CODES AND STANDARDS ENHANCEMENT INITIATIVE (CASE)

High-efficiency Water Heater Ready

2013 California Building Energy Efficiency Standards

California Utilities Statewide Codes and Standards Team

October 2011

This report was prepared by the California Statewide Utility Codes and Standards Program and funded by the California utility customers under the auspices of the California Public Utilities Commission.

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1. Overview

a. Measure Title	Residential Gas High-efficiency (HE) Water Heater Ready

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Description</td>
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Adoption of HE water heaters will be greatly accelerated by federal and local regulations:

The new federal residential water heater standards, which will take effect in April 2015, require gas storage water heaters larger than 55 gallons to be condensing type and require instantaneous (tankless) water heaters to be power vented. Within the next 30 years, the federal efficiency standards for all gas-fired water heaters are likely to require condensing water heaters, or at least HE power vent models.
More than 77% of California (based on population) is required to install low-NOx water heaters. Low NOx Energy Star water heaters requires electrical power connection.

A CPUC market evaluation study revealed that tankless water heaters had a 24% market penetration in 2008. The water heater industry projected that the growth rate for tankless water heaters would be more than 10% per year.
Given the existing regulatory requirements and market trend, homes built today should be prepared for future upgrades to HE water heaters.
This CASE study proposes that new construction homes shall be equipped with the following water heater supporting components to help reduce future water heater upgrade costs and to encourage installation of HE water heaters.

A 120V electrical receptacle close to the water heater
A Category III or IV vent, or a Type B vent with a straight pipe between the outside vent termination and the space where the water heater is installed
A condensate drain line
A gas supply line with a capacity of at least 200kBtu/hr to support the installation of a tankless water heater

This CASE study demonstrates the cost effectiveness of the above measures in two scenarios:

If the measures are installed with a condensing storage water heater or a tankless water heater with energy factor (EF) rating higher than 0.82, the overall system is cost effective.
If the measures are installed with a standard-efficiency water heater, the avoided future retrofit costs to accommodate a HE water heater required by future regulations are much higher than the initial incremental costs of these measures.

This CASE study also investigated the possibility of enhancing the existing Title 24 water heater blanket requirement. However, it was found that installing a thicker water heater blanket is not cost effective.
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c. Type of Change	The proposed changes are mandatory requirements applicable to DHW systems in single-family homes and DHW systems serving individual dwelling units in multi-family buildings.
d. Energy Benefits	The proposed changes will encourage the installation of HE gas-fired water heaters, especially condensing storage and tankless water heaters in both new construction buildings and for future water heater replacement. The corresponding natural gas energy savings are calculated based on the following assumptions: ◆ Prototype building: 2500 sqft single-family home ◆ Water heater load: 2008 Title 24 RACM Appendix E ◆ Water heater efficiency: several efficiency level based on DOE water heater efficiency rulemaking documents ◆ Baseline (for all scenarios): a 40-gallon natural draft storage water heater just meeting the new federal residential water heater efficiency standards, or EF = 0.615. Section 3 Analysis and Results provides energy savings in different climate zones. The following table presents the average energy savings for the prototype single-family buildings with water heaters at different efficiency levels.

Water Heater Type	Electricity Savings (kwh/yr)	Demand Savings (kw)	Natural Gas Savings (Therms/yr)	TDV Electricity Savings	TDV Gas Savings (KBtu/yr)
Gas-fired Storage Water Heater					
EF = 0.63	None	None	5.7	None	919
EF = 0.64	None	None	9.4	None	1507
EF = 0.65	None	None	12.9	None	2078
EF = 0.67	None	None	19.7	None	3168
EF = 0.77	None	None	48.4	None	7767
Gas-fired Tankless Water Heater					
EF = 0.82	None	None	44.4	None	7130
EF = 0.84	None	None	49.1	None	7879
EF = 0.85	None	None	51.3	None	8240
EF = 0.92	None	None	65.7	None	10549
EF = 0.95	None	None	71.2	None	11435

Statewide first year energy savings were estimated as following:

Electricity Savings (GWh)	Demand Savings (MW)	Natural Gas Savings (MMtherms)	TDV Energy Savings (TDV kBtu)
None	None	0.150	24.1×10^{6}

e. Non-Energy Benefits	The proposed change will greatly facilitate compliance with low-NOx water heater regulations adopted by several local air quality districts, which together represents about 77% of the California population.

f. Environmental Impact

The greatest environmental impact of the proposed measure is the expected emissions reduction due to reduced natural gas use for water heating. The total impact will be estimated in the final report based on statewide energy savings estimate. The proposed change does not have any potential adverse environmental impacts.

The proposed measure will slightly increase material uses during new construction, due to the use of larger gas pipes and connectors, and installation of condensate drain pipes. However, these items will most likely need to be installed in future anyway when the water heater is upgraded to a HE model. For the retrofit upgrade, the existing vent and gas lines need to be replaced with new ones compatible with HE water heaters. The proposed changes will be able to avoid some of the replacement. Therefore, the proposed changes will reduce material uses in the long term.

The proposed changes have no direct impact on water consumption or water quality.

Material Increase (I), Decrease (D), or No Change (NC): (All units are lbs/year)

	Mercury	Lead	Copper	Steel	Plastic	Others (Identify)
Per Single family home	0	0	0.23	3.6	0.98	NC
Statewide	0	0	6837	110482	29666	NC

Water Consumption:

	On-Site (Not at the Power plant) Water Savings (or Increase) (Gallons/Year)
Per Prototype Building[2]	NC

Water Quality Impacts:

	Mineralization (calcium, boron, and salts)	Algae or Bacterial Buildup	Corrosives as a Result of PH Change	Others
Impact (I, D, or NC)	NC	NC	NC	NC
Comment on reasons for your impact assessment				

g. Technology Measures	**Measure Availability:** The proposed measures are standard practices used for HE water heater installations. The CASE study simply recommends homes to be made ready during the new construction phase, since it costs much less to install these HE water heater supporting components during new construction than during a retrofit. **Useful Life, Persistence, and Maintenance:** All recommended HE water heater supporting components are expected to have the same useful life as the building itself. They do not require any maintenance. They will encourage building owners to choose HE water heaters because installation cost will be greatly reduced.
h. Performance Verification of the Proposed Measure	Site inspection of installation of HE water heater measures is required.

i. Cost Effectiveness

Cost effectiveness of the proposed measure is demonstrated in two different ways.

First, cost effectiveness of new construction installation of HE water heaters is investigated using the Energy Commission Life Cycle Costing (LCC) Methodology for 2013 Title 24 Standards. The following table shows the averaged LCC analysis results across all climate zones, and it indicates that condensing storage water heaters and tankless waters with EF>0.82 are cost effective during new construction. These results indicate that the proposed measures are cost effective if HE water heaters are installed during new construction. Detailed LCC results for all sixteen (16) climate zones can be found in Section 3 Analysis and Results.

a	b	c	d	e	f	g	
Measure Name – HE Water Heater Options	Mea-sure Life (Years)	Additional Costs– Current Measure Costs ($ Per Building)	Additional Cost– Post-Adoption Measure Costs ($ Per Building)	PV of Additional Maintenance Costs (PV$ Per Building)	PV of Energy Cost Savings (PV$ Per Building)	LCC Per Prototype Building ($)	
						(c+e)-f Based on Current Costs	(d+e)-f Based on Post-Adoption Costs
Gas-fired Storage Water Heater							
EF = 0.63	13	$593	$593	$0	$159	$434	$434
EF = 0.64	13	$593	$593	$0	$261	$332	$332
EF = 0.65	13	$672	$672	$0	$360	$313	$313
EF = 0.67	13	$1328	$1328	$0	$549	$779	$779
EF = 0.77	13	$1328	$1328	$0	$1345	($17)	($17)
Gas-fired Tankless Water Heater							
EF = 0.82	20	($525)	($525)	$0	$1235	($1,760)	($1,760)
EF = 0.84	20	$386	$386	$0	$1365	($979)	($979)
EF = 0.85	20	$546	$546	$0	$1427	($881)	($881)
EF = 0.92	20	$793	$793	$0	$1827	($1,034)	($1,034)
EF = 0.95	20	$1114	$1114	$0	$1980	($866)	($866)

Second, the CASE study assessed the cost savings produced by the proposed HE ready measures to demonstrate that they are cost effective even if a HE water heater is not installed with these measures during new construction. The measure incremental cost is estimated to be $133 per home. The future avoided cost savings is $1357 if the baseline water heater is upgraded to a HE model. The CASE study estimated that if more than 6.8% of 2014 homes upgrade their water heaters from a standard natural draft model to a HE model within the assumed 30-year building life, the total measure cost savings would be higher than total measure incremental cost. Water heater manufacturers already estimate a 10% growth rate for tankless water heaters, which is higher than the 6.8% threshold value. DOE will almost certain to require all water heaters to be force-draft types within the next 30 years. Therefore, the proposed change is cost effective.

j. Analysis Tools	The CASE study used an EXCEL spreadsheet tool that is based on the ACM calculation rules for single-family DHW system, as defined in the 2008 Title 24 RACM Appendix E.
k. Relationship to Other Measures	The CASE study is indirectly related to the Single-family DHW CASE study, which proposes mandatory requirements for distribution system designs. Water heater location within a home could potentially be affected by the corresponding requirements.

2. Methodology

This section describes the methodology that we followed to assess the market information, energy savings, cost and cost effectiveness of the proposed code changes. The key elements of the methodology are as follows:

- Data Collection
- Cost Analysis
- Energy Savings Analysis
- Lifecycle Cost (LCC) Analysis
- Cost Savings Analysis
- Statewide Energy Savings Analysis
- Stakeholder Meeting Process

This work was publicly vetted through our stakeholder outreach process, which through in-person meetings, webinars, email correspondence and phone calls, requested and received feedback on the direction of the proposed changes. The stakeholder meeting process is described at the end of the Methodology section.

2.1 *Data Collection*

In April 2010, the Department of Energy (DOE) adopted new residential water heater standards1 based on extensive studies of residential water heater efficiency, equipment cost, and installation cost, as well as the economic and environmental impacts from the adoption. Methodologies and findings were published by DOE as rulemaking supporting documents, and they were thoroughly vetted by all participating stakeholders. These documents represent the most recent, comprehensive, and reliable data source for residential water heater efficiencies and costs. In addition, DOE's studies included a forward-looking approach to estimate water heater costs in 2015, when the standards will become effective. The information is very relevant to the CASE study analysis as the 2013 Title 24 is expected to take effect in 2014. The CASE study team obtained the DOE rulemaking documents, including the supporting EXCEL workbooks, which provided detailed source data and calculation procedures, from the DOE website. The documents were reviewed and relevant efficiency data and cost information were extracted to support the CASE study analysis.

The CASE study team also reviewed Energy Star program information and local jurisdiction low-NO_x regulations in order to understand their impact on the market adoption of HE water heaters.

The CASE study team interviewed a broad range of industry experts and practitioners, including manufacturers, contractors, distributors, energy consultant, and researchers to seek their input on application issues, market trends and cost information.

[1] Federal Register / Vol. 75, No. 73 / Friday, April 16, 2010 / Rules and Regulations

2.2 *Cost Analysis*

Water heater equipment and installation costs were estimated based on cost information provided in the DOE rulemaking documents. The CASE study collected additional price data for gas piping components to estimate the cost difference between ½ inch and ¾ inch gas supply lines.

The installation cost for water heater vent and gas supply lines depends on the location of the water heater in the house. The CASE study estimated the vent pipe and gas pipe lengths based on typical California single-family home floor plans provide by the PIER study conducted by the Davis Energy Group on water heaters and hot water distribution systems (DEG PIER Study).[2]

Water heater blanket costs were obtained from various distributors and installation costs were estimated based on the same labor cost rates provided in the DOE rulemaking documents.

2.3 *Savings Analysis*

Energy savings per home were calculated by comparing annual natural gas consumption of different water heater options to the federal minimum efficiency baseline water. The hourly hot water draw schedule and distribution loss multipliers were obtained from the 2008 Title 24 Residential Alternative Calculation Manual (RACM) Appendix E. The prototype building is a 2,500 sqft two-story single family home, based on the typical floor plans provided by the DEG PIER Study. For each climate zone, the cold water supply temperatures were the same as ground temperature provided in the RACM, and the hot water supply temperature was 135°F according the RACM.

Energy savings from water blanket were estimated based on heat transfer analysis using data provided by an early study conducted by Laurence Berkeley National Laboratory (part of the CEC report CEC-500-2008-082, referred as LBL study hereafter). This study provides the jacket heat loss for a 40-gallon gas water heater using the TANK simulation program, the same simulation tool used by US DOE for water heater standards developments. The CASE study assessed the relative reduction of tank jacket heat transfer coefficient by a blanket, so that jacket heat loss reduction was calculated accordingly.

2.4 *Lifecycle Cost (LCC) Analysis*

This CASE study considered two types of measure cost effectiveness, the LCC of HE water heaters and the cost savings of HE measures.

