Smart Grid Demonstration Cost/Benefit Analysis

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Outline

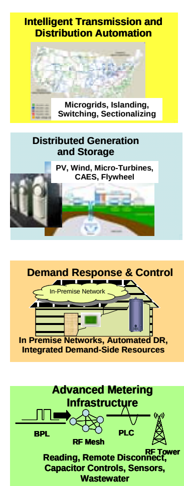
A. Cost and Benefit Analysis (CBA) Defined
B. What constitute Smart Grid Benefits?
C. Measuring Smart Grid Impacts
D. Monetizing Smart Grid Benefits
E. The Cost to Realize Smart Grid Benefits
F. CBA Application to EPRI Smart Grid Demonstration

Cost and Benefit Analysis (CBA) Defined

A

Cost and Benefit Analysis (CBA) – Design Principles

- Adaptable to all Smart Grid demonstrations
- Provides for a consistent and fair comparison of alternative Smart grid technologies and systems
- Adaptable to new findings and expanded applications
- Identifies all attributable benefits
- Minimizes redundancy in benefit attribution
- Distinguishes benefits according to:
  - Level (how much)
  - Distribution (who is the beneficiary)
  - Timing (when they are realized)



A Useful Semantic Distinction

- The first order, and therefore defining, impact of Smart Grid technology is a change in the technical performance of the electric system
- The term benefit connotes a monetary result
- A transformation function is required link the two
- An important distinction is:
  - ***Impact*** (cause) = the first-order impact of the investment on the system (what aspect of service or performance changed?)
  - ***Benefit*** (effect)= the monetary equivalent of the impact

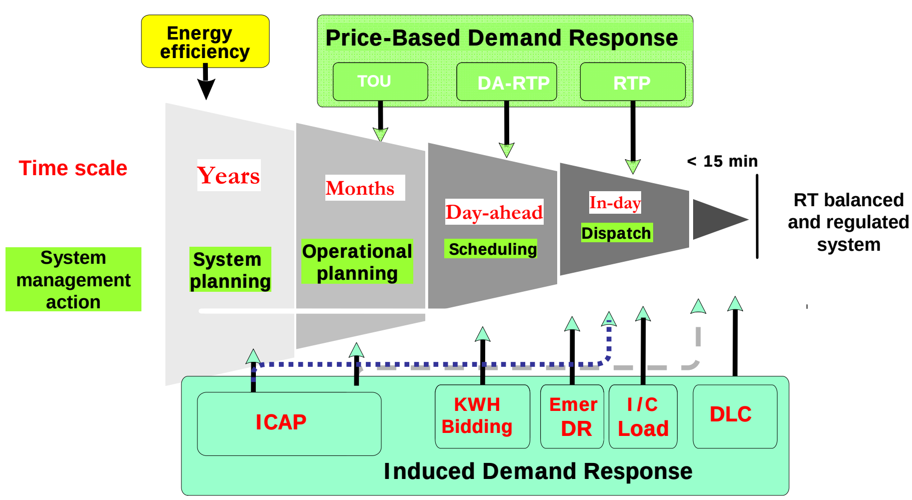
Defining and Categorizing Smart Grid Benefits

B

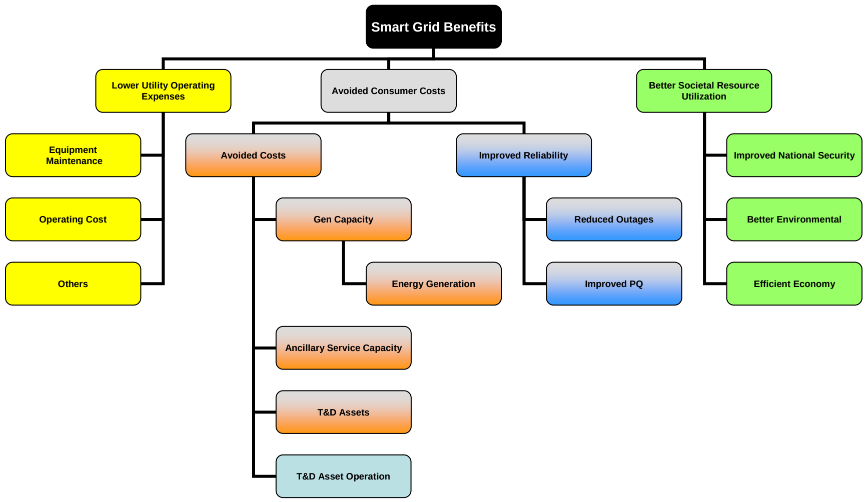
Benefits 1st Order Distinction

- **Operating cost savings** that result from increased productivity attributable to the investment
  - Operating costs savings (relative to what is incorporated into existing rates) provide a stream of funds that can be used by the utility to service the Smart Grid investment carrying costs.
- **Consumer cost avoidance** from reduced generation, transmission, and distribution investment or operational requirements
  - Avoided capital and operating costs result in rates that are lower than they otherwise would have been
- **Societal Benefits** that inure to consumers, but in less obvious ways
  - These benefits inure directly to consumers and are:
    - Speculative, subjective, and challenging to monetize
    - Not necessarily evenly distributed among consumers

