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Ernest Orlando Lawrence Berkeley National Laboratory

Phase I Results: Incentives and Rate Design for Energy Efficiency and Demand Response

Orans, Ren, et al.

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Collaborative Report

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April 2006

This work described in this report was coordinated by the Demand Response Research Center and funded by the California Energy Commission, Public Interest Energy Research Program, under Work for Others Contract No. 500-03-026 and by the U.S. Department of Energy under Contract No. DE-AC02-05CH11231.

PREFACE

The Public Interest Energy Research (PIER) Program supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

The PIER Program, managed by the California Energy Commission (Commission), annually awards up to $62 million to conduct the most promising public interest energy research by partnering with Research, Development, and Demonstration (RD&D) organizations, including individuals, businesses, utilities, and public or private research institutions.

PIER funding efforts are focused on the following six RD&D program areas:

- Buildings End-Use Energy Efficiency
- Industrial/Agricultural/Water End-Use Energy Efficiency
- Renewable Energy
- Environmentally-Preferred Advanced Generation
- Energy-Related Environmental Research
- Energy Systems Integration

What follows is the final report for the Incentives and Rate Design for Energy Efficiency and Demand Response Project, 500-03-026 Task 4.I, conducted by Energy and Environmental Economic, Inc. The report is entitled "Phase 1 Results: Incentives and Rate Design for Energy Efficiency and Demand Response". This project contributes to the Energy Systems Integration Program.

For more information on the PIER Program, please visit the Commission's Web site at: http://www.energy.ca.gov/research/index.html or contact the Commission's Publications Unit at 916-654-5200.

Acknowledgements

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Abstract

This proposal describes the work performed in response to the Demand Response Research Center's Research Opportunity Notice DRRC RON-02, "Incentives and Rate Design for Energy Efficiency and Demand Response." A research team led by Energy and Environmental Economics, Inc. (E3) creates, and validates as a proof of concept, an analytical framework for evaluating incentives and rate design for demand response.

The framework consists of a number of screens that evaluate different aspects of DR rate design performance. The assessment includes economic efficiency and fit with the California emerging market structure, potential for significant load reduction, value to the system and customers, potential bill savings, and customer acceptance. Taken together, the screening steps should help to ensure that a DR rate design that scores highly against these criteria would be implementable within the California market, regulatory, and policy context.

The E3 team then evaluates illustrative DR rate designs with the evaluation framework as a proof of concept. The analysis, which is completed without input from stakeholders, uses only readily available or proxy data, and therefore the results are not necessarily meaningful beyond a validation of the concept. In Phase 2, the research team proposes further refinement of the analytical process through collaboration with all of the major stakeholders (customers, California ISO, utilities, 3rd party DR providers, and regulators) in the further development of demand response incentive and rate designs.

Executive Summary

- **Introduction**

Demand response (DR) offers potential economic and reliability benefits to consumers and utilities, by reducing peak electrical demand at times when cost of service is high or reserve margins are low. How best to encourage effective development of DR programs, however, remains a subject of debate. There is no clear consensus on the lessons or applicability of existing rates and programs, which include a variety of pricing-based (e.g., time of use, real-time pricing, critical peak pricing) and quantity-based (e.g., direct load control, interruptible/curtailable rates, demand subscription) rate designs. The problem is complicated by uncertainty about California's future market structure and regulatory environment.

For these reasons, there is an acute need for an effective methodology for analyzing a wide variety of existing and proposed rate designs, in order to evaluate their effectiveness in encouraging DR and their ability to fulfill multiple state policy objectives. Ultimately, this analysis should lead to the implementation of rates and program options that cost-effectively encourage DR and efficiency under a variety of future market and policy scenarios.

- **Purpose**

The objective of Phase 1 is to develop a proof of concept for an evaluation framework capable of assessment of a broad set of DR designs from the perspective of different California stakeholders.

- **Project Objectives**

This framework is in the form of a set of screens that can objectively answer fundamental questions regarding proposed new DR designs, and provide a mechanism to increase understanding of the strengths and weaknesses of DR rate design alternatives.

To demonstrate the approach, Phase 1 developed a series of screens and a number of illustrative rate designs were evaluated. The Phase 1 work was completed entirely by our team, without the input and perspective of California stakeholders, and only used data that were readily available. Therefore, the results of the Phase 1 work only illustrate the concept of the evaluation framework, which we propose to develop further with stakeholder involvement in Phase 2.

- **Project Outcomes**

The researchers identified four major screens that are significant for evaluating a potential rate design. While these screens do not necessarily cover a comprehensive set of all characteristics that affect rate design, they do represent a starting point for the ‘design charrette’, incorporating the most important issues to the major stakeholders in the rate design process. The design screens are:

- Screen 1: Technical Potential
- Screen 2: Resource Value
- Screen 3: Bill Impact and Free Riders
- Screen 4: Customer Acceptance

The research team identified and analyzed each of these screens individually and then explored ways in which they could be integrated into a general design framework. The experience of the team, which was selected to provide experts at each step, includes industry-leading experience in stakeholder engagement (E3 and LBNL), avoided costs and market design (E3, LBNL, NA), rate design (E3 and NA), and customer research (FSC).

- **Conclusions**

The research team identified four major screens for evaluating a DR program design, The team believes that these four screens will provide useful areas to analyze when considering the favorability of a particular design to customers in terms of acceptance and bill savings, to utilities in terms of resource value and technical potential of a DR program, and to regulators in terms of overall improvement in net social welfare. Used together, these screens can greatly enhance understanding of what kinds of program designs will work and why.

- **Recommendations**

The research team recommends that the four research screens developed in Phase 1 of this project be used a starting point for the proposed Phase 2 of this project. The proposed Phase 2 work would consist of four steps, which are briefly outlined below.

