Smart Grid Technical Advisory Project

Mid-Atlantic Conference of Regulatory Utility Commissioners

Smart Grid
Metering, Cost Recovery, Demand Response

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Issues and Opportunities

1.0 Defining the Smart Grid (another definition)

4.0 Metering

(1) Advanced metering technology

(2) Cost Recovery

6.0 Demand Response

8.0 Smart Grid Technologies

1.3 Define Smart Grid

Smart Grid is System Integration

The Smart Grid is a system of information and communication applications integrated with electric generation, transmission, distribution, and end use technologies which will :

Promote Customer Choice	[1] **enable consumers** to manage their usage and chose the most **economically** efficient offerings
Improve Reliability	[2] use **automation** and alternative resources to maintain delivery system **reliability** and **stability**, and
Integrate Renewables	[3] utilize the most environmentally gentle **renewable**, **storage**, and **generation alternatives**.

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1.7 Define Smart Grid

Feature	Current System	Smart Grid
Utility Business Model	• Utility Centric ownership • Centralized operation	• Distributed ownership • Distributed operation
Obligation to Serve	• Utility Provides All • Customer Pays	• Utility Provides Some • Customer Pays
Generation Resources	• Centralized • Thermal dominates	• Distributed • Renewable emphasis
Transmission / Distribution	One Way Power Flow	Micro Grids
Metering-Measurement	Accumulated Usage	Interval Measurement
Rates (Pricing)	Rates not Pricing	Actionable Prices
Customer Role	Passive	Active

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4.0 Metering

4.1 Metering

What is Electric Metering ?

An electric meter or energy meter is a device that measures the amount of electrical energy consumed by a residence, business, or an electrically-powered device. *

Electric meters are typically calibrated in billing units, the most common one being the kilowatt hour. Summing kilowatts (kW) over a discrete period of time (hours) provides energy measures to support billing. Periodic readings of electric meters establishes billing cycles and energy used during a cycle.

- http://en.wikipedia.org/wiki/Electricity_meter

4.2 Metering

Why is metering important to Smart Grid ?

1. Electric meter provide an information link between the utility system (supply) and customer (demand).
2. Metering with integrated communications is expected to provide essential smart grid functions, including:
   - More timely usage and status information to the utility.
   - More timely usage information to the customer.
   - Support for more informative rates and pricing options.
3. Advanced metering is a required consideration for all Smart Grid investments under the American Recovery and Reinvestment Act of 2009 of the PURPA Standards in the Energy Independence and Security Act of 2007

4.3 Metering

What are the Smart Grid metering choices?

Standard Meters (1)

- **Standard kWh Electromechanical**
  - kWh Cumulative
- **Remote Metering [AMR]**
  - kWh Cumulative or TOU

Advanced Meters (2)

- **Advanced Metering Infrastructure [AMI]**
  - kW Interval
  - Communication Network
  - Meter Data Management
- **Smart Metering**
  - kW Interval
  - Enhanced Communication Network
  - HAN Gateway
  - Remote Service Switch [connect / disconnect]
  - Enhanced Meter Data Management

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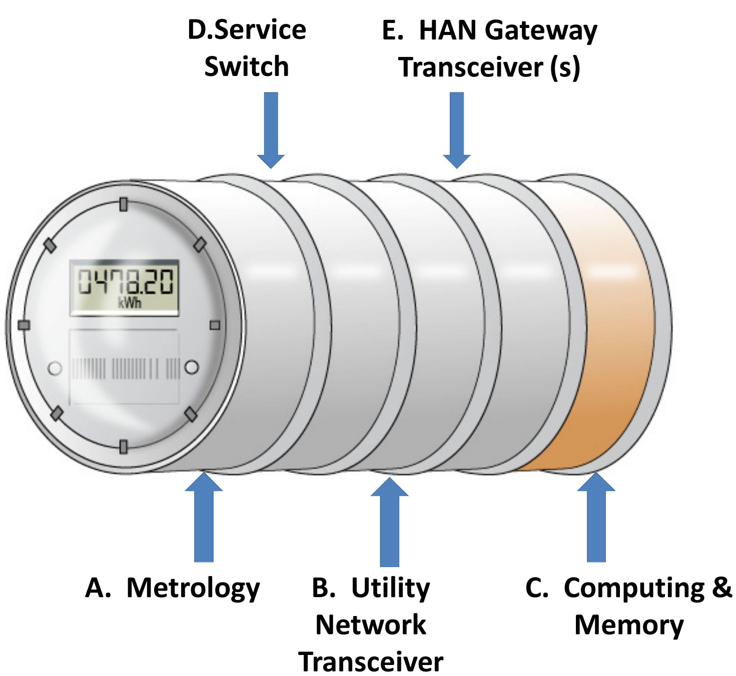
4.31 Metering