Many Benefits Originate at Wholesale and Flow to Retail



Smart Grid Benefits Categorization



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Things that appear to be left out – based on typical list of benefits

- **Impact on electricity markets**
  - More efficiency operations
  - Customer participation
  - Flatter load profiles
  - Reduced LMP/MC volatility

Impact on System Operations
  - Integration or renewable generation resources
  - Optimized PHEV charging/discharging
  - Better unit operating efficiency

- Customer impacts
  - Lower electricity rates
  - End-use and premise load control
  - More consumer choices
  - Lower electricity consumption

- Externalities
  - Lower emissions form renewable
  - Achievement of RPS goals

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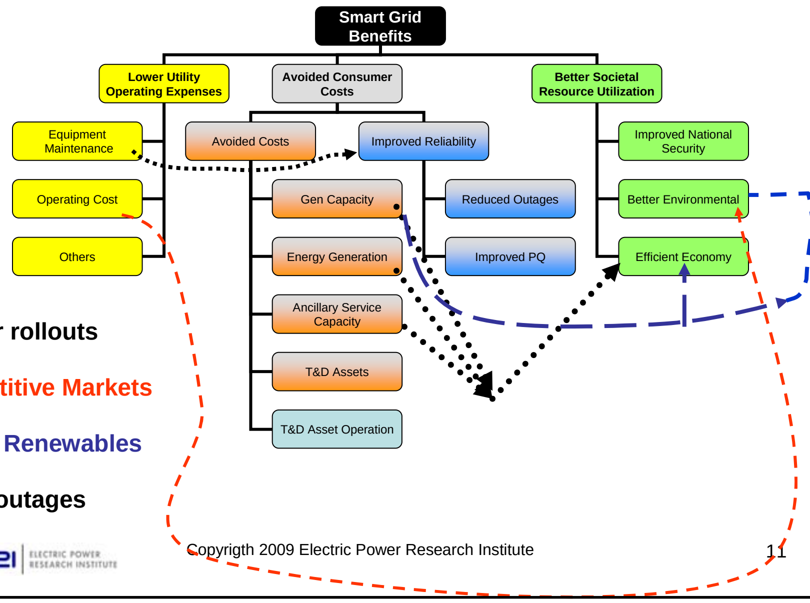
Smart Grid Benefits – Collateral Impacts



Fewer rollouts

Competitive Markets

Enable Renewables

Fewer outages

Some Puzzlers

- Devices and controls specifically added to mitigate the adverse impact of distributed PV which itself is claimed as a benefit
  - Is that a benefit to consumers? or
  - A reduction in the value attributed to PV?
- Reduced cost of Smart Grid elements due to economies of scale
  - Is this attributable to the SG? or
  - Just the way of the world, a coincidental, not attributable, benefit?
- Improved perception of utilities, other entities – who gains from good will, and what is it worth to monopoly entity?
- Enabling more retail competition,
  - Is the real benefit measured already in induced kW and kWh changes?
- Horizontal and vertical expansion of utility economic activity
  - If utilities provide PHEV charging service, offer HAN systems, who gains and how , especially if those are regulated services? Does this restrict their competitive supply that might be cheaper or more robust?

Summary

- The DOE/EPRI CBA framework provides a foundation for consistent and credible evaluation of Smart Grid benefits
- Some adaptations improve its suitability
  - A functional definition of benefits
  - Methods for measuring the benefits by category
  - Monetizing the benefits
  - Clear linkage of cause and effect

Measuring Smart Grid Impacts

C

Metrics for Utility Expense Reduction

- Impacts that are direct measures of benefits:
  - Reduced expenses
    - Lower theft losses
    - Reduced outage restoration expenses
    - Lower maintenance expenses
    - Lower system dispatch costs
  - Increased net revenues (another source to offset investment costs)
    - Prepaid service enabled
    - Seasonal shut off
    - Reduced read-to-pay time
    - Fewer estimated bills
    - Faster account service initiation/termination
    - In-home device monitoring services

Data Sources

- **Utility customer billing records**
- **Utility** general accounts
- Department account records
- Cost of service studies
- Customer demographics
- Estimates of new service enrollment and usage

Metrics for Avoided Costs

- **Avoided capital costs**
  - Reflect the reduction in the cost to serve load
    - Generation plant investments
    - T&D investments
  - Generally measured in terms of kW avoided
- **Avoided energy costs**
  - Reflect the cost of operating cost of the generation unit that otherwise would have been dispatched

- **Measurement issues**
  - How is capacity adequacy affected (kW impact)?
  - What generation units are not built
    - Peaking
    - Base load
    - Cycling
  - How is total dispatch effected?
  - Are ancillary services requirement affected?
  - Impact of market structure

Baselines

- A baseline establishes:
  - For a specific impact
  - The level of impact that would have otherwise realized
  - But for the Smart Grid investment
  - Need to forecast outcomes (baseline) over the SG investment lifetime to account of base dynamic influences
- Perspective
  - Marginal perspective- how did things change
  - Measures temporal and spatial changes
  - Historic data generally used to establish the basis for impact measurement, but may have to model the baseline in some cases
  - Dynamic adjustments if investments system usage changes would been made (occurred) anyway

