A CRITICAL LOOK AT THE UTILITY BENEFITS OF SOLAR WATER HEATING IN AN AGE OF BOOMING PV

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ABSTRACT

The drivers for electric utilities to promote solar water heating (SWH) have included benefits related to load management, efforts toward renewable energy goals, and sometimes toward efficiency goals. Drivers also have included utility interest in promoting electric backup water heating, job impacts, and offering an affordable customer solar option. From 2007-12, the authors completed four impact studies of utility solar water heating programs in the Western US, using field monitoring and/or advanced modeling, as well as economic analysis. The research assessed each driver and identified new potential drivers for utility SWH programs. The studies were completed separately; however, they were compared to see if popular thinking about SWH programs needs to be updated.

All the utilities studied showed coincident winter peak demand reduction (0.4 kW or more per system), with less dramatic summer demand benefits. Some utilities also could use SWH toward renewable energy goals, or if preferred, energy-efficiency goals. However, utility economics are not necessarily aligned with these and other benefits. Wholesale cost structures, as well as regional climate, mains inlet temperatures, competing water-heater options, and other factors affect outcomes. SWH impact modeling can estimate the economics for specific drivers under specific conditions, with results that are sometimes counter-intuitive. Of note, the research suggested SWH might have particular benefits for utilities in a booming PV market. Those benefits include the complementary load characteristics of PV and SWH, the benefits of SWH storage capabilities, and significant avoided interconnection and integration costs.

1. INTRODUCTION

Natural gas is the most common fuel for water heating in the US, serving 54% of households, but electricity is still a major energy source for this purpose, serving 39% of households nationwide.[1] While natural gas has long held a cost advantage for water heating, some customers live in regions where relatively low heating loads or low population density has discouraged gas service expansion and promoted the all-electric option. In a small percentage of markets, electricity is even a cost-competitive choice—compared to fuel oil or propane used in conventional water heaters. In short, there are many electric utilities that are interested in capturing and managing water heating loads.

According to the utility solar interest group, USH2O, at least 30 electric utilities are actively promoting solar water heating. (SWH), and at least 40 states offer some type of SWH incentive[2] One driver is that SWH can use electricity for backup heating, discouraging fuel-switching and keeping at least part of the load. Utility SWH program bench-marking studies[3] suggest utilities may be responding to other benefits, too, including

- Reducing customer bills
- Providing a solar option more affordable than PV
- Meeting the utility's energy efficiency or renewable energy policy targets
- Generating valuable RECs, where allowed
- Managing peak loads (demand-side management)
- Diversifying the utility resource mix
- Reducing purchased power or generation costs
- Supporting local economic development

Utilities can monetize some of these benefits, creating a "triple-win" for utilities, customers (the portion that would, in fact, save money), and policymakers with green energy goals. Since the 1990s, a number of utility impact studies have been completed to test utility benefits and to identify factors that affect program outcomes. For example, the potential for coincident demand reduction has been confirmed, in a range up to 0.7 kW per system, depending on variables, such as solar resource, water use patterns, inlet water temperature, and utility load profile.[4] When deployed on a massive scale, such small savings add up. Hawaiian Electric Company (HECO), in the highest-penetration SWH market in the US, documented 12.7 MW of reduced demand and 53.8 million kWh in total energy savings from some 19,500 SWH systems, between the mid-1990s and 2002.[5]

Some findings, such as demand savings, are approximately replicated from study to study, but more recent research, including that described in the four studies highlighted here, suggests that impacts differ greatly depending on specific utility, market, and policy conditions. Industry players might overstate—or understate—potential benefits if they simply map the findings of popular studies onto their own locales.

Here the authors compare four studies, along with nation-wide program benchmarking information, in order to paint a more detailed picture of SWH program benefits today:

Cliburn, J., Bourg, J., and Robertson, C., *Solar Water Heating Performance and Business Model Assessment, CRN Project 07-13*, Cooperative Research Network January 2008. This study ("Valley Electric") included field monitoring of 40 conventional electric and SWH systems, utilizing one type of SWH system in different installation conditions for Valley Electric Association in Pahrump, NV.

