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# Statewide Joint IOU Study of Permanent Load Shifting

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Prepared for:  
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Pacific Gas and Electric,  
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December 1, 2010

CALMAC Study ID SCE0292.01



**Energy+Environmental Economics**



**StrateGen**  
*Strategies for Clean Energy*

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## Glossary

CE	Cost effectiveness
CEC	California Energy Commission
CPUC	California Public Utility Commission
DR	Demand Response
DSIRE	Database of State Incentives for Renewable Energy
EM&V	Evaluation, Measurement and Verification
IMIOC	Internal melt ice on coil
ISAC	Ice storage air conditioning
PAC	Program Administrator Cost Test
PG&E	Pacific Gas and Electric Company
PLS	Permanent load shifting
RIM	Ratepayer impact measure test
SCE	Southern California Edison
SCHW	Stratified chilled water
SDG&E	San Diego Gas and Electric
TES	Thermal energy storage
Ton-hour	Unit of cooling energy (equivalent to 12,000 BTUs)
TOU	Time of use
TRC	Total resource cost test

## 1. Executive Summary

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The purpose of this study is to investigate cost-effectiveness and program design to expand the use of permanent load shifting (PLS) within the SCE, PG&E, and SDG&E service territories (“Joint Utilities”). PLS refers to a broad set of technologies that shift electricity use from peak to off-peak periods. This report is an outcome of the California Public Utility Commission (CPUC) Order D.09-08-027 “Decision adoption demand response activities and budgets for 2009 through 2011” and will provide more information to the Joint Utilities on PLS for use in preparing proposed Demand Response programs, including PLS, to the CPUC.

Energy and Environmental Economics, Inc. (E3) and StrateGen Consulting were selected by the Joint Utilities and the CPUC to conduct this study. E3 and StrateGen Consulting (the “project team”) used a collaborative stakeholder process with two workshops, numerous stakeholder interviews and meetings, and the release of a publicly available cost-effectiveness tool to develop the study results. The project team also gathered and used data from each of the utility PLS Pilot Programs, and technology vendor data in the public domain and under Non-Disclosure Agreements (NDAs).

As described in this report, the study addresses the following areas:

- Definition of Permanent Load Shifting
- Cost-effectiveness of PLS
- PLS Program ‘Best Practices’ and Stakeholder Input
- Proposed PLS Program Design Elements, including Standard Offer

### 1.1. Definition of PLS

For the purposes of this study, the project team proposed and uses a broad definition of PLS. With support of the stakeholder group, a ‘technology neutral’

definition was proposed based on the impact of the electricity usage profile, rather than the technology used to create the impact. Additional guiding principles include business/ownership neutrality, and the measurable shift at program level for EM&V. PLS is defined with the overarching goal of “routine shifting from one time period to another during the course of a day to help meet peak loads during periods when energy use is typically high and improve grid operations in doing so (economics, efficiency, and/or reliability).”

The type of load shape impact that meets the PLS definition can be delivered by technologies in three broad categories; electrical energy storage, thermal energy storage, and process shifting (see Table 1). Each technology category and individual technologies within each class have their own unique costs, benefits, strengths and limitations. For example, some of the technologies are mature and in wide use, such as thermal storage systems for building cooling systems, and some are still emerging such as electric battery storage; some provide a ‘static’ set shift in load pattern, while others can provide a ‘dynamic’ response based on electric system conditions. There are also process shifting efforts that involve rescheduling the use of electricity. For all of these categories, it will be extremely challenging to create a single, simple, technology neutral PLS program design that appropriately addresses the differences in the costs and benefits of the technologies to establish a common design framework.