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4.4 Metering

Describe the differences between AMI and Smart Metering

- **AMI [advanced metering infrastructure]**: a **utility-owned** communication system that links interval meters at each customer site with back-office meter data management , billing and other application software.
- **Smart Meter: AMI with an integrated service switch, HAN gateway, enhanced two-way communications network, and enhanced back office Meter Data Management, Demand Response and Price signaling software.**
  - **HAN [home area network]** - communication system(s) within the customer facility that link **consumer-owned** communicating devices including thermostats, pool pumps, appliances, distributed generation sources, gateways, routers, entertainment devices, health monitors, fire, security and other applications. SmartMeter OpenHAN gateway integrates the HAN into the meter. HAN typically remains independent of the meter.
  - **Service Switch:** a switch that allows the utility to remotely: (a) disconnect and reconnect the customer's electric service and (b) establish a demand limit, which if exceeded will disconnect the customer's electric service.

4.5 Metering

Describe the difference between AMI and Smart Metering

Metering System	Advanced	Smart	Tradeoffs - Issues
Primary Function	Interval Recording	Interval Recording	Identical, no issues
Communications Capability	Network, two-way	Network, two-way into customer premise	•Focus on Meter Network •Reach into customer premise
Remotely Configurable Demand Limit Connect-Disconnect Service Switch	A separate piece of equipment	Integrated	Hardware Integration
Home Area Network Gateway	Separate system or piece of equipment	Partially Integrated	Partial Hardware Integration
Cost Range per Meter [excludes customer devices]	**$70-$150**	**$130-$250**	**Cost, Depreciation, Obsolescence**
Data Collection	Interval kWh	•Interval kWh •Customer device status	•More complex data • Security and Privacy
Rate Forms Supported	Flat, Tiered, TOU, Dynamic	Flat, Tiered, TOU, Dynamic	No issues
Support for Usage Displays	Remote Access Separate Service	Integrated Plus Separate Service	Thru the Meter
Obsolescence Ranking	Low to Moderate	Moderate to Uncertain	Increased Risk
Support for Market Based Devices and Services	Open	"Gate Keeper" Potential	May Limit Open Market

4.6 Metering

Meter Function	Description
Metrology	Interval recording of usage.
Service Switch	• Remote connect / disconnect • Remote whole facility demand limiting
Utility Network Transceiver (e.g. radio or plc)	Connects the meter via a network or multiple networks to the utility back office
HAN Gateway Transceiver(s)	One or more transceivers to link the Utility Network Transceiver into the customer facility.
Computing and Memory	• Supports meter computations, storage of interval data, storage of price or billing metrics, rating periods, billing parameters ,storage of customer usage, device , other data. • Support upgrades, bug fixes, security, etc.

4.7 Metering

Meter Function	Advanced Meters	Smart Meters	Technical, Performance and Polity Issues
Metrology	1	1	1. Storage capacity and organization determine support for time-differentiated / other rate forms.
Service Switch		2,3,4	2. Notice and operation of remote connect / disconnect. 3. Notice and operation of 'full outage" demand limiting 4. Increased cost for smart meter capability.
Utility Network Transceiver (e.g. radio or plc)	5,6,7	4,5,6,7	5. Carrying capacity for interval data retrieval 6. Carrying capacity for outage management and customer service inquiries 7. Carrying capacity for DR signals, near real-time usage, appliance registrations, parameter retrieval
HAN Gateway Transceiver(s)		4,8,9, 10,11	8. . Potentially constrains customer third-party service EE, DR, DER, and information service providers 9. Potential conflict s with other customer networks (entertainment, security, IT, health, etc.) 10. Privacy implications for retrieval of customer appliance parameters, settings 11. Potential liability with customer appliance operations
Computing and Memory	12	4,12,13	12. Sufficient processing and storage to support customer service, DR and DER operations, upgrades, security and bug fixes. 13. Potential obsolescence with HAN and related components

4.8 Metering

Policy Issues

1. **Should there be a demarcation point between the customer and utility?**
   a) **Should the utility be collecting data from inside the customer premise ?**
   b) **Should the meter communication network also be used to support pricing and demand response?**
   c) **Should a HAN be incorporated into the residential meter?**
2. **Should utility or some other entity broadcast or make price and reliability signals available over a public network or should the meter communication network be the exclusive channel for this information?**
3. **What are the privacy implications of AMI and Smart Meters and how can they be mitigated?**
4. **Do AMI and smart meters have different obsolescence issues?**
5. **Should a service switch be integrated into every meter?**