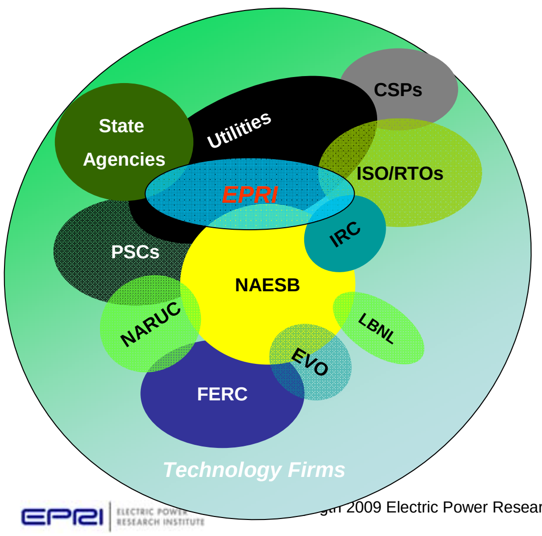
Baseline for Measuring Impacts Attributable to Smart Grid Investments

- Asset performance
  - Measures of currently generation efficiency (unit and portfolio)
  - Measure of today's T&D system performance
- Consumer behavior
  - What would consumption otherwise have been?
  - What is today's level of reliability? Service quality?
- Economic activity
  - Oil consumption for generation
  - Character of electricity sector
    - Expenditures by sector
    - Labor multipliers

Area of active inquiry

Needs devlopment

Who is Responsible for, or Concerned about, Demand Response EM&V Protocols?



North American Energy Standards Board

National Association of Regulatory Utility Commissioners

Curtailment Service Providers

ISO/RTO Council

Public Service Commissions

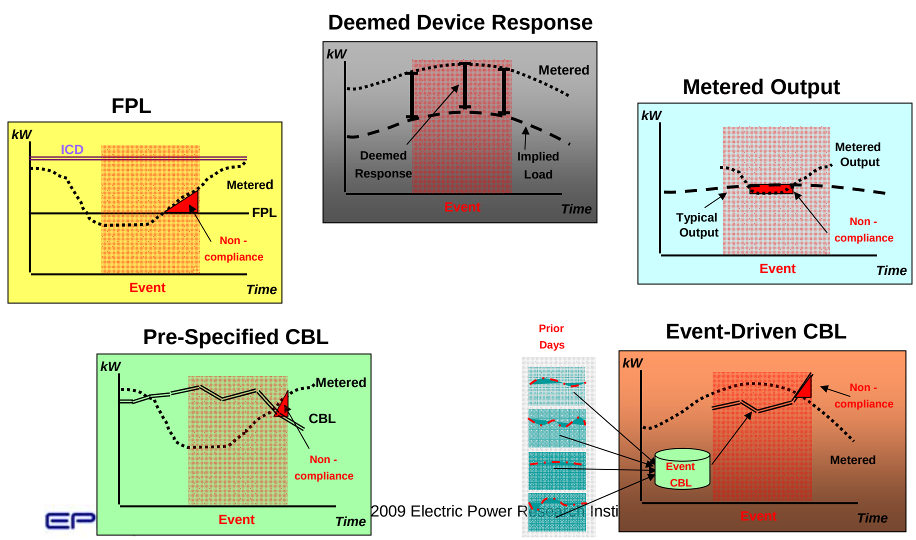
Public Service Commissions

Federal Energy Regulatory Commission

Lawrence Berkeley National Laboratory

Efficiency Valuation Organization

How demand response product performance is measured



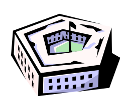
Metrics for Improved Reliability

- Outage Mitigation
  - Fewer outages
  - Shorter duration outages
  - Increased outage notice
- Power Quality Improvement
  - Reduced voltage sags and spikes
  - Harmonic stability

- Measurement issues
  - What constitutes an outage?
  - Impacts of sags on premise service
  - Spatial and temporal measurement requirements
    - Premise
    - Circuit
    - Network

Metrics for Better Societal Resource Utilization

- National security
  - Reduced imported oil consumption for generation
- Better environment
  - Lower net emissions from electricity generation
- Efficient economy
  - Employment
    - Net job creation, character of the jobs
    - Wages
  - Economic output – GNP
  - Social welfare
    - Economic measure of resource productivity



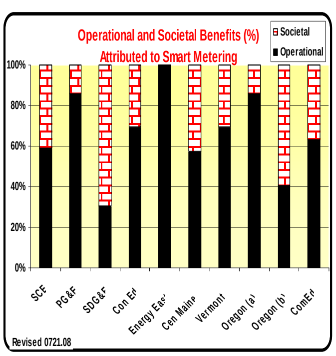
Most are difficult to quantify, but methods have been developed

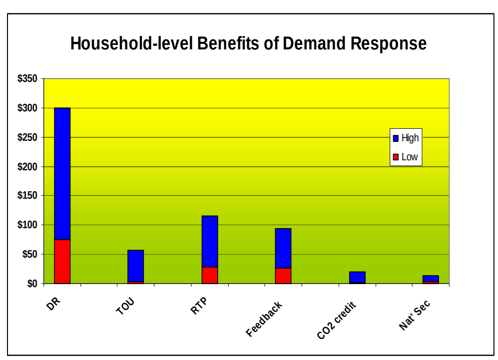
Monetizing Smart Grid Benefits

D

All Roads Lead to Demand Response

On Average, 34% of Attributed Smart Meter Benefits are Societal (Customer)

