LBNL-60128

ERNEST ORLANDO LAWRENCE BERKELEY NATIONAL LABORATORY

Phase I Results: Establish the Value of Demand Response

Orans, Ren, et al.

April 2006

LBNL-60128
Collaborative Report

Phase 1 Results: Establish the Value of Demand Response

Orans, Ren et al.
Energy and Environmental Economics, Inc.

333 Sacramento Street, Suite 1700
San Francisco, CA 94111

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 Establish the Value of Demand Response Project, 500-03-026 Task 4.G, conducted by Energy and Environmental Economic, Inc. The report is entitled "Phase 1 Results: Establish the Value of 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

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

Please cite this report as follows:

Orans, Ren et al. 2006. *Phase 1 Results: Establish the Value of Demand Response.* California Energy Commission, PIER DRRC. LBNL-60128. April 2006.

Table of Contents

Abstract

This report describes the work performed in response to the Demand Response Research Center's Research Opportunity Notice DRRC RON-01: "Establish the Value of Demand Response." A research team led by Energy and Environmental Economics, Inc. (E3) reviews approaches for demand response (DR) valuation applied in California and other states, and recommends an approach for developing a comprehensive DR valuation methodology. The review identifies no complete DR valuation framework that can be applied directly in California, and recommends the current standard practice for cost-benefit analysis of energy efficiency be modified to capture the attributes of DR. The team identifies a minimum of six gaps in the existing standard practice that need to be addressed to appropriately value demand response. A Phase 2 proposal is developed to address these gaps, and others that may be identified, in a stakeholder process.

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 supply is high or reserve margins are low. However, DR implementation in California is hampered by the lack of a systematic methodology for assigning value to DR under different economic and power system conditions, especially when this value critically depends on the method of deployment and dispatch.

Despite advances in the application of market-based, area-and-time specific avoided costs to DSM in California, the existing standard practice has a number of identifiable shortcomings when valuing dispatchable DR resources.

- **Purpose**

The main objective of this project is to provide a clear path for developing a comprehensive methodology and framework for the evaluation of different DR technologies and program designs suitable for California.

- **Project Objectives**

The Phase 1 portion of this project can be separated into the following goals:

- Identify the most appropriate framework for DR valuation
- Determine any gaps that require further investigation to value demand response appropriately
- Propose methods of future research that could serve to fill the gaps that are identified

- **Project Outcomes**

Based on the review of existing DR valuation approaches in California and in other states, no complete valuation framework that could be applied in California was identified. The most complete approach is the existing standard practice for cost-effectiveness evaluation of energy efficiency. The current standard practice (a) provides a comprehensive framework for cost-effectiveness evaluation from multiple stakeholder perspectives, (b) is familiar to stakeholders in the California process, and (c) captures many important aspects of DR valuation.

The project team identified six research gaps that are important to address in the standard practice valuation methodology to value DR appropriately as a dispatchable resource.[1] The research gaps identified are:

- Gap 1: Generation Capacity Value ($/kW-Time Period)
- Gap 2: Consumer Surplus ($/Time Period)
- Gap 3: Option Value ($/kW-Time Period)
- Gap 4: DR Modularity and Value of Information
- Gap 5: Value of Lost Load ($/Use)
- Gap 6: Portfolio Hedge Value ($/Portfolio)

- **Conclusions**

The current standard practice used to value energy efficiency in California contains many useful elements for DR evaluation, but does not completely capture the entire value of DR. Our research identifies and describes six major research gaps that must be further analyzed to more accurately value DR programs. Based on discussions with both the project managers and the technical advisory group, we revised our proposal to incorporate a phased research approach with the first phase focusing on the development of a DR Benefits and Valuation Issues Concept Paper.

- **Recommendations**

Task 1. Prepare DR Benefits and Valuation Issues Concept Paper

Building off of our initial work, in this task, we will prepare a comprehensive Concept Paper on DR Benefits and Valuation Issues that discusses the following issues and topics, as part of four sub-tasks: (1) identify and define various types of DR benefits, (2) discuss the relative importance of different types of DR benefits to various stakeholders, (3) discuss how a more comprehensive, enhanced DR benefits/valuation framework could help policymakers and utility managers address key policy issues and challenges, and (4) develop methods to rank different types of DR benefits in terms of their relative value and ease of developing quantitative estimates of their value (which will aide in prioritizing software model and/or analytic tool development in Task 2). A Concept Paper on DR Benefits and Valuation Issues could establish an economic and analytic framework that would help identify the requirements and uses for DR benefits methods in various policy contexts and help prioritize analytic tools and method enhancements needed in various policy venues.

In order to ensure that the Concept Paper is focused on the policy and analytic needs of the CEC DRRC and key stakeholders, we would prepare and present several interim

[1] For a more detailed discussion of the research results of this project, see the Appendix to this report.

products to the TAG, including an in-depth outline of major sections of the Concept Paper and periodic briefings on preliminary findings/results.

Sub-task 1.1 – Identify and Define Types of DR Resource Benefits

In this sub-task, we will identify and define the benefits of Demand Response. Benefits of demand response can be grouped into direct benefits to participants (including financial and reliability benefits), collateral benefits that are realized by most or all consumers (including short- and long-term market impacts, reliability benefits), and other benefits that accrue to some or all market participants but are not easily quantified or monetized. Other benefits, include improved choice for customers, more robust and competitive wholesale and retail markets, and possible environmental benefits. Any discussion of benefits must also define and recognize costs; quantitative assessments should identify net benefits.