Bourg, J., and Cliburn, J. (Millennium Energy), *Investigation of Solar Water Heating as a Demand-Side Management and Peak Reduction Strategy For Consumer-Owned Electric Utilities (#09-038)*, Colorado Governor's Energy Office, December 2009. This study ("United Power") utilized transient simulation (TRNSYS) modeling, based on one type of SWH system and control systems in different installation conditions for the Boulder, CO area co-op, United Power, and its power supplier, Tri-State G&T.

Bourg, J., and Cliburn, J. (Millennium Energy), *Utility Load and Economic Impacts of Solar Water Heating Market Penetration for Salt River Project and Its Customers*, September 2012. This study ("SRP") utilized TRNSYS-interface modeling of the utility's 4,600-unit SWH fleet, based on seven representative systems with electric and natural-gas backup heating, in different installation conditions for the Phoenix, AZ area.

Bourg, J., and Cliburn, J. (Millennium Energy), *Utility Load and Economic Impacts of Solar Water Heating Market Penetration for Arizona Public Service and Its Customers*, January 2012. This study ("APS") utilized TRNSYS-interface modeling of the utility's 6,500-unit SWH fleet, based on seven representative systems with electric and natural-gas backup heating in different installation conditions, for three climate zone regions in APS territory. This study has not yet been published.

2. METHODOLOGY

The first-completed (Valley Electric) study utilized field performance data, including TWACS automated meter reading technology on whole-house loads and submetering of each water heater. In addition, Metrima Btu meters were added to the SWH test group, to facilitate detailed data collection on solar thermal energy use. Due to the challenges of data collection (e.g., engaging customers in data collection for more than one season), some modeling was used to benchmark and enhance the field-data analysis.

The United Power study was initially designed for field data collection, but the limitations of that approach caused the utility to turn to modeling as a preferable option. The modeling approach utilized TRNSYS software, an industry standard for solar thermal performance analysis. TRNSYS support was provided by Thermal Energy Systems Specialists (TESS), drawing on extensive data from the Solar Rating & Certification Corporation (SRCC), US DOE Build America program, and other sources. Subsequently Millennium utilized this same modeling methodology for the two Arizona utility studies. The team introduced refinements, notably by creating a test group that was comprised of a weighted average of the seven most popular systems in the respective programs, and adding detailed customer demographics, dealer pricing, installation data, etc.

Millennium then applied its spreadsheet-based screening tool, called the Utility Economic Screening Tool (U-EST), to analyze the fleet's value from the utility perspective. This tool results in metrics such as SWH program savings on demand-related capacity charges, wholesale energy costs and lifecycle value of renewable energy certificates (RECs), as well as overall utility net benefit or cost. The U-EST requires utility data and data from a related Customer Economic Screening Tool (C-EST). This customer-focused step provides the utility with a more complete picture, including the ability to see how program design (quality controls, incentive levels, etc.) affects overall impacts.

Results from the analysis were presented in each report in narrative and graphic form. The graphic results (shown on a per system or per unit (kW or kWh) basis are used here as a quick way of showing how varied the utility impacts of SWH can be, given different geographic, market, and utility cost-structure conditions.

3. SWH PERFORMANCE CHARACTERISTICS

On an annual basis, per-system kWh savings varied as follows:

Valley Electric	1,751 kWh/year
United Power	2,703 kWh/year
SRP	1,722 kWh/year
APS	1,736 kWh/year

Total annual energy-savings, as well as daily and hourly variations by season, depend on:

- Solar resource (geography and climate)
- Water inlet temperature
- System design performance (OG-300 rating) for the overall fleet
- System installation factors
- Customer demographics and habits

Because of the importance of each of these influences, rule-of-thumb metrics for SWH value are often misleading. For example, the common metric *solar fraction* shows the percentage of the water-heating load that SWH could cover, but it says nothing about the magnitude of the load itself or about the actual performance of the fleet. In Phoenix, very warm inlet water temperatures (averaging about 81 degrees) and low plumbing heat losses depress the amount of energy that is needed for water heating. Although SWH covers a very high fraction of the water heating need, total savings in kWh is relatively low. By contrast, Boulder, CO, has a fairly low inlet water temperature (about 60 degrees). The solar resource cover only about 65% the water heating load, but it is a large load—thus yielding greater kWh energy savings.

