THE CADMUS GROUP, INC.

Date: **October 5, 2012**

To: **PacifiCorp**

From: **The Cadmus Group, Inc.**

Re: **Overview of Solar Water Heating Inputs and Results**

Introduction

The Cadmus Group, Inc., under contract to PacifiCorp, has calculated the total market potential and associated levelized cost for solar water heating (SWH) systems projected to be installed in PacifiCorp territory over the next 20 years. The results of this analysis will be used in PacifiCorp's 2013 Integrated Resource Plan (IRP).

This memorandum discusses the assumptions, data sources, results, and updates to Cadmus' analysis. It also addresses the feedback from the public stakeholder meeting held on August 24, 2012, at which preliminary results were presented. A further discussion of all findings will be included in the forthcoming report.

Levelized Cost of Energy

The levelized cost, which is based on a single representative SWH system for each state and sector, compares the life-cycle costs to the energy savings. It is calculated based on the Total Resource Cost (TRC) perspective for all states except Utah, where the Utility Cost Test (UCT) is the accepted perspective. Levelized cost is calculated separately for residential customers (separated into single-family and multifamily buildings) and commercial customers (health, lodging, large office, large retail, and school buildings).Applicable commercial segments were chosen based on average annual hot water heating electricity consumption of at least 9,000 kWh, as these facilities are more likely to have sufficient hot water heating load to justify investment in a SWH system.

TRC

The TRC levelized cost consists of these elements:

- The incremental installation cost, as a retrofit, which is the installed cost of the SWH system.
- The incremental operations and maintenance (O&M) costs. These are the O&M costs for the SWH minus the O&M costs of a standard-efficiency electric water heater (which are assumed to be zero). The SWH O&M costs include regular system checkups and replacing the heat transfer fluid. The costs are assumed to occur every three years for residential systems and are adjusted to net present value. Costs for commercial and multifamily systems are assumed to occur annually.

- The federal tax incentive, which is 30% of the installed system cost and is unaffected by utility or state rebates. This incentive expires December 31, 2016, and that is taken into account in the analysis. The state tax incentive is not included because the TRC sees the incentive as a benefit to the customer who installs the system, but a cost to the state's taxpayers, making the net effect zero.
- The program administration costs (such as marketing expenses) are assumed to be 20% of the installed measure cost. Utility incentives are not included in the TRC because the TRC sees the incentive as a benefit to the customer who installs the system, but a cost to the ratepayers, making the net effect zero.

UCT

The UCT levelized cost is the utility's cost of administering the program. This cost consists of:

- The incentives (an amount is assumed to be 10% of the installed cost after the federal tax credit); and
- The dollars spent on program administration and marketing. These costs are assumed to be 20% of the incremental installed cost.

Additionally, a nominal discount rate of 6.88% is used with an inflation rate of 1.9% to adjust the costs in future years.

Sources

In early 2009, Itron released an Interim Evaluation report for the California Center for Sustainable Energy (CCSE) Solar Water Heating Pilot Program (SWHPP). This report contained a compilation of SWH information from numerous sources, including cost data from incentive programs in the United States and information from contractor interviews.[1]

For this SWH analysis, Cadmus reviewed the Itron report and other sources of information, such as the ENERGY STAR® Website and the National Renewable Energy Laboratory. Cadmus also downloaded the most recent California Solar Thermal program data from the California Public Utilities Commission to update the installed system costs for residential and nonresidential systems and obtained information about average system costs for residential systems from the Energy Trust of Oregon (ETO).

Resources for Calculations

The solar fraction, which is the percentage of energy used for heating water that is provided by the SWH, was used to calculate energy savings. Solar fractions for each segment and location combination were developed using both RETScreen International[2] and assumptions of gallons of hot water used per day and sector-specific load shapes. The number of collectors was adjusted

[1] The CCSE SWHPP Interim Report can be downloaded from http://energycenter.org/uploads/CCSE_SWHPP_Interim_Report_Final.pdf

[2] RETScreen International was developed by Natural Resources Canada and can be downloaded for free from http://www.retscreen.net/

until the solar fraction was near 70%, as systems are typically designed to reach a solar fraction of 40 to 80%.[3]

The utility incentive level is defined as 10% of the incremental cost, determined using recent ETO rebate information for program years 2009 to 2011. Cadmus' analysis applies this 10% rebate after the 30% federal rebate during program years 2013 to 2016. Cadmus' review of other states' SWH programs has shown incentives to range from 10% to 20%, so the ETO incentive is a reasonable—if slightly conservative—level to assume for all states.

Overview of Installed System Cost Data

Table 1 compares the installed costs for residential retrofit SWH systems in the United States. SWH systems, unlike some other types of water heater efficiency improvements, do not typically replace a customer's existing hot water heater. In fact, most SWH systems are installed to supplement the existing hot water heater by pre-heating the cold water supply (e.g., well, municipal) before it enters the existing hot water heater.