Sub-task 1.2 – System and Stakeholder Perspectives on Valuation of DR Resource benefits

In this sub-task, we will discuss DR benefits, incorporating various stakeholder perspectives. A primary focus will be describing benefits and costs to participating customers, all other ratepayers, load serving entities and utilities, ISO/system operator, and a broader societal perspective.

Sub-task 1.3 – Key Policy Issues and Challenges: How they influence requirements for assessing and valuing DR Resource benefits

In this sub-task, we will examine several key DR policy issues facing state policymakers and utility program managers and the role of enhanced methods to value DR resources. The goal of this exercise is to obtain a more detailed understanding of the types of DR valuation analytic methods and tools that are most appropriate and useful to inform key policy issues and challenges. At a minimum, we will examine the following policy and programmatic issues: (1) benefit/cost methods that are most suitable to screen various types of DR programs and tariffs, (2) valuation methods that are useful in assessing optimal levels of dispatchable resources for utility/control area systems, (3) valuation methods that allow program managers and policymakers to establish either a preferred mix or relative ranking among types of DR resources, (4) benefit/cost methods that can assess the relative valuation of DR resources under alternative market structures and load/resource balances , and (5) policy options, such as changes to codes and standards, that institutionalize demand response capabilities in new equipment.

The results of this exploratory analysis will be summarized along the following dimensions: 1) identification of key policy issues where DR resources are considered/evaluated, 2) summary of how DR is currently considered and assessed through existing benefit/cost methods and tools, 3) enhancements/improvements that could be considered to ensure more comprehensive characterization and valuation of DR resource benefits, and 4) identification of specific analytic tools/methods that would enable a more comprehensive characterization.

Sub-task 1.4 – Exploring Analytic Methods to quantify and rank DR benefits

In this sub-task, we will identify the major gaps in accurately characterizing and quantifying DR Benefits, discuss the relative importance and magnitude of these benefits to the power system and customers, and develop a ranking scheme that reflects both their relative value and ease of estimation. Conducting this sub-task will require both theoretical and analytic activities in order to assess relative importance and explore alternative analytic methods and techniques to quantify various types of DR benefits. At a minimum, we will explore the following six key areas, as described below:[2]

- Capacity Value. We will characterize and monetize three new types of capacity costs corresponding to Planning Reserves, Operating Reserves, and Emergency response/outage reduction.
- Consumer Surplus Value. We will develop a method for estimating both the gain in welfare and the transfers from producers to consumers associated with mandatory and voluntary DR programs. This will be calculated as an aggregate value to consumers in California and for individual program participant.
- Option Value. We will explore methods for estimating the value of specific program-based DR resources available for dispatch in a volatile energy market.
- Value of Flexibility in Expansion Planning. We will explore methods for estimating the incremental value of including resources that can be developed and implemented in a short time period ("capacity in a hurry"), within an overall resource planning and procurement paradigm.
- Portfolio Hedge Value. We will examine and monetize the incremental value of having more dispatchable demand resources and reduced forward purchase requirements within an overall resource portfolio, and characterize how this value changes with the proportion of demand resources as a share of overall resources procured.
- Value of Lost Load. We will characterize and bound the potential value attributable to demand response programs that are capable of preventing or capping unserved energy beyond the level required by reliability targets.

Task 2. Implement Methods to quantify and value DR Benefits

In this task, we will either enhance existing benefit/cost models (e.g., Standard Practice Manual) or develop new analytic tools that will improve the characterization of DR resource benefits. The scope and focus of Task 2 activities will depend on the following factors: 1) the key findings and recommendations from the DR Benefits and Valuation Issues Concept Paper; 2) feedback on these recommendations by the DRRC Project Manager, the CEC and TAG; and 3) related regulatory policies and program developments that may affect the timing and breadth of efforts to enhance DR valuation methods.

---

[2] See E3, "Phase 2 Workplan for Developing a New Standard Practice for Valuation of Demand Response," January 13, 2006 for more detailed discussion of gaps in existing benefit/cost methods.

In order to expedite and test acceptance of an improved DR valuation methodology, we will establish a small technically-oriented group to actively Beta-test the methods that will ultimately be incorporated into existing benefit/cost spreadsheet models. By including utility practitioners and other stakeholders, we will improve the chances that valuation methods are "user friendly" and also provide an advance opportunity for utility practitioners to test their current and planned DR program and tariff designs against the new valuation metrics.

Deliverables

Task 1:

- Draft Concept Paper on DR Benefits and Valuation Issues (8 months after project is approved)
- Critical Project Review (8.5 months after project is approved)
- Final Concept Paper on DR Benefits and Valuation Issues (9 months after project is approved

Task 2:

- Enhanced Benefit/Cost Spreadsheet Model (8-12 months after Task 1); or
- New Benefit/Cost Model or Analytic Tools (12-18 months after Task 1)

- **Benefits to California**

Proper valuation of DR 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 provides an approach and identifies a preliminary list of the important valuation areas that need to be addressed to establish a methodology that will value the benefits of DR more accurately and consistently, 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 supply is high or reserve margins are low. However, DR implementation in California is hampered by the lack of a systematic methodology for assigning value to DR under different economic and power system conditions, especially when this value critically depends on the method of deployment and dispatch. The valuation problem is further complicated by institutional constraints, absence of key data, differences in technology attributes, and differences in level of the net benefits among stakeholders.

Despite advances in the application of market-based, area-and-time specific avoided costs to DSM in California, existing frameworks such as the Standard Practice Manual (SPM) have important shortcomings when it comes to assigning value to dispatchable DR resources. Fortunately, it is not necessary to create a new valuation methodology from scratch. Substantial strides have been made in other jurisdictions, including those that have adopted competitive markets, to establish the value of demand response as an economic and reliability resource.