2.4.1 Cost Effectiveness of High-Efficiency Water Heaters

The LCC analysis of water heaters used the methodology explained in the California Energy Commission report *Life Cycle Cost Methodology 2013 California Building Energy Efficiency Standards*, written by Architectural Energy Corporation, using the following equation:

$$\Delta LCC = Cost\ Premium - Present\ Value\ of\ Energy\ Savings$$ [3]

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[2] Water Heaters and Hot Water Distribution Systems, PIER Final Project Report, December 2008, CEC-500-2008-082, Prepared By: Jim Lutz, Lawrence Berkeley National Laboratory, Commission Contract No. 500-05-007

[3] The Commission uses a 3% discount rate for determining present values for Standards purposes.

$$\Delta LCC = \Delta C - (PV_{TDV\text{-}E} * \Delta TDV_E + PV_{TDV\text{-}G} * \Delta TDV_G)$$

Where:

ΔLCC	change in life-cycle cost
ΔC	cost premium associated with the measure, relative to the base case
$PV_{TDV\text{-}E}$	present value of a TDV unit of electricity
$PV_{TDV\text{-}G}$	present value of a TDV unit of gas
ΔTDV_E	TDV of electricity
ΔTDV_G	TDV of gas

We used a 30-year lifecycle as per the LCC methodology for residential measures. Since this CASE study only addresses gas-fired water heaters, there are no electrical energy savings.

2.4.2 Cost Savings Analysis

The basic idea of making a home HE water heater *ready* is based on the assumption that it would reduce the cost of a future installation while adding relatively little cost during the time of new construction. Therefore, in addition to the energy cost savings benefits, there are also direct cost savings expected from the measure.

There is a main difference between the evaluation of other measures and this *readiness* measure. While other measures with energy cost savings can be evaluated on a per home basis, the cost-effectiveness of this readiness measure highly depends on just how many of the homes in the state will decide to retrofit for HE water heaters within the 30 year measure life.

For HE measure cost savings, the CASE study estimated new construction and retrofit costs of the HE water heater ready measures. The incremental cost introduced by the potential code change is calculated as:

$$\Delta Total\_Ready\_Cost_{NC} = \Delta Unit\_Ready\_Cost_{NC} \times Annual\_Unit_{NC} \times (1 - e\%)$$

Where:

$\Delta Total\_Ready\_Cost_{NC}$	Statewide incremental cost due to the proposed measures ($/year)
$\Delta Unit\_Ready\_Cost_{NC}$	Incremental cost per DHW system ($/unit)
$Annual\_Unit_{NC}$	Annual new construction system ($/unit)
e%	Existing market adoption rate of HE water heaters.

The cost savings generated by the proposed measures are calculated as:

$$\Delta Total\_Avoided\_Cost_{retrofit} = \Delta Unit\_Avoided\_Cost_{retrofit} \times Annual\_Unit_{NC} \times r\%$$

Where:

$\Delta Total\_Avoided\_Cost_{retrofit}$	Statewide cost savings from the proposed measures ($/year)
$\Delta Unit\_Avoided\_Cost_{retrofit}$	Cost savings per DHW system ($/unit)
r%	Upgrade rate: percentage of homes that are expected to upgrade from a standard water heater to a HE water heater within the 30-

year building lifecycle. It includes homes that are encouraged by the code change to install a HE water heater during construction.

If $\frac{\Delta Total\_Avoided\_Cost_{retrofit}}{\Delta Total\_Ready\_Cost_{NC}} > 1$, the proposed code change is considered to be cost effective. To satisfy this condition, the retrofit upgrade rate r% should be greater than the following value according to the above-listed equations:

$$\frac{\Delta Unit\_Ready\_Cost_{NC}}{\Delta Unit\_Avoided\_Cost_{retrofit}} \times (1 - e\%)$$

2.5 *Statewide Energy Savings*

The proposed code changes will remove HE water heater installation barriers related to flue vent, power supply, condensate disposal, and gas supply. They will promote HE water heater installation during new construction as well as during water heater replacement in future. The statewide energy savings depend on the number of HE water heater installation and installed models directly due to the influence of these measures. It is difficult to quantitatively predict the effect of the proposed measures on the market in the future. To demonstrate the scale of energy savings, the CASE study estimates statewide energy savings assuming 5% increase in adoption of Energy Star™ gas storage and tankless water heaters.

The HE ready measures will also impact future adoption of HE water heaters for retrofit and replacement. Since necessary supporting components will be in place, building owners will be more likely to replace broken water heaters with a HE model. Energy savings will be generated years after new construction. The corresponding future energy savings depend on future market conditions, which are hard to predict. Similar to statewide energy savings estimation for new construction homes, the CASE study used an assumption of 5% increase in future adoption of Energy Star™ gas storage and tankless water heaters to demonstrate the level of energy savings.

2.6 *Stakeholder Meeting Process*

All of the main approaches, assumptions and methods of analysis used in this proposal have been presented for review at three public Stakeholder Meetings hosted by the California investor-owned utilities (Pacific Gas and Electric, Southern California Edison, San Diego Gas and Electric, and Southern California Gas Company).

At each meeting, the utilities' CASE team asked for feedback on the proposed language and analysis thus far, and sent out a summary of what was discussed at the meeting, along with a summary of outstanding questions and issues.

A record of the Stakeholder Meeting presentations, summaries and other supporting documents can be found at www.calcodesgroup.com. Stakeholder meetings were held on the following dates and locations:

- First Stakeholder Meeting: May 25th, 2010, San Ramon Conference Center, San Ramon, CA
- Second Stakeholder Meeting: January 19th, 2010, San Ramon Conference Center, San Ramon, CA
- Third Stakeholder Meeting: June 1st, 2011, Webinar

3. Analysis and Results

This section provides details on market data, savings estimate, cost effectiveness analysis and statewide energy savings resulting from the proposed measures.

3.1 *Data Collection*

3.1.1 Federal Residential Water Heater Standards

The U.S. Department of Energy (DOE) issued a final rule[4] in March 2010 to amend the energy conservation standards for residential water heaters. The new rules are shown in Figure 1. The new standards will be effective on April 16, 2015, while the 2013 Title 24 codes are projected to take effect in January 2014. Analysis of this CASE study is based on the new DOE standards, which will affect most of the new construction projects under the 2013 Title 24. The new DOE standards create a separate category for storage water heaters with tank volume larger than 55 gallons and the corresponding minimum efficiency can only be met by a condensing water heater. For the two popular storage volumes of 66 gallons and 75 gallons, the corresponding minimum energy factor (EF) requirements are 0.75 and 0.74 respectively, using the equation in Figure 1.

Residential water heaters*

Gas-fired Storage	For tanks with a Rated Storage Volume at or below 55 gallons: EF = 0.675 − (0.0015 × Rated Storage Volume in gallons).	For tanks with a Rated Storage Volume above 55 gallons: EF = 0.8012 − (0.00078 × Rated Storage Volume in gallons).
Electric Storage	For tanks with a Rated Storage Volume at or below 55 gallons: EF = 0.960 − (0.0003 × Rated Storage Volume in gallons).	For tanks with a Rated Storage Volume above 55 gallons: EF = 2.057 − (0.00113 × Rated Storage Volume in gallons) .
Oil-fired Storage	EF = 0.68 − (0.0019 × Rated Storage Volume in gallons).	
Gas-fired Instantaneous	EF = 0.82 − (0.0019 × Rated Storage Volume in gallons).	

Figure 1. DOE 2015 Residential Water Heater Efficiency Standards

To develop the standards, DOE evaluated several levels of water heater performance and their corresponding cost effectiveness. Figure 2 provides a summary of the different test standards levels, the corresponding EFs, and general technology requirements to meet those levels. The adopted DOE standards correspond to the level S1 of the storage type and the level I4 of the instantaneous (tankless) type. Detailed information on these test standard levels can be found in the DOE rulemaking documents available from the DOE website[5].

[4] Energy Conservation Standards for Residential Water Heaters, Direct Heating Equipment, and Pool Heaters: Final Rule, Federal Register, 75 FR 20112, April 16, 2010

[5] http://www1.eere.energy.gov/buildings/appliance_standards/residential/water_pool_heaters_nopr.html

Level	Water Heater Test Standard Levels	Energy Factor
	Gas-fired Storage Water Heater	
S0	Standing Pilot, 1” ins	0.59
S1	Standing Pilot, 1.5” ins	0.62
S2	Standing Pilot, 2” Ins	0.63
S3	Electronic ignition, 1” ins, power vent	0.64
S4	Electronic ignition, 1.5” ins, power vent	0.65
S5	Electronic ignition, 2” ins, power vent	0.67
S6	Condensing, 2” ins, power vent	0.77
	Gas-fired Instantaneous Water Heater	
I0	Standing pilot (BASELINE)	0.62
I1	Standing Pilot, Improved HX	0.69
I2	Electronic Ignition, Improved HX	0.78
I3	Electronic Ignition, Power Vent	0.80
I4	Electronic Ignition, Power Vent, Improved HX	0.82
I5	Electronic Ignition, Power Vent, Improved HX	0.84
I6	Electronic Ignition, Power Vent, Direct Vent, Improved HX, Low NOx Burner	0.85
I7	Electronic Ignition, Power Vent, Direct Vent, Condensing	0.92
I8	Electronic Ignition, Power Vent, Direct Vent, Condensing (Max-Tech)	0.95

Figure 2. DOE Residential Gas Water Heater Test Standard Level[6]

[6] Federal Register / Vol. 75, No. 73 / Friday, April 16, 2010 / Rules and Regulations, Table IV. 8 (page 10143) and Table IV. 11 (page 10145).

3.1.2 EPA Energy Star Programs for Residential Water Heaters

The US Environmental Protection Agency (EPA) introduced the new Energy Star criteria, shown in Figure 3, in 2009. For the storage type, the Energy Star criterion is equivalent to the DOE test standard level S5 in Figure 2. For the tankless type, the corresponding DOE test standard level is I4, which is also the new minimum DOE EF requirement for the instantaneous (tankless) type. For both product categories, power vent is required to meet the Energy Star EF criteria. Energy Star products are preferred by the majority of general consumers. Future homes should be built to provide proper supporting components, such as vent, electricity connection, drain disposal, and gas supply, to allow consumers to install these Energy Star water heaters.

ENERGY STAR Criteria	Energy Factor	First-Hour Rating	Warranty	Safety
Gas Storage (Ending 8/31/2010)	EF >= 0.62	FHR >= 67 gallons per hour	Warranty >= 6 years on sealed system	ANSI Z21.10.1/CSA 4.1
Gas Storage (Beginning 9/1/2010)	EF >= 0.67	FHR >= 67 gallons per hour	Warranty >= 6 years on sealed system	ANSI Z21.10.1/CSA 4.1
Gas Condensing	EF >= 0.8	FHR >= 67 gallons per hour	Warranty >= 8 years on sealed system	ANSI Z21.10.1/CSA 4.1
Whole-Home Gas Tankless	EF >= 0.82	GPM >= 2.5 over a 77°F rise	Warranty >= 10 years on heat exchanger and 5 years on parts	ANSI Z21.10.3/CSA 4.3

Figure 3. EPA Energy Star Program Specifications for Residential Water Heaters

3.1.3 Ultra-low NO_X Water Heaters

Following the South Coast Air Quality Management District (AQMD), several other AQMDs have adopted regulations to require residential water heater (<75,000 Btu/hr heat input) NOx emission to be less than 10 nanograms per joule of heat output. The South Coast AQMD also requires that tankless water heaters to have NOx emission less than less than 14 nanograms per joule of heat output or less than or equal to 20 ppm (at 3% O2, dry). These AQMDs and their jurisdiction areas are provided in Figure 4. The South Coast AQMD covers about 42% of the California population and the other AQMDs in Figure 4 covers about 34% of the California population.

Water heaters with lower NOx emission tend to be less energy efficient because ultra-low NOx burners usually have higher pressure drops than conventional burners. Ultra-low NOx water heaters also need to comply with flammable vapor ignition resistance (FVIR) requirements by using flame arrestors on the air inlet, which add additional pressure drop to the system. In an atmospheric venting, low NOx design, flue baffle pressure drop has to be reduced to compensate for the additional pressure drop caused by the ultra-low NOx burner and FVIR. This implies that flue bafflers will be less effective and thermal efficiency will be reduced. Manufacturers use three design approaches to increase the water heater efficiency in order to meet the Energy Star criteria. The first approach is to use a power vent design[7] so that flue baffle design can be optimized to meet thermal efficiency targets. This design needs a Category III or IV vent since the vent pressure is positive (see details in

[7] A.O. Smith used a small internal fan to overcome the additional pressure drop caused by the low-NOx burner.

section 3.1.5). The second design is to install a flue damper to reduce standby loss to improve the EF rating. However, water heater thermal efficiency is still lower than an equivalent water heater without ultra-low NOx features. The third design uses a power burner with an internal fan that compensates for the pressure drop caused by the ultra-low NOx burner and FVIR, while the venting still utilizes the stack buoyancy effects. The second and third approaches will work with a Type B vent (see details in section 3.1.5). For all three approaches, electrical power supply is needed to support a blower for power venting, a flue damper, or a power-burner.