**Table 1: PLS technology applications, categories and examples**

<b>Application</b>	<b>Category</b>	<b>Primary characteristics/ examples</b>
Stationary	Thermal storage	Generate ice or chilled water at night, then use this stored ice or chilled water to provide cooling during the day.
Stationary	Non-thermal storage	Chemical batteries, mechanical storage – e.g., fly wheels, modular compressed air (CAES)
Stationary	Facility process shifting	Processes conducted within a facility that are shifted from one time period of the day to another
Mobile	Plug-in electric vehicles	Not in scope (Because mobile storage has a concurrent proceeding at the CPUC)

While the PLS definition is broad, there are many elements that this report has found to be outside the scope of PLS. First, PLS is not solely event-based demand response. Second, PLS is not behavior-based energy efficiency. PLS is provided and quantified by discrete equipment or controls, not solely by general customer behavior modification, and it does not reduce the level of customer service. Third, the load reduction and shifting that can be achieved by best practices commissioning, retro-commissioning or adjustment of controls is not considered PLS, unless such practices are being applied directly to existing legacy PLS technologies (such as unused thermal storage tanks) and are not currently being implemented through energy efficiency programs. We also exclude, by stakeholder consensus, the inclusion of electric vehicles in PLS. Finally, PLS is not achieved through fuel switching.

## **1.2. PLS Cost-Effectiveness**

The project team emphasized the importance of cost-effectiveness of PLS throughout the development of the study. E3 focused on the overall societal and ratepayer cost-effectiveness of PLS, given current California electricity market conditions. StrateGen Consulting focused on the value proposition to the end-user and whether a given PLS program design was likely to result in significant adoptions. This approach was designed to provide more information to the Joint Utilities as they decide the scope and scale of their proposed PLS programs and to provide more information for establishing incentive levels that balance the costs to ratepayers and expected program adoption rates.

To value the benefits of PLS to ratepayers, and to California as a whole, E3 developed a PLS cost-effectiveness framework that is similar to the framework used to evaluate the benefits of utility distributed generation programs such as the California Solar Initiative (CSI) and the Self-Generation Incentive Program (SGIP) [Decision 09-08-026, August 20, 2009]<sup>1</sup>. A similar framework is also currently being considered for use in evaluating the cost-effectiveness of demand

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<sup>1</sup> [http://docs.cpuc.ca.gov/published/FINAL\\_DECISION/105926.htm](http://docs.cpuc.ca.gov/published/FINAL_DECISION/105926.htm)

response [R. 07-01-014]. The precursor to each of these was the development of avoided costs for energy efficiency adopted by the CPUC in 2004 and 2005 [R.04-04-025]<sup>2</sup>.

The avoided cost benefits provided by PLS include electrical energy, losses, ancillary services, system (generation) capacity, transmission and distribution capacity, environmental costs, and avoided renewable energy purchases. We also investigated the renewable integration benefits of load following and over-generation that could be provided by PLS.