Modeling of a system fleet sheds light on the difference that system performance can make. Figure 1 shows the annual kWh backup energy consumption of OG-300-rated systems in the SRP fleet. Given that systems with the greatest backup energy requirements held a large market share, the overall energy savings of the fleet was not as robust as it would have been with more targeted system choices. Figure 1 (and a similar chart in the APS study) also dispels the widely held belief that SWH is always better for larger households. The range of backup energy requirements for different systems, matched to different household sizes, suggests that there are better and worse energy-saving choices for households of all sizes. On the same theme, the Valley Electric study showed that there, the single model system that was being installed was over-sized for many of the small households in that market.

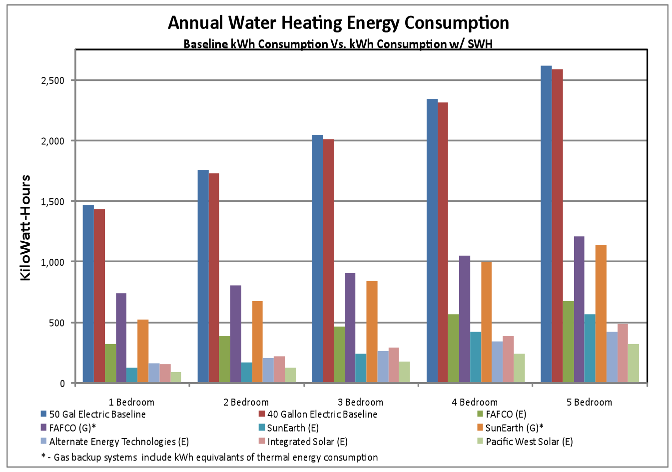

Fig. 1. Annual energy consumption for BWH and SWH systems, on a per-system basis

Further, customer economic analyses in every study showed that customers do not necessarily choose the most cost-effective system; popular systems were selected on the basis of availability or a marketing push. In every case, customer cost-effectiveness was not the primary market driver. This finding bears on the utility's approach to set an incentive with the right marketing appeal. This was demonstrated to be more important to successful program design than hitting a particular payback or ROI target.

Daily SWH performance patterns in winter and summer are potentially central to utility cost-effectiveness, because utilities can see how SWH might offset monthly or seasonal peak demand costs. Hot water energy use typically rises steeply in the morning, falling in mid-afternoon, and rising again less dramatically in the evening. The amount of hot water used differs seasonally, but the pattern is usually the same. Winter peak-day energy-savings curves for each of the four utilities studied were similar, and summer peak-day energy-savings curves also were consistent. For example, the APS winter-day curve was similar to that for SRP, despite coming from three different locations in the state. The Valley Electric data showed a similar curve, as well, though it was "spiky," due to the small sample size. The United Power curve was similar, though missing the dramatic winter morning peak, probably because there are fewer electric space heating customers.

The thermal storage characteristic of SWH is evident in these curves. Stored heat contributes greatly to the SWH customer's morning hot water needs, as well as to needs in the early evening. The research, including actual performance monitoring (submetering) of systems at Valley Electric, suggests that backup water heaters may be coming on more readily than would be necessary, and that solar's thermal storage capabilities are even greater than indicated.

4. <u>MODELING UTILITY ECONOMIC VALUE</u>

Intuitively, one would think that SWH would contribute to winter and summer peak-day load management. By mapping specific utility load data against system performance (using TMY, 30-year solar resource data to verify availability for specific days and times), this research verifies load management impacts, but with potentially very different economic results for each utility. For example, Figures 2(a), 2(b), and 2(c) show the winter peak-day load curves for Valley Electric, United Power, and SRP, with the (kW) demand-savings from SWH superimposed. Valley Electric, which has a significant electric home-heating load, shows a dramatic winter morning peak. SRP also has a relatively pronounced winter morning peak. United Power demand savings are less pronounced at that time. In each case, SWH can address the utility winter morning peak. SWH addresses winter evening peaks, too, to varying degrees.