1. *Validate Proof of Concept*
   Using the tools developed in Phase 1, work closely with the project manager and at least one active participant from the CEC, to form an initial “strawperson” set of high potential DR designs for California using several plausible market structures. High potential is defined as being both valuable to the system and to at least one identifiable and significant segment of customers.

2. *Customer Acceptance Focus Groups*
   Test the acceptance of the different high potential DR programs attributes with different customer segments. We propose that this phase of the project be conducted as a series of focus groups. The format of the focus groups would leverage both the materials and the successful logistical implementation process used in the LBNL Customer Friendly DR Project, recently completed this year. For mass market customers, the focus would be on design attributes rather than on the DR designs themselves, and would provide the material that we would use to

construct and conduct a telephone survey among mass market customers. The latter focus group as well as survey would also draw upon the SPP evaluation results as another source of inputs. The more sophisticated larger customers would be asked to provide direct feedback on attributes as well as specific designs. The customer preferences would then be used in the customer acceptance screening tool, which is one screen used in the overall design charrette process.

3. *Stakeholder Design Charettes*
   Using our updated set of design tools, as well as inputs derived from Task 2, we would facilitate the development of high potential DR designs through design charrettes, built around the perspective of four different stakeholder groups:

   a. ISO and possibly WECC representatives
   b. Utilities (together as a single group)
   c. Third party providers of DR (e.g., program implementers, aggregators)

   The design charrettes would be developed separately for each group. Each group would participate in 3 facilitated working group sessions. In the first meeting, the group would be introduced to the process, the tools used to facilitate the process and the data, assumptions and preferences needed to seed the design tools. The consulting team would then develop initial design(s) which would be shared with the group in the 2^{nd} working session in order to elicit additional feedback and revisions/enhancements for inclusion as we move forward. A third working session would be offered if there were sufficient comments or revisions needed. We anticipate that the first working group session would last 3 hours, the second session 2-3 hours, and, if a third session was needed, it could be completed in approximately 1 hour.

   Interim progress reports would be developed at the completion of the process for each group, and will be used to help construct the policy design charrette discussed in Task 4 below.

4. *Policy Design Charette*
   Based upon the results of the working session design charrettes above, we would work with the DRRC Project Oversight Team to construct a similar charrette process for California's regulators. Note that we are defining regulators in a more encompassing manner than usually intended when discussing energy issues; here we are including the CARB and the Governor's office as well. In the first working session of the regulatory charrette, we would again share an overview of the process, as well as tools used to facilitate it. We would then review the DR design perspectives and their regulatory policy ramifications under the various market constructs envisioned.

- **Benefits to California**

Proper assessment of DR rate and program designs has many significant potential benefits to California. As energy prices and electricity reliability are issues that affect all California residents, optimal implementation of DR programs designed to improve reliability and lower costs has the potential to create economic and societal benefits, in addition to reducing emissions. This report identifies four major screens that are significant for evaluating a potential rate design, thus improving the ability of public and private resources to meet the electricity needs of Californians cost-effectively.

Introduction

1.1 Background

Demand response (DR) offers potential economic and reliability benefits to consumers and utilities, by reducing peak electrical demand at times when cost of service is high or reserve margins are low. These benefits were recognized during the California electricity crisis of 2000–2001, when California utilities and the California Independent System Operator (CAISO) inaugurated a variety of DR programs, and in ongoing proceedings of the California Public Utilities Commission (CPUC) and California Energy Commission (CEC).

How best to encourage effective development of DR programs, however, remains a subject of debate. There is no clear consensus on the lessons or applicability of existing rates and programs, which include a variety of pricing-based (e.g., time of use, real-time pricing, critical peak pricing) and quantity-based (e.g., direct load control, interruptible/curtailable rates, demand subscription) rate designs. The problem is complicated by uncertainty about California's future market structure and regulatory environment. For these reasons, there is an acute need for an effective methodology for analyzing a wide variety of existing and proposed rate designs, in order to evaluate their effectiveness in encouraging DR and their ability to fulfill multiple state policy objectives. Ultimately, this analysis should lead to the implementation of rates and program options that cost-effectively encourage DR and efficiency under a variety of future market and policy scenarios.

1.2 DR Incentives and Rate Design Phase 1 Objectives

The objective of Phase 1 is to develop a proof of concept for an evaluation framework capable of assessment of a broad set of DR designs from the perspective of different California stakeholders. This framework is in the form of a set of screens that can objectively answer fundamental questions regarding proposed new DR designs, and provide a mechanism to increase understanding of the strengths and weaknesses of DR rate design alternatives.

To demonstrate the approach, Phase 1 developed a series of screens and a number of illustrative rate designs were evaluated. The Phase 1 work was completed entirely by our team, without the input and perspective of California stakeholders, and only used data that were readily available. Therefore, the results of the Phase 1 work only illustrate the concept of the evaluation framework, which we propose to develop further with stakeholder involvement in Phase 2.

The starting point for the evaluation framework is the definition of two important assumptions that significantly affect the DR rate evaluation results. The first is a definition of the wholesale market design expected to emerge in California and the second is the objective of the DR design. In the Phase 1 analysis we assume the market structure will include long-term resource adequacy and energy procurement with day-ahead and real-time spot markets. The objective we evaluate of the rate designs in the Phase 1 screening process is the maximization of net benefits for California and its consumers. With a different market structure, or a different goal for the DR rate design, the results of the evaluation would change.

Figure 1 is an illustration of the four main screening steps developed in Phase 1 to test the designs. Each screening step is described in more detail later in the report describing project outcomes.