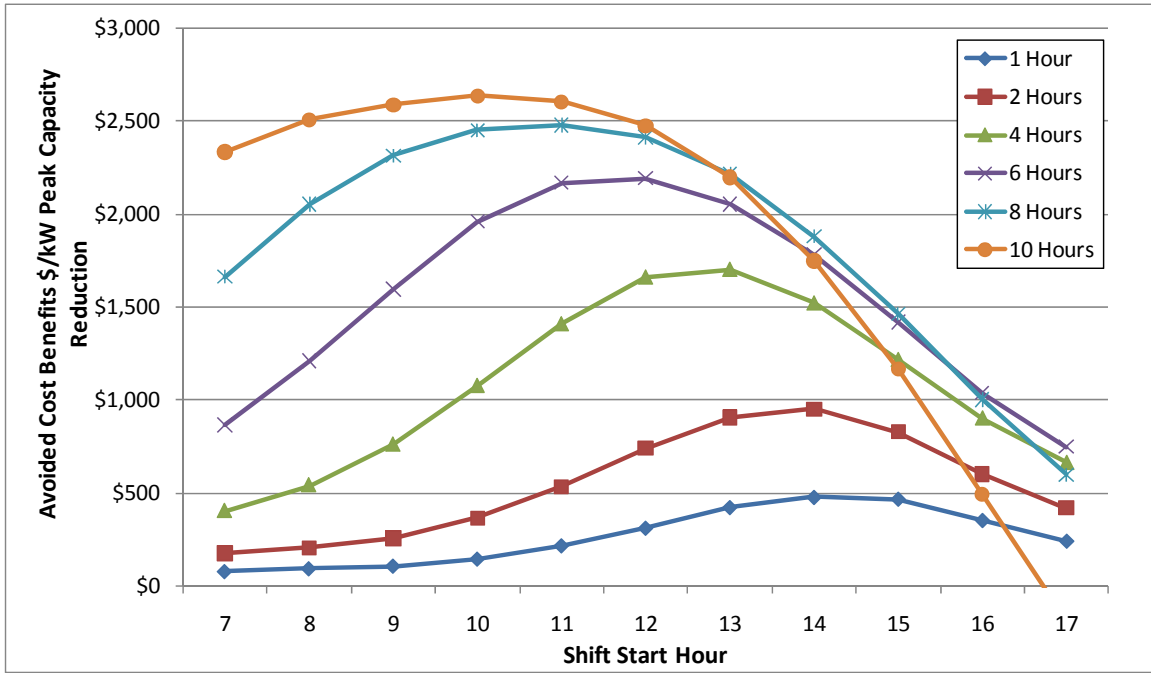
As shown in Figure 1, using this new PLS cost-effectiveness framework, the lifecycle value of the avoided cost benefits of PLS technologies (assuming 15 year project life estimates) is in the range of \$500/peak kW to \$2500/peak kW, depending on the number of hours the PLS system can shift load, and what hour the load shifting starts. These figures are calculated based on the kW value of the load shift and are 'technology neutral', and do not include benefits from other value streams. They assume the 'best case' operational profile in that they assume the maximum load shift every day of the year, and off-peak usage at the least cost period during the night. For example, a 6-hour load reduction beginning at 12pm over an assumed 15-year life is valued at ~ \$2200/kW (or \$365/kWh stored capacity).

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<sup>2</sup> [http://docs.cpuc.ca.gov/word\\_pdf/FINAL\\_DECISION/36203.pdf](http://docs.cpuc.ca.gov/word_pdf/FINAL_DECISION/36203.pdf)



**Figure 1: Broad Scenario Analysis – Avoided Costs**



While the project team believes these figures are appropriate for currently available PLS technologies, we note that the benefits in Figure 1 do not include the provision of ancillary services such as regulation that some PLS technologies plan to provide<sup>3</sup>. In addition, some stakeholders have suggested that a 15-year life is too short and longer lived installations will have greater lifecycle value.

To address these issues, the report presents these sensitivities and many others. For example, an assumed 30-year project life cycle is estimated to increase lifecycle avoided cost benefits by approximately 30%. The main results are also shown in terms of lifecycle \$/kWh-stored, which is a common capacity metric for batteries. The “in-situ” cost-effectiveness of both simulated and real installations (such as from the utility PLS pilots) are also provided.

Using the California Standard Practice Manual (SPM) framework for evaluating the cost effectiveness of ratepayer funded programs that the CPUC relies on for

<sup>3</sup> A number of battery technologies providers have indicated their ability and interest to provide ancillary services as well as load shifting.

other distributed resources, the installed PLS system costs must be less than the lifecycle benefits in order to pass the Total Resource Cost (TRC) test. While the installed system costs specific to PLS are often difficult to ascertain (for example, due to customer confidentiality), or the costs were obtained under a nondisclosure agreement (NDA) and cannot be shared in this report, certain classes of thermal storage are likely to pass the TRC (e.g., warehouse precooling achieved by controls modifications, improvement of existing thermal storage systems, medium-sized ice-based storage, chilled water for new construction and expansion applications); these technologies are more mature and their lifecycle values tend to be within the range of the avoided cost benefits. Emerging grid connected battery technologies and smaller scale<sup>4</sup> thermal storage systems with higher costs are less likely to pass the TRC cost-effectiveness test at their current system costs.