AQMD	Jurisdiction Area	Regulation
South Coast AQMD	All of Orange County and the urban portions of Los Angeles, Riverside and San Bernardino counties	Rule 1121, Rule 1146.2
Bay Area AQMD	All of Alameda, Contra Costa, Marin, San Francisco, San Mateo, Santa Clara and Napa counties, southwestern Solano and southern Sonoma counties	Regulation 9, Rule 6
San Joaquin Valley Air Pollution Control District	San Joaquin, Stanislaus, Merced, Madera, Fresno, Kings, Tulare counties and the San Joaquin Valley Air Basin portion of Kern	Rule 4902
Sacramento Metropolitan AQMD	Sacramento county	Rule 414
Yolo-Solano AQMD	Yolo County and the northeast portion of Solano County, from Vacaville on the west, to Rio Vista	Regulation II, Rule 2.37
Ventura County Air Pollution Control District	All of Orange County and the urban portions of Los Angeles, Riverside and San Bernardino counties	Rule 74.11

Figure 4. California AQMDs with Low NOx Regulations

3.1.4 Market Penetration and Future Trend

Although there is not a comprehensive market study available to reveal market penetrations of HE water heaters in the California new construction market, several data sources have indicated a fast rate of market adoption. The California Public Utility Commission (CPUC) evaluation of 2006-08 IOU energy efficiency programs[8] (CPUC Evaluation Study) revealed:

"The percentage of water heaters that were instantaneous increased from 0% in homes built under the 1995 standards to 24% in homes built under the 2005 standards."

The CPUC evaluation study didn't reveal the types of instantaneous (tankless) water heaters that were installed. A standard-efficiency tankless water heater is more expensive than a standard-efficiency storage water heater and, after including the 8% efficiency discount specified by the 2008 Title 24, the standard-efficiency tankless water heater is less efficient than a standard-efficiency storage water heater. Therefore, we can expect that home builders would have installed HE tankless water heaters to gain compliance credits.

[8] Residential New Construction (RNC) Programs Impact Evaluation Volume I California Investor-Owned Utilities' Residential New Construction Program Evaluation for Program Years 2006-2008, Final Evaluation Report, Prepared by KEMA, Inc., The Cadmus Group, Inc., Itron, Inc., Nexus Market Research, Inc., February 8, 2010, Page 3-44

Water heater manufacturers also observed fast sales growth of tankless water heaters and project the future annual growth rate to be more than 10%.[9]

Using 2002-2006 shipment data from the Air-Conditioning, Heating, and Refrigeration Institute (AHRI) and market penetration goals set by the ENERGY STAR program, DOE projected the market shares of different water heaters at each EF level. Figure 5 presents the market shares of water heaters that households would purchase in 2015 in the absence of the revised DOE water heater efficiency standards. For gas-fired storage water heaters, models with EF>0.67 (Energy Star level) represent about 6.3% of the market and for gas-fired instantaneous water heaters, models with EF>0.82 (Energy Star level) represent about 90% of the market.

Increase in market adoption of HE water heaters observed in the last several years can mostly be attributed to the market condition changes, such as increased product availability, reduced product costs and promotion by utility programs. The adopted new federal heater standards will accelerate the market penetration of HE water heaters.

TABLE IV.24—WATER HEATERS: BASE-CASE ENERGY EFFICIENCY MARKET SHARES*

Gas storage		Electric storage		Oil storage		Gas-fired instantaneous	
EF	Market share (%)	EF	Market share (%)	EF	Market share (%)	EF	Market share (%)
0.59	63.9	0.90	29.8	0.53	0.0	0.62	1.0
0.62	23.4	0.91	16.8	0.54	20.0	0.69	2.9
0.63	1.6	0.92	11.2	0.56	0.0	0.78	1.0
0.64	4.8	0.93	26.1	0.58	0.0	0.80	4.9
0.65	0.0	0.94	7.5	0.60	10.0	0.82	52.4
0.67	5.3	0.95	3.7	0.62	20.0	0.84	1.9
0.77	1.0	2.0	4.0	0.66	25.0	0.85	3.9
		2.2	1.0	0.68	25.0	0.92	20.4
						0.95	11.7
	100%		100%		100%		100%

* The base-case market shares of each product class are estimated in the shipment analysis, as described in chapter 9 of the final rule TSD.

Figure 5. DOE Projection of Water Heater Market Share in 2015 (DOE Rulemaking Supporting Data[10])

The combination of federal standards, Energy Star programs, and California low NOx emission regulations will drive the market towards use of power vented water heaters or even condensing water heaters. Condensing technology is necessary in order to meet the new minimum efficiency standards for storage water heaters larger than 55 gallons, and power venting is necessary to meet the new standards for instantaneous models. Similarly, to meet the Energy Star program specifications, instantaneous (tankless) water heaters need to be at least power vented and storage water heaters need to have an EF rating equivalent to power vented models. Atmospheric combustion storage water heaters have been developed to meet the Energy Star specifications. However, for the majority of California, in order to meet both the low NOx emission requirements and Energy Star specifications, a water heater would need to be power vent type or require electrical supply to operate a flue damper or a power burner.

[9] Presentation by Mike Park of A.O. Smith at the 2011 ACEEE Hot Water Forum, May 10, 2011, Berkeley, California

[10] Federal Register / Vol. 75, No. 73 / Friday, April 16, 2010 / Rules and Regulations, Page 20160.

The market is embracing more instantaneous (tankless) water heaters as indicated by the CPUC 2006-08 IOU energy efficiency program evaluation study and industry predictions. This market trend can be attributed to several benefits of instantaneous (tankless) water heaters, such as their compact size, longer product lifetime and higher EF ratings, all of which are due to the fact that a storage tank is not used. With the new federal standards, which imply the requirement of power venting for instantaneous (tankless) water heaters, more homes will be expected to have power vent water heaters.

3.1.5 Water Heater Installation

Installation of gas-fired water heaters requires a combination of the following supporting components:

- Cold water supply
- Natural gas supply
- Venting system
- Electrical connection
- Condensate disposal system

Except for the cold water supply, the necessary combination of components depends on the type of water heater.

Natural Gas Supply

Black iron pipes are usually used for natural gas supply. Pipe sizing is determined by appliance heat input rate, natural gas pressure, and distance between the appliance and meter (with consideration of fitting pressure loss). Natural gas pressure in US home is about 7″ W.C. (or 0.25 PSI). Since heat input for residential storage water heaters is less than 75,000 Btu/hr,½ inch gas pipes are usually used. Typical residential instantaneous (tankless) water heaters have a heat input rate of 199,000 Btu/hr. While the exact pipe size depends on specific water heater ratings and building specifications, in most single-family home, ¾" gas supply lines are adequate for both storage and instantaneous (tankless) water heaters. Most new California homes have a slab-on-grade foundation, and gas pipe lines go through the concrete slab to reach water heaters from underground. For new construction, the incremental cost for a ¾-inch gas pipe is the material cost difference between ¾-inch pipes and connectors and ½-inch pipes and connectors. For retrofit upgrade, the existing ½-inch gas supply line usually is discarded and a new ¾ -inch pipe line needs to be installed separately. The corresponding costs include both material cost of ¾-inch pipes and connectors and necessary installation labor cost.

Venting System

The National Fuel Gas Code (NFGC), ANSI Z223.1[11], divides gas appliances into four categories based on vent operating pressure and the likelihood of condensation occurring in the vent. The four categories, which are used to determine which type of vent is appropriate for a given appliance, are shown in Figure 6. Negative pressure systems, also known as non-positive pressure systems, operate at static pressures that are less than the surrounding room pressure. The joints of negative pressure

[11] National Fire Protection Association, National Fuel Gas Code—2009 Edition. http:// www.nfpa.org

systems do not need to be gas tight. If vent leakage occurs, room air will be sucked into the lower pressure flue stream. On the other hand, positive pressure systems require gas tight seals. If a leak occurs in a positive pressure system, flue gases will escape into the equipment room or, even worse, into the living space causing a potentially fatal buildup of carbon monoxide.

The appliance category does not directly indicate the type of venting material needed. Nearly all residential natural draft water heaters are Category I appliance and use a 3 or 4 inch diameter double wall metal type-B vent. There are no Category II gas-fired water heaters. Most residential water heaters with power vent fall into Category III or IV, and they require different venting materials than a standard natural draft water heater. Manufacturers usually provide certified vent materials and installation specifications for their products. Plastic vent pipes, such as PVC, CPVC or ABS pipes, are typically used, although aluminum and stainless steel vents are also used for some models. Size of the vent pipe depends on heat input rating, length of the entire horizontal and vertical pipe sections, and the number of installed elbows. For residential applications, 2-inch diameter pipes are usually used. Some manufacturers require the use of proprietary concentric vent pipes, instead of generic plastic pipes.

There is not a vent product that can be used for all types of water heaters. Some stainless steel vent products, e.g. Z-Flex vents, are certified for Category I through IV applications. When they are used for a Category I natural draft water heater, 3-inch or 4-inch pipes are used. If the water heater is to be upgraded to a power vent water heater, the venting system still might have to be replaced even though it is certified for Category III and IV appliances because the new power vent water heater may only certify the use of a 2-inch diameter pipe vent.

Appliance Category	Vent Pressure	Condensing
I	Non-Positive	Non-Condensing
II	Non-Positive	Condensing
III	Positive	Non-Condensing
IV	Positive	Condensing

Figure 6. National Fuel Gas Code Gas Appliance Category

Electrical Connection

Conventional atmospheric combustion water heaters with standing pilot do not require electrical power supply while power vent water heaters require electrical power supply. As described above, water heaters that meet both the California low NOx emission requirements and Energy Star specifications also require an electrical power supply. In a typical California single-family home, water heaters are installed in the garage. Electrical receptacles are always installed in the garage, but not necessarily near the water heater. A small design adjustment would allow an electrical receptacle to be located near the water heater.

Condensate Disposal System

Condensing water heaters and many power vent water heaters require proper disposal of combustion flue condensate. Since flue condensate is acidic, it needs to go through a neutralizer, containing limestone, before being discharged. Local jurisdictions have different requirement as to where neutralized condensate can be discharged. Some allow it to be discharged to the building side walk as HVAC system condensate, while others may require it to be discharged through a trapped and primed indirect drain. Nevertheless, it is very easy to install a drain line, either to the building drain or to the side walk, during new construction. It is much harder when retrofitting, since it can be very difficult to find a drain pipe path. Holes have to be cut in walls to let drain pipe through. A condensate drain pump may also be needed to carry condensate to the proper discharge as required by local jurisdiction requirements.

3.2 *Cost Analysis*

DOE conducted extensive cost analysis to support the development of the new residential water heater standards. These costs have been well vetted with a broad range of stakeholders, including all domestic water heater manufacturers, and they, therefore, represent the best available information on average water heater purchase and installation costs. Water heater retail costs are summarized in Figure 7, and installation costs are summarized in Figure 8. DOE cost data were in 2009 dollars, and they were converted to 2010 dollar using a 6.5% discount rate, as specified by the DOE rulemaking document.

Installation costs for flue vent and gas supply line depend on water heater locations in the house. Appendix A provides six typical single-family building floor plans from the DEG PIER study. As shown in Figure 17, the average building floor area is 2517 sqft and water heaters are located in the garage. The average vent pipe length from the water heater to side wall is 11 ft. With one (1) additional foot for connecting to the outside terminator, we assumed the total vent pipe is 12 ft long. Vertical vent configurations may lead to slightly shorter vent pipe. To adequately include incremental cost, we used the slightly longer vent pipe assumption. In a similar way, the gas supply line was estimated to be 25 ft long.

Water blankets are available from most hardware stores. They are mostly made of fiber glass, which has a R-value of 3.1 per inch of thickness, with 2-inch thick being the most common product. The average price of a 2-inch blanket is $21.75 based on survey of different distributors. It should be noted that the minimum R-value required by the 2008 Title 24 section 150(j) is 12. In order to meet this requirement, two 2-inch blankets have to be installed. This CASE study assumes that it takes about 15 minutes to install water heater blanket. Using the labor rates provided by DOE to support heater standard development, the installation cost was estimated to be $18.29.