1.2 DR Valuation Phase 1 Objectives

The main objective of this project is to provide a clear path for developing a comprehensive methodology and framework for the evaluation of different DR technologies and program designs suitable for California. The framework should be informed by the best DR valuation research inside and outside the state; be accepted by California stakeholders; to the extent possible, be consistent with other valuation methodologies in place in California; and recognize the institutional roles, and regulatory and market structure in California.

The Phase 1 portion of this project can be separated into the following goals:

- Identify the most appropriate framework for DR valuation
- Determine any gaps that require further investigation to value demand response appropriately
- Propose methods of future research that could serve to fill the gaps that are identified

Project Approach and Methods

The approach for developing a plan for DR valuation included (a) assembling an experienced team familiar with California and other jurisdictions including the Northeast, (b) reviewing relevant valuation methodologies and precedent from California regulatory proceedings at the CEC, CPUC, and California ISO, and (c) reviewing relevant DR valuation research and literature.

2.1 Assemble experienced and multidisciplinary team

E3 assembled an experienced research team 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 (DRRC Research Opportunity Notice -02). A diagram of the research team and their particular research areas is shown in Figure 1 below.

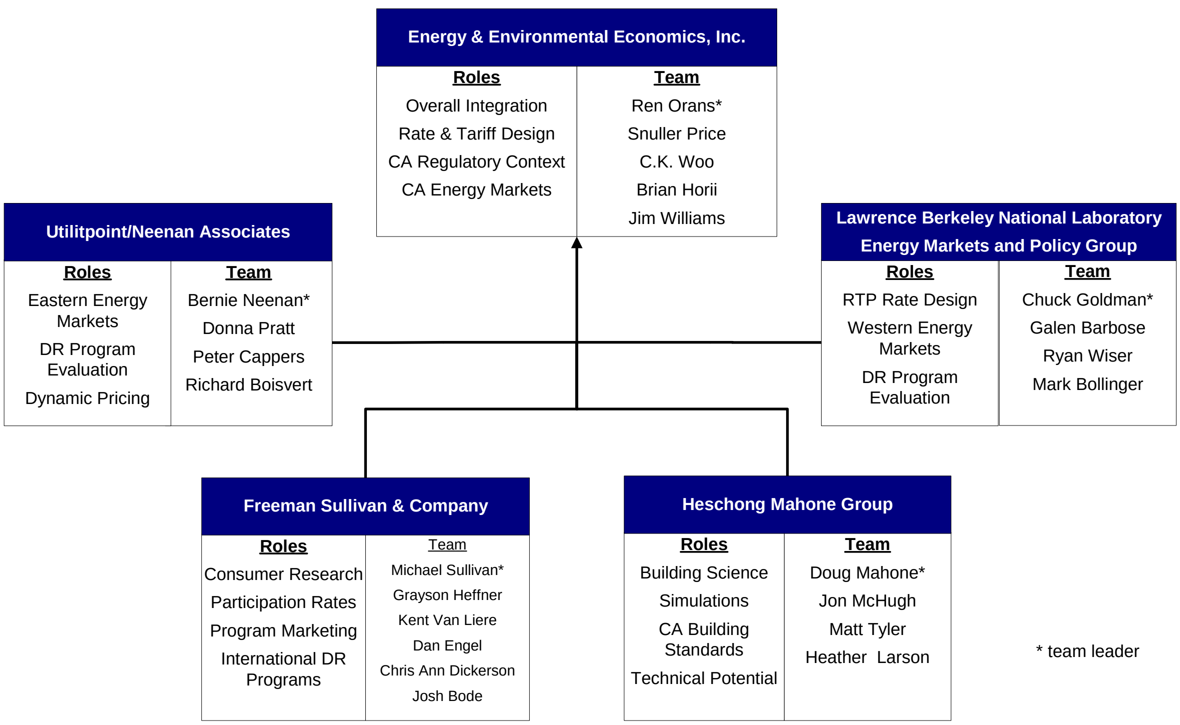

Figure 1: Research Team and Roles

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 Berekeley National Labs Energy Markets and Policy Group focused primarily on the impact of evolving market structure on cost effective design. This focus area relates to such key California market issues as Ancillary Services (AS), 2007 nodal market structure, capacity markets, and the 2006 Avoided Cost proceedings.

Heschong Mahone Group and Freeman Sullivan & Company assumed a primary focus on the technical potential and customer acceptance issues involved in valuing DR 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 technologies, enhanced metering technologies, customer acceptance and program enrollment (for non-institutional DR options), and customer response.

2.2 Review of current California Regulatory context

To achieve the goal of developing a DR valuation methodology that fits in California and is acceptable to California stakeholders, the team reviewed relevant proceedings at the CPUC, CEC, and California ISO. Ultimately, the DR valuation methodology used by California utilities will be adopted in Phase 3 of the avoided cost proceeding at the CPUC (R04-04-025). This creates an opportunity before Phase 3 (expected in the beginning of 2007) to develop methodology and stakeholder understanding and support for an approach to DR valuation. Table 1 below provides a list of the proceedings, orders, and publications reviewed in characterizing the regulatory context for DR in California.