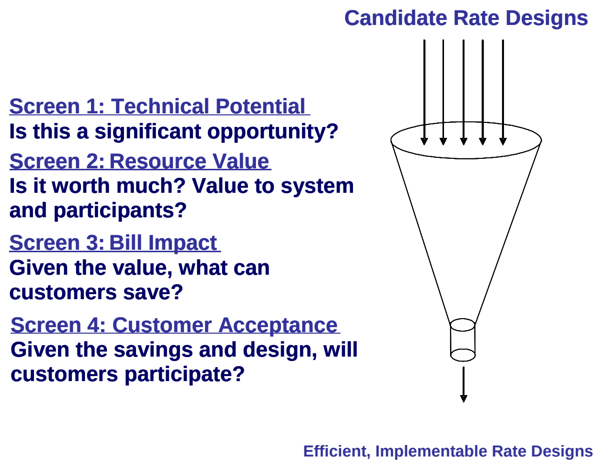

Figure 1: The Four Screening Steps Developed to Test Rate Designs

In Phase 2, the E3 team proposes to work with the DRRC and the California Energy Commission to test the screening process as a proof of concept with a broader group, then develop customer focus groups to get actual data on customer acceptance, and finally work to develop 'design charrettes' with the major stakeholders including the ISO (and possibly WECC), California utilities, 3rd party demand response providers, and conclude with the CPUC to test DR rate designs

Project Approach and Methods

The framework for evaluating the effectiveness of DR rate design is developed as a set of screens used to evaluate DR programs from a variety of perspectives. Creating this set of screens required combining knowledge and analysis from multiple disciplines, understanding of California stakeholder perspectives, and reviewing the current practices of DR rate design in California and other jurisdictions. Illustrative DR rates and programs were analyzed using the screens to evaluate the effectiveness of these screens and to test and refine the framework.

2.1 Assemble experienced and multidisciplinary team

E3 assembled a multi-institutional team of researchers with complementary specialties to address the research objectives of this project. These researchers' skills allowed them both to contribute to the analysis of DR valuation and to address issues arising from the integration of this research objective into the design and evaluation of programs intended to promote DR. A diagram of the research team and their particular research skills is shown in Figure 2 below.

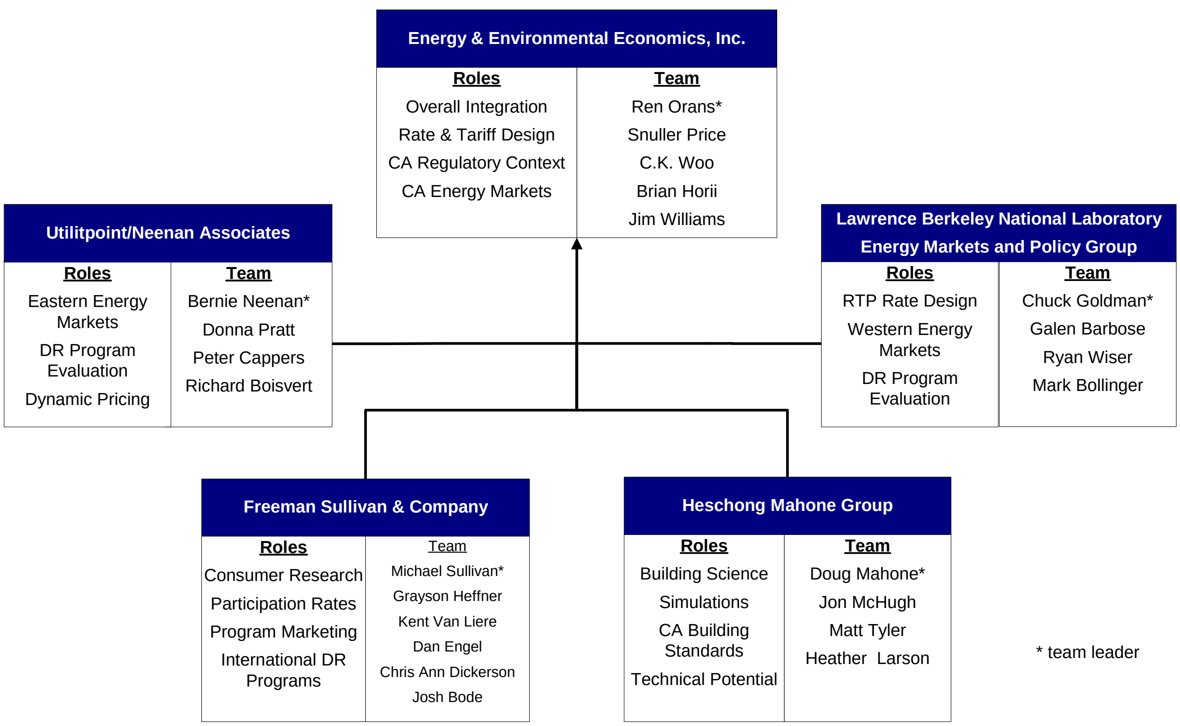

Figure 2: Research Team and Roles

Each member of the E3 Team contributes specific expertise to address complex California electricity market issues, but these specific skills can be divided into two primary areas of research focus. E3, Utilipoint/Neenan, and Lawrence Berkeley National Labs Energy Markets and Policy Group focused primarily on the impact of evolving market structure on cost effective design. This focus area is embodied in such key

California market issues as Ancillary Services, 2007 nodal market structure, capacity markets, and the 2006 Avoided Cost proceedings. Heschong Mahone Group and Freeman Sullivan & Company assumed a primary focus of the technical potential and customer acceptance issues involved DR program design and in implementing initiatives that foster greater use of DR. This research area is significant to the California market in the evolution of demand response pricing to capture enhanced enabling and metering technologies, customer acceptance and program enrollment, and customer response.