One of the objectives of this study was to determine what level of incentive payment would be appropriate. From a ratepayer perspective, an incentive can be provided to reduce the incremental costs of PLS systems over standard non-PLS technology without any 'cross-subsidy' at a level equal to the lifecycle benefits presented in Figure 1 **less** the bill savings the end-user receives by operating the PLS system. One can think of the bill savings as 'paying' the end-user for the societal benefits they provide with their PLS system. This study finds that even when the PLS operations are designed to maximize bill savings, there are some situations when an incentive payment can be provided without any cross-subsidy. The actual value of this 'ratepayer neutral' incentive level depends on the PLS system operation and the specific retail tariff.

Using a 'generic' rate that is representative of medium and large commercial customers' rate structures, we find an incentive payment of ~ \$100/peak kW to \$800/peak kW for PLS is possible without any cross-subsidy. When modeling specific IOU rates, the rate payer neutral incentive levels range from roughly

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<sup>4</sup> Smaller scale thermal storage is defined as units < 10kW, such as those installed on small commercial buildings that do not have central cooling plants.

-\$800/peak kW to \$1600/peak kW. Ratepayer neutral incentive levels for specific installations are also provided in the main body of the report.

### **1.3. Value Proposition to End-User**

While the economic analysis of demand side programs focuses on the costs and benefits to society and the funding levels needed to develop cost effective programs, customers will ultimately need to see the direct benefits of PLS technology adoption to their core business to justify their investment of capital and time, and their assumption of various project risks. The StrateGen Consulting team evaluated the end-user value proposition to determine incentive levels that would be needed to promote the likely adoption of specific PLS technologies, based on stakeholder feedback on customer-specific required payback periods. The analysis also provides insights into other elements of the program design that are important to encourage PLS technology adoption, such as the investment business model, financeability, and mitigation of tariff risk related to changes in bill savings over time.

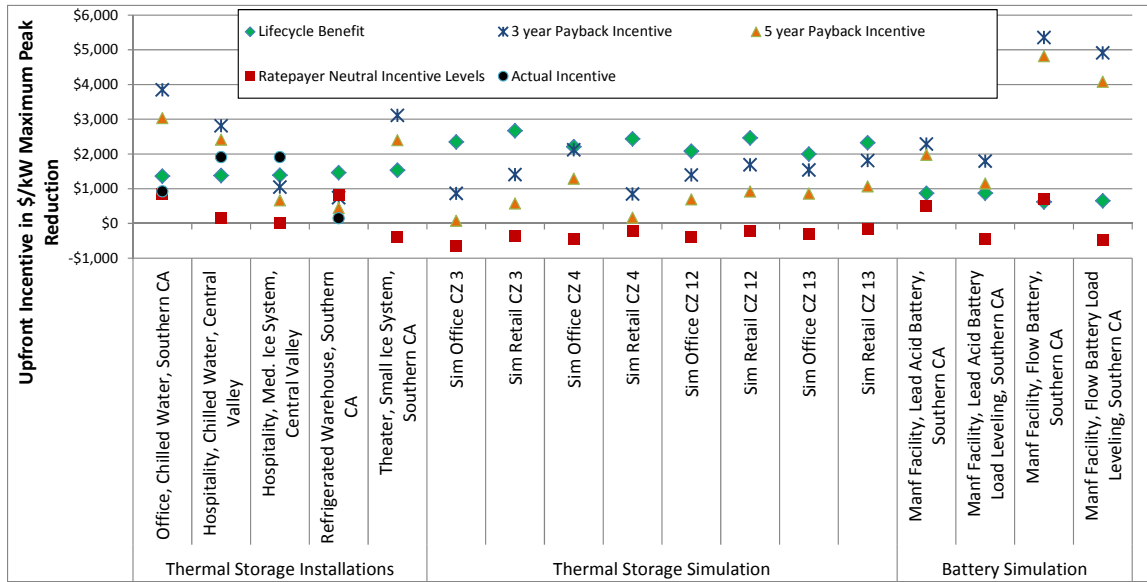
Numerous stakeholders provided consistent input that the end-user's financial hurdle for adoption is a minimum 3 to 5 year payback. This is a significant financial hurdle that typically requires greater than 15% internal rates of return. Stakeholders also uniformly expressed concern on how tariff structure changes can undermine the economic return of PLS projects, and that to date, such 'tariff' risk' has been largely uncontrollable. StrateGen tested these required payback hurdles by conducting a project-specific value proposition analysis of simulated PLS systems and IOU pilot project data.