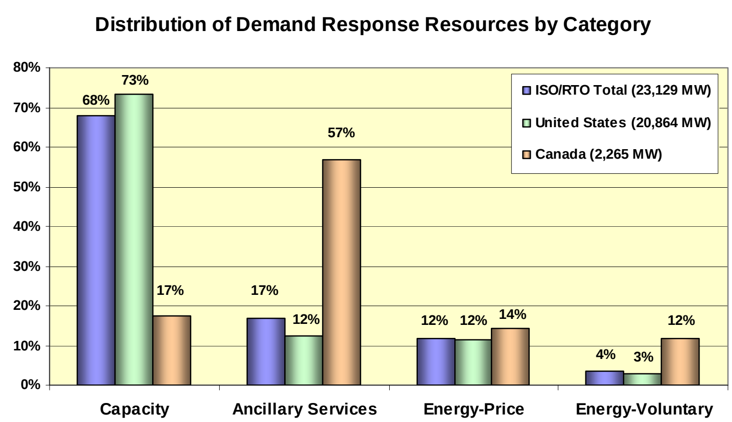




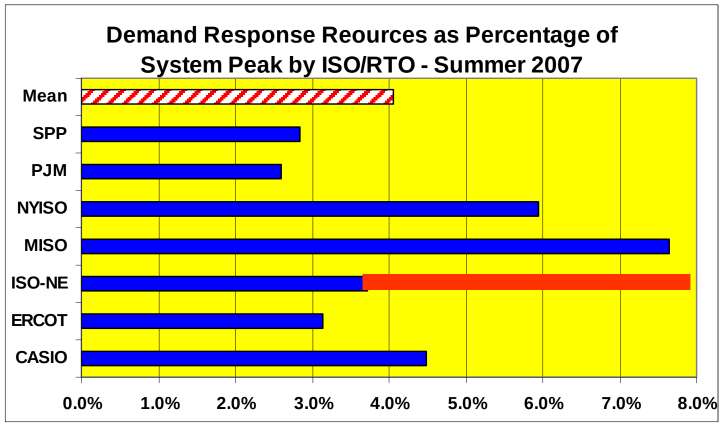
What is the Value of Demand Response?

- Demand response is a change in the consumption of electricity due to a change in the price paid, or another inducement to do so
- The value of such changes depend on:
  - Economic outcomes
    - Market price changes
    - Dispatch costs
  - Reliability conditions
    - Value of reliability
- Net demand response benefits

Lots of Demand Response Already DR Resources by Type



IRC Estimates of DR Resources as Percentage of Peak

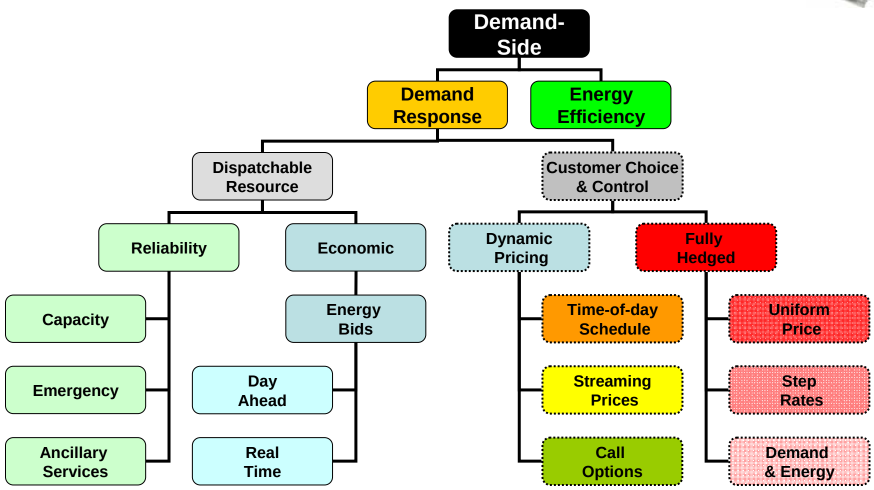


ISO/RTO Council, Markets Committee. October 16, 2007. Harnessing the Power of Demand. Available from *www.isorto.org*.