4.90 Metering

Metering – Cost Recovery

Approach	At Risk	Description
Regulatory Assets	Shareholder	▪ Shareholder at risk ▪ Reasonableness determination to rate-based when 'used and useful'
Trackers and Bill Riders	Depends on Application.	▪ Tracks and recovers unpredictable costs ▪ Forecasted costs with next year reconciliation ▪ Typically ends after next rate case
Balancing Accounts	Depends on recovery time	Recovers costs unrecovered through rate due to external conditions
Customer Surcharge	Customer	Applied to all customer classes
State and Federal Funding	Depends on treatment	Costs may be covered by state and/or federal funding sources
Other	Uncertain	▪ Typically results from settlement agreements for non-smart grid issues ▪ May include a investment on behalf of shareholders in smart grid/AMI components

4.90 Metering

Metering – Cost Recovery

Example 1: First Energy

- Pennsylvania PUC Implementation Order , June 2009
  "Those costs that provide benefit across multiple classes should be allocated among the appropriate classes using reasonable cost of service practices" (Implementation Order at 32).
- First Energy proposal – allocate costs based on class and number of customers because smart meter costs are "akin to traditional metering and meter-related costs" (PUC Order at 48).
  Consumer advocates argued to allocate based on energy and demand to better reflect the benefit realization.
- PUC adopts First Energy's proposal –
  "costs will be incurred without regard to energy consumption or customer demand, and because the smart meter technology will be provided to all metered customers" (PUC Order at 55).
- PUC decision - functionalization of customer costs is made regardless of usage. The typical costs assigned to customer costs include meters, meter reading, and billing.

4.91 Metering

Metering – Cost Recovery

Example 2: Pacific Gas & Electric

- California PUC addressed risk in two ways:
  1) Established formula for cost overruns
     - **10% of $100 million in additional project costs at shareholder risk**
     - **Cost overruns greater than $100 million subject to reasonableness review for any rate recovery**
  2) Per-meter offset from operational benefits

     Most of this benefit is a result of reduction in meter reading costs and based on four-year forecast
- This model was adopted for SCE and SDG&E

4.92 Metering

Metering – Cost Recovery

Other Issues

Societal benefits

- Hard-to-quantify and long-term realization by customers
- Ratio of societal to operational benefits greater than one suggests over-reliance on societal benefits

	Duke Energy (Indiana)	SDG&E	SCE
Program Timeline	20 years	20 years	25 years
Meters	810,000	1,300,000	5,300,000
Capital Costs ($MM)	483	490	1,227
Operational Benefits ($MM)	372	1,433	1,990
Societal Benefits ($MM)	602	1,196	295
Societal/Operational Benefit Ratio	**1.62**	**.97**	**.15**

4.93 Metering

Metering – Cost Recovery

Other Issues

- **Depreciation**
  - Must consider both the remaining life of existing meters and depreciation of new, digital meters
  - Function of rate of meter replacement
  - Potential credit to customers if current depreciation schedules yield greater depreciation expenses than new depreciation schedules
- **Back office billing systems**
  - Shared expense not attributable to a specific customer class
  - Capability to support dynamic pricing and new billing features
- **Customer Education**

  Link to meter investment or efficiency, demand response, program initiatives?

4.93 Metering

6.0 Demand Response

6.1 Demand Response

Transforming Demand Response to a Smart Grid Environment

Conventional Grid

Incentives
Technology
Utility Control

Programs

Smart Grid

Technology Platform

Price, Reliability, Event Signals

Customer Control Strategies

Infrastructure

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6.2 Demand Response

Technology Platform

Providing Demand Response Signals - Two Options

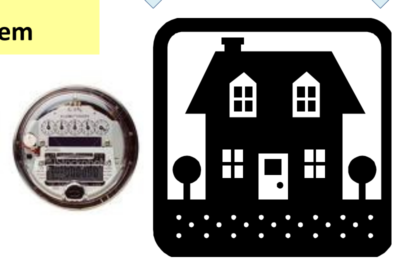
2 Public Network
Broadband or Narrowband