Level	Water Heater Test Standard Levels	Retail Cost
	Gas-fired Storage Water Heater	
S1	Standing Pilot, 1.5” ins	$691
S2	Standing Pilot, 2” Ins	$929
S3	Electronic ignition, 1” ins, power vent	$949
S4	Electronic ignition, 1.5” ins, power vent	$981
S5	Electronic ignition, 2” ins, power vent	$1,243
S6	Condensing, 2” ins, power vent	$1,243
	Gas-fired Instantaneous Water Heater	
I4	Electronic Ignition, Power Vent, Improved HX	$1,168
I5	Electronic Ignition, Power Vent, Improved HX	$1,775
I6	Electronic Ignition, Power Vent, Direct Vent, Improved HX, Low NOx Burner	$1,882
I7	Electronic Ignition, Power Vent, Direct Vent, Condensing	$2,047
I8	Electronic Ignition, Power Vent, Direct Vent, Condensing (Max-Tech)	$2,261

Figure 7. Water Heater Costs

	New Construction	Retrofit Upgrade	Replacement
Basic Installation			
Putting in Place & Setting up Water Heater	$233	$233	$233
Water/Gas Piping	$196	$0	$0
Trip Charge/Remove Old Water Heater	$0	$185	$185
Permit & Removal/Disposal Fees	$0	$70	$70
Venting System			
Plastic	$158	$204	$0
Type-B steel	$482	n/a	$0
Electric Connection	$0	$259	$0
Condensate Disposal			
Drain Connection	$57	$113	$0
Neutralizer Condensate Filter	$86	$86	$86
Condensate Pump	$0	$40	$0
3/4" Gas Supply (incremental cost compared to ½" pipe)	$76	$741	$0

Figure 8. Installation Cost Items

3.3 *Energy Savings Analysis*

3.3.1 High-efficiency Water Heater

The new federal residential water heater standards were used as the baseline for energy savings estimates, since they will take effect one year after the projected 2013 Title 24 effective date and are expected to affect most of the buildings covered by the 2013 Title 24.

A spreadsheet tool was developed to perform hourly hot water heating energy consumption and savings calculations. Based on the six typical single-family building floor plans presented in Appendix A, the prototype building is a single-family home with 2517 sqft of conditioned floor area, and the corresponding daily hot water demand is 56.5 gallons. Assuming the building has two stories, the distribution loss multiplier was calculated to be 1.163. The total water heater demand is $56.5 \times 1.163 = 64.7$ gallon/day. This assumption is consistent with the daily hot water draw of 64.3 gallons/day specified in the DOE residential water heater test standards. Hourly hot water draw was determined using the hot water draw schedule defined in the 2008 Title 24 Residential ACM. The residential 30-year natural gas TDV values and conversion factors were used to calculate present values of hot water heating energy savings.

Figure 9 presents the annual natural gas savings, compared to the new DOE standard for a 40-gallon storage water heater. Annul TDV energy savings are provided in Figure 10 and PV of energy savings are listed in Figure 11.

Consistent with the 2008 Title 24 RACM, EF ratings for tankless water heaters are multiplied by 92% to reflect the potential increase in hot water consumption. The discounted EFs are also included under the EF column in the result tables.

3.3.2 Water Heater Blanket

Water heater jacket heat loss is determined by tank insulation levels. According to a LBNL study (CEC report CEC-500-2008-082), the daily jacket heat loss for a 40-gallon water heater with 2-inch internal insulation is 2771 Btu/day. The R-value of water heater internal insulation is typically 8.33 per inch of thickness. Adding a water heater blanket will increase the overall tank R-value so that jacket heat loss will be reduced proportionally. Since a water heater blanket only covers part of the water heater exterior surface, we estimate the combined tank insulation R-value according to basic heat transfer principles, as following.

$$\frac{1}{R_{with\_blanket}} = \frac{\%Area\ covered}{R_{Covered}} + \frac{\%Area\ uncovered}{R_{uncovered}}$$

$$R_{uncovered} = 8.33 \times Internal\ Insulation\ Thickness$$

$$R_{covered} = R_{uncovered} + 3.14 \times Blanket\ Thickness$$

Water heater jacket heat loss with blanket can be calculated using the following formula:

$$Q_{jacket\_loss\_with\_blanket} = Q_{jacket\_loss\_without\_blanket} \times \frac{R_{without\_blanket}}{R_{with\_blanket}}$$

Or

$$Q_{jacket\_loss\_with\_blanket} = Q_{jacket\_loss\_without\_blanket} \times \left(\frac{\%Area\ covered}{R_{Covered}} + \frac{\%Area\ uncovered}{R_{uncovered}} \right)$$

$$Energy\ Savings_{blanket} = Q_{jacket\_loss\_without\_blanket} - Q_{jacket\_loss\_with\_blanket}$$

When the internal insulation is 2-inch thick, $Q_{jacket\_loss\_without\_blanket} = 2771\ Btu/day$, according to the LBNL study. When the internal insulation is not 2-inch thick,

$$Q_{jacket\_loss\_without\_blanket} = 2771 \times \frac{2}{Internal\ Insulation\ Thickness}$$

Using above equations, energy savings for 40-gallon water heater with several internal insulation thickness are estimated and presented in Figure 15, along with cost and LCC analysis results.

		Climate Zone																
Level	EF	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Average
Gas-fired Storage Water Heater																		
S2	0.63	6.2	6.0	6.0	5.8	5.9	5.7	5.6	5.5	5.5	5.5	5.7	5.8	5.5	5.7	4.7	6.5	5.7
S3	0.64	10.3	9.8	9.8	9.6	9.7	9.3	9.1	9.1	9.0	9.0	9.3	9.5	9.0	9.3	7.8	10.7	9.4
S4	0.65	14.1	13.5	13.5	13.2	13.4	12.8	12.6	12.6	12.4	12.4	12.9	13.1	12.4	12.8	10.7	14.7	12.9
S5	0.67	21.5	20.6	20.5	20.2	20.5	19.5	19.2	19.1	18.9	18.9	19.6	20.0	18.9	19.5	16.3	22.4	19.7
S6	0.77	52.8	50.5	50.4	49.4	50.2	47.8	47.1	46.9	46.4	46.4	48.2	49.1	46.2	47.9	40.0	55.0	48.4
Gas-fired Instantaneous Water Heater																		
I4	0.82 (0.75)	48.5	46.3	46.2	45.4	46.1	43.9	43.3	43.1	42.6	42.6	44.2	45.0	42.4	43.9	36.7	50.5	44.4
I5	0.84 (0.77)	53.6	51.2	51.1	50.1	50.9	48.5	47.8	47.6	47.1	47.1	48.9	49.8	46.9	48.6	40.6	55.8	49.1
I6	0.85 (0.78)	56.0	53.5	53.4	52.4	53.3	50.8	50.0	49.8	49.2	49.2	51.1	52.1	49.0	50.8	42.4	58.3	51.3
I7	0.92 (0.85)	71.8	68.5	68.4	67.1	68.2	65.0	64.0	63.7	63.0	63.0	65.4	66.6	62.8	65.0	54.3	74.7	65.7
I8	0.95 (0.87)	77.8	74.3	74.1	72.8	73.9	70.4	69.4	69.1	68.3	68.3	70.9	72.2	68.1	70.5	58.9	81.0	71.2

Figure 9. Annual Water Heater Energy Savings (Therm/building)

		Climate Zone																
Level	EF	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Average
Gas-fired Storage Water Heater																		
S2	0.63	998	956	952	936	949	910	881	893	884	885	915	930	878	915	766	1050	919
S3	0.64	1638	1568	1563	1535	1557	1494	1445	1466	1450	1452	1501	1527	1441	1502	1256	1722	1507
S4	0.65	2258	2162	2154	2116	2147	2059	1993	2020	1999	2001	2069	2104	1986	2070	1732	2374	2078
S5	0.67	3442	3296	3284	3226	3273	3139	3038	3080	3047	3050	3154	3208	3028	3156	2640	3619	3168
S6	0.77	8441	8082	8053	7912	8025	7697	7449	7552	7472	7480	7733	7867	7426	7740	6474	8875	7767
Gas-fired Instantaneous Water Heater																		
I4	0.82 (0.75)	7748	7419	7392	7263	7367	7065	6838	6933	6859	6866	7099	7221	6817	7105	5943	8147	7130
I5	0.84 (0.77)	8562	8198	8168	8026	8140	7807	7556	7661	7579	7588	7845	7980	7533	7851	6567	9003	7879
I6	0.85 (0.78)	8955	8574	8543	8394	8514	8165	7902	8012	7927	7936	8204	8346	7878	8211	6868	9415	8240
I7	0.92 (0.85)	11464	10977	10937	10745	10899	10453	10117	10257	10148	10159	10503	10684	10085	10512	8792	12053	10549
I8	0.95 (0.87)	12426	11898	11854	11647	11814	11331	10966	11118	11000	11012	11385	11581	10932	11394	9530	13065	11435

Figure 10. Annual TDV Energy Savings (kBtu/building)

		Climate Zone																
Level	**EF**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**Average**
Gas-fired Storage Water Heater																		
S2	0.63	$173	$166	$165	$162	$164	$158	$153	$155	$153	$153	$158	$161	$152	$159	$133	$182	$159
S3	0.64	$284	$272	$271	$266	$270	$259	$250	$254	$251	$251	$260	$264	$250	$260	$218	$298	$261
S4	0.65	$391	$374	$373	$367	$372	$357	$345	$350	$346	$347	$358	$364	$344	$359	$300	$411	$360
S5	0.67	$596	$571	$569	$559	$567	$544	$526	$533	$528	$528	$546	$556	$524	$547	$457	$627	$549
S6	0.77	$1462	$1400	$1395	$1370	$1390	$1333	$1290	$1308	$1294	$1295	$1339	$1362	$1286	$1340	$1121	$1537	$1345
Gas-fired Instantaneous Water Heater																		
I4	0.82 (0.75)	$1342	$1285	$1280	$1258	$1276	$1224	$1184	$1201	$1188	$1189	$1229	$1251	$1181	$1230	$1029	$1411	$1235
I5	0.84 (0.77)	$1483	$1420	$1415	$1390	$1410	$1352	$1309	$1327	$1313	$1314	$1359	$1382	$1305	$1360	$1137	$1559	$1365
I6	0.85 (0.78)	$1551	$1485	$1480	$1454	$1474	$1414	$1369	$1388	$1373	$1374	$1421	$1445	$1364	$1422	$1189	$1631	$1427
I7	0.92 (0.85)	$1985	$1901	$1894	$1861	$1888	$1810	$1752	$1776	$1758	$1759	$1819	$1850	$1747	$1821	$1523	$2088	$1827
I8	0.95 (0.87)	$2152	$2061	$2053	$2017	$2046	$1962	$1899	$1926	$1905	$1907	$1972	$2006	$1893	$1973	$1651	$2263	$1980

Figure 11. PV of Water Heater Energy Savings

3.4 *Lifecycle Cost (LCC) Analysis*

Cost effectiveness of the proposed code change was assessed according to the method provided in section 2.4. First, LCC of water heater options were analyzed to demonstrate that HE ready measures are cost effective when HE water heaters are also installed at the same time during new construction. Second, when HE water heaters are not installed during new construction, the retrofit cost savings from HE water heater ready measures were calculated to show these measures can be easily justified by the existing market trend.

3.4.1 Cost Effectiveness of High-efficiency Water Heaters

The CASE study investigated the cost effectiveness of new construction installation of water heaters with efficiency levels above the new 2015 federal minimum standard. The cost of the installed DHW system includes water heater cost and installation cost. Retail costs of the different water heater options are listed in Figure 7. Installation cost figures are listed in Figure 8. Assumptions about which installations costs will be applicable in each type of system are listed in Figure 12, below

According to the DOE rulemaking document, the average lifetime is 13 years for gas-fired storage water heaters and 20 years for gas-fired instantaneous water heaters. For the 30-year LCC analysis, we included 2.5 times of storage water heater installed costs and 1.5 timers of instantaneous water heater installed costs accordingly. The resulting present value energy savings are presented in Figure 11. PV of Water Heater Energy Savings.

Following the analysis methodology described in section 2.4, LCC of each water heater option was evaluated. The results, shown in Figure 13, indicate that condensing storage water heaters are cost effective in some climate zones and all tankless water heater options are cost effective in all climate zones.