How DR Generates Value

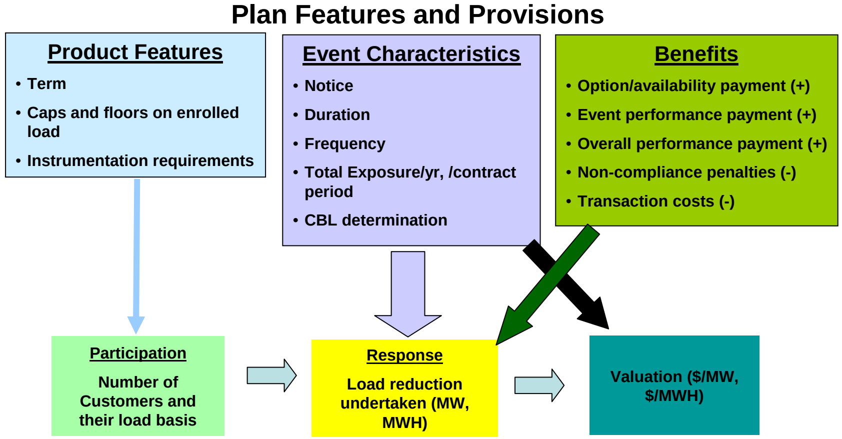
- Product design determines how the demand response program is activated and produces benefits
  - Autonomous. The consumer decides at what price it changes consumption
  - Directly dispatched. An external entity has the ability to curtail a device's usage
  - Self-dispatched the consumer controls the response decision
- Market or enterprise circumstances determine when an event is manifested
  - Prevailing energy prices
  - Level of system operating reserves
  - Demand response provider's internal value
- Value is determined by how markets and consumers are impacted
  - Wholesale value is transparent
  - Vertically integrated utility value is like administratively determined

Modified NERC and NAESB characterization to accommodate retail pricing structures



DR Program Features

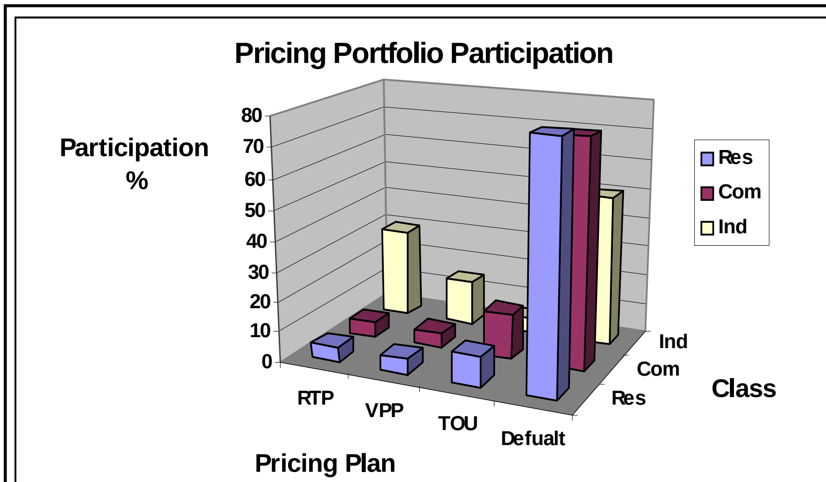
Plan Features and Provisions



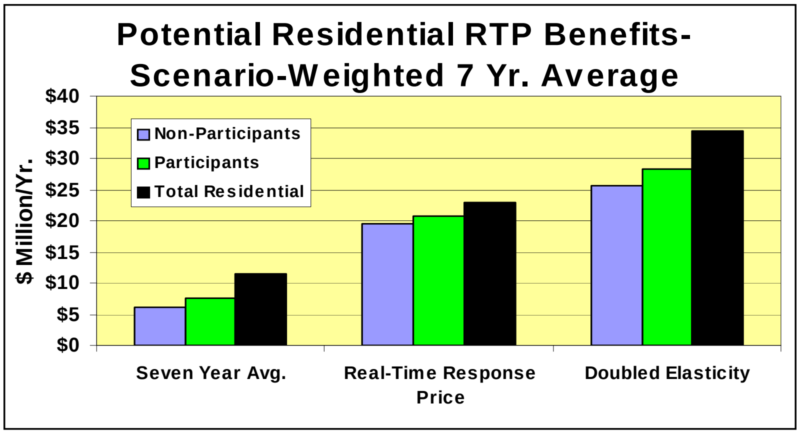
Dynamic Pricing Participation

- Residential Dynamic Pricing
  - EDF = 75% or more on dynamic TOU rate
  - Salt River and APS + 20% or more on TOU rate schedule
  - Gulf Power = 30% of target on TOU/CCP
  - CA pilots estimate
    - ~30% predicted acceptance
    - 5% actual participation
  - Pilots report 20-25% subscription rates for pilots
    - Target recruiting
    - Participation incentives

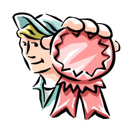
Simulated DR Plan Participation Rates



Potential Benefits Attributable to Residential RTP



Reliability Improvements

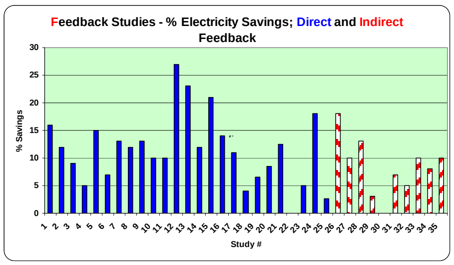


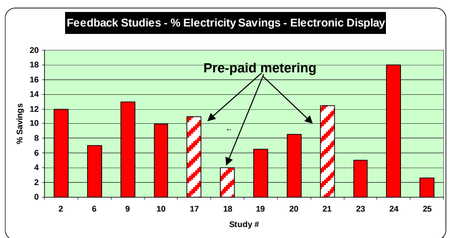
- Smart Grid provides for more localized measurement of individual premise service status
- If this information is integrated into restoration systems, the duration of outages may be reduced, which translates into more value to consumers
- Such an analysis requires:
  - Identifying changes in CAIDI that would be attributable to Smart Metering
  - Estimating customer outage costs