2.2 Formulate 'Ideal' DR Rate Designs

A key aspect of any rate design, and a particular goal for demand response, is to induce economically efficient consumption decisions. During extremely costly hours in California, which typically occur during capacity shortages, existing rates do not provide customers an incentive to use any less electricity. The price for consumption remains unchanged, and customers do not have the information, or the incentive, to reduce usage. In contrast, a perfectly efficient rate design constantly would signal to customers the total cost of their consumption and would provide an incentive to reduce consumption when costs are high. Identifying 'ideal' rate designs can guide the assessment of the economic efficiency of actual DR designs during the screening process.

Which rate design is the most efficient depends on the market design. Ideally, customers' value of a change in consumption would be equal to the costs saved by not providing the energy (marginal cost). Since the costs that are saved can vary significantly with market structure, we developed an 'ideal' rate design for two fundamentally different market design approaches; one in which all of the costs are determined in short-term day ahead or real-time energy markets ("all-in spot market"), and another with a long-term resource adequacy market and balancing energy ("forward capacity market").

With an all-in spot market, an ideal rate design would have the following components:

- *monthly customer charge* - to recover costs that vary with the number of customers on the system, such as metering, billing, and customer service
- *distribution facilities charge per kW of design/contract demand* – to recover the costs of local distribution facilities
- *location-specific, time varying firm energy charge* – to recover the time and location differentiated marginal costs of generation, transmission, and high-voltage distribution

With forward capacity market, an ideal rate design would have the same components listed above for an all-in spot market, plus one additional component :

- *generation capacity charge per kW of maximum demand* - to recover the forward costs of generation capacity

2.3 Define Screens for DR Rate Design

Economic efficiency of the rate design is not the only important criteria in assessment of DR designs. The multi-disciplinary E3 team defined a number of additional evaluation steps based on traditional criteria of rate design such as those presented by Bonbright (1961) and based on experience working with California stakeholders.

The screens were designed to assess a range of DR rate designs and program types, including;

- Institutional (mandatory) vs. voluntary rate designs
- Price-based (customer-controlled) vs. quantity based (utility-controlled)
- Technology-based (provided in conjunction with an enabling technology)

In addition, there is a range of customer types for DR rates and programs. Different customer segments have diverse needs and varying ability to respond to price signals or emergency events, with different levels of advanced notice.

Since the range of DR designs and customer types is broad, not all the screens need to apply to all rate types.

For each rate design, the research team developed four screening steps, which are described in detail in the results section of the report. The goal of the screens is to address the most important questions in evaluating DR rate designs. Each evaluation screens each encompasses a number of specific questions. Through the proposed Phase 2 project, we expect that the screening steps would be refined and perhaps augmented to capture the breadth of important questions.

2.4 Test Screens with Illustrative Designs

After initially developing screens for evaluating DR rate designs, the E3 team applied the screens toward a variety of illustrative rate designs and compared the results across the designs. The performance of the illustrative designs was then used as feedback to refine and improve the effectiveness of the screens.

To develop an understanding of the prevailing rate designs for evaluation, and to populate the list of illustrative designs to test, the research team conducted a survey of current and past DR rates and programs offered by the 50 largest utilities in the U.S. and 15 large international utilities. The goals of the survey were to assess the prevalence of different DR rates and programs, and to characterize the range of attributes within each type. Table 1 summarizes of the types of DR programs offered by the utilities surveyed. This table illustrates the wide variety of DR rate designs employed.

Table 1: DR Program Types offered by Sample Utilities

Residential Rates and Programs offered by US utilities (sample of 50)

US Res	TOU	RTP	CPP	DSS	DLC	CIS	Hybrid
Number	41	2	6	6	15	0	6
Percentage	82%	4%	12%	12%	30%	0%	12%

Non-Residential Rates and Programs offered by US utilities (sample of 50)

US Non-Res	TOU	RTP	CPP	DSS	DLC	CIS	Hybrid
Number	48	24	4	0	6	41	15
Percentage	96%	48%	8%	0%	12%	82%	30%

Residential Rates and Programs offered by International utilities (sample of 15)

Int'l Res	TOU	RTP	CPP	DSS	DLC	CIS	Hybrid
Number	10	0	1	5	0	0	5
Percentage	67%	0%	7%	33%	0%	0%	33%

TOU = Time of use rates; RTP = Real time pricing rates; CPP = Critical peak pricing; DSS = Demand Subscription Service; DLC = Direct load control; CIS = Curtailable/Interruptible System

Results of Project

3.1 Development of Four Screens for Rate Design

The researchers identified four major screens that are significant for evaluating a potential rate design. While these screens do not necessarily cover a comprehensive set of all characteristics that affect rate design, they do represent a starting point for the 'design charrette' the most important issues to the major stakeholders in the rate design process. The design screens are:

- Screen 1: Technical Potential
- Screen 2: Resource Value
- Screen 3: Bill Impact and Free Riders
- Screen 4: Customer Acceptance

The research team, which was selected to provide experts at each step, identified and analyzed each of these screens individually and then explored ways in which they could be integrated into a general design framework. The experience of the team includes industry-leading experience in stakeholder engagement (E3 and LBNL), avoided costs and market design (E3, LBNL, NA), rate design (E3 and NA), and customer research (FSC).

3.2.1 Technical potential screen

The first screen our team evaluated for DR rate options, particularly those linked to particular enabling technologies, is technical potential. Technical potential assesses the maximum load reduction and determines whether the candidate design represents a significant opportunity. As shown in Figure 3, certain areas contribute significantly to system peaks. DR programs should target these areas, which have higher potential. The end-uses colored in blue indicate those areas that were investigated in the Phase 1 research project.

