The greatest cost factor in retrofits is upsizing the existing gas line size, which is typically 1/2" for storage water heaters but must be increased to 3/4" or 1" for tankless systems because of their higher heating capacity. Also, tankless heaters cannot be connected to the Type B commonly vents used with storage water heaters due to potential vent corrosion concerns.

The following list of barriers was compiled from interviews with manufacturers, contractors, and building officials. Some of the identified barriers apply only to retrofit installations while some apply to both new and retrofit installations. Barriers are listed based on our perceived ranking from most significant to least significant.

1. Cost is the single greatest barrier, mentioned by everyone interviewed
2. Because of their higher gas input rating, tankless heaters require 3/4" or 1" piping, depending on the distance from the meter to the heater, compared to the ½" pipe size required for most tank-type water heaters. The incremental cost for installing larger diameter pipe for new construction is minimal. For retrofit applications the existing line will typically need to be replaced, and this cost may exceed the cost of the tankless heater.
3. Indoor installations require a Category 3 stainless steel exhaust vent. This code requirement contributes to the cost barrier. Minimal vent piping is required for indoor units vented through an exterior wall, and outdoor units do not require venting.
4. Unlike gas-fired storage water heaters, tankless units require 120-Volt power. The cost impact in new construction is minimal. For retrofit applications the cost will vary depending on whether there is an existing outlet within 6' of the heater (the maximum length allowed for appliance cords).
5. Most tankless water heaters will not operate during a power outage. This fact may not be recognized as a barrier initially, but negative homeowner experience with loss of hot water during power failures could eventually impact the market. Although California

utilities are probably less affected by weather induced outages than other regions of the country, consumers need to be aware of the potential.

6. Periodic maintenance is recommended by manufacturers to remove water deposits from the heat exchanger. This involves isolating the water heater from the hot & cold water system and flushing the heat exchanger with a mild acid solution. The frequency of maintenance depends upon the local water quality; in areas with extremely hard water flushing may be required annually. The cost per service interval ranges from zero (for do-it-yourselfers) to about $100. If not flushed, tankless heaters may fail in several years, depending upon water quality. Some units include a diagnostic output that alerts the homeowner when the heat exchanger needs to be flushed.
7. Specialized training is required for proper installation and servicing of tankless heaters. No such training is required for gas storage water heaters. While manufacturers offer training classes, contractors have little incentive to attend if they seldom encounter tankless heaters in the field.
8. Lack of widespread homeowner and contractor experience with tankless water heaters diminishes their confidence in performance and durability.
9. Tankless water heaters require about 10 or 20 seconds to provide sufficiently hot water to satisfy user requirements. If there are already long waiting times for hot water delivery to remote fixtures (because of poor piping design), the added waiting time could make delivery times unacceptable. This problem is more significant in retrofit applications where the owner has prior experience with the waiting time associated with their storage water heater.
10. One vendor noted that the building department in his area does not allow tankless heaters. While there is nothing in the Uniform Plumbing Code to prohibit tankless heaters, lack of building official understanding is still a barrier.
11. Tankless water heaters can be purchased from "big box" retailers by owner-installers, but vent kits are only offered through wholesalers, preventing owners from installing indoor units without contractor participation. A potential safety concern may exist with homeowners installing these units with sub-standard venting.
12. Because they lack water storage that serves as a buffer to hot water use, tankless water heaters require more careful sizing than storage-type heaters. Under-sizing has led to experiences of inadequate hot water delivery when multiple fixtures are in use, and has generated a small population of dissatisfied users. This barrier can be overcome by education.
13. Some of the building professionals interviewed felt that the largest market for tankless water heaters is luxury homes where unlimited hot water volume is more important than reducing hot water use energy use. If this is an accurate assessment, then rebates may serve mainly affluent customers who would have installed the tankless units anyway. The unlimited supply of hot water could result in "take-back" stemming from longer showers or increased use of jetted tubs, diminishing overall energy savings.
14. When tankless water heaters are used with hot water recirculation systems that use motion sensors or pushbuttons to activate the recirculation pump, the pump may shut off before the hot water draw begins. Because of the startup delay of the water heater, the

user may experience a stream of hot water followed by a brief stream of cold water (while the heater is firing), followed again by hot water. Education of the owner on the proper timing for activating the pump can prevent dissatisfaction with the tankless heater.