Level	Water Heater Test Standard Levels	Venting	Electric Connection	Condensate Line	3/4" Gas Line
	Gas-fired Storage Water Heater				
S2	Standing Pilot, 2” Ins	Type-B steel	No	No	No
S3	Electronic ignition, 1” ins, power vent	Plastic	Yes	Yes	Yes
S4	Electronic ignition, 1.5” ins, power vent	Plastic	Yes	Yes	Yes
S5	Electronic ignition, 2” ins, power vent	Plastic	Yes	Yes	Yes
S6	Condensing, 2” ins, power vent	Plastic	Yes	Yes	Yes
	Gas-fired Instantaneous Water Heater				
I4	Electronic Ignition, Power Vent, Improved HX	Plastic	Yes	Yes	Yes
I5	Electronic Ignition, Power Vent, Improved HX	Plastic	Yes	Yes	Yes
I6	Electronic Ignition, Power Vent, Direct Vent, Improved HX, Low NOx Burner	Plastic	Yes	Yes	Yes
I7	Electronic Ignition, Power Vent, Direct Vent, Condensing	Plastic	Yes	Yes	Yes
I8	Electronic Ignition, Power Vent, Direct Vent, Condensing (Max-Tech)	Plastic	Yes	Yes	Yes

Figure 12. New Construction Water Heater Installation Assumptions

		Climate Zone																
Level	**EF**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**Average**
Gas-fired Storage Water Heater																		
S2	0.63	$420	$428	$428	$431	$429	$436	$441	$439	$440	$440	$435	$432	$441	$435	$461	$411	$434
S3	0.64	$309	$321	$322	$327	$323	$334	$342	$339	$342	$341	$333	$328	$343	$333	$375	$294	$332
S4	0.65	$281	$298	$299	$306	$301	$316	$327	$323	$326	$326	$314	$308	$328	$314	$373	$261	$313
S5	0.67	$732	$757	$759	$769	$761	$784	$802	$794	$800	$800	$782	$772	$803	$781	$871	$701	$779
S6	0.77	($134)	($72)	($67)	($42)	($62)	($5)	$38	$20	$34	$32	($11)	($35)	$42	($13)	$207	($209)	($17)
Gas-fired Instantaneous Water Heater																		
I4	0.82 (0.75)	($1,867)	($1,810)	($1,805)	($1,783)	($1,801)	($1,749)	($1,709)	($1,726)	($1,713)	($1,714)	($1,755)	($1,776)	($1,706)	($1,756)	($1,554)	($1,936)	($1,760)
I5	0.84 (0.77)	($1,097)	($1,034)	($1,029)	($1,004)	($1,024)	($967)	($923)	($941)	($927)	($928)	($973)	($996)	($919)	($974)	($752)	($1,174)	($979)
I6	0.85 (0.78)	($1,005)	($939)	($933)	($908)	($928)	($868)	($822)	($841)	($827)	($828)	($875)	($899)	($818)	($876)	($643)	($1,084)	($881)
I7	0.92 (0.85)	($1,192)	($1,108)	($1,101)	($1,068)	($1,095)	($1,017)	($959)	($983)	($964)	($966)	($1,026)	($1,057)	($954)	($1,027)	($730)	($1,294)	($1,034)
I8	0.95 (0.87)	($1,038)	($946)	($939)	($903)	($932)	($848)	($785)	($811)	($791)	($793)	($858)	($891)	($779)	($859)	($536)	($1,149)	($866)

Figure 13. LCC of Water Heater Options (New Construction)

3.4.2 Cost Savings Analysis

For new construction homes made ready, but not equipped with HE water heaters, the proposed measures will increase the new construction cost. However, the implementation of the proposed measures will reduce future retrofit costs associated with upgrading a water heater from a standard natural draft model to a HE model. Section 2.4.2 provides the methodology for comparing the new construction cost and retrofit upgrade cost.

Figure 14 compares installation costs of the following three scenarios:

- New construction baseline: a standard natural draft storage water heater is installed, and the associated flue vent is a galvanized Type B vent.
- New construction HE ready: a standard natural draft storage water heater is installed. Improvements are made to include proper electric connection, condensate drain and gas supply line. A 3/4 inch gas supply line is assumed because it can be used to support a tankless water heater for typical single-family homes in California.
- Retrofit HE water heater upgrade: a standard natural vent water heater is replaced with a HE water heater. The new water heater is assumed to be one of the models proven to be cost effective in the previous section, a condensing storage water heater or a power vent tankless water heater (condensing or noncondensing).

	Baseline (New Construction)		**HE Ready (New Construction)**		**HE Water heater Upgrade (Retrofit)**	
Venting System	Type-B Galvanized	$482	Type-B Galvanized	$482	Category (III or IV) Plastic	$204
Electric Connection	No	$0	Yes	$0	Yes	$259
Condensate Disposal	No	$0	Drain Connection	$57	Drain Connection & Condensate Pump	$153
Gas Line Upgrade	No (1/2")	$0	Yes (3/4")	$76	Yes (3/4")	$741
Total		$482		$615		$1,357
New Construction Incremental Cost per DHW System				**$133**		
Retrofit Cost Savings per DHW System						**$1,357**

Figure 14. High-efficiency Ready Incremental Cost Comparison

Market penetration if HE water heaters in 2014 is estimated based DOE projection and the CPUC Evaluation study. According to the DOE project, shown in Figure 5, 6.3% of the storage water heaters and 90% of the tankless water heaters will meet the respective Energy Star levels in 2015 without the new DOE standards. With the adoption of new DOE standards, HE water heater penetration rates will be higher. We also expect new construction in California will have higher market penetration rates due to stringent Title 24 requirements and utility incentive program efforts. Therefore, we moderately assume that HE water heater penetration in 2014 California new construction homes will be 10% and 95% for storage and tankless water heaters, respectively. DOE's rulemaking documents do not explicitly provide market breakdown of storage and tankless water heaters. According to the CPUC Evaluation Study, new construction market penetration of tankless water heaters was 24% in 2008. To be conservative, we assume that the ratio between the storage and tankless water heaters in new construction homes will remain the same in 2014. The combined HE water heater market penetration of both storage and tankless water heater can then be estimated to be

$$24\%\times95\% + (1-24\%)\times10\% = 30.4\% \ (e\% = 30.4\%)$$

Using the formula provided in Section 2.4.2, the resulting cost effective adoption rate r% is 6.8%. This means that if more than 6.8% of the homes built in 2014 (excluding those already equipped with HE water heaters at new construction) will be upgraded to a HE water heater within their 30-year lifetime, the total avoided cost will be less than the total new construction incremental cost.

The existing market and regulatory trends indicate that the above threshold HE water heater upgrade rate of 6.8% will be easily exceeded. The annual growth rate of tankless water heater projected by the water heater industry is about 10%, with at least more than 90% of them being HE models (as implied by DOE project in Figure 5). More importantly, it is certain that DOE will update its water heater efficiency standards within the next 30 years to levels equivalent to performance of forced draft water heaters, if not condensing water heaters. This implies that all water heaters installed in 2014 new construction homes will have to be replaced with HE models when they are broken about 13 years later. Therefore, we certainly expect that more than 6.8% of additional homes built in 2014 will upgrade their water heaters to HE models within 30 years.

In Summary, since the avoided future upgrade cost will be much higher than the initial new construction incremental cost based on projected penetration rates. Therefore, the proposed measure is cost effective.

3.4.3 LCC of Water Heater Blanket

Combining the cost and energy savings results, LCCs of different water heater blanket configurations were obtained and listed in Figure 15. Residential 30-year natural gas TDV values were used. It was assumed that new water heater blanket were installed when water heaters were replaced, based on the above water heater lifetime assumption. The results are not sensitive to climate zones.

The results indicate that installation of water heater blanket is cost effective when water heater internal insulation is less than 2-inch thick. Since the new DOE standard is based on a minimum internal tank insulation of 2-inch, adding a water heater blanket is not a cost-effective measure anymore.

Water Heater Internal Insulation Thickness	1.5”	2”	2.5”	3”
R-12 Water Heater Blanket (4” thick)				
Overall tank insulation improvement	84%	64%	52%	43%
Jacket heat loss w/o blanket (Btu/day)	3695	2771	2217	1847
Energy savings (Therm/yr)	6.1	3.9	2.8	2.0
TDV energy savings (TDV KBtu)	981	629	440	325
PV Energy Savings	$167.66	$107.50	$75.10	$55.55
Blanket Cost (material + labor)	$154.48	$154.48	$154.48	$154.48
LCC	-$13.18	$46.98	$79.38	$98.94
R-6 Water Heater Blanket (2” thick)				
Overall tank insulation improvement	43%	33%	26%	22%
Jacket heat loss w/o blanket (Btu/day)	3695	2771	2217	1847
Energy savings (Therm/yr)	4.1	2.5	1.7	1.2
TDV energy savings (TDV KBtu)	650	398	269	194
PV Energy Savings	$111.09	$68.02	$45.97	$33.17
Blanket Cost (material + labor)	$100.11	$100.11	$100.11	$100.11
LCC	-$10.99	$32.09	$54.13	$66.94

Figure 15. Water Heater Blanket Energy Savings and LCC

3.5 *Statewide Energy Savings*

The proposed the code change will encourage HE water heater installation during new construction and water heater replacement. However, because HE water heater installation is not required, it is difficult to estimate the exact market impact. In addition, water heater selections can also be affected by other code changes when whole building performance approach is used as the compliance method. This makes it even more difficult to quantify the impact by this CASE study.

For gas storage water heaters, we expect that those just meeting the Energy Star™ criteria (EF=0.67) will be favored because of the public recognition of Energy Star™ labeling. For tankless water heaters, models with EF =0.82 will be favored because of they are highly cost-effective and they can provide large energy savings to improve overall building compliance margin. If we assume that the proposed code changes will drive the new construction market adoption of each type of water heater by 5%, the corresponding annual energy savings can be calculated using unit energy savings provided in Figure 9 and CEC’s projection of new single-family home start in 2014 (Appendix 6.3). The calculation results are summarized in Figure 16.

In addition to new construction energy savings, the proposed measures will generate energy savings when water heaters are replaced. It is hard to predict market conditions in future. If we use the assumptions as those used for new constructions above, the same amount of energy savings will be added about one lifetime (13 years) after new construction.

Climate Zone	2014 SF Home Start	Annual Energy Savings from Storage Water Heaters (EF=0.67)	Annual Energy Savings from Tankless Water Heaters (EF=0.82)
1	378	407	917
2	1,175	1209	2721
3	1,224	1257	2829
4	2,688	2709	6097
5	522	534	1203
6	1,188	1159	2609
7	2,158	2074	4669
8	1,966	1881	4234
9	2,269	2147	4832
10	8,848	8370	18841
11	3,228	3171	7138
12	9,777	9782	22018
13	6,917	6520	14677
14	1,639	1600	3601
15	1,925	1570	3534
16	1,500	1682	3786
Subtotal (Therms/Yr)		**46,000**	**104,000**
Total (Therms/Yr)		**150,000**	

Figure 16. Statewide Energy Savings Estimate

4. Recommended Language for the Standards Document, ACM Manuals, and the Reference Appendices

This CASE study recommends the revision of the Title 24 section 150(n) to include the following mandatory requirements. The original requirement on recirculation loop serving multiple dwelling units is not affected this proposal.

The Appendix B lists the recommended language provided during the pre-rulemaking workshop. It includes a compliance option of using a vent retrofit plan to meet the flue vent requirements. Building industry stakeholders indicated that this option might not be feasible because homes can be built very close to each other, so the flue vents may not be able to be retrofitted to vent from a side wall as specified in a building plan. Based on further discussion with water heater installers, we changed the recommendation to require straight B-type flue vent. This would allow Category III or IV vents, which have smaller pipe sizes, be easily installed through the existing B-type vent with little retrofit effort.

Stakeholders also pointed out that the original recommendation did not clearly specify the height of condensate drain. If it is too high, a condensate drain pump might have to be installed. The CASE study team addresses this comment by specifying drain height.

Section 150(n)

(n) <u>Water Heating System.</u>

<u>1. Systems using gas or propane water heaters to serve individual dwelling units shall include the following components:</u>

<u>A. A 120V electrical receptacle within 3 feet from the water heater without partition walls in between; and</u>

<u>B. A Category III or IV vent, or a Type B vent with straight pipe between the outside termination and the space where the water heater is installed, and</u>

<u>C. A condensate drain that is no more than 2 inches higher than the base of the installed water heater, allows natural draining without pump assistance, and meets local jurisdiction requirements, and</u>

<u>D. A gas supply line with a capacity of at least 200,000 Btu/hr.</u>

<u>2.</u> **Water Heating Recirculation Loops Serving Multiple Dwelling Units.** Water heating recirculation loops serving multiple dwelling units shall meet the requirements of Section 113(c)5.

5. Bibliography and Other Research

Energy Conservation Program: Energy Conservation Standards for Residential Water Heaters, Direct Heating Equipment, and Pool Heaters, Department of Energy, 10 CFR Part 430, Docket Number: EE–2006–BT-STD–0129, RIN 1904–AA90, Federal Register, 75 FR 21981, April 27, 2010

Residential New Construction (RNC) Programs Impact Evaluation Volume I California Investor-Owned Utilities' Residential New Construction Program Evaluation for Program Years 2006-2008, Final Evaluation Report, Prepared by KEMA, Inc., The Cadmus Group, Inc., Itron, Inc., Nexus Market Research, Inc., February 8, 2010

Water Heaters and Hot Water Distribution Systems, PIER Final Project Report, December 2008, CEC-500-2008-082, Prepared By: Jim Lutz, Lawrence Berkeley National Laboratory, Commission Contract No. 500-05-007

6. Appendices

6.1 *Appendix A: California Single-family Home Layout*

The PIER research on DHW systems[12] conducted by the Davis Energy Group provided six typical California six-family home floor plans, as shown in Figure 18 through Figure 23. Based on these typical floor plans, water heater vent pipe length for side-wall venting configuration were obtained and summarized in Figure 17.