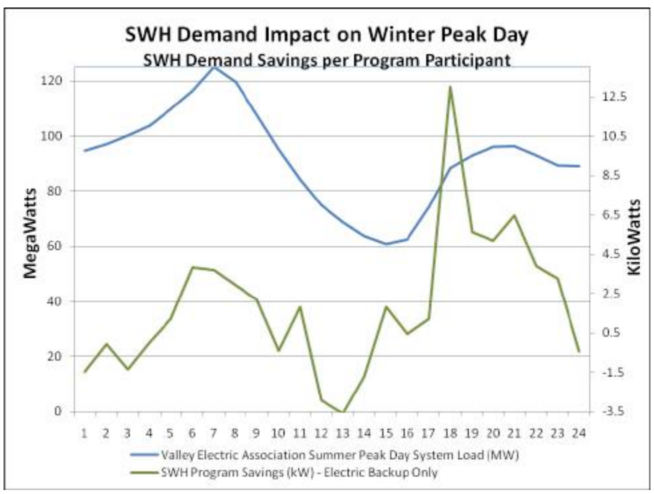

Fig. 2(a). SWH Demand Impact on Winter Peak Day Loads for Valley Electric Association

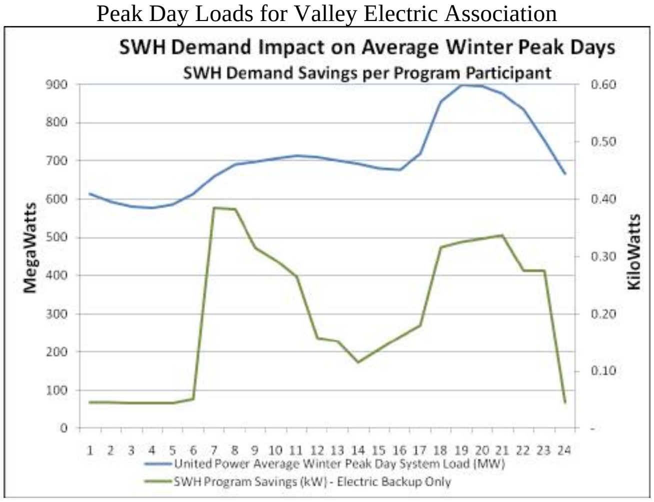

Fig. 2(b). SWH Demand Impact on Winter Peak Day Loads for United Power

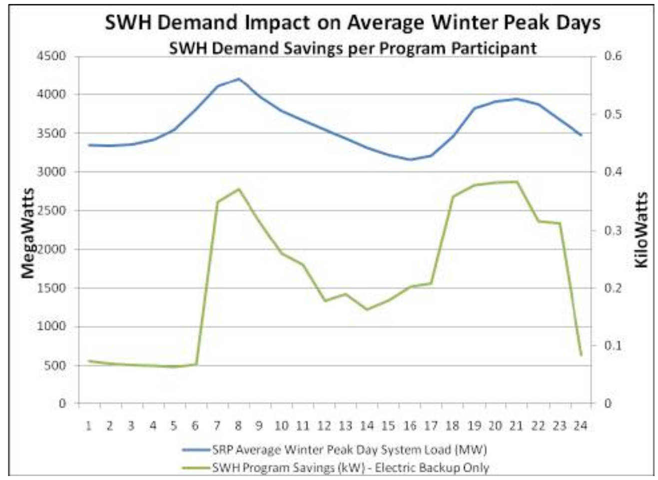

Fig. 2(c). SWH Demand Impact on Winter Peak Day Loads for Salt River Project

Figure 3 shows the summer peak-day load curve for SRP, with the demand savings from SWH superimposed. Here, the utility's morning peak is "washed out" by the steady rise in electricity demand for air conditioning. Yet SWH continues to contribute to peak-load reduction well into the evening. Note how this graphic is potentially deceptive; the utility has a very high air-conditioning-driven peak. At the same time, its summer water-heating load is suppressed by the warm water inlet temperature and lack of plumbing heat loss. Thus, the coincident summer peak day demand savings from SWH was calculated to be only 0.14 kW per system. By contrast, SRP's winter coincident peak day demand savings from SWH in winter was calculated to be 0.46 per system—a modest, but viable load-reduction opportunity.