Table 1. Comparison of Installed Costs for U.S. Residential Single-Family SWH Systems

Program	Average Residential System Cost (2012 $)	Typical System Type
California Solar Thermal Program 2012	$8,401*	Active glycol and drainback systems
Eugene Water and Electric Board 2008	$7,607	Active glycol and drainback systems
Energy Trust of Oregon 2011-2012	$8,688	Active glycol and drainback systems

*Adjusted to remove sales tax

Installation costs for non-residential SWH projects come from data reported by the California Solar Hot Water Program in 2012.

The cost of SWH systems is assumed to be constant over time, with increased market adoption balancing increasing material costs for SWH system components.

[3] National Renewable Energy Laboratory. The Technical Potential of Solar Water Heating to Reduce Fossil Fuel Use and Greenhouse Gas Emissions in the United States. March 2007, page 5, Accessed August 2, 2010, from http://www.nrel.gov/docs/fy07osti/41157.pdf.

Residential, Multifamily, and Commercial Inputs

Table 2 lists the inputs for Cadmus' analysis of and the assumptions for residential systems.

Table 2. Residential Single FamilyAssumptions

Input	Value	Reasoning
Average size	48 square feet	Assumes two collectors. Typical collector area for a home is 40 to 60 square feet.
Measure Life	20 years	Minimum collector lifetime from warranty claims in Hawaii See SWHPP Interim Report Table 5-3; ENERGY STAR also lists a 20 year lifetime. See website: http://www.energystar.gov/index.cfm?c=solar_wheat.pr_savings_benefits
Installed Cost for Retrofit Systems	$8,500	Average cost (rounded) reported by the CA Solar Thermal Program and Energy Trust of Oregon
Assumed Rebate	10% of incremental cost	The Energy Trust of Oregon has given a 10% rebate on average for the last several years.
Annual change in nominal installed cost	0%	Costs have increased steadily over the past six years due to increases in material costs. We assume that costs will stabilize over the next 20 years
O&M Cost	$120 every three years; $40 per year (nominal)	Assumes customers have the system inspected every three to four years and occasionally have the heat transfer fluid flushed and replaced. (SWHPP Interim Evaluation Report Table 7-6). Cadmus has assumed a three year replacement cycle, which is at the conservative end of the given range.
Tilt	32 degrees	Average residential system tilt in the Utah Solar PV Incentive Pilot Program from 2010 - 2011
Azimuth	South	Average residential system azimuth in the Utah Solar PV Incentive Pilot Program
Annual Change in Efficiency	0%	Solar thermal is a mature technology and no improvements in efficiency are expected
Annual Performance Degradation	1%	Assumption used in the NREL Solar Advisor Model which can be downloaded for free from https://www.nrel.gov/analysis/sam/
Solar Fraction	Varies by location.	Modeled using RETScreen International
Federal Tax Incentive	30% of installed cost. No cap.	This is the current federal tax incentive for renewable energy measures, set to expire on December 31, 2016.

Table 3 lists the inputs for Cadmus' analysis of and the assumptions for commercial systems.

Table 3. Commercial and Multifamily Assumptions

Input	Value	Reasoning
Average size	Varies by sector and location	Size was calculated based on gallons of hot water used per day in each segment within each state.
Measure Life	20 years	Minimum collector lifetime from warranty claims in Hawaii See SWHPP Interim Report Table 5-3; ENERGY STAR also lists a 20-year lifetime. See Website: www.energystar.gov/index.cfm?c=solar_wheat.pr_savings_benefits
Installed Cost for Retrofit Systems	$106 per square foot	Average cost per square foot for commercial and multifamily systems in the California Solar Thermal program in 2012
Assumed Rebate	10% of incremental cost	The Energy Trust of Oregon has given a 10% rebate on average for the last several years.
Annual change in nominal installed cost	0%	We assume that costs will remain stable over the next 20 years
Annual O&M Cost	10% of installation cost divided by 20 years	Assumes customers have the system inspected and have the glycol flushed and replaced periodically. (SWHPP Interim Evaluation Report Table 7-11)
Tilt	25 degrees	Average commercial system tilt in the Utah Solar PV Incentive Pilot Program from 2010 - 2011
Azimuth	South	Average commercial system azimuth in the Utah Solar PV Incentive Pilot Program from 2010 - 2011
Annual Change in Efficiency	0%	Solar thermal is a mature technology and no improvements in efficiency are expected
Annual Performance Degradation	1%	Assumption used in the NREL Solar Advisor Model which can be downloaded for free from https://www.nrel.gov/analysis/sam/
Solar Fraction	Varies by location and sector.	Modeled using RETScreen International
Federal Tax Incentive	30% of installed cost. No cap.	This is the current federal tax incentive for renewable energy measures, set to expire on December 31, 2016.