15. Tankless water heaters require a minimum flow rate (usually 0.5 to 0.75 gpm minimum) to operate. Under rare circumstances this minimum flow rate may require users to change their hot water use habits and could increase hot water usage. On the contrary, accidental demand for hot water from improperly positioned single lever faucets may result in hot water flow less than the 0.5 gpm threshold, thus eliminating hot water flow that would occur with a storage gas unit.
16. Contractor estimates for the percentage of existing homes that are candidates for tankless heaters ranged from 25% to 50%.

A final potential barrier that may affect gas utilities such as PG&E is the impact widespread tankless penetration may have on the gas distribution system infrastructure. As shown in Table 2, most residential tankless units have input capacities in the 150,000 – 200,000 Btuh range, or four to five times higher than typical gas storage units. Although tankless units are more efficient than storage units, high load situations such as several showers coincident with winter morning furnace operation may result in peak loads exceeding the local gas infrastructure. It is difficult to accurately quantify this problem without a better understanding of how common simultaneous hot water loads are during morning furnace setup operation. Although the modulating capacity control capability of the modern tankless units is beneficial in regulating the Btu requirements[24], the potential does exist for simultaneous loads that may cause the unit to operate at full rated input capacity. Better data is needed on hot water draw patterns before the potential of peak demand impacts can be assessed.

New construction applications with tankless water heaters may typically require a larger gas meter. Similarly customers retrofitting a system may have to increase their meter size (at no cost to the homeowner in PG&E territory). This requires the plumber to plan ahead and properly assess the sizing situation since typical gas meter replacement may take a few weeks. A bigger concern is whether the gas line to the house is adequately sized. If the gas line were found to be undersized, the homeowner would be liable for the significant expense associated with upsizing the line. The likelihood of the gas line being undersized is remote, but needs to be evaluated.

<u>Plumber Survey Results</u>

Approximately fifteen plumbers were contacted via phone to assess tankless issues related to cost, performance issues, reliability, and maintenance. Of the original 15 contacted, seven plumbers (three in the greater Sacramento area and four in the Fresno/Bakersfield area) responded to our survey questions. One of the seven had only installed three units and wasn't expecting to install units in the coming year. Three of the seven had installed more than 50 units to date. One survey question addressed how many units they installed in the prior year and how many they anticipated installing in the year ahead. The six active plumbers expected to increase tankless installations from 238 (current year) to 451 in the coming year.

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[24] Testing completed at the Davis Enegy Group lab at a 1.2 gpm flow rate and 61°F inlet water temperature resulted in a gas demand of 46,350 Btu/hour, or only 15% higher than a standard 40,000 Btu/hour storage water heater.

None of the plumbers reported any negative feedback on the performance of tankless units they had installed. They all gave the units favorable reviews in terms of overall reliability with only one reporting a significant operational problem, apparently related to a faulty circuit board that was ultimately replaced. In terms of maintenance issues, only two of the seven reported that they have done service work on tankless units. Maintenance work involves heat exchanger flushing with a mild acidic solution to remove scale deposits. This is typically done on a one to two year time interval[25] depending upon local water quality.[26] Several of the contractors reported poor water quality in their area, although there was no consensus on whether water softeners should be installed to reduce scaling potential. Some plumbers aggressively promote water softeners to prospective buyers, while others do not.

Market Potential

A variety of sources were relied on to characterize the market potential, including the National Association of Home Builders, Construction Industry Research Board data, and gas storage water heater sales reported by *Appliance* Magazine. Installed cost estimates were obtained by interviewing a production homebuilder, surveying plumbers, and gathering data from other studies. Retrofit costs are difficult to define because of the wide variety of site conditions encountered such as size of existing gas piping, and the ability to accommodate venting and provide electrical power.

The 2004 Davis Energy Group PG&E study based new construction market potential on 2002 NAHB California data and 2003 Construction Industry Research Board data provided to the California Energy Commission. These datasets were averaged to provide projected 2004 single and multi-family housing start estimates of 115,000 and 39,000, respectively. 2005 Construction Industry Research Board data presented during the current Title 24 proceedings[27] shows 155,000 single family and 53,000 multi-family starts in 2005. Using an average of these three data points to represent near term construction trends, we estimate single and multi-family starts of 130,000 and 44,000, respectively, over the next few years. Conservatively estimating that 83% of these housing units (Table 1) will have natural gas available and that 80% of the multi-family units will be served by individual water heaters instead of central boiler systems, results in annual new construction potential of approximately 108,000 single-family and 29,200 multi-family units.