Change in Outage Duration X **Outage Cost** = **Smart Metering Premise-level Reliability Value**

OUTPUT	Residential	Small Commercial
Baseline Cost per Outage	$5.73	$295 - $475
Marginal Cost per CAIDI Minute	$0.01	$5.45

Improved Utilization Efficiency- Feedback





- **A wide variety of studies have been conducted over the past 20 years to quantify the impact of information on electricity consumption:**
  - **Indirect feedback** – provides consumers with more detailed and in-depth analyses of billing information
  - **Direct feedback** – provides consumers direct access to the meter contents
- **The reported impacts over both feedback types, reductions in total kWh consumed, range from zero to 25%**
- **Electronic display results also exhibit a wide range of energy reduction values**
- **Most studies involved only very few (under 150) participants for a year or less.**

Feedback Impacts

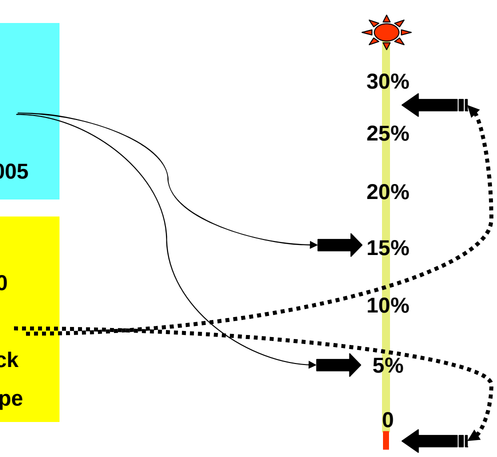
% Reduction in HH Energy

Metastudies

- **Darby 2001, 2006**
- **Fischer 2007**
- **Abrahamse, *et al.*, 2005**

Pilots

- **Before and after 2000**
- **Direct vs. indirect**
- **Slow vs. fast feedback**
- **North America, Europe**



Feedback Hierarchy

- Darby provided an important distinction; indirect vs. direct
- EPRI added a functional hierarchy

Feedback Hierarchy					
1	2	3	4	5	6
Standard Billing	Enhanced Billing	Estimated Feedback	Daily/Weekly Feedback	Real time Feedback	Real time Plus
Monthly invoice (actual or estimated usage)	Tips on how to save	Tailor audits and advice	Periodic reports on actual usage	Readily available usage data	Real – tie data plus controls
"Indirect" Feedback provided after consumption occurs				"Direct" Feedback provided as consumption occurs	

Low — Information availability — High

Low — Cost/Effort to implement — High

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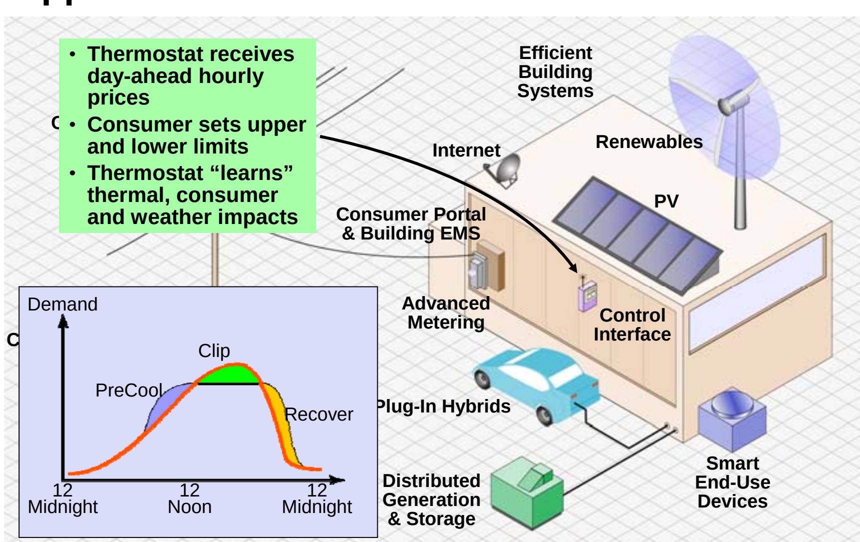
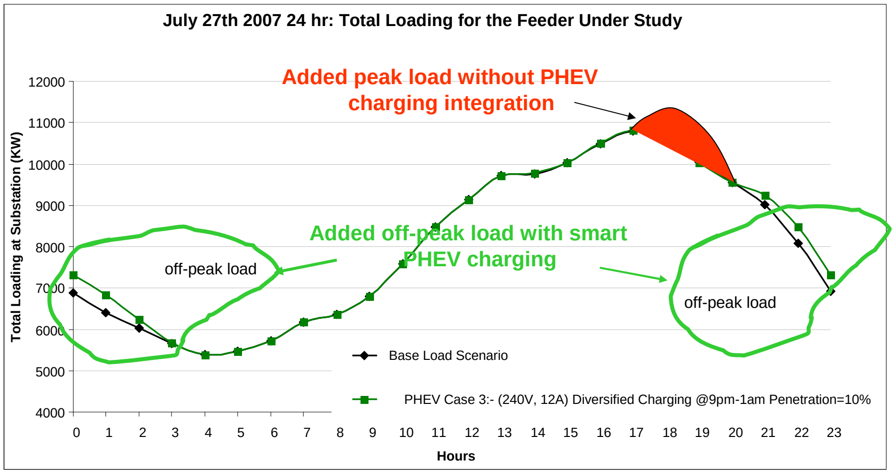
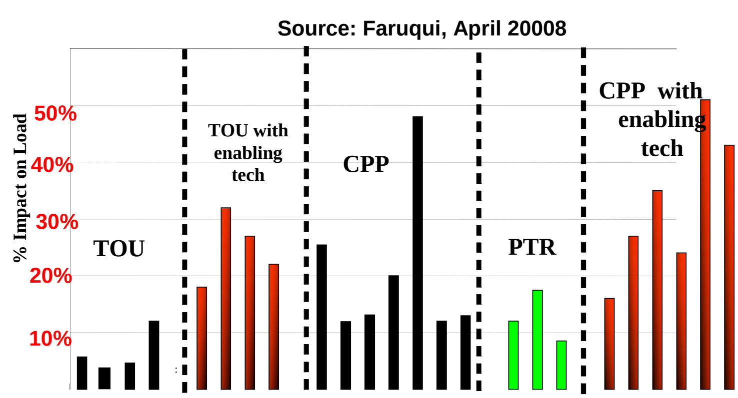
Smart Grid & Smart Pricing- Example Application