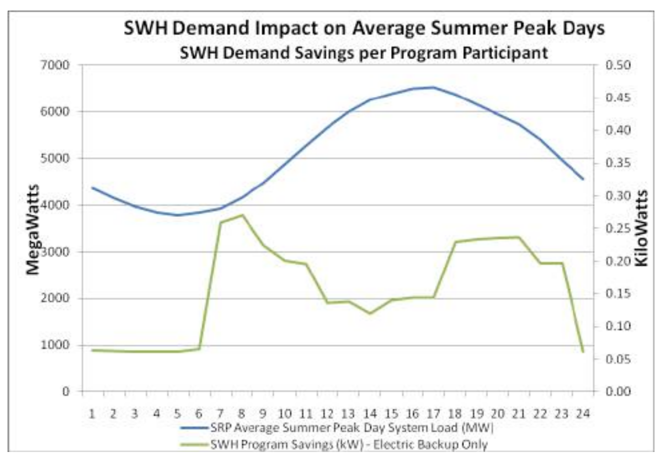

Fig. 3. SWH Demand Impact on SRP Summer Peak Day Loads

The potential for SWH to reduce winter peak loads was consistently significant in these studies, though the magnitude of savings differed, based on what drives the utility load, the size of the water-heating load on peak, and other market conditions. The range is less than 0.8 kW on a per-unit basis, but total SWH impacts depend on multiplying a relatively small savings by many systems.

More important is whether the utility can monetize load-reduction impacts or benefit in some other, tangible way. For example, a wholesale demand charge imposed on United Power at the time of the study made a big difference, from the utility's point of view. Once wholesale demand charge savings of $21.50 per kW were applied to the United Power analysis, the savings from existing and potential SWH market penetration would begin to add up. Total demand savings over the 20-year course of the analysis added up to more than $2,000 per SWH unit. United Power customers also could benefit from federal tax credits and a state rebate, which lowered the utility's marketing cost. Even accounting for lost kWh sales and program administration costs, United's program offered robust savings of some $1,200 over the life of each system. By contrast, the SRP analysis showed a utility economic loss over the SWH system life of about $2,000. Despite cost-effective program administration and potential REC value benefitting program cost-effectiveness, SRP owns excess generating capacity and did not face wholesale demand charges. SRP also provided a SWH incentive in addition to a state tax credit. It has justified the program based on progress toward utility Sustainable Portfolio goals.

In summary, each utility's SWH program cost-effectiveness is based on drivers including:

- Federal and/or state incentives or rebates to support marketing/incentives
- Support (from government or industry) to lower administrative costs related to quality assurance
- Avoided wholesale demand charge and/or
- Wholesale supply structure that rewards avoided kWh
- Other policy targets (avoided compliance costs)
- Marketable RECs and value relative to PV RECs

The relative value of SWH and PV RECs is discussed the Section 4 of this paper.

5. <u>COMPARING UTILITY IMPACTS OF PV AND SWH</u>

If one utility objective is to acquire solar RECs, the question is whether SHW helps, and at what cost? In most states, SWH RECs have no compliance value at all.[6] In a few locations, SWH REC value is keyed to an avoided compliance payment, potentially high. More often, the question is simply, which REC costs less—PV or SWH? The margin (positive or negative) between the lifetime values of these RECs is the SWH REC value. For example, the current SWH REC value for SRP is $0.0087, because that is the marginal benefit for the utility to purchase a SWH REC over a PV REC. In future years, the marginal value of this SWH REC is expected to go negative, because PV incentives (and thus REC values) will continue to fall. Under these conditions, utilities must consider whether to reduce the SWH incentive, in line with PV incentives per kWh offset. Alternatively, they might consider whether there is added value of SWH, which could justify slightly higher SWH incentives, relative to PV.

The compatibility of SWH and PV as a combined solar resource was explored in this research. As indicated in previous Figures, the daily demand-savings curves for SWH and the utility peak-day load curves are often compatible. For the utilities studied, SWH delivered demand savings throughout the winter morning and evening peaks. In summer, SWH tended to offer an added shoulder-period benefit, extending into later hours.

By adding modeled local PV performance as a third curve on each graph, a new perspective on the SWH resource emerges. Figures 4(a), 4(b), and 4(c) show SWH and PV performance against utilities' winter peak-day load curves, and Figures 5(a), 5(b), and 5(c) show SWH and PV performance against utilities' summer peak-day load curves. This exercise assumes utilities would institute large-scale SWH programs, so per-unit, kW-scale impacts would be mapped up to MW scale. (In fact, SRP, APS, and Valley Electric have seen SWH market growth that is on-track for at least 2% market penetration, with greater potential yet untapped.) The exact timing and magnitude of impacts differ for each utility, but in each case, SWH and PV could apply solar-resource benefits throughout winter peak days. In fact, SWH addresses utility winter peaks more directly than does PV. If the SWH contribution were scaled up, it might be considered in combination with PV to resemble a strong intermediate resource—available from about 7 am to 11 pm, though with a notable peak in PV generation during the mid-day hours.