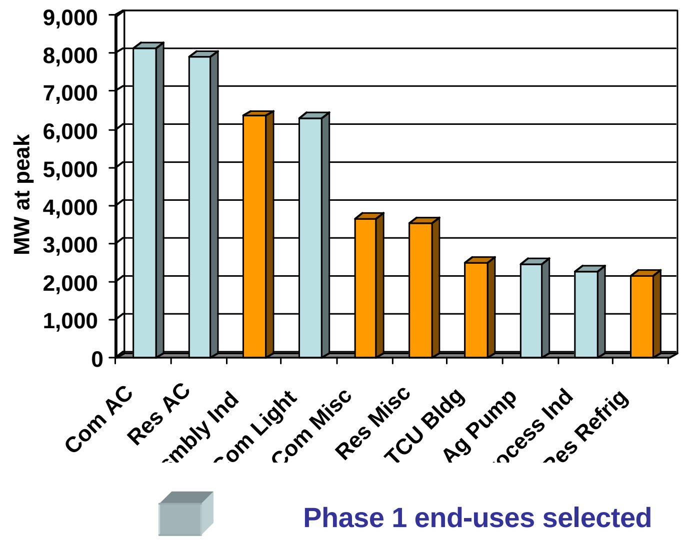

Figure 3: Largest contributors to California peak load (Source: CEC Demand Forecast Office)

In addition to the largest contributors to peak load, other non-time-critical loads also should be researched for "low hanging" opportunities. Less time-critical customer loads have a high potential for demand response because customers do not incur a cost if the end-use is turned off during the critical peak period. Figure 4 highlights pool pumps and electric water heaters as strong opportunities for DR programs.

2001 California Peak Demand		
End Use	Peak Demand (MW)	Pct
Com AC	8,139	15%
Res AC	7,917	14%
Assembly Industry	6,373	11%
Com Light	6,322	11%
Com Misc	3,674	7%
Res Misc	3,556	6%
TCU Buildings	2,508	4%
Ag & Water Pumping	2,487	4%
Process Industry	2,289	4%
Res Refrigerator	2,175	4%
Com Ventilation	1,946	3%
Res Cooking	1,433	3%
Mining and Construction	1,095	2%
Res Clothes Dryers	1,086	2%
Com Refrigerators	996	2%
[illegible]	[illegible]	[illegible]
Res Television	548	1%
[illegible]	[illegible]	[illegible]
Res Freezer	400	1%
Res Dishwashing	377	1%
Com Office Equipment	314	1%
Res Spa Pump	270	0%
[illegible]	[illegible]	[illegible]
Res Water beds	162	0%
Res Clothes washer	131	0%
Com Domestic hot water	129	0%
Com Exterior Lighting	111	0%
Com Cooking	102	0%
Res Spa Heater	49	0%
Res Solar Hot Water Pump	36	0%
Res Pool Heating	9	0%
Res Solar Domestic Hot Water	4	0%
Res Solar Pool	0	0%
Total	**55,846**	**100%**

Figure 4: Top contributors to California peak load with non-time critical loads highlighted (electric hot water heat, swimming pool pumps).

3.2.2 Resource value screen

The resource value screen evaluates whether the rate design provides significant energy and capacity value. The value of the DR is important for the overall savings that can be achieved, the opportunity for customers, and for the level of societal net benefits that can be achieved. Thus, a correct valuation of DR's benefits provides essential information for designing a DR rate program. To get an 'efficient' level of demand response, accurate DR valuation also determines the rate levels or incentives offered to customers who participate. This connection between DR valuation and rate design underlines the importance of the research team's experience gained both in this project and the report for the DDRC's Research Opportunity Notification DRRC-01 (RON1), "Establish the Value of Demand Response."

To illustrate the potential value of different DR types, the research team developed a valuation matrix, illustrated below in Figure 5, that assigns a value to each component of the capacity DR provides: planning reserve, operating reserve, and emergency reserve. Using products defined in the California market enables the resource value screen to link a DR program design and its attributes to the resource value it provides. Three types of DR programs are evaluated: a utility-controlled DR program whereby the utility has final control of an end-use or customer load; a customer-controlled DR rate whereby the customer receives a price signal and then decides how much load, if any, to reduce; and a utility control with customer ability to over-ride. To determine the value of a rate design, the analysis would estimate the value of the resource (planning, operating, or emergency reserves) and then multiply by the amount of that resource that is provided (load reduction times a factor to provide equivalent reliability).

Value Matrix

Control	Utility (Quantity)	Utility w/ customer over-ride	Customer (Pricing)
Emergency reserve	$K_1D_1V_E$	$K_4D_4V_E$	$K_7D_7V_E$
Operating reserve	$K_2D_2V_O$	$K_5D_5V_O$	$K_8D_8V_O$
Planning reserve	$K_3D_3V_P$	$K_6D_6V_P$	$K_9D_9V_P$

Components of Value

Vx = capacity value $/kW

Kx = enrolled kW

Dx = derating factor

(equivalent reliability)

Likely high value

Uncertain

Likely zero value

Figure 5: Value matrix and likely results for different types of DR

Given current resource counting rules in place in California, it is difficult for customer-controlled loads to count towards emergency and operating reserves. Even if a customer receives a high price signal, it is difficult for the utility to ensure that the load reduction will be achieved within the required time and with the level of certainty required by the

California ISO and the Western Electricity Coordination Council (WECC). Therefore, the valuation matrix provides no value to these resources for customer-controlled loads. Even for planning reserves, it is uncertain how customer-controlled demand response will count towards targets. We recognize that the reliability criteria and counting rules for DR resources are in flux and that the value attributed to a DR rate or program should be linked to the definition of the resource that is claimed.