Table 1: California Proceedings, Orders, and Publications Reviewed

Regulatory Body	Proceeding/Order/ Publication	Description
California Public Utilities Commission	R0504024 / D0404025	Adopts E3 Methodology for calculation of utility avoided costs for use in energy efficiency programs. Rulemaking looks to adopt consistent methodology across proceedings, including DR.
California Public Utilities Commission	R0206001 / D0501056	Policies and practices for advanced metering, demand response, and dynamic pricing. Sets forth IOU DR goals.
California Public Utilities Commission	R0404003 / D040728	IOU procurement guidelines regarding reliability, local-area contraints, and RMR contracts, applicable to IOU decisions on DR programs.
California Public Utilities Commission	R0404003 / D0412048	Reinforces IOU DR goals as set forth in D0501056 and emphasizes cost-effectiveness evaluation.
California Public Utilities Commission	R0404003 / D0410035	Non-dispatchable demand response programs should be treated as debits from load forecasts, while dispatchable demand response programs should be counted as "other resources."
California Public Utilities Commission	R0110024 / D0406015	MPR decision establishes methodology for determining the long-term market price of electricity from conventional fossil fuel resources to be applied in renewable portfolio standard program.
California Public Utilities Commission	R0404003 / Capacity Markets Whitepaper	Evaluates capacity markets in other jurisdictions and argues that they may be used to improve resource adequacy in California. DR used.
California Public Utilities Commission	Core / Non-Core Electric Market Structure Proposal	Separation of Utility Customers into "core" and "non-core" still under discussion. One issue with implications for DR is whether non-core customers would be required to purchase ancillary services (AS).
California Energy Commission	P400-03-001JAF / Building and Energy Efficiency Standards for Residential and Non-Residential Buildings	Adopts E3 time-dependent valuation (TDV) method for calculation of avoided costs in 2005 revision of Title 24 building standards.
California Energy Commission	Demand Response Evaluation Methodology and Programmable Communicating Thermostat CASE Initiative Activities	Develop valuation methodology for DR for use in 2008 revision of Title 24 building standards and evaluation of programmable communicating thermostats for inclusion in the standards.
California Independent System Operator	WECC Minimum Operating Reserve Requirements (MORR)	Sets operating reserve requirement and the type of resources that can be used toward this requirement, including "load which can be interrupted within 10 minutes of notification."
California Independent System Operator	Market Redesign and Technical Upgrade (MRTU) Program	CAISO program to institute locational marginal pricing (LMP), day-ahead markets and other fundamental changes in California electricity market.

2.3 Literature Review

In addition to reviewing regulatory context, a wider range of literature was surveyed to compare DR valuation in other areas to those in California. Table 2 shows highlighted studies, and the DR valuation gap(s) that the report addresses. The gaps are structured into the six research gaps described in the results section of this report. The reference section of this report contains a full list of the information reviewed, which includes studies from sources ranging from the International Energy Agency (IEA), Northwest Power and Conservation Council (NPCC), New York ISO, Electric Power Research Institute (EPRI) and LBNL.

Table 2: DR Valuation Gaps Addressed in Highlighted Studies

Study	Research Gap Addressed					
	1	2	3	4	5	6
IEA DRR Valuation Study	x					x
Northwest Power and Conservation Council (NPPC) 5th Power Plan	x					x
Efficient Frontiers for Electricity Procurement (Woo *et al.* 2006)						x
ISO- NE and NYISO DR Program Evaluations	x	x				
LBNL Option Value of Electricity Demand Response (Sezgen *et al.* 2005)			x			
Integrated Generation Transmission and Distribution Planning (EPRI study)				x		

Notes: **Gap 1** = Generation Value of Capacity; **Gap 2** = Consumer Surplus; **Gap 3** = Real Option Value; **Gap 4** = Flexible Expansion Planning; **Gap 5** = Value of Lost Load; **Gap 6** = Portfolio cost risk mitigation

Results of Project

This section summarizes the larger body of research on DR valuation performed by the team. For a more extensive description of the results of the project, including a characterization of the current standard practice and analysis of each of the six research gaps in DR valuation, please see the Appendix to this report.

3.1 Characterization of Current Standard Practice

Based on the review of existing DR valuation approaches in California and in other states, no complete valuation framework that could be applied in California was identified. The most complete approach is the existing standard practice for cost-effectiveness evaluation of energy efficiency. The current standard practice (a) provides a comprehensive framework for cost-effectiveness evaluation from multiple stakeholder perspectives, (b) is familiar to stakeholders in the California process, and (c) captures many important aspects of DR valuation. Review of other DR valuation approaches identified approaches to value components of DR value that can be incorporated into the existing standard practice, but not an alternative comprehensive framework.

The existing avoided cost methodology for energy efficiency adopted by CPUC (R. 04-04-003 / R.04-04-025) includes the following avoided cost components:

- Generation Energy and Capacity ($/kWh by hour at NP15, SP15)
- Transmission Capacity ($/kWh by hour and climate zone)
- Distribution Capacity ($/kWh by hour and climate zone)
- Marginal Losses at the Generation, Transmission and Distribution voltage levels by utility service territories (% by time-of-use period)
- Emissions Avoided Costs ($/kWh by hour at NP15, SP15)
- Market price effect of reduced demand (% by time-of-use period)
- Ancillary Services ($/kWh by hour at NP15, SP15)

Though this methodology was designed to reflect the value of long-term, non-dispatchable energy efficiency and conservation programs, many of its components are also important characteristics for valuing shorter-term, dispatchable demand response initiatives. Figure 2 shows how those components vary with time by displaying a three-day snapshot of disaggregated electric avoided costs.