As indicated in Table 1, there are nearly 10 million gas water heaters in California, the great majority of which are storage units. Although the September 2006 *Appliance* magazine estimates an average 9 year service life for storage type water heaters, PG&E survey data estimates that 21% of the existing stock of gas water heaters are eleven or more years old and 7.4% (one out of 13.5 units) are less than a year old (PG&E, 1997). These data suggest a 13-year service life is more representative of typical California water heaters.

Appliance Magazines 2006 Statistical Review indicates that nationally 4,618,338 gas water heaters were shipped in 2006. Factoring national shipments by California's 12.1% share of national population indicates California shipments totaling 558,800 units. Since California's

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[25] Estimated service call cost of $70 and $100 from the two respondents.
[26] Extra valves are required to allow flushing to be done without having to shut off the house water supply.
[27] http://www.energy.ca.gov/title24/2008standards/documents/2006-03-28_workshop/2006-03-27_RES_STARTS-PROTOTYPES.PDF

83% share of gas water heaters is significantly higher than the 50/50 gas/electric national split, proportioned California shipments would total 927,600 or nearly 20% of the national gas water heater sales. Apportioning the California replacement market shipments results in estimates of 505,900 single family and 245,000 multi-family replacement units[28].

Not all existing gas storage water heater installations are candidates for replacement by tankless water heaters. Tankless heaters require larger gas lines than storage types, and in many cases replacing gas lines will be prohibitively expensive. This is particularly true in larger multi-family buildings, where gas lines typically travel long distances through framing. With this constraint, we estimate that only 5% of multi-family water heater replacement projects annually represent feasible retrofit applications. The feasibility of single-family retrofits is considerably higher and is estimated at 20% of the annual gas water heater replacements.

Table 8 summarizes annual gas tankless technical savings potential based on reaching 100% of the non-central water heating new construction market, 20% of the single family retrofit market, and 5% of the multi-family retrofit market. Per unit savings are based on projections estimates of new construction and retrofit market potential for tankless water heaters in California. Savings are based on the assumed 47.0 therm savings identified for the average California household and amount to 11.8 million therms per year. In terms of added electrical usage, the statewide impact is estimated at 14.3 GWH/year. Table 9 estimates the savings potential within PG&E service territory. The PG&E gas savings are estimated at 4.5 million therms per year with added electrical consumption equal to 5.4 GWH/year.

Table 8: Projected Tankless Gas Water Heater Statewide Savings Potential

Housing Segment	New Construction (units/yr) Market	New Construction (units/yr) Savings*	Retrofit (units/yr) Market	Retrofit (units/yr) Savings*	Total Annual Savings*
Single Family	108,000	5.1	101,200	4.8	9.9
Multi-family	29,200	1.4	12,200	0.6	2.0
Total	137,200	6.5	113,400	5.3	11.8

* Savings in millions of therms.

Table 9: Projected Tankless Gas Water Heater PG&E Savings Potential

Housing Segment	New Construction (units/yr) Market	New Construction (units/yr) Savings*	Retrofit (total units) Market	Retrofit (total units) Savings*	Total Annual Savings*
Single Family	41,200	1.9	38,600	1.8	3.8
Multi-family	11,100	0.5	4,700	0.2	0.7
Total	52,300	2.5	43,300	2.0	4.5

*Savings in millions of therms.

[28] The California Energy Commission estimates that 64% of California households are single-family dwellings, 31% are multi-family, and 5% are mobile homes.

The 250,000 unit per year volume identified in Table 8 represents our estimate for tankless technical potential in California. According to the 2007 GTI study, annual tankless sales are estimated at 1-2% of the gas storage water heater market, amounting to approximately 11,000 units per year sold in California based on population weighting. Given the higher saturation of gas water heaters in California and the state's reputation as an early adopter of new technologies, actual sales are likely higher. The GTI study references the 2000 and 2005 RLW Analytics CLASS studies that indicate tankless penetration rates went from 0% in 2000 to 1.4% in 2005. This equates to 140,000 units installed over the five-year period, or an average of 28,000 per year. Since tankless market activity is on the upswing, the current tankless installation rate could be as high as 35,000 to 40,000 units per year.