Number of Story	Floor Area (sqft)	Location of the Water Heater	Distance from the Nearest Side Wall (ft)	Vertical Vent Length (ft)	Total Vent Length (ft)
1	1,367	Garage	14	1.5	15.5
1	2,010	Garage	17.5	1.5	19
1	3,080	Garage	12	1.5	13.5
2	1,430	Garage	10	1.5	11.5
2	2,811	Garage	2	1.5	3.5
2	4,402	Garage	2	1.5	3.5
Average	**2,517**		**9.6**	**1.5**	**11.1**

Figure 17. Summary of Typical Water Heater Locations and Vent Pipe Length

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[12] Water Heaters and Hot Water Distribution Systems, PIER Final Project Report, December 2008, CEC-500-2008-082, Prepared By: Jim Lutz, Lawrence Berkeley National Laboratory, Commission Contract No. 500-05-007

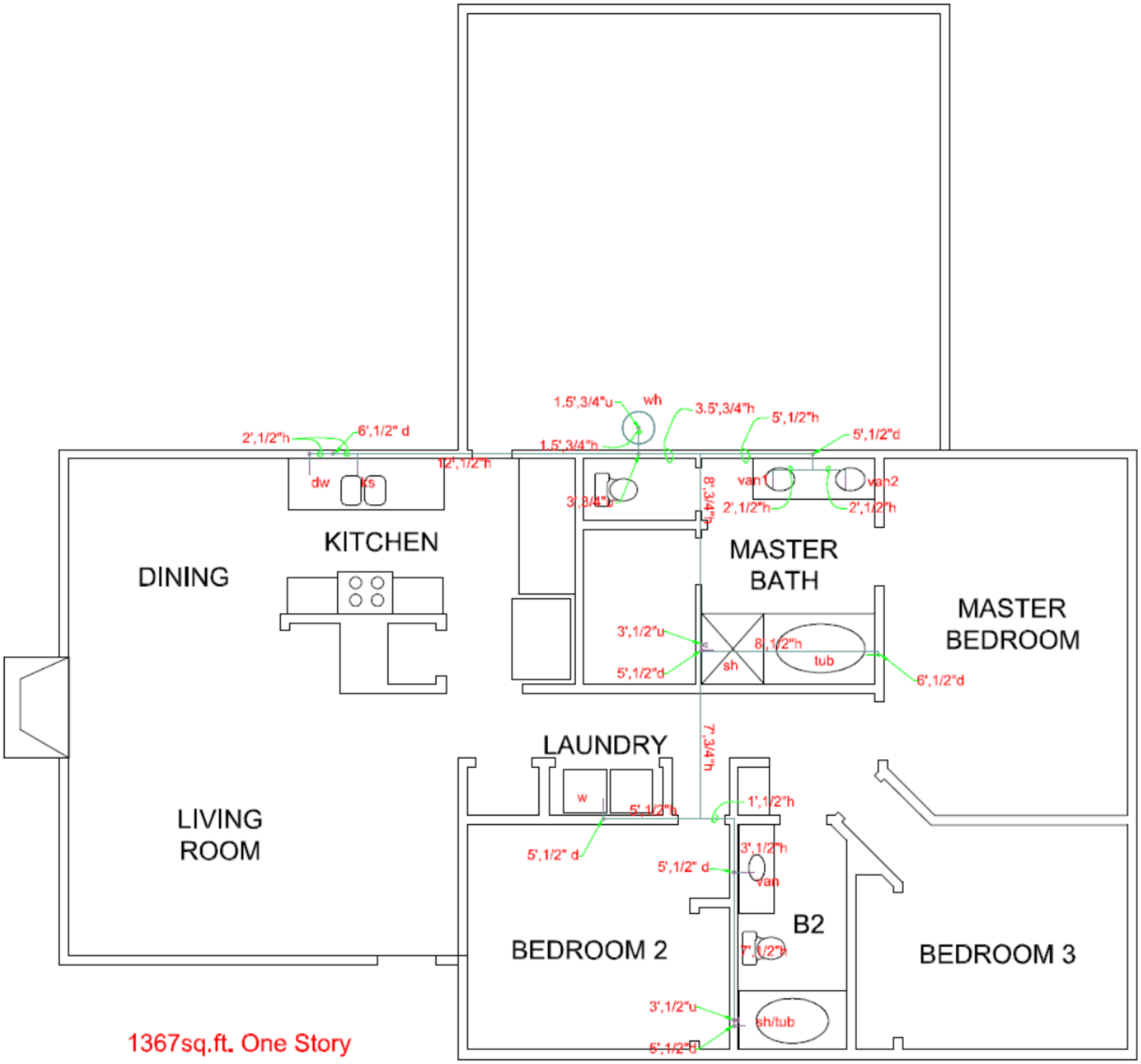


Figure 18. Floor Plan – 1367 sqft, One Story

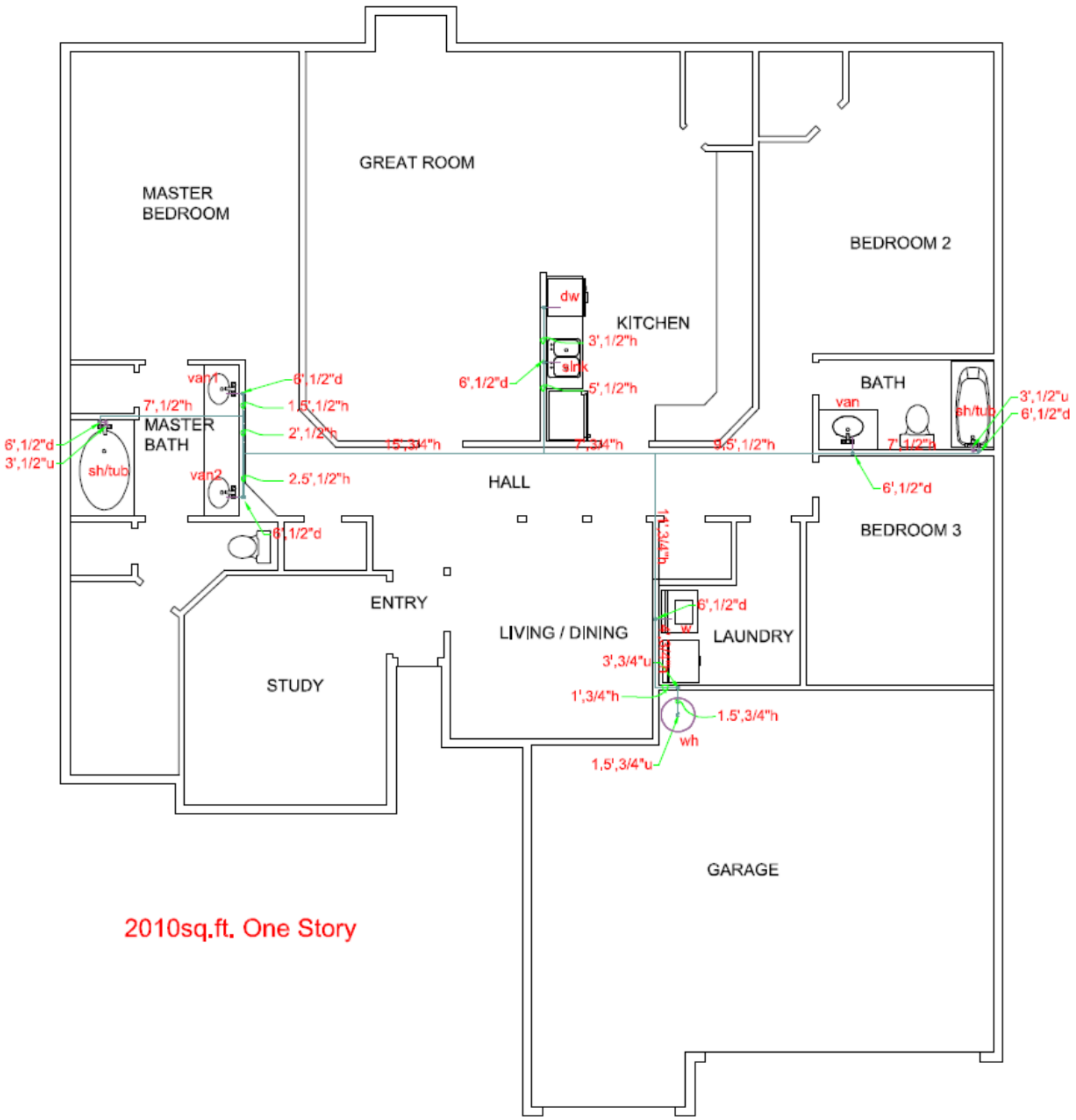


Figure 19. Floor Plan – 2010 sqft, One Story

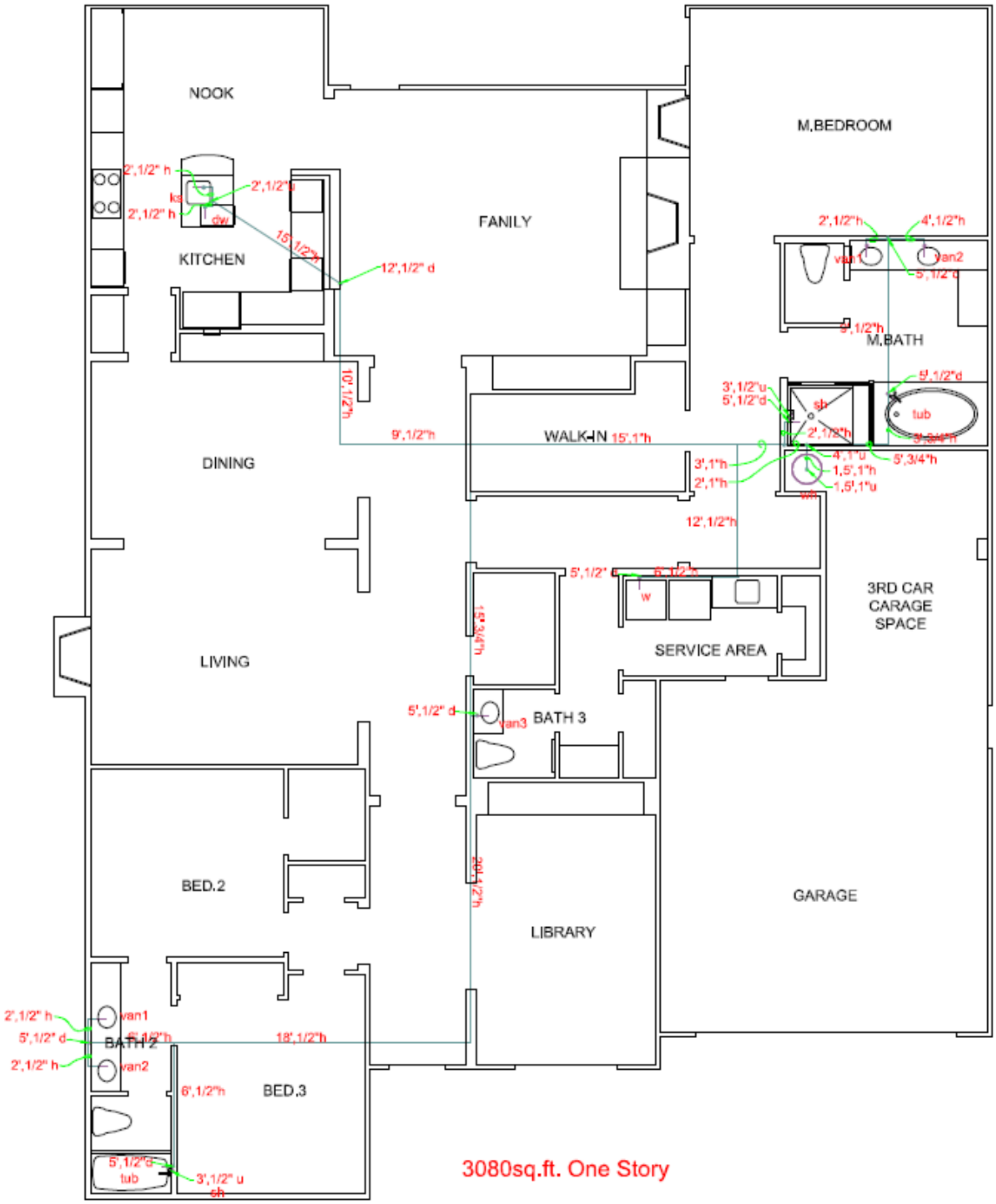


Figure 20. Floor Plan – 3080 sqft, One Story

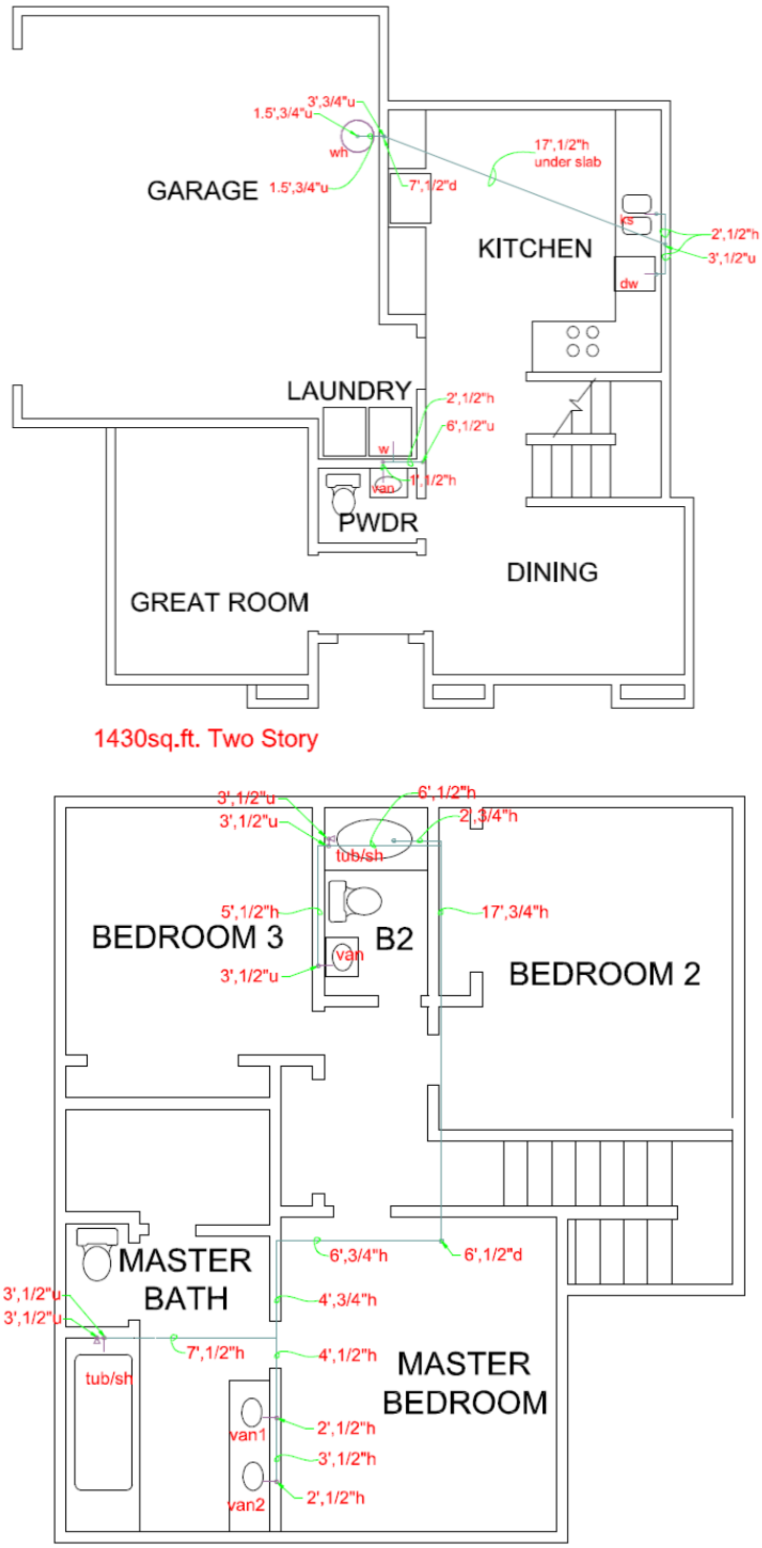
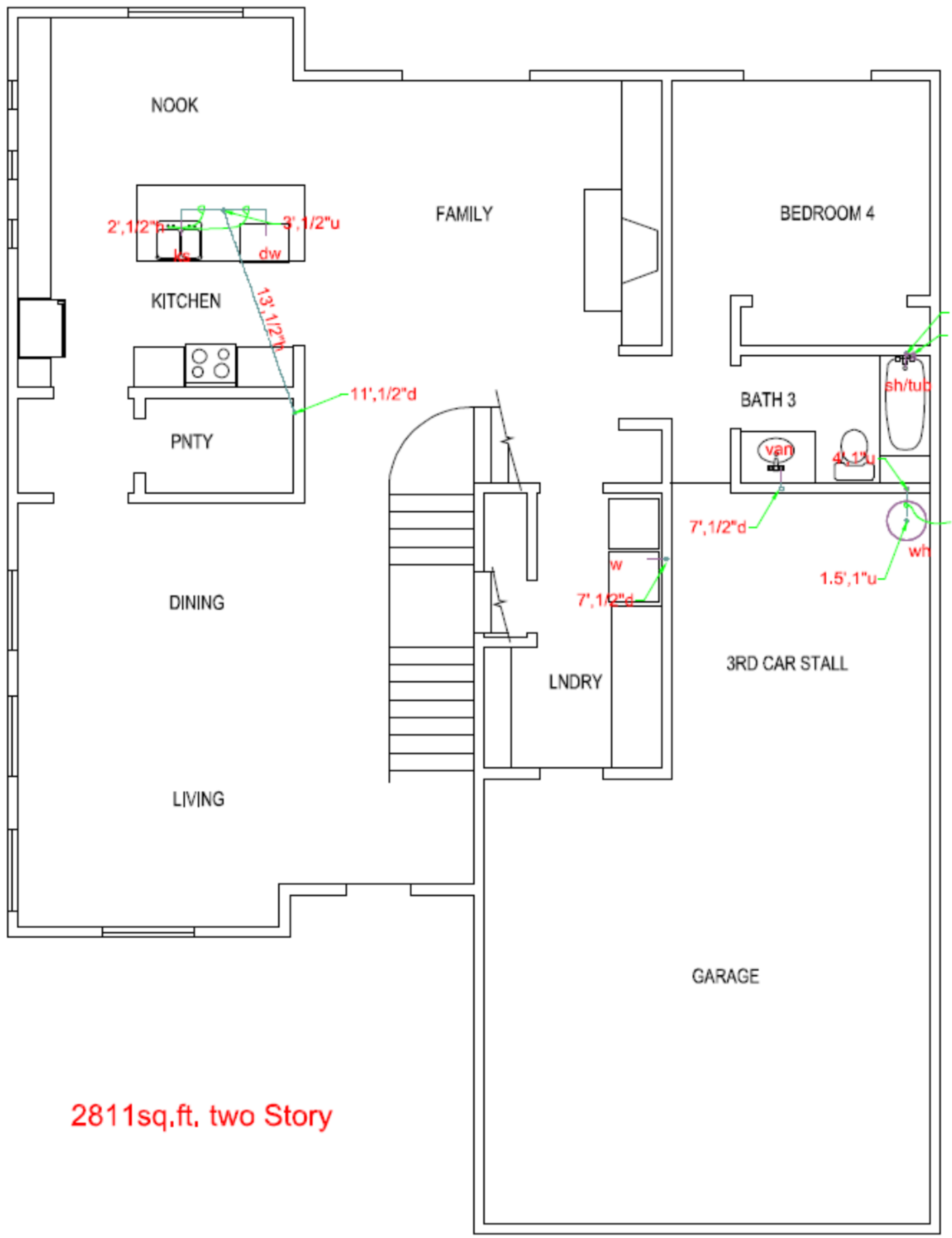


Figure 21. Floor Plan – 1430 sqft, Two Story



NOOK
FAMILY
BEDROOM 4
KITCHEN
2',1/2"h
3',1/2"u
ks
dw
13',1/2"h
11',1/2"d
PNTY
7',1/2"d
3',1/2"u
sh/tub
BATH 3
van
4',1"u
7',1/2"d
1.5',1"h
wh
1.5',1"u
w
7',1/2"d
DINING
LNDRY
3RD CAR STALL
LIVING
GARAGE
2811sq.ft. two Story

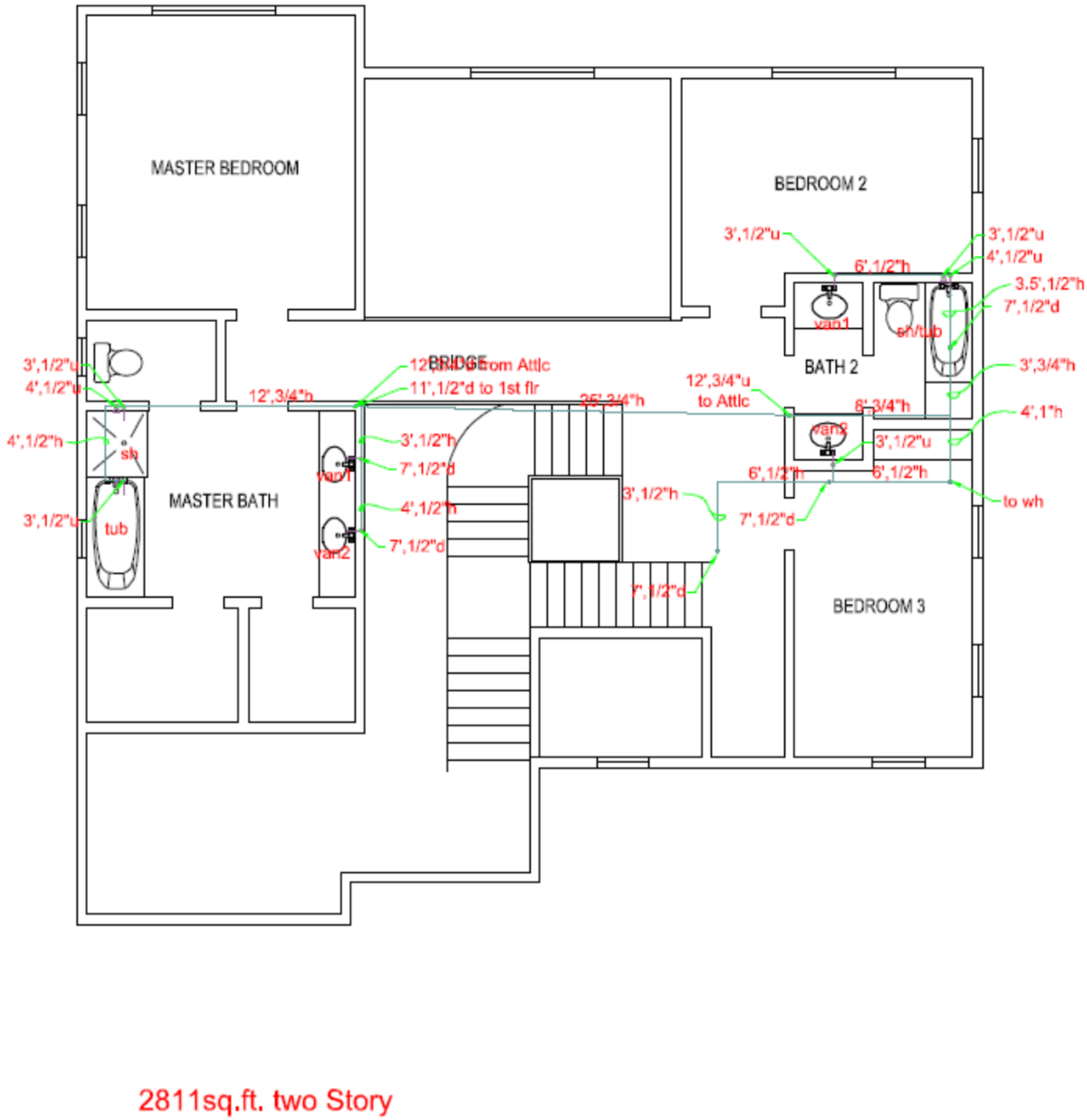
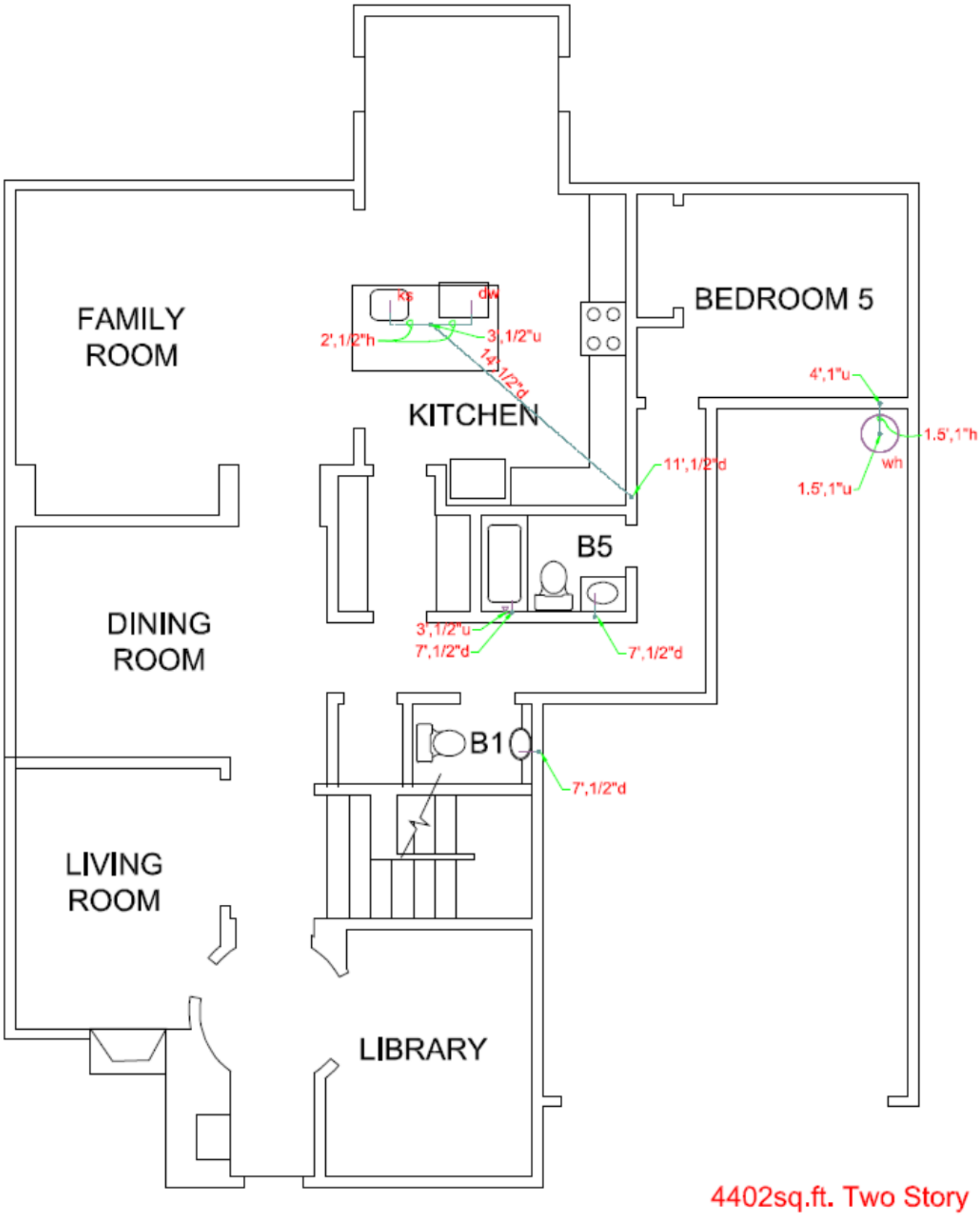