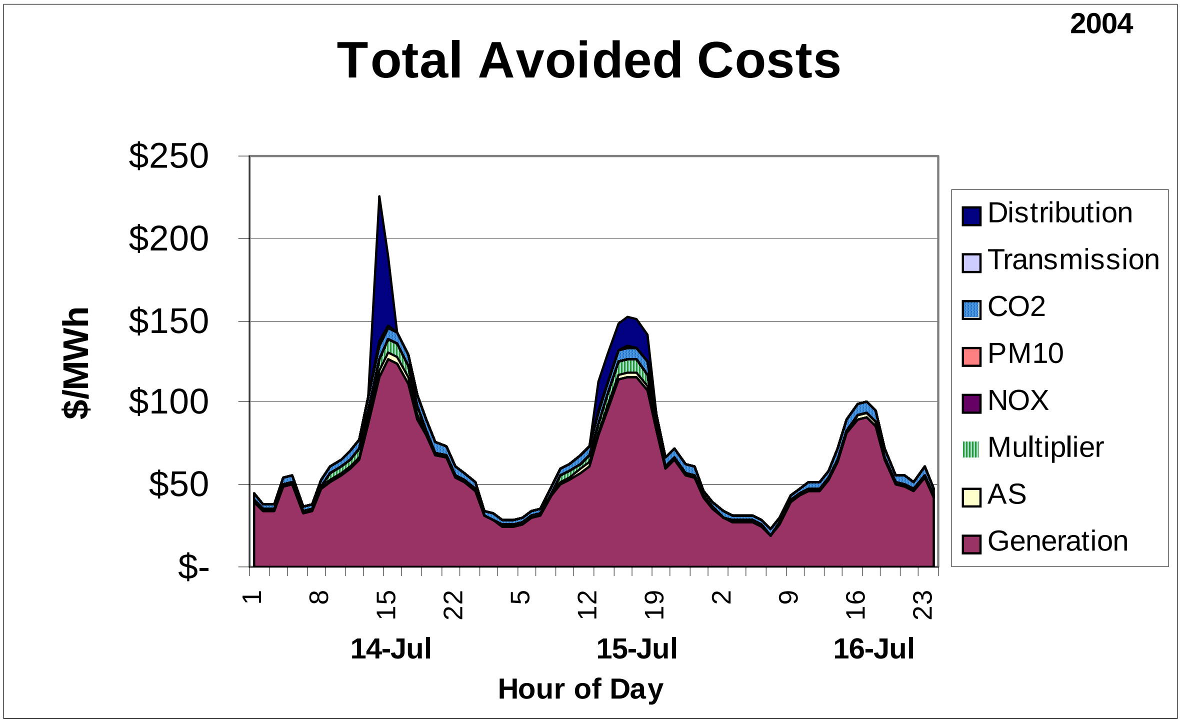

Figure 2: Electric Avoided Costs over 3-Day Period

Figure 2 illustrates the avoided cost components that apply to energy efficiency and also apply to demand response during periods of load reduction. The components already incorporated into the standard practice include avoided costs of distribution, transmission, and generation, together with ancillary services. Additionally, the decrease in energy production needed also creates avoided environmental costs, represented by NOx, PM10, and CO2 avoided costs.

While many types of avoided costs are accounted for in the framework, the avoided costs adopted in California were designed to reflect the value of long term, non-dispatchable energy efficiency and conservation programs. The evaluation of DR requires modification of the standard practice to reflect the dispatchable nature of DR and to value resources appropriately that are available year-to-year (or hour-to-hour) rather than over many years. Table 3 shows the resource types that fall into short-term/long-term and dispatchable/non-dispatchable categories.

Table 3: Categorization of Resource Types

	Dispatchable	Non-dispatchable
Short-term	Demand Response (RTP, CPP, DLC, DB, I/C)	
Long-term	CT, CCGT, DR infrastructure	Current standard practice for energy efficiency

RTP = Real time pricing rates; CPP = Critical peak pricing; DLC = Direct load control; DB = Demand Bidding Program; PCT = Programmable controllable thermostats (Title 24 Building Standards); TOU = Time of use rates; I/C= Interruptible/Curtailable Program

3.2 Gaps in current standard practice

The project team identified six research gaps that are important to address in the standard practice valuation methodology to value DR appropriately as a dispatchable resource. While these research areas, which are discussed individually below, do not include all benefits of DR, the research team considered them to be some of the most important areas to investigate. The list of research gaps should not be considered necessarily as additive components of DR value. The research gaps identified are:

- Gap 1: Generation Capacity Value ($/kW-Time Period)
- Gap 2: Consumer Surplus ($/Time Period)
- Gap 3: Option Value ($/kW-Time Period)
- Gap 4: DR Modularity and Value of Information
- Gap 5: Value of Lost Load ($/Use)
- Gap 6: Portfolio Hedge Value ($/Portfolio)

3.2.1 Generation capacity value ($/kW-time period)

A dispatchable DR program is often used only during a few critical hours each year. It is important to measure the value of such a program to the generation system. Load relief during those few critical hours can offer two direct benefits. First the load relief created by DR programs can offer a long-term procurement benefit in the form of less capacity and energy needed to maintain the same reliability target (e.g., 1-day-in-10-years or the 15% reserve margin under the resource adequacy requirement). In this case, DR should receive the appropriate capacity value of generation and energy price. The valuation methodology must capture the value of replacement energy, capacity, and ancillary services (operating reserves).

Additionally, in the event that DR reduces the need to curtail loads to maintain system reliability, reliability benefits provide a second potential source of value attributable to reducing peak load. The methodology must be careful not to double-count the value of capacity and the value of maintaining reliability. Incremental improvements in reliability should be assigned only incremental value.

3.2.2 Consumer surplus ($/time period)

In valuing the effect of DR programs, changes in consumer surplus are important to evaluate. We identify three related aspects of consumer surplus to investigate: California consumer surplus, mitigation of market power, and individual consumer net benefits.