Builder Economics, Homeowner Economics, and Incentives

Builder Economics

Under current Title-24 Standards, builders can obtain credits by installing energy features more efficient than an assumed standard. Tankless water heaters generate Title-24 credits that can used to trade off against other measures than may be necessary to achieve compliance. This credit has value to the builder in terms of providing flexibility in demonstrating compliance, potentially offsetting additional investment in other required energy features, and also helps the builder move towards the performance necessary for Federal credits and utility incentives. To quantify the Title-24 benefit under the 2005 Standards, MICROPAS runs were completed for 1,600 and 2,600 ft^2 houses with both standard and tankless water heaters. For the smaller 1,600 ft^2 house, the water heating budget was reduced by 35% generating a credit of 4.8 source TDV/ft^2-year[29]. For the larger 2,600 ft^2 house, the water heating budget is reduced by 29% resulting in a 2.9 TDV/ft^2-year credit[30]. In comparison, a 90% AFUE condensing furnace would generate a credit of 1.92, or only 40% the size of the tankless credit for the 1,600 ft^2 house in Sacramento (climate zone 12). Credits of this magnitude have, and will continue to attract attention from builders.

Because of increased pressure from local governments to the mitigate the environmental impacts of new developments, developers and builders are finding it expedient to include measures which go beyond Title 24, including designing homes to ENERGY STAR and LEED standards. Improving water heater efficiency is one more tool builder/developers can use to earn entitlements for new development by demonstrating improved efficiency and reduced carbon emissions.

Customer Economics

Tankless water heaters offer significant savings relative to gas storage water heaters due primarily to eliminated standby losses, but also due to slightly higher combustion efficiencies.

[29] TDV, or "time dependent valuation", is the metric used to value electricity, natural gas, and propane on an hourly basis with the Title 24 Building Standards.

[30] The way Title 24 is structured, water heating measures have a far greater impact on smaller houses than on larger houses. For houses above 2,500 ft^2, water heating loads are capped, resulting in further reduction in the impact of any efficiency measure.

Typical savings are projected at $55 per year at current gas and electric rates. Savings will vary slightly with hot water load, installed equipment, and what the customer's marginal electric and gas rates are on the PG&E tiered rate structure.

To determine overall cost effectiveness 2004 PG&E study costs were updated by surveying seven plumbing contractors through the Central Valley. 2004 new construction costs were obtained from two builders that have installed a few units and do not represent mature production costing. Both builder estimates indicate an incremental cost of close to $1,000. An $1,100 incremental cost to the home buyer was calculated assuming 10% builder overhead and profit. Three of the seven plumbers interviewed for this update study had some experience with new construction installations. New construction incremental costs ranged from $800 to $1000 for Plumber A, $500 to $1000 for Plumber B, and $700 to $1200 for Plumber C. An average $867 was calculated based on these three estimates. 10% builder markup raises the average cost to the homeowner to $950. Table 10 presents new construction homeowner economics (ignoring mortgage interest benefits) for a standard 30 year fixed rate loan at various interest rates and incremental costs based on the projected $55/year savings.

Table 10: Projected Annual Homeowner Cash Flow (New Construction Case)

Incremental	Interest Rate			
Cost	5%	6%	7%	8%
$300	$36	$35	$31	$29
$600	$16	$12	$7	$2
$900	($3)	($10)	($17)	($24)
$1200	($22)	($31)	($41)	($51)
$1500	($42)	($53)	($65)	($77)

At the $950 incremental cost level, all the scenarios shown demonstrate slightly negative cash flow. However the current Federal tax credit[31] and incentives through PG&E's new construction program[32] could provide up to a $500 incentive to the builder, with some portion of that going to the homebuyer. A final factor that may improve tankless economics in the next year is expected appearance of low NO_x storage water heaters designed to meet South Coast Air Quality Management District Rule 1121 emission requirements for small gas storage water heaters. These units should appear in the 4th quarter of 2007 and industry experts suggest that compliance with these tighter emission requirements may add up to $125 per storage water heater. Other California air quality districts are also considering adopting Rule 1121 requirements[33], bringing the higher cost storage water heaters into PG&E service territory. Tankless units currently do not have to meet the stringent 1121 requirements, although a proposed 2012 requirement would require emissions improvements in tankless units.

[31] Provides a $300 credit through 2007 for tankless units with an EF of 0.80, or greater.
[32] Tankless incentives of $200 for qualifying installations. For more details go to http://pge.com/res/energy_tools_resources/efficient_new_homes/info_for_builders/index.html
[33] Personal communication with Marshall Hunt

For the 2004 PG&E study, retrofit installed costs were obtained from a local plumber who had completed a modest number of installations. For the best case scenario[34], an $1,100 incremental cost over a standard storage water heater replacement was estimated. Actual costs may easily be twice that depending upon site-specific issues related to water heater location, gas line sizing, and other issues[35]. Additional retrofit costs obtained from the 2006 plumber survey suggest an average incremental cost of $1375, although the four leading volume contractors contacted all indicated high-end incremental costs of $1600 to $1800. The 2005 Oregon Energy Trust report found an average incremental cost of $1471 based on several hundred units installed in both new construction and retrofit situations. Given the high degree of variability in retrofit situations, we estimate an additional $500 in cost over the $950 new construction cost estimate ($1450 total). The $300 Federal tax credit would reduce the $1450 incremental cost to about $1150, resulting in a ~ 20 year simple payback.