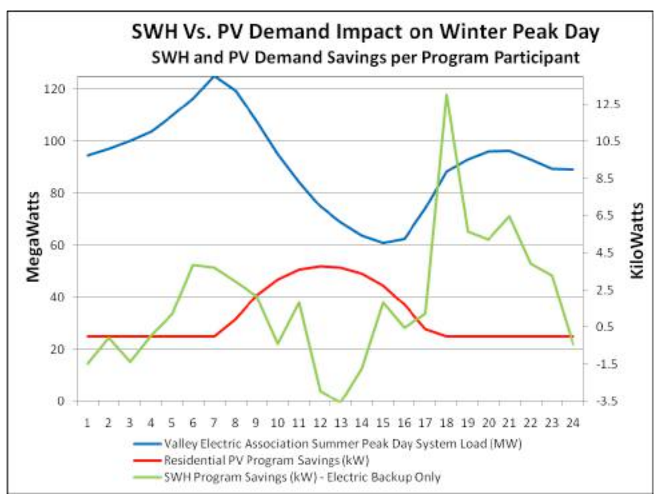

Fig. 4(a). SWH and PV Demand Impacts on Winter Peak Day Loads for Valley Electric Association

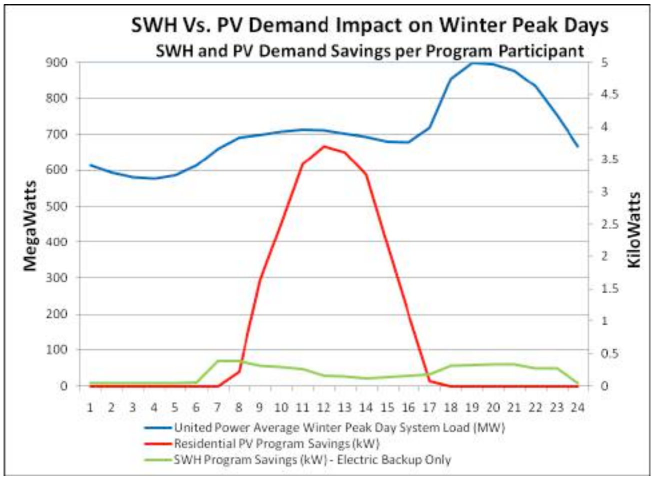

Fig. 4(b). SWH and PV Demand Impacts on Winter Peak Day Loads for United Power

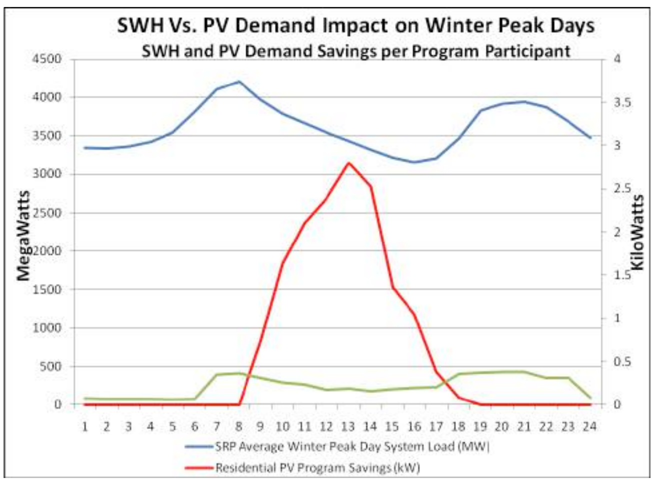

Fig. 4(c). SWH and PV Demand Impacts on Winter Peak Day Loads for SRP

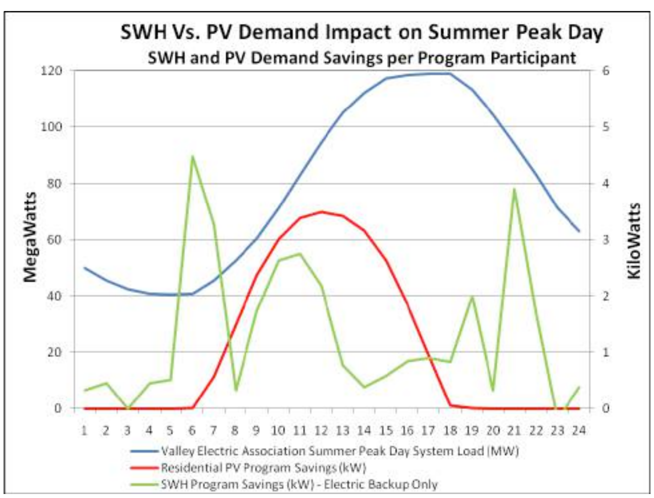

Fig. 5(a). SWH and PV Demand Impacts on Summer Peak Loads for Valley Electric Association

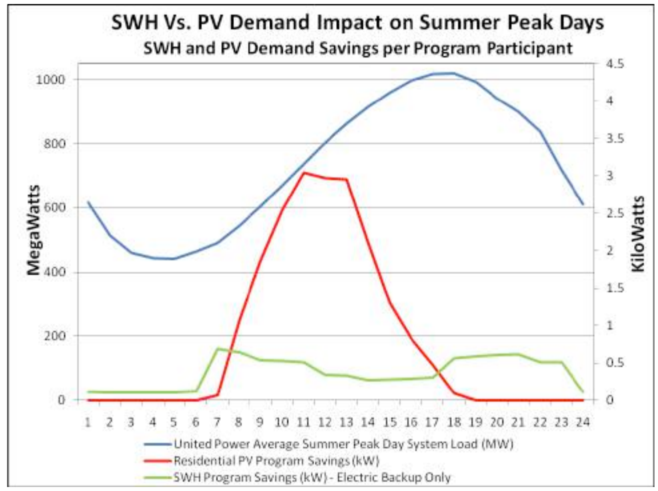

Fig. 5(b). SWH and PV Demand Impacts on Summer Peak Loads for United Power

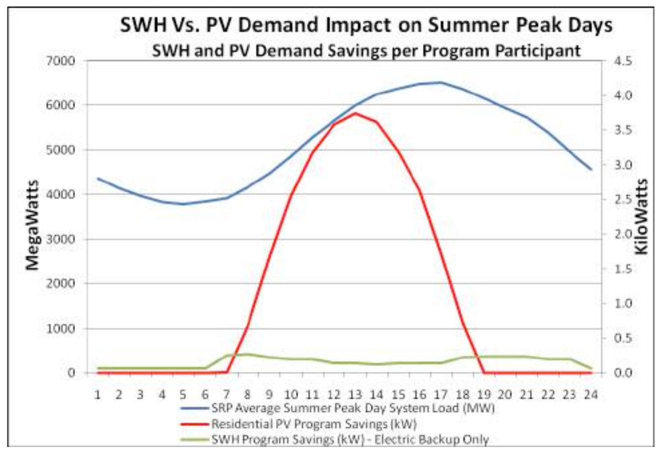

Fig. 5(c). SWH and PV Demand Impacts on Summer Peak Loads for SRP

In summer, SWH contributes to peak load reduction on the afternoon peak, generally better than does PV. This is because of the thermal storage capability of SWH. The impact differs from utility to utility, however. At SRP and APS, a very low summer water-heating load (due to high water inlet temperatures and low plumbing heat loss) diminishes the ability of SWH to contribute to peak load reduction. At United Power, the relatively strong summer coincident peak demand savings per unit of SWH is striking, as is the misalignment of PV summer daily peak generation and the utility's peak demand. Here, PV could offset rising summer peak demand, and SWH could extend benefits throughout utility peak hours. As noted above, utility load benefits do not necessarily yield *economic* benefits. In each case, the economic impact of a combined PV-SWH fleet must be modeled, to see if price signals would support the strategy.