An example of potential conflict with current reliability criteria and customer-controlled, price-based DR is the current reliability rules for resources that count towards nonspinning reserves. WECC holds stringent standards for counting load resources towards reserve requirements. According to WECC, to qualify as nonspinning reserves a load must be interruptible "within 10 minutes of notification." (WECC Minimum Operating Reliability Standards Standards BAL-STD-001-0-WECC — Real Power Balancing Control Performance). Without control and monitoring of the end-use, it is difficult to be sure that the load is interrupted, and within this time-frame.

3.2.3 Bill impact and free riders screen

The design of a DR rate or program affects customer bill savings resulting from the DR program. The bill impact screen evaluates whether the rate design will provide the customer significant savings. Customer bill savings is an important input into the customer acceptance screen for voluntary rate designs, and will also influence overall satisfaction of customers on institutional rate designs.

The value of the effect of a DR program on a customer's bill can be calculated using the following four steps.

1. Compute the customer's bill without the DR program
2. Estimate the change in a customer's load as a result of the DR program.
3. Use (2) to calculate the customer's estimated billed amount with DR.
4. Calculate the bill savings from using DR by subtracting (3) from (1).

In conjunction with the bill savings, the potential for free-riders is evaluated. If those customers that receive bill savings are not, on average, providing commensurate benefits to the system, then the bill savings will result in a transfer between customers, but will not lead to overall increase in societal net benefits. The free riders screen evaluates the portion of consumers who will, even without changing their behavior to consume less energy at critical times, still receive some of the savings that are intended to create an incentive for load reduction. A rate design that caries a significant free rider problem risks giving bill reductions to participating consumers but experiencing no overall change in consumption patterns, and therefore no reduction in cost of providing energy.

Generally, voluntary enrollment DR programs are significantly more subject to free-rider problems than are mandatory programs. This result is in part due to the fact that, in a voluntary system, customers have the opportunity to analyze the choice given their situation, and, frequently, the most likely customers to enroll are those who would receive the greatest bill savings for making the least amount of change in behavior, and thus creating the least incremental reduction demand.

Similarly, the type of system, in terms of who controls whether demand response is used at a particular time, can also can affect the a rate designs' number of free riders. DR programs in which the customer has control, but reacts to price signals from the utility, are more affected by free rider issues because customers who gain most with the least reduction in demand by responding to the incentive prices are the most likely to participate. Also, customer-controlled DR allows customers to participate selectively on days when it is least intrusive for them to participate.

3.2.4 Customer acceptance

In addition to the bill reductions, there are a number of other factors that ultimately affect customer acceptance of a DR rate or program. The customer acceptance screen is designed to address these factors and to result in an estimate of the achievable load reduction from the DR rate or program. Insight from the customer acceptance screen can also be used as feedback in developing DR rate designs. In Phase 2, the team proposes using customer focus groups to provide more detailed information on customer acceptance for different customer classes. In Phase 1, once the framework was developed, the research team then calculated projected enrollment rates for illustrative DR rate designs. The research team analyzed two major dimensions, enrollment and responsiveness, of factors customer acceptance of a given rate design because the factors can be different for each category. Additionally, existing studies of customer acceptance show a large connection between enrollment, response, and the impact of the DR program. For a given rate design, enrollment evaluates the percent of eligible customers who choose to enroll in the program, whereas responsiveness measures the DR program's effect on energy demand for a given number of enrolled consumers.

Figure 6 below depicts some of the program and rate design factors that can affect enrollment rate or responsiveness, and as a result, influence the DR impact. These factors and their relative importance are well studied; however, the results of those studies are often not complete and vary depending on what attributes are included in the study.

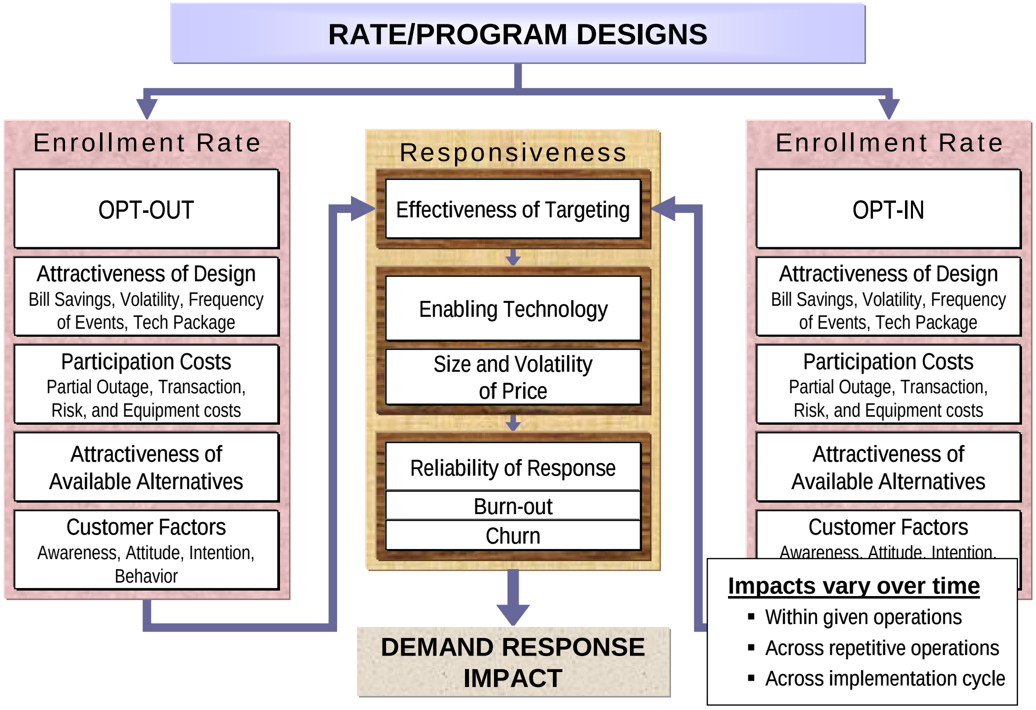

Figure 6: Program Design Factors Affecting Enrollment Rate or Responsiveness

3.2 Testing of Illustrative Rate Design Models

The Phase 1 results from each of the screens illustrate the type of results that the screening analysis can produce. Since the Phase 1 results were done without stakeholder interaction, and with proxy data, the results serve only as a proof of concept. More details on the rate designs that were tested, and the results, are provided in the appendix on Phase 2 results.