For simplicity, a \$/max kW incentive level for shifted off peak load was calculated to achieve three and five year paybacks. However, it is important to note that such incentives can be structured in a variety of ways, which is further described in the program recommendations section.

The following graph overlays several simulated PLS system payback scenarios for various building types in different California climate zones for thermal storage, along with simulations for battery storage simulations for manufacturing building

load profiles. The simulations compare the amount of the required incentive levels (\$/kW) for encouraging PLS customer adoption for 3 and 5 year paybacks. Also included are two of the SPM cost effectiveness evaluation tests<sup>5</sup> for comparison:

**Figure 2: Required Incentives. Lifecycle Benefit & Ratepayer Neutral Incentive Levels**



The chart above indicates that the required incentive levels for the thermal storage simulations range from about \$100 to \$1,000/kW to achieve a 5 year payback for the end user and approximately \$860 to \$1,800/kW to achieve a 3 year payback. The battery simulations' required incentive levels range from \$1,100 (5 year payback) to over \$5,000 (3 year payback) to achieve required customer investment payback levels. It is important to note that the battery simulations were performed for only two different battery technologies among a wide range of possible battery technologies. The results will vary tremendously depending on the specific type of battery technology used. For many simulated examples, the 3 and 5 year payback incentive levels are less than the total lifecycle benefits, but are still greater than the ratepayer neutral incentive levels.

<sup>5</sup> The Program Administrator Cost (PAC) and Ratepayer Impact Measure (RIM) tests

## 1.4. PLS Market Assessment

The assessment of the PLS market opportunity is based on an overview of PLS incentive programs in the U.S. and stakeholder feedback gathered from California IOU program personnel, third party vendors, engineers, PLS technology suppliers, and other individuals and companies<sup>6</sup>.

The majority of the programs around the country are utility-sponsored thermal energy storage standard offers. Other program types include special TOU rate structures or technology-neutral load shifting programs. The following conclusions are based on a review of fifteen utility programs in the U.S.:

- Funding feasibility studies improves outcomes and customer commitment, and is a core part of many programs' incentive structure.
- A number of programs offer special TES/PLS rates that accompany incentives, which not only reduce tariff risk and provide greater certainty for economic return, but also improve payback and encourage efficient system operation.
- Programs that do not provide an adequate up front incentive will struggle to attract customers, particularly in today's challenging economic climate.
- Utility-ownership reduces costs through increased purchase volume and more efficient customer targeting, but this model may not be of interest to many utilities due to the complexity of utility ownership for behind-the-meter, customer sited assets (particularly very small PLS systems).

While this study is exploring a variety of PLS technologies, due to PLS program eligibility requirements, it is important to note that most of the program design feedback reflects experience with thermal energy storage systems from the PLS pilots. Table 2 summarizes the stakeholder feedback into consensus feedback, or feedback that was expressed and agreed upon by most stakeholders, and non-

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<sup>6</sup> Over 30 stakeholder interviews were conducted

consensus feedback, representing areas of disagreement regarding the ideal approach to encouraging PLS.