Figure 22. Floor Plan – 2811 sqft, Two Story


FAMILY ROOM
KITCHEN
BEDROOM 5
B5
DINING ROOM
B1
LIVING ROOM
LIBRARY
ks
dw
2',1/2"h
3',1/2"u
14',1/2"d
11',1/2"d
4',1"u
1.5',1"h
wh
1.5',1"u
3',1/2"u
7',1/2"d
7',1/2"d
7',1/2"d
4402sq.ft. Two Story

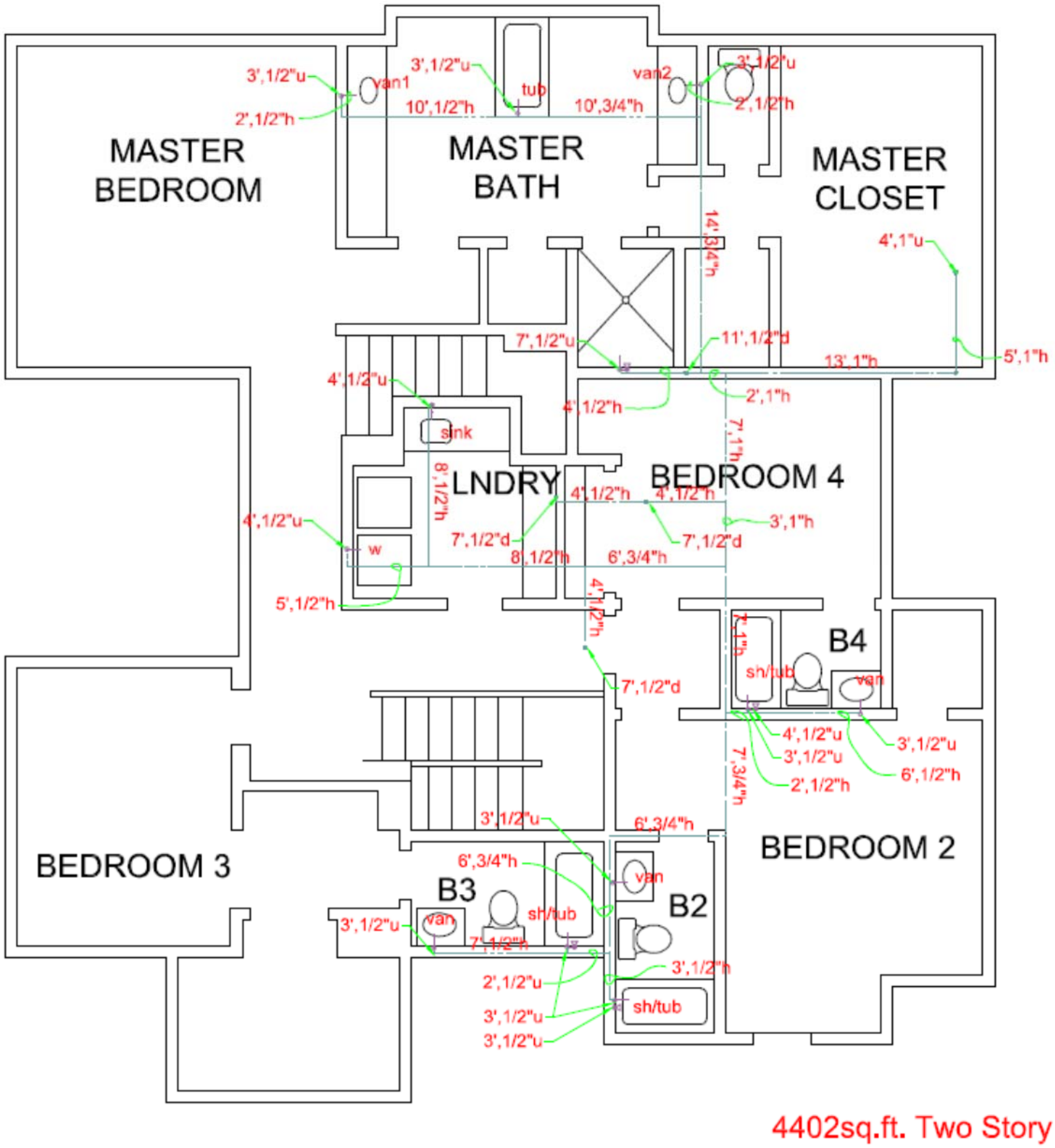


Figure 23. Floor Plan – 4402 sqft, Two Story

6.2 *Appendix B: Code Language Recommendations Provided in the pre-Rulemaking Workshop*

Section 150(n)

(n) <u>Water Heating System.</u>

<u>1. Systems using gas or propane water heaters to serve individual dwelling units shall include the following components:</u>

<u>A. A 120V electrical receptacle within 3 feet from the water heater without partition walls in between; and</u>

<u>B. A Category III or IV vent, and</u>

<u>C. A condensate drain that meets local jurisdiction requirements, and</u>

<u>D. A gas supply line with a capacity of at least 200,000 Btu/hr.</u>

<u>Exception to 151(n)1B: The building plan includes a vent retrofit plan for future upgrade to a Category III or IV vent. The plan shall include a vent path less than 12 Ft without any interior walls along the path and a side-wall vent location in compliance with the National Fuel Gas Code.</u>

<u>2.</u> Water Heating Recirculation Loops Serving Multiple Dwelling Units. Water heating recirculation loops serving multiple dwelling units shall meet the requirements of Section 113(c)5.

6.3 *Appendix C: Residential Construction Forecast Details*

6.3.1 Summary

The Residential construction forecast dataset is data that is published by the California Energy Commission's (CEC) demand forecast office. This demand forecast office is charged with calculating the required electricity and natural gas supply centers that need to be built in order to meet the new construction utility loads. Data is sourced from the California Department of Finance and California Construction Industry Research Board (CIRB) building permits. The Department of Finance uses census years as independent data and interpolates the intermediate years using CIRB permits.

CASE stakeholders expressed concern that the Residential forecast was inaccurate compared with other available data (in 2010 CEC forecast estimate is 97,610 new units for single family and the CIRB estimate is 25,526 new units). In response to this discrepancy, HMG revised the CEC construction forecast estimates. The CIRB data projects an upward trend in construction activity for 2010-2011 and again from 2011-2012. HMG used the improvement from 2011-2012 and extrapolated the trend out to 2014. The improvement from 2011-2012 is projected to be 37%. Instead of using the percent improvement year on year to generate the 2014 estimate, HMG used the conservative value of the total units projected to be built in 2011-2012 and added this total to each subsequent year. This is the more conservative estimate and is appropriate for the statewide savings estimates. Based on this trend, the new construction activity is on pace to regain all ground lost by the recession by 2021. The multi-family construction forecasts are consistent between CEC and CIRB and no changes were made to the multi-family data.

Residential New Construction Estimate (2014) in total dwelling units			
	Single Family	**Multi-family Low Rise**	**Multi-family High Rise**
CZ 1	378	94	-
CZ 2	1,175	684	140
CZ 3	1,224	863	1,408
CZ 4	2,688	616	1,583
CZ 5	522	269	158
CZ 6	1,188	1,252	1,593
CZ 7	2,158	1,912	1,029
CZ 8	1,966	1,629	2,249
CZ 9	2,269	1,986	2,633
CZ 10	8,848	2,645	1,029
CZ 11	3,228	820	81
CZ 12	9,777	2,165	1,701
CZ 13	6,917	1,755	239
CZ 14	1,639	726	-
CZ 15	1,925	748	-
CZ 16	1,500	583	-
Total	47,400	18,748	13,845

Figure 24. Residential construction forecast for 2014

6.3.2 Additional Details

The demand generation office publishes this dataset and categorizes the data by demand forecast climate zones (FCZ). These 16 climate zones are organized by the generation facility locations throughout California, and differ from the Title 24 building climate zones (BCZ). HMG has reorganized the demand forecast office data using 2000 Census data (population weighted by zip code) and mapped FCZ and BCZ to a given zip code. The construction forecast data is provided to CASE authors in BCZ in order to calculate Title 24 statewide energy savings impacts. Though the individual climate zone categories differ between the demand forecast published by the CEC and the construction forecast, the total construction estimates are consistent; in other words, HMG has not added to or subtracted from total construction area.

The demand forecast office provides two (2) independent data sets: total construction and decay rate. Total construction is the sum of all existing dwelling units in a given category (Single family, Multi-family low rise and Multi-family high rise). Decay rate is the number of units that were assumed to be retrofitted, renovated or demolished. The difference in total construction between consecutive years (including each year's decay rate) approximates the new construction estimate for a given year.

In order to further specify the construction forecast for the purpose of statewide energy savings calculation for Title 24 compliance, HMG has segmented all multi-family buildings into low rise and high rise space (where high rise is defined as buildings 4 stories and higher). This calculation is based on data collected by HMG through program implementation over the past 10 years. Though this sample is relatively small (711), it is the best available source of data to calculate the relative population of high rise and low rise units in a given FCZ.

Most years show close alignment between CIRB and CEC total construction estimates, however the CEC demand forecast models are a long-term projection of utility demand. The main purpose of the CEC demand forecast is to estimate electricity and natural gas needs in 2022, and this dataset is much less concerned about the inaccuracy at 12 or 24 month timeframe.

It is appropriate to use the CEC demand forecast construction data as an estimate of future years construction (over the life of the measure), however to estimate next year's construction, CIRB is a more reliable data set.

6.3.3 Citation

"Res Construction Forecast by BCZ v4"; Developed by Heschong Mahone Group with data sourced September, 2010 from Sharp, Gary at the California Energy Commission (CEC)

6.4 *Appendix D: Environmental Impact Analysis*

The CASE study analyzed measure cost effectiveness for two scenarios, a HE water heater is installed during new construction or during future water heater upgrade. However, the proposed code changes only affect the second scenario, in which a HE water heater in not installed during new construction but components for HE water heaters are required. Figure 25 summarizes increases in material use associated with the corresponding measures, following the same assumptions used in the cost analysis in section 3.2.

Measure	**Baseline**	**HE Ready**	**Difference in Material Use**	**Mercury (lb)**	**Lead (lb)**	**Copper (lb)**	**Steel (lb)**	**Plastic (lb)**	**Others (Identify)**
Venting System	Type-B Galvanized	Type-B Galvanized	None	0	0	0	0	0	None
Electric Connection	None	Yes	Additional 6 ft electric wire (Bring an existing receptacle close to the water heater in garage)	0	0	0.23	0	0.01	None
Condensate Disposal	None	Drain Connection	6 ft ¾" PVC pipe for drain connection	0	0	0	0	0.97	None
Gas Line Upgrade	No (1/2")	Yes (3/4")	Larger pipe	0	0	0	3.6	0	None
Total per home				**0**	**0**	**0.23**	**3.6**	**0.98**	None
Statewide				**0**	**0**	**6,837**	**110,482**	**29,666**	**NC**

Figure 25. Material Increase for HE Water Heater Ready Measures