The results of the technical potential screen were provided in the description of that screen, and the analysis used to develop the estimates of peak load by utility and climate zone are described in the appendix. Overall, residential and commercial HVAC represent that largest opportunity for peak load reduction in California, representing approximately 16,000 MW of a peak load of an estimated 2001 peak load of 54,000 MW. End-uses that are not critical also represent an opportunity because of the low cost of shifting their consumption; examples include swimming pool pumps (588 MW) and electric water heating (616 MW).

Figure 7, below, shows the summary results of the DR value and free-rider screen in ‘consumer reports’ style evaluation. For each rate design tested in Phase 1, the team evaluated the value components of each rate, whether there was a free-rider problem. In addition, simplicity of the rate for purposes of the customer acceptance rate is provided. The approach used to evaluate each component is described in greater detail in the appendix.

	Simplicity	Avoids free riders	Control		Value		
			Utility	Customer	Planning	Operating	Emergency
Residential TOU Rate	⊙	⦿	●	⊙	◉	●	●
Res Tier w/ PCT or Switch	○	○	○	⦿	●	●	○
Res Demand Subscription	◉	⊙	○	◉	○	○	○
Res CPP	⊙	◉	⦿	◉	⦿	⦿	⦿
Com PCT w/ Override	○	○	○	⊙	●	◉	⊙
Commercial Emergency	○	○	○	●	●	●	○
Commercial CPP	⊙	◉	⦿	◉	⦿	⦿	⦿
Com Demand Subscription	⊙	⊙	◉	◉	⊙	◉	◉
Ind Emergency	○	○	○	●	●	●	○
Ind CPP	⊙	◉	⦿	◉	⦿	⦿	⦿
Ind I/C - Customer Control	⊙	◉	◉	○	⊙	●	◉
Ind I/C - Utility Control	⊙	◉	○	◉	●	●	⊙
Real Time Pricing	●	⦿	◉	◉	⊙	◉	●
Dmd Subscription w/ RTP	●	⦿	○	◉	⊙	◉	◉

○⊙ ◉ ⦿●
Good → Poor

Figure 7: 'Consumer' reports style evaluation of the DR design value screen

Figure 8, below, shows the expected peak load reduction and resulting change in the customer bill for an example rate, the residential critical peak pricing tariff. For this example, the CPP rate was assumed to be $0.90/kWh with a four-hour period. Also, the percentage bill change is only that change that results from the CPP period, and does not account for bill increases due to increased consumption in periods with lower electricity prices. The table shows the savings and annual percentage of bill reduction for residential customers of different size and load factor. Results for many other illustrative rate designs tested in Phase 1 are provided in the appendix.

Peak kW Change	Monthly kWh											
Monthly Load Factor	100	200	300	400	500	600	800	1000	1500	2000	2500	3000
10%	(0.9)	(1.9)	(2.8)	(3.3)	(2.2)	(2.7)	(2.3)	(2.9)	(3.5)	(4.7)	(5.9)	(7.1)
20%	(0.5)	(0.9)	(1.4)	(1.6)	(1.1)	(1.3)	(1.2)	(1.4)	(1.8)	(2.4)	(3.0)	(3.5)
30%	(0.3)	(0.6)	(0.9)	(1.1)	(0.7)	(0.9)	(0.8)	(1.0)	(1.2)	(1.6)	(2.0)	(2.4)
40%	(0.2)	(0.5)	(0.7)	(0.8)	(0.6)	(0.7)	(0.6)	(0.7)	(0.9)	(1.2)	(1.5)	(1.8)
50%	(0.2)	(0.4)	(0.6)	(0.7)	(0.4)	(0.5)	(0.5)	(0.6)	(0.7)	(0.9)	(1.2)	(1.4)
60%	(0.2)	(0.3)	(0.5)	(0.5)	(0.4)	(0.4)	(0.4)	(0.5)	(0.6)	(0.8)	(1.0)	(1.2)
70%	(0.1)	(0.3)	(0.4)	(0.5)	(0.3)	(0.4)	(0.3)	(0.4)	(0.5)	(0.7)	(0.8)	(1.0)

% Bill Change	Monthly kWh											
Monthly Load Factor	100	200	300	400	500	600	800	1000	1500	2000	2500	3000
10%	-30%	-30%	-30%	-25%	-13%	-12%	-6%	-6%	-4%	-3%	-3%	-3%
20%	-15%	-15%	-15%	-13%	-7%	-6%	-3%	-3%	-2%	-2%	-2%	-2%
30%	-10%	-10%	-10%	-8%	-4%	-4%	-2%	-2%	-1%	-1%	-1%	-1%
40%	-7%	-7%	-7%	-6%	-3%	-3%	-2%	-1%	-1%	-1%	-1%	-1%
50%	-6%	-6%	-6%	-5%	-3%	-2%	-1%	-1%	-1%	-1%	-1%	-1%
60%	-5%	-5%	-5%	-4%	-2%	-2%	-1%	-1%	-1%	-1%	-1%	-1%
70%	-4%	-4%	-4%	-4%	-2%	-2%	-1%	-1%	-1%	0%	0%	0%

Figure 8: Example bill reduction estimate for residential CPP based on $0.90/kWh CPP rate and 4 hour dispatch periods.