**Table 2: Consensus and non-consensus feedback**

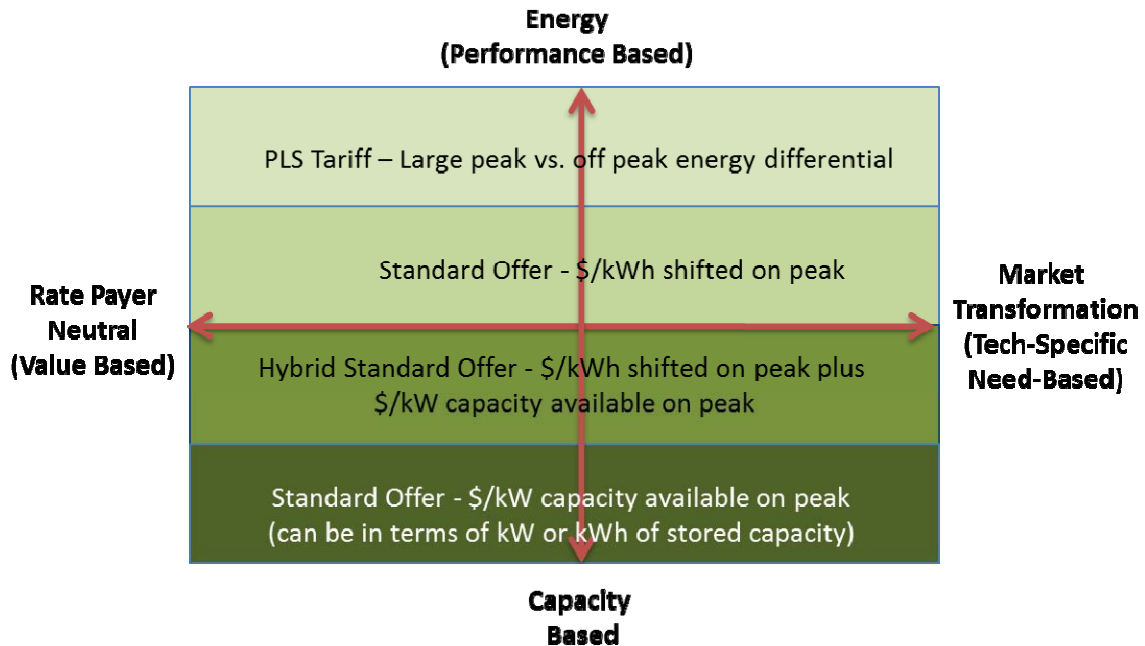
Consensus	Non-Consensus
Lack of consistent and transparent rate structures that promote PLS are an impediment	Desired incentive levels and structure of incentive (e.g., Tariff based only or tied to capacity/ hours shifted)
A standard offer is preferable to an RFP, as it more easily encourages technology neutrality, and participation by smaller stakeholders	Tailoring of incentives to technology class and size.
Incentive levels need to take into account all project and market entry costs, deliver 3-5 year payback, and not exclude any technologies from participation	Required metering/monitoring, specifics as to what needs to be monitored and at what level of detail
Consistency in programs across IOU service territories is important	Allocation of PLS budget (e.g. marketing vs. implementation funding)
Program complexity adds costs and discourages market participation	Potential for market expansion
Lack of education/training about PLS technologies — their design, implementation and operation — is a severe challenge	

## 1.5. PLS Program Recommendations

There are a number of dimensions by which the CPUC can consider standard offers for PLS program design. The most fundamental dimensions are the program structure and the monetary value of the incentive itself. The following chart illustrates these dimensions, each with its own respective continuum. Shown left to right, a PLS program at one end of the spectrum can have no impact to ratepayers. In this case, the incentive would be ‘ratepayer neutral’. This level of incentive could have a lenient program limit since there is no ‘cross-subsidy’ for ratepayers, nor an explicit goal of encouraging large amounts of well-operated PLS systems in the field. At the other end of the spectrum would be incentives whose levels are set based on the technology cost to encourage more ‘robust’ commercial adoption at the technology specific level, perhaps based on achieving certain payback or internal rate of return requirements by targeted end-users. This level of incentive would be useful to encourage ‘market

transformation’ of the PLS technology, would have tighter program caps to protect ratepayers, and a goal to reduce costs (and incentives) over time. From top to bottom, the program can be geared toward incentivizing energy shifting on peak over time, or, at the other end of the spectrum, be more focused on pure capacity.