Smart Charging: Key to Reducing PHEV Impacts



Comparison of DR Plan Event Impacts

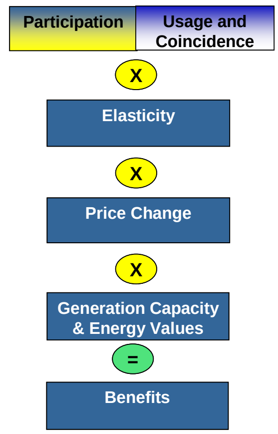


- Differences among pricing structures are largely due to event price differences, not elasticity differences
- Participation levels and sustainability is highly speculative

Valuing Demand Response Benefits - An Elemental Method

Basic Program Characterization

- Participation rate
- Reference load profiles for target customers
- Price change
  - Event prices, penalties
  - Reference price
- Price response
  - Event load
  - Level of price response
  - Event/Peak coincidence
- Avoided cost
  - Energy
  - Capacity
- Reliability benefit
- Costs of program implementation



For Smart Metering business cases, the frame of reference is incremental; how does Smart Metering enhance the levels of key parameters?

An Illustrative Example

- An example of a specific demand response product illustrates the assumptions required and their implications for the resulting level of benefits
- The Peak Time Rebate (PTR) serves to illustrate the methods and implications
- PTR is assumed to be deployed to reduce coincident peak demand and thereby reduce capacity costs
- PTR Events are declared each year to coincide with the system peak load

Peak Time Rebate

- Participation is voluntary
- Utility determines when to declare an event
- Participants that reduce load are paid the Rebate price
- No penalty for failure to respond

Assumptions

- Perfect foreknowledge of when the system peak occurs
- Avoided capacity cost = $100/kW year
- 20 year lifetime for Smart Metering
- 100,000 households
- Average 14,000 kWh/yr
- 65% coincidence of peak energy and system peak kW
- System cost - $20 million (NPV)

NPV 20-Year Value at Higher Buy-back Rebate

- **Lightly shaded (green) cells exceed the Smart Metering capital cost of $20 million.**
  - Participation rate of at least **30%** (corrected value)
  - Elasticity of at least 0.10

  What some pilots exhibited
- **The dark shaded (black) cells exceed the capital cost plus the participant incentives**
  - Participation of at least **50%** (corrected value)
  - Elasticity of at least 0.175

  Not yet demonstrated
- **Values assume that only one event is called per year to achieve the peak reduction. If more events are required, then the net benefits are less.**

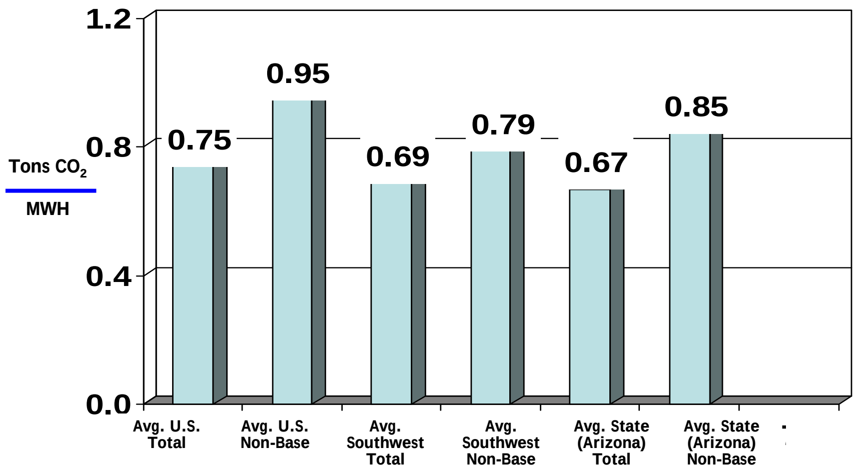
NPV 20-Year Value at Buy-back Rebate 8 times Standard Rates