Public or Private
Two-way
Broadband

Radio Broadcast
One-way
Narrowband

1 Private Network
Meter Communication System

Through the
Meter
Two-way
Narrowband



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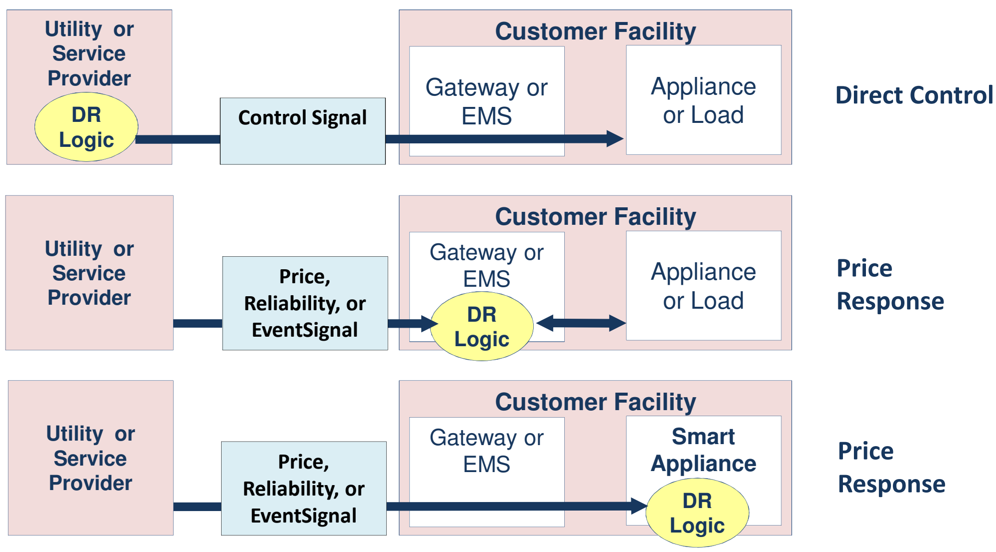
6.3 Demand Response