**Figure 3: Standard Offer Program Design Framework**



Given the currently higher costs of grid connected battery applications and smaller scale thermal systems, the Joint Utilities and the CPUC may consider developing programs to encourage these technologies for market transformation reasons, as they can play a role in providing a high value use of ‘super off-peak’ renewable energy generation (“over-generation”) in the future.

As described in the program design findings, should the Joint Utilities and CPUC seek to develop an incentive program for PLS, we recommend segmenting the PLS program offering into at least two general technology categories; a ‘mature’ PLS technology category that is available to any PLS technology with nearly ‘ratepayer neutral’ incentive levels; and an ‘emerging’ PLS technology category that provides higher incentive payments (though limited in quantity) to specific PLS technologies such as small’ thermal storage and electrical battery storage that have the potential to provide more ‘dynamic’ system response in the future

suitable to support renewable integration. We recommend that process shifting be further evaluated to determine appropriate industries and loads to target for program development.<sup>7</sup>

In addition, a number of best practices were observed from the pilots and other PLS programs nationwide that are worth considering for California. The following summary of the PLS program design recommendations should be considered:

- Divide PLS Program into at least two categories based on technology; one for mature large scale PLS, and one for emerging PLS technologies, with different program designs and goals.
  - Mature: Large scale PLS deployment that minimizes ratepayer incentives and provides thermal-based solutions
  - Emerging: Market transformation for storage with focus on integration with renewable resources and energy efficiency
- Program design should address each of the three stages of the PLS system deployment through incentives, reports, or EM&V, to increase the quality of the deployed PLS systems. These include;
  - (1) feasibility and design of PLS systems,
  - (2) quality control of construction and post-construction functional performance testing, and
  - (3) persistence of PLS operations.
- Provide consistent and predictable bill savings to encourage long term customer investment in PLS technology, that

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<sup>7</sup> These program recommendations are based on our survey of best practices, utility pilot data analysis, stakeholder interviews, cost-effectiveness results, and workshop discussion.



- Provides a financeable level of long term rate stability to encourage the initial capital outlay in a PLS system. This can be done with a separate PLS rate, or by a 'guarantee' of minimum on- to off-peak rate differentials or 'grandfathering' existing TOU rates
- Offers a 'super' off-peak rate to encourage charging after midnight or 2am when the overgeneration problem is expected to be the worst and energy has the lowest cost, and
- Encourage sustained PLS performance using performance-based incentives and regular EM&V;
  - Performance-based incentives could be achieved through one of two approaches depending on technologies;
    - A 'PLS' tariff with TOU rate differentials provides some incentive to operate the PLS system well, and does not require a specific baseline development. This approach is more suitable for thermal storage.
    - A standard offer model based on an energy payment (\$/kWh shifted) provides a direct performance-based incentive, but would require strict guidelines for calculating baselines for thermal or process shifting PLS technologies. Therefore, this approach is easier to provide to electrical battery systems. This approach also reduces potential for "gaming" with battery systems (where batteries are used for non-PLS purposes such as for providing uninterruptible power supply).
  - Both incentive approaches should be coupled with an EM&V requirement to provide an 'operations report' and operational data of the system and the whole customer load.

- Incentives and incentive structure directly influence PLS design and operations, so it is important to provide incentives consistent with program goals
- Simplicity and transparency of the performance metrics are critical to minimizing program cost and encouraging customer adoption

As per the CPUC order that initiated this report, the Project Team has included a detailed discussion of a PLS standard offer proposal that could apply generally to any permanent load shifting technologies including, but not limited to, thermal energy storage. The specifics of the Standard Offer are covered in detail in Section 6 of this report.