In California, consumer surplus is captured in the standard practice evaluation of efficiency programs through what is called a "multiplier effect." The multiplier effect accounts for the impact of additional conservation on market prices paid by electricity consumers. The multiplier effect can be calculated using historical data, which is how it is calculated when applied to efficiency program, or it can be calculated under a forward-looking scenario that makes use of DR to reduce market prices by reducing high demand during critical hours. This also produces consumer surplus, mainly in the form of bill savings for all customers. Finally, there is the calculation of consumer surplus that is calculated for each individual customer. This approach measures the gains or losses that accrue to individual customers when they modify their usage in response to variations in prices. A standard practice for evaluating DR programs needs to be able to calculate consumer surplus for all customers under both normal and market power cases, as well as for individual customers facing time varying prices.

Two legislative and regulatory proceedings provide guidance as starting points for estimating general consumer surplus. First, Section 7(b)(8) of AB970 of 2000 requires a "[r]eevaluation of all efficiency cost-effectiveness tests in light of increases of wholesale electricity costs and natural gas costs to explicitly include the system value of reduced load on reducing market clearing prices and volatility".

Additionally, CPUC D.00-07-017 begins to value the effect of DR on consumer surplus in stating "the escalators are determined by looking at the 'load reduction value' or 'consumer surplus' relative to the market price and taking a ratio. The escalators are multiplied by the market price - either during peak or off-peak - to arrive at system value" (ALJ Linda R. Bytof's 10/25/00 ruling in connection to UDC compliance with D.00-07-017, p.13).

Figure 3 displays the effect of DR on California consumer surplus in the form of bill savings for all customers in times of high demand when the hourly supply of energy is fixed. The decrease in demand created by the use of DR causes a price drop, which can be multiplied by the hourly consumption in MWH to calculate size of the bill savings for all customers.

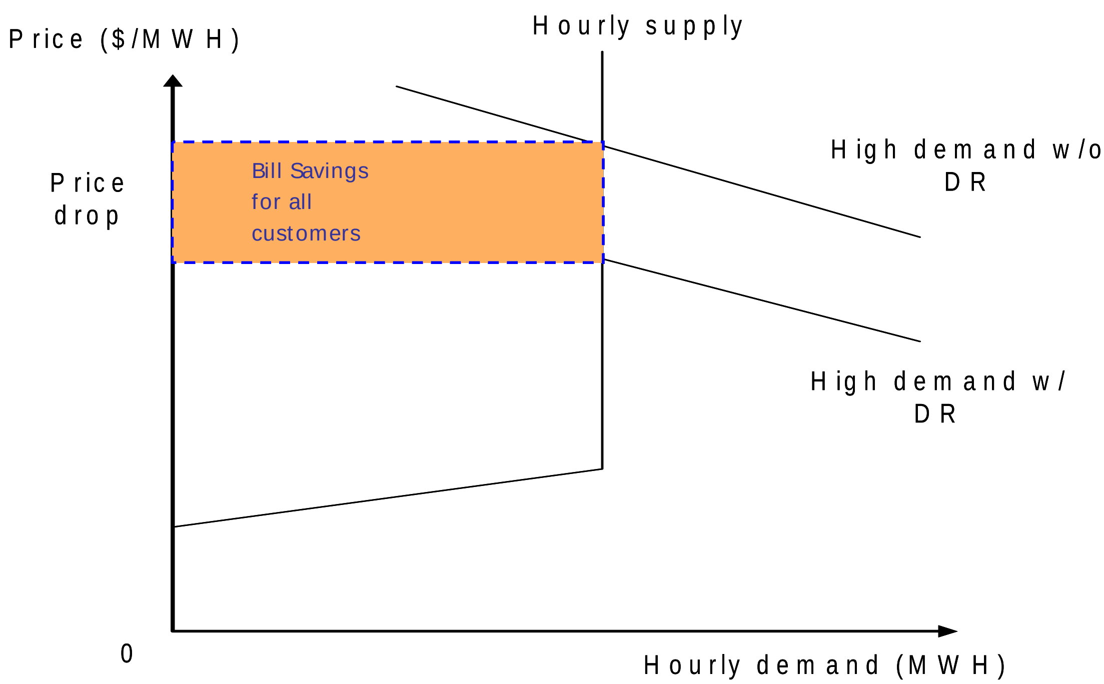

Figure 3: Effect of DR on California Consumer Surplus

Related to the reduction in market prices caused by the shifting of the demand curve is the mitigation of market power. Introducing price responsive loads into the marketplace through the implementation of DR reduces the ability of suppliers with market power to charge a premium for energy and capacity. This effect is particularly pronounced during the critical peak hours when DR resources would be dispatched.

A third consideration related to consumer surplus, but distinct from the change in consumer energy costs, is the change in utility of increased (decreased) consumption during lower (higher) priced periods. For example, even if an individual customer's bill remains unchanged, there may be value of additional energy consumption attributable to DR. The change in customer utility may relate to increased (decreased) productivity, comfort, or other attributes that affect customers. The impact on the individual consumer of different DR rate designs and approaches is discussed in more detail in the Appendix to this report.

3.2.3 Real option analysis

The third research gap in DR valuation results from the fact that the existing standard practice is designed to reflect the benefits of non-dispatchable resources. Dispatchable resources provide an additional option value because the load reduction need only be exercised when it provides value (e.g. when the cost of load reduction is less than the value of the reduction).

DR in particular provides an option to dispatch against energy costs. In this context, the buyers purchase rights to curtailments though DR programs. Customers, who are the sellers of the option, sell curtailment obligations. The buyer of these options will exercise them if they are "…in the money", that is, if it would be less costly to compensate customers for curtailment of energy use during a critical time than it would be to find a way to meet the level of demand without curtailment.