In territories where PV market penetration has been booming, SWH may provide an added advantage. Here, applications for interconnections and net metering have raised utility concerns about how to keep up with paperwork and potential infrastructure costs. A sometimes-heated regulatory debate about PV solar net value calculations continues, beyond the scope of this research. But regardless of that debate, SWH is clearly above the fray. There are no interconnection or net metering costs involved and no grid impacts except a slight per-system improvement in load factor and grid stress relief. And with significant SWH and PV together, those benefits would be enhanced. For example, it would take five household SWH systems to about match the kW-equivalent capacity of the average Phoenix-area household PV system. A utility could—at least in theory—promote five times the market penetration of SWH as PV, in order to maximize the overall (PV + SHW) resource benefit. This would vastly increase the number of "solar homes," while maintaining (or modestly slowing) PV market growth. A prerequisite customer economic analysis indicated that PV and SWH (at least in the Phoenix area) had, on average, about the same "payback" on customer investment in 2011, so both are viable choices, depending on customer preference.

This research recognizes countervailing pressures. Currently, the US SWH market is waning. Customers prefer PV for its modern image, apparent simplicity, and ready financing. Utility SWH case studies are peppered with concerns about system and installation quality. In fact, this research showed a wide range in system performance and cost-effectiveness in a single utility fleet. New, competing water heater technologies have emerged too, along with a growing—if temporary—supply of cheap natural gas that SWH cannot beat. A successful SWH initiative would have to address or accept all these risks. Yet the US has not seen a strong policy and utility push for SWH in a generation, if ever. The combined benefits of PV and SWH could change the conversation about SWH.

6. DISCUSSION OF ANALYTIC RESULTS

This paper has drawn on impact studies of four utility SWH programs in the Western US. Each of these studies demonstrated the importance of understanding SWH fleet performance—i.e., which specific systems and households characterize the market. This includes understanding the match between fleet performance and utility seasonal and daily load requirements. SWH generally is a good tool to address utility winter load management concerns, and for most utilities and to a lesser degree, those same concerns in summer. If the utility wholesale cost structure monetizes load factor improvement or peak shaving benefits, the payoff could be strong.

These findings come at the same time as utility interest is being drawn from SWH toward PV. In 2011 US PV capacity increased by more than 100%, and incomplete data for 2012 suggest the strongest market growth ever for residential system installations. By contrast, the annual percentage SWH market growth remains in single digits. More striking, state and utility PV incentives are falling, so today's SWH incentives are or soon will be greater on a levelized cost basis than incentives for PV. Utilities have wondered whether to continue to incentivize SWH.

This team performed a limited comparative analysis of PV and SWH value, from the utility's point of view. As described above, SWH benefits are potentially strong and uniquely suited to many utilities' daily resource needs. Together, SWH and PV resources are compatible. If the SWH resource were "scaled up," comparably with PV, the combined solar resource could contribute all day—from about 7 am to 11 pm, due largely to SWH's natural thermal storage capability. This benefit, along with SWH's considerable (but so far uncalculated) benefit of avoiding or deferring PV interconnection, integration, and net metering costs, justifies a significant SWH program investment for many utilities.

This paper discusses some cautionary concerns, the greatest of which is whether utilities could deploy SWH on a scale great enough to complement growing distributed PV capacity. Based on average system size in Phoenix, AZ, a resource "match" would require at least five residential SWH systems per average PV installation. While this would be steep market growth, SWH market penetration in some other cold countries (and in Hawaii, a unique US market) suggests that, with policy and utility support, this would be an achievable goal. Several of the utilities in this study were on track for 2% or greater SWH market penetration, an encouraging start. Also, promising opportunities in the commercial SWH market were not yet considered.

Further analysis could estimate values for the full range of utility benefits of SWH, such as the value of deferred interconnection and net metering costs. Business models also could be assessed, such a buildout of the best performers in the fleets studied and the potential in utility partnerships with third parties who might offer "hot water energy services" businesses. From a practical perspective, SWH might, at least, be viable as a way to satisfy customers' interests in "going solar," until issues associated with the today's booming PV market can be addressed.

7. ACKNOWLEDGEMENTS

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[5] Richmond, R., *HECO Solar Water Heating Program*, presentation to the San Diego, California, Solar Water Heating Summit, January 2007
[6] See www.dsireusa.org/solar/summarymaps/ for up to date listing of states allowing SWH RECs. Current list includes New York, Maryland, Washington DC, Virginia, Arizona and Nevada.