Participation	Elasticity						
	0.025	0.05	0.1	0.15	0.175	0.2	0.25
10%	$ 872,603	$ 1,745,205	$ 3,490,411	$ 5,235,616	$ 6,108,219	$ 6,980,822	$ 8,726,027
20%	$ 1,745,205	$ 3,490,411	$ 6,980,822	$ 10,471,233	$ 12,216,438	$ 13,961,644	$ 17,452,055
30%	$ 2,617,808	$ 5,235,616	$ 10,471,233	$ 15,706,849	$ 18,324,658	$ 20,942,466	$ 26,178,082
40%	$ 3,490,411	$ 6,980,822	$ 13,961,644	$ 20,942,466	$ 24,432,877	$ 27,923,288	$ 34,904,110
50%	$ 4,363,014	$ 8,726,027	$ 17,452,055	$ 26,178,082	$ 30,541,096	$ 34,904,110	$ 43,630,137
60%	$ 5,235,616	$ 10,471,233	$ 20,942,466	$ 31,413,699	$ 36,649,315	$ 41,884,932	$ 52,356,164
70%	$ 6,108,219	$ 12,216,438	$ 24,432,877	$ 36,649,315	$ 42,757,534	$ 48,865,753	$ 61,082,192
80%	$ 6,980,822	$ 13,961,644	$ 27,923,288	$ 41,884,932	$ 48,865,753	$ 55,846,575	$ 69,808,219
90%	$ 7,853,425	$ 15,706,849	$ 31,413,699	$ 47,120,548	$ 54,973,973	$ 62,827,397	$ 78,534,247
100%	$ 8,726,027	$ 17,452,055	$ 34,904,110	$ 52,356,164	$ 61,082,192	$ 69,808,219	$ 87,260,274

Externalities

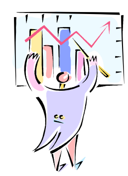
- Externalities are costs associated with economic activity that are not included in the price paid by consumers
- As a result, resources are not used optimally from a societal perspective
- Smart Metering may enable changes that reduce externalities
  - Reduced kWh usage that is oil-based reduces reliance on imports, which may have implications for national security
  - Reduced kWh usage that reduces generation carbon emission reduces costs associated with the associated adverse environmental impacts
- Externalities are sometimes associated with market failure – the missing cost element in the good is an indication that the market is not functioning properly
- But, in the absence of a market, how are such costs monetized?
  - **Cicchetti- implied national security adder = $.057 to $.014 /kWh**
  - **Synapse – implied CO_2 emissions = $.016 to $.018/kWh**

Different Average Emissions Approaches Yield Different Results



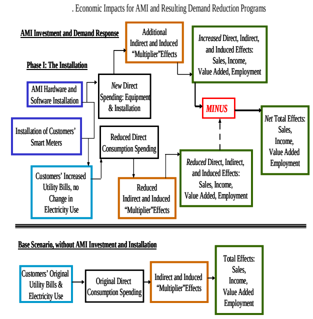
Source: U.S. EPA eGrid Database

Macroeconomic Impacts



- Disruptive changes in sector spending behaviors
  can trigger beneficial changes in the economy:
  - Expanded regional economic activity
  - Increased employment and wages
- Smart Grid may be the source of such
- changes arising from:
  - Changes in utility expenditures
  - Changes in consumer expenditures associated with
    - Reduced electricity costs (if applicable)
    - Purchase of other products and services
- Characterizing and quantifying them involves economic sector macroeconomic (Input/Output) modeling
  - Requires using very specialized and generally expensive modeling techniques
  - The expenditure changes associated with Smart Metering may not involve substantial changes in expenditure

. Economic Impacts for AMI and Resulting Demand Reduction Programs



The Cost to Realize Smart Grid Benefits

E

Issues to Resolve

- What is the purpose of the CBA?
  - Calculate demonstration project net benefits
  - Estimate the net benefits for the project
    - Under repeated applications at the same scale
    - Scaled-up applications
- What costs need to be measured?
  - All project costs
  - Distinguish R&D (one-time) from project requirements costs
  - Today's cost or cost at full scale and scope
  - Collateral costs
- Access to pertinent data
  - Utility
  - Vendor/contractor

CBA Application to EPRI Smart Grid Demonstration

F

Step-wise process

1. Characterize project outcomes
2. Map goals to impacts
3. Monetize estimated impacts
4. Estimate costs
5. Establish performance tracking requirement
    1. Cost reporting
    2. M&V protocols
    3. External variable measurement

Next Steps

- Develop operational manual to guide protocol application
- Test out protocols on one or more projects
- Revise and document protocols
  - Application guides for EPRI Smart Grid (and Energy Efficiency) demo
  - Coordinate with DOE
    - Coordinate development of protocols
    - Share experiences
- Develop analytical tools