This option value concept is analogous to power plant operations that are dispatched when market prices or other market mechanisms exceed the operating cost. DR rates and programs are flexible options that can vary by strike price to meet the needs of different customer types with different value of load, the number of times that they are exercisable, the notice for use, and the duration of use.

3.2.4 DR modularity and value of information

Demand response can be more pliable, nimble, scalable, and targeted to high value areas than other energy resources. For instance, DR has the ability to be purchased in smaller quantities to meet a particular need and can be ramped up and down quickly relative to the other resource options that are available. Also, to the extent that DR can be expanded more quickly than traditional generation investments, DR can better capture the value of information over time.

As a starting point to analyzing the value of modularity and information of DR, the research team evaluated three components of flexibility believed to have the largest value. These components are:

- Value of shorter lead time and gaining additional information before the resource commitment is made
- Value of being able to sign shorter contracts and having the option to 'retire' a DR resource

- Value of local targeting or being able to move the impact of high demand from area to area

To provide an initial assessment of the magnitude of each of these components, the research team used a combustion-turbine as a proxy for the value of capacity, which illustrated the improved characteristics and the type of flexibility that DR can provide. Table 4 shows that in each case, the additional flexibility provided by some forms of DR can provide additional value. The percentages represent additional value beyond the value of a perfectly reliable combustion turbine (CT). Of these components, the ability to target DR in high value areas and provide both local and system capacity relief had the highest value.

Table 4: Additional Value Provided by DR Compared to Combustion Turbine

Option Value	Low Value	Base	High Value	Description
Value of Information	**1%**	**2%**	**4%**	The value of a shorter lead-time does not provide significant value given our assumptions. The reason is that even if the CT is built a year or two early, it has a low probability of being built more than a few years earlier than needed.
Early Retirement	**1%**	**7%**	**21%**	The value of shorter contract periods is larger and depends on the assumption about the relative value of the plant over time.
Local Targeting	**16%**	**43%**	**82%**	The value being able to target the program to capture local value as well as system value has the greatest increase in potential benefits.

3.2.5 Value of Operating Reliability

DR, as an emergency resource, has the ability to reduce the number, scope, and size of rotating blackouts. This research gap addresses the value customers receive through improved system reliability. To quantify this aspect of DR's value, it is necessary to evaluate the ability of DR to improve system reliability, and then to estimate the value of that improved reliability in terms of the improvement in welfare from a reduction in outages.

Research from the Northeastern United States provides an approach to estimate reliability improvement. A similar approach has been used in the 2008 update to California's Title 24 Building Standards and analysis of the programmable-communicating thermostat (PCT). This analysis contains two components used to monetize the value of improved reliability: an estimate of the difference in Expected Unserved Energy (EUE) between a scenario with and one without DR, and an estimate of the value to customers of this change in reliability using their Value of Lost Load (VOLL).

3.2.6 Portfolio Hedge Value

The energy efficiency standard practice valuation approach considers each resource as an alternative to the “avoided cost” of the utilities portfolio. It does not consider cost variance. Adding DR to a utilities portfolio can reduce the portfolio’s exposure to high market price scenarios.

It is important to determine if the existing valuation framework adequately captures this risk mitigating benefit of DR and whether portfolio hedge value would still be needed once option value (GAP 3) is built into the standard practice. To the extent that DR does add value to the portfolio that had not yet been captured, the best valuation methodology for this uncaptured value should be identified.

Assessment of risk mitigation can be done using a number of different approaches including simulation with DR optimization, simulation without DR optimization, and direct computation. In Phase 1 of this project, the researchers used a close-form solution of cost and variance to calculate the portfolio risk efficiency frontier with and without DR.

Using a set of input assumptions that can be developed based on historical market data, the research team estimated the cost and risk of the supply portfolio with and without DR. The results of this illustrative example are depicted in Figure 4 below. The introduction of DR reduces the portfolio risk at a given cost point on the efficiency frontier. It is important to note, however, that the usefulness of these results depends on whether reasonable and verifiable input data can be developed for the portfolio evaluation. However, the approach illustrates that with assumptions of cost and cost variance, it is possible to evaluate the change in portfolio risk with a closed-form solution. It is not necessary to use monte carlo or other simulation techniques which are much more computationally intensive, less transparent to stakeholders, and require data that is more difficult to develop or may be proprietary.

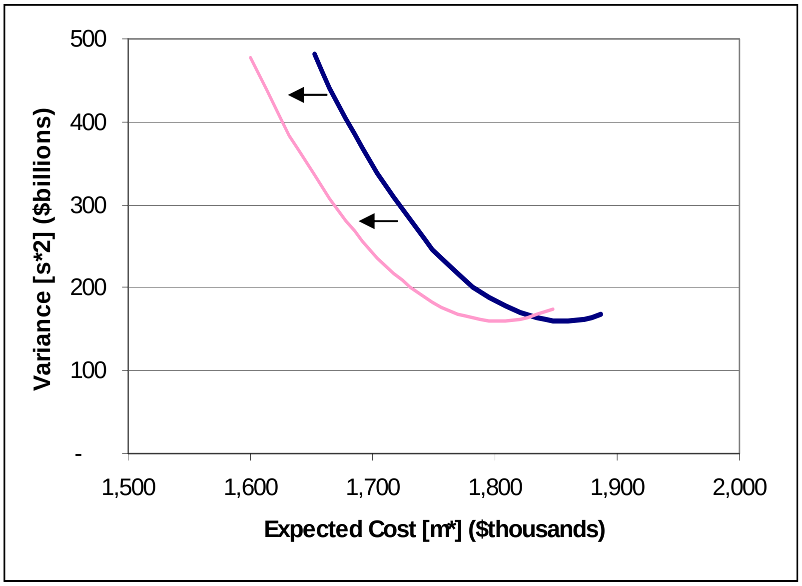

Figure 4: Change in Portfolio Cost and Risk with the Introduction of DR

Assumptions used to develop the illustrative portfolio value approach are shown in the Table 5 below[3].