Technical Potential and Market Penetration Methodology

Cadmus calculated the technical potential for SWH using these steps:

1. The total number of electric hot water heaters in each state and sector, based on survey and field-collected data, was reduced by the number of projected heat pump water heaters installed over the 20 year study period. This was done to avoid double counting of savings (SWH is rarely used in conjunction with heat pump water heaters), with preference given to the more cost-effective heat pump water heater installations.

2. The water heater quantity was then multiplied by the water heater unit energy consumption (UEC) in each segment, calculated as part of the Class 2 (energy efficiency) analysis.

3. A series of RETScreen models was used to determine representative solar fraction values for each state and sector, which were applied to the total hot water heater UECs.

Cadmus assumed that the maximum market penetration is 15% for all segments. This percentage of market potential was derived using actual rebate data from ETO (for program years 2009 through 2011) and the technical potential calculated by ETO.

To avoid double-counting of savings with Class 2 DSM (energy efficiency) resources, this percentage is in addition to those water heaters assumed to be converted to high-efficiency units (that is, heat pump water heaters), as noted above. Also, Cadmus used the same lost opportunity ramp rate as the Northwest Power and Conservation Council to determine how many systems would be installed each year. [4]

Results

Table 4 shows the results of Cadmus' analysis and summarizes the cumulative technical and market potential by year 20 by state and sector.[5]

[4] http://www.nwcouncil.org/energy/powerplan/6/default.htm The Council's potential does not include manufactured homes.

[5] Oregon potential and LCOE results reported by Energy Trust of Oregon and not included in this analysis

Table 4. Cumulative Technical and Market Potential by Year 20 by State and Sector

Sector	Potential by Year 20 (aMW)[6]				
	CA	ID	UT	WA	WY
Technical Potential*					
Non-Residential	0.12	0.12	0.96	0.27	0.20
Residential	1.85	3.20	10.5	2.47	2.43
Total	**1.97**	**3.32**	**11.4**	**2.74**	**2.63**
Market Potential*					
Non-Residential	0.02	0.02	0.14	0.04	0.03
Residential	0.28	0.48	1.57	0.37	0.36
Total	**0.30**	**0.50**	**1.71**	**0.41**	**0.39**

*Some variation in totals may occur due to rounding

Table 5 shows the levelized cost of energy for SWH systems before and after the expiration of the ITC. The levelized cost was calculated based on the TRC perspective for all states except Utah, which is based on the UCT perspective. Note that the incentive levels before and after the expiration of the ITC were held constant, assuming no additional utility funds are provided to offset the additional costs from 2017 onwards.

Table 5. Levelized Cost of Energy Before and After the ITC Expiration

Sector	Levelized Cost of Energy ($/kWh)				
	CA	ID	UT*	WA	WY
2013-2016					
Non-Residential	$0.18	$0.16	$0.02	$0.18	$0.15
Residential	$0.45	$0.29	$0.04	$0.45	$0.36
2017-2032					
Non-Residential	$0.25	$0.22	$0.02	$0.26	$0.21
Residential	$0.63	$0.40	$0.04	$0.62	$0.50

* LCOE values for Utah are calculated using the UCT, all other states use the TRC cost test

[6] One average Megawatt (aMW) is equal to 8,760 Megawatt-hours (MWh)

Response to Stakeholder Comments from August 24th, 2012 Meeting

SWH 1. Assumption of 50% incentive after federal tax incentive seems too high. Explain rationale.

Incentive levels were set at 50% of the total project cost as, in Cadmus' opinion, this is what would be required to achieve 25% of the technical potential over the 20-year planning period. The revised analysis uses incentive levels and market penetration rates from the Energy Trust of Oregon solar hot water program.

SWH 2. Assumption of 20% administrative adder seems too high. Explain rationale.

An assumed administrative cost adder of 20% is consistent with administrative costs reported by the Energy Trust of Oregon for their ongoing SWH program.

SWH 3. Fluid replacement cycle of three years is too short – should be at least 10 years. Check manufacturer specifications.

Most SWH system manufacturers do not dictate replacement rates based on time, but rather, based on measured pH level of the heat transfer fluid. This approach is also supported by the North American Board of Certified Energy Practitioners (NABCEP). In our research, which included a survey of readily available maintenance documents from major equipment vendors, only one manufacturer included a default recommendation for heat transfer fluid replacement. That recommended interval is four years. Several manufacturers also recommend a general inspection/tune up in one to two year intervals, which would include pH testing and replacement, if warranted, of the heat transfer fluid. Absent any additional data from a reputable source, we believe that the assumed fluid replacement rate of three years is reasonable.