As with any manufactured product, increased demand will eventually translate into lower costs as the technology achieves full maturity and the installation market becomes more competitive. Other factors such as rising gas costs and higher costs for NO_x compliant units will improve economics.

Federal Tax Credit and Utility Program Incentives

The Energy Policy Act of 2005 included at $300 tax credit for efficient water heaters with Energy Factors or 0.80 or greater. Most tankless units qualify for this credit. The credit is currently slated to expire the end of 2007, however there is a reasonable possibility that the credit will be extended although it is not clear if, or how, details related to water heaters will change.

The 2007 GTI literature review completed a thorough review of current residential incentive programs for tankless water heaters. The utility incentives being offered often have short periods of availability. Several of the identified programs include:

- PG&E, Southern California Gas, and SDG&E all offer new construction incentives of $200 per unit for both single and multi-family qualifying applications. Qualifying units must have a minimum EF of 0.80 and no standing pilot.
- Oregon has a maximum $350 tax credit for tankless units with an EF of 0.80 or greater.
- TECOS Peoples Gas in Florida is offering up to $525 for a tankless gas water heater that replaces an existing electric storage water heater. A $450 incentive is offered for replacing a gas storage water heater.
- All GasNetworks[36] utilities are offering a $300 rebate for tankless gas water heaters with an EF of 0.82 or greater.
- Avista Utilities in Washington and Idaho is offering a $25 incentive for 0.65 EF or greater gas water heaters.

[34] Assumes existing water heater is on exterior wall to facilitate venting, electrical outlet is available, and gas line sizing is adequate.
[35] For the Building America site where the storage water heater was replaced with an instantaneous unit, installation costs (excluding the Rinnai unit) were $1,350.
[36] GasNetworks includes several New England natural gas suppliers

Conclusions

Tankless gas water heaters represent a rapidly emerging technology in California. Sales in California appear to be climbing through a combination of successful industry marketing, Federal and utility tax credits, Title 24 credits, and generally favorable reviews from the marketplace. The economics appear favorable for typical new construction applications assuming available incentives make their way to the homeowners. Long term reliability of these units appears favorable, but additional field experience is needed to validate system reliability.

Features in the newer generation of tankless heaters such as variable burner capacity and sophisticated controls have significantly improved delivery temperature characteristics under a range of flow rates. Elimination of standing pilots has also significantly improved the standby performance of tankless units.

The primary market barrier is first cost, due to both higher equipment and installation costs. The estimated incremental cost for new homes of $950 may be justified based on a positive cash flow for the homebuyer, builder Title 24 advantages, and developer entitlement advantages. In addition Federal tax credit incentives and utility new construction incentives further improve tankless economics. The economic picture for retrofit applications is less favorable due to higher installation costs.

Projected annual savings under typical hot water load assumptions range are estimated at $55 per year. For single-family new construction, the estimated $950 incremental cost translates to a monthly increase in mortgage costs less than the projected gas savings. Retrofit applications demonstrate simple paybacks in the 20 year range. Variations in site conditions may significantly affect retrofit economics.

Recommendations for Future Work

In collaboration with other stakeholders and utilities, PG&E should consider performing detailed testing on a wide range of tankless units currently on the market given the increasing interest in tankless water heaters. The PG&E San Ramon water heater operational characteristics test facility is an ideal site for testing tankless and storage water heater performance under a variety of load and use pattern assumptions.

In collaboration with other stakeholders and utilities, PG&E should support efforts to collect improved data on hot water use patterns and load magnitudes to improve the understanding of gas tankless units' "real world" performance. Improved understanding of hot water load patterns would allow PG&E to better assess the winter peak load situation where tankless units may operate at full burner capacity coincident with morning furnace setup operation.

In collaboration with other stakeholders and utilities, PG&E should develop a simple computer model to represent tankless performance based under varying load pattern assumptions. Test results collected at the San Ramon facility could be used to develop this model.

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