Table 5: Assumptions used for Portfolio Value Approach

Forward Price ($/MWh)	F	$39
Expected Demand (D) MW	μ_D	50,000
Variance (D)	σ_D	12,131
Expected Price (P)	μ_P	43.19
Variance (P)	σ_P	11.7
Correlation (P,D)	*r*	0.42
Correlation (PD,P)	ρ	0.93

[3] For a complete methodology description, see Woo, C.K., I. Horowitz, A. Olson, B. Horii and C. Baskette (2006) "Efficient Frontiers for Electricity Procurement by an LDC with Multiple Purchase Options," OMEGA 34(1): 70-80; and Woo, C.K., I. Horowitz, B. Horii and R. Karimov (2004) "The Efficient Frontier for Spot and Forward Purchases: An Application to Electricity," Journal of the Operational Research Society 55: 1130-1136.

Conclusions and Recommendations

4.1 Conclusions

The current standard practice used to value energy efficiency in California contains many useful elements for DR evaluation, but does not completely capture the entire value of DR. At least six major research gaps exist that must be further analyzed to value DR programs more accurately.

4.2 Recommendations

The research gaps discussed in the results section have led the researchers to determine that a new standard practice for valuation of dispatchable resources is needed. The research team recommends beginning with the development of a DR Benefits and Valuation Issues Concept Paper that will identify, describe, and rank all of the benefits provided by DR in the energy processes used in California. This work will then be used to confirm, expand, or modify the list of gaps necessary to modify or rebuild the existing standard practice for evaluation of energy efficiency in California.

When building on the current standard practice methodology, the research team recommends that a similar approach be taken to that which was used in the development of avoided costs for energy efficiency to develop broad stakeholder support and understanding. In particular, the new methodology would:

- Be fully documented and transparent
- Have consistent valuation across all dispatchable resources
- Clearly define differences between non-dispatchable (DSM) and dispatchable (DR) resources
- Make full use of publicly available market price data
- Not depend on the use of proprietary data or models

Developing such a DR valuation approach will require substantial theoretical and analytic development to address the major gaps identified in this Phase 1 work and other gaps that are produced from the development of the Benefits and Valuation Issues Concept Paper. Development is needed in each of the six key areas, and this work should comprise the bulk of work during the next phase of the process.

The research team recommends a two-track process to achieve the objectives outlined in this research: (1) an economic framework and analytic development track led by a small, technically-oriented group to actively Beta-test the methods that will ultimately be incorporated into benefit/cost spreadsheet models; and (2) a stakeholder utility practitioner participation track that will improve the chances that the valuation methods are both useful and "user friendly". The two tracks will also allow for stakeholder and practitioner participation that will inform and connect the analytic work to the regulatory and policy agenda in California, ensuring that the analytic outputs are transparent, understandable, defensible, and relevant to regulatory and energy policy agendas. Finally, this will also allow for interested parties to anticipate the results of the work and even pre-test its likely effect on design and implementation of utility and ISO demand response programs.

4.3 Benefits to California

Proper valuation of DR 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 provides an approach and identifies a preliminary list of the important valuation areas that need to be addressed to establish a methodology that will value the benefits of DR more accurately and consistently, thus improving the ability of public and private resources to meet the electricity needs of Californians cost-effectively.

References

Violette, D., Freeman, R., Neil, C. September 26, 2005. DRR Valuation and Market Analyses, Volume I, II: Assessing the DRR Benefits and Costs. Prepared for International Energy Agency, Demand Side Programme.

Northwest Power and Conservation Council. July 2005. The Fifth Northwest Electric and Conservation Plan. NPCC Document 2005-07.

RLW Analytics, Neenan Associates. December 2004. An Evaluation of the Performance of the Demand Response Programs Implemented by ISO-NE in 2004. Annual Demand Response Program Evaluation submitted to FERC. Available at www.ISO-NE.com

New York ISO. December 2004. NYISO 2004 Demand Response Programs (Attachment I) Compliance Report to FERC. Docket No. ER01-3001-00. Available at http://www.nyiso.com/public/index.jsp

Electric Power Research Institute. December 1994. Integrated Generation Transmission and Distribution Planning. EPRI TR-100487.

Woo, C.K., I. Horowitz, A. Olson, B. Horii and C. Baskette. 2006. Efficient Frontiers for Electricity Procurement by an LDC with Multiple Purchase Options. OMEGA, 34:1, 70-80.

Sezgen, O., C. Goldman, and P. Krishnarao. October 2005. Option Value of Electricity Demand Response. Lawrence Berkeley National Laboratory, LBNL-56170.

Glossary

AS	Ancillary Services
CPUC	California Public Utilities Commission
CT	Combustion Turbine
DR	Demand Response
DSM	Demand-side management
EE	Energy efficiency
EPRI	Electric Power Research Institute
I/C	Interruptible/Curtailable Program
IEA	International Energy Agency
LBNL	Lawrence Berkeley National Labs
LOLP	Loss of Load Probability
NPCC	Northwest Power and Conservation Council
SPM	Standard Practice Manual
TDV	Time-dependent valuation
TOU	Time of Use
UDC	Utility Distribution Company
VOLL	VOLL

Appendix: DR Valuation – RON-01 Phase 1 Results Presentation

(Please see attached document titled "Appendix - DR Valuation-RON-01 Phase 1 Results Presentation.pdf".)