Figure 9, below, shows the quantitative results of the customer acceptance screen for the illustrative rate designs. The results show the estimated range of enrollment rates and responsiveness of customers. Coupling this information with the technical potential screen provides an estimate of the resulting impact on peak system demand in California. More details of the process used to develop the technical potential, enrollment rates, and responsiveness are provided in the appendix.

Rate Scenario	Low Case Middle Range of Actual Program Experience	High Case Low Range of Momentum Study	Response rate (1-overrides)	Low Estimate On-peak System Demand (kW)	High Estimate On-peak System Demand (kW)
Residential PCT	10%	41%	50%	97,293	398,901
Residential A/C Cycling	10%	41%	100%	274,401	1,125,045
Residential Pool Pump	10%	41%	100%	143,187	587,066
Small Office PCT	7%	37%	50%	19,313	102,081
Small Office Lighting	7%	34%	50%	7,250	35,212
Retail Lighting	7%	34%	50%	25,094	121,886
Colleges Lighting	7%	34%	50%	3,388	16,457
Industrial Sector	5%		50%	7,651	

Figure 9: Expected participation and achievable load reduction for select technology-based DR designs.

Notes:

(a) residential programmable communicating thermostats (PCTs) and residential A/C cycling are not additive

(b) industrial sector includes reductions based on existing control equipment, not installation of new enabling technology

Conclusions and Recommendations

4.1 Conclusions

The research team identified four major screens for evaluating a DR program design, The team believes that these four screens will provide useful areas to analyze when considering the favorability of a particular design to customers in terms of acceptance and bill savings, to utilities in terms of resource value and technical potential of a DR program, and to regulators in terms of overall improvement in net social welfare. Used together, these screens can greatly enhance understanding of what kinds of program designs will work and why.

Analysis using the technical potential screen revealed the importance of focusing DR on end-uses that contribute significantly to system peaks. Additionally, "low-hanging fruit", that is, smaller load segments with less time critical customer loads, have a high potential for demand response.

The resource value screen highlighted the importance of a correct valuation of DR's benefits to enable the utility to offer the right prices or incentives to the customer and encouraging an 'efficient' amount of demand responsiveness. Additionally, the research team's experience and findings for the DDRC's Research Opportunity Notification DRRC-01 (RON1), "Establish the Value of Demand Response" are integral for this evaluation screen. To get the correct DR value for the California market, the valuation must be linked to the rules governing the 'counting' of capacity resource in California. Current rules indicate that utility-controlled DR is more likely to have high value than customer-controlled, price-based options.

The bill savings and free riders screen consists of a relatively simple bill comparison with and without DR, and a test of whether the DR program design is likely to provide net societal benefits given the existence of free-riders. This screen also identified mandatory participation programs and utility controlled response designs as less susceptible to free rider problems than their alternatives. Mandatory and utility-controlled program designs prevent self-selection into the program of customers who would gain high savings with very little behavioral change in consumption, and little impact on the DR effectiveness.

The customer acceptance screen highlighted the strong connection between enrollment rates, responsiveness, and DR impacts. Research in the area of this screen demonstrates that targeting strategies, enabling technologies, and marketing have a substantial effect on both enrollment rates and response rates. Enrollment rates are also significantly influenced by whether the DR program has an opt-in or opt-out design. However, implementation and time still create large variations in results and increased field testing in the area of enrollment could be useful for supplementing a somewhat thin current body of research.

4.2 Recommendations

The research team recommends that the four research screens developed in Phase 1 of this project be used a starting point for the proposed Phase 2 of this project. The proposed Phase 2 work would begin with validating the proof of concept by using the tools developed in Phase 1 to form a set of high potential DR designs for California with several plausible market structures.

The acceptance of these different high potential DR programs should then be tested through a series of customer acceptance focus groups. For mass market customers, the focus would be on design attributes rather than on the DR designs themselves, and would provide the material that we would use to construct and conduct a telephone survey among mass market customers. The more sophisticated larger customers would be asked to provide direct feedback on attributes as well as specific designs. The customer preferences would then be used in the customer acceptance screening tool, which is one screen used in the overall design charrette process.

Using our updated set of design tools, as well as inputs derived from the focus groups, we would facilitate the development of high potential DR designs through design charrettes, built around the perspective of four different stakeholder groups: ISO and possibly WECC representatives, utilities (together as a single group), and third party providers of DR (e.g., program implementers, aggregators). The design charrettes would be developed separately for each group, and each group would participate in 3 facilitated working group sessions.

Finally, based upon the results of the working session design charrettes above, we would work with the DRRC Project Oversight Team to construct a similar charrette process for California's regulators. We would then review the DR design perspectives and their regulatory policy ramifications under the various market constructs envisioned.

4.3 Benefits to California

Proper assessment of DR rate and program designs has many significant potential benefits to California. As energy prices and electricity reliability are issues that affect all California residents, optimal implementation of DR programs designed to improve reliability and lower costs has the potential to create economic and societal benefits, in addition to reducing emissions. This report identifies four major screens that are significant for evaluating a potential rate design, thus improving the ability of public and private resources to meet the electricity needs of Californians cost-effectively.

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Glossary

AS	Ancillary Services
CPP	Critical Peak Pricing
CPUC	California Public Utilities Commission
CT	Combustion Turbine
DR	Demand Response
DSM	Demand-side management
EPRI	Electric Power Research Institute
I/C	Interruptible/Curtailable Program
IEA	International Energy Agency
PCT	Programmable Communicating Thermostat
TOU	Time of Use
UDC	Utility Distribution Company
WECC	Western Electricity Coordination Council

Appendix: DR Rate and Program Design – RON-02 Phase 1 Results Presentation

(Please see attached document titled "Appendix - DR Rate and Program Design-RON-02 Phase 1 Results Presentation.pdf".)