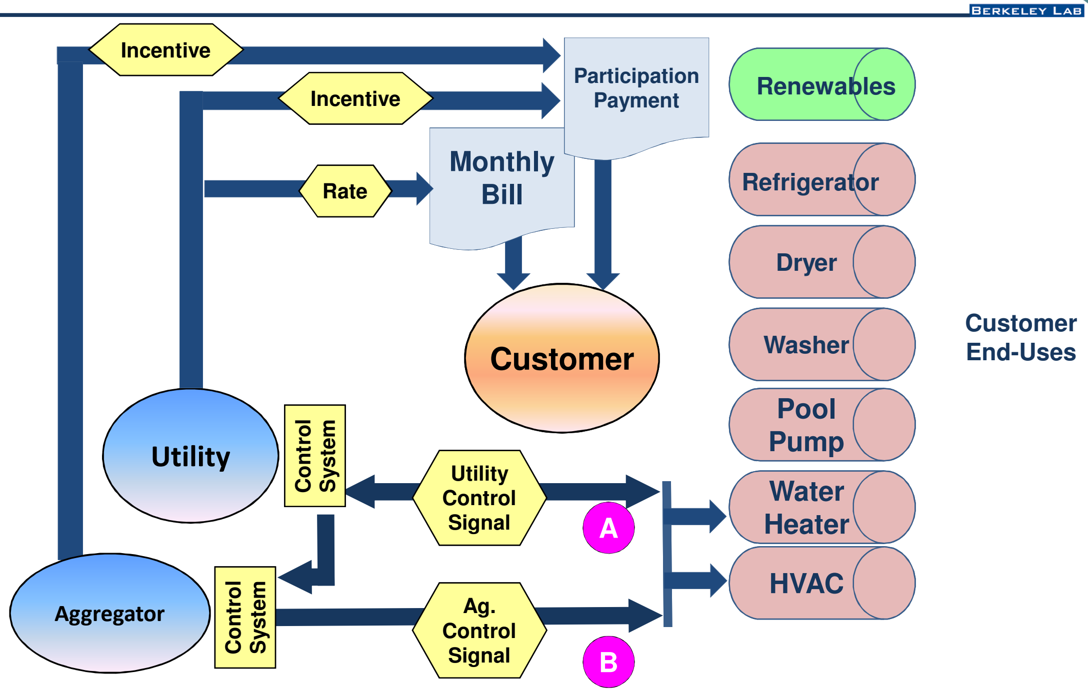
Customer Control Strategies

Facilitating Demand Response– Three Options



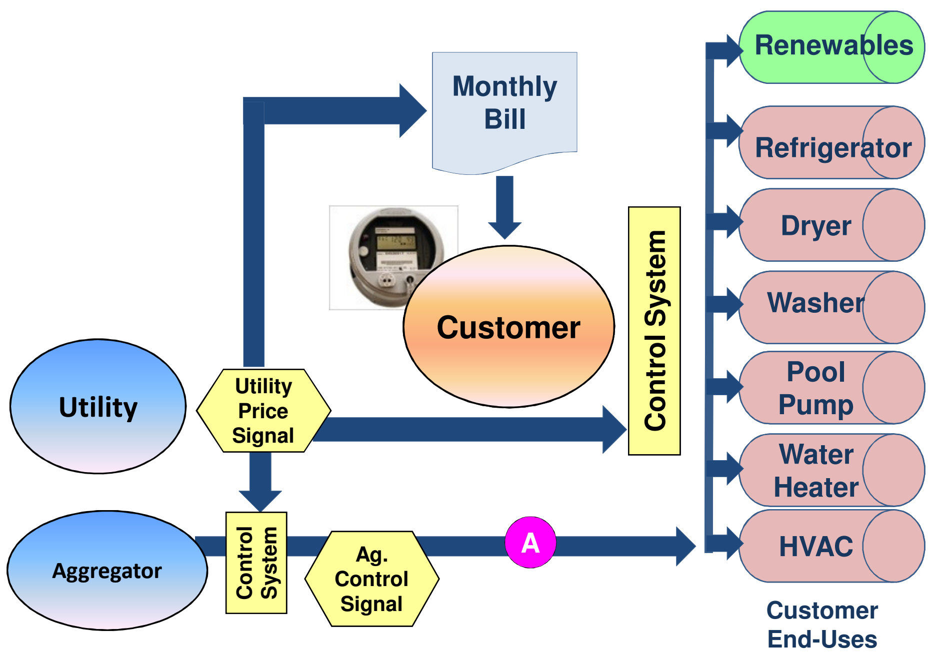
Source: "Direct versus Facility Centric Load Control for Automated Demand Response, Grid Interop 2008, Koch,E., Piette, M"

6.4 Demand Response



Flat Rate, Fixed Incentive, Direct Control

6.5 Demand Response



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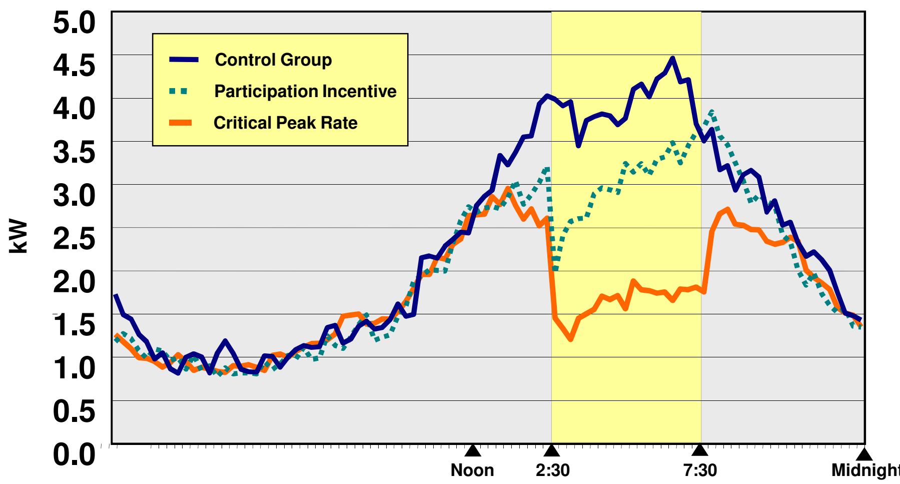
6.6 Demand Response

Direct Control and Participation Payments vs. Price Response



Hot Day, August 15, 2003, Average Peak Temperature 88.5^0

* Source: California Statewide Pricing Pilot, 2003-2004.

6.7 Demand Response

	Conventional DR	Smart Grid DR
Participation	Targeted, Limited to Large C/I & Residential	All Customers
Who Controls	Utility	Customer
What is Controlled	• Interruptible Rates • Res. HVAC, Water Heating	All Loads Available
Control Equipment	•Utility Provided •Few Suppliers	•Customer Provided •Many Market Suppliers
Incentives	• Fixed / Participation Payments • Baseline metrics	•Retail Dynamic Prices •Reservation payments •Pay-for performance
DR Products	Generally limited to Reliability	Capacity, Energy, Ancillary Services Markets; Congestion Management
DR, EE, Renewable Integration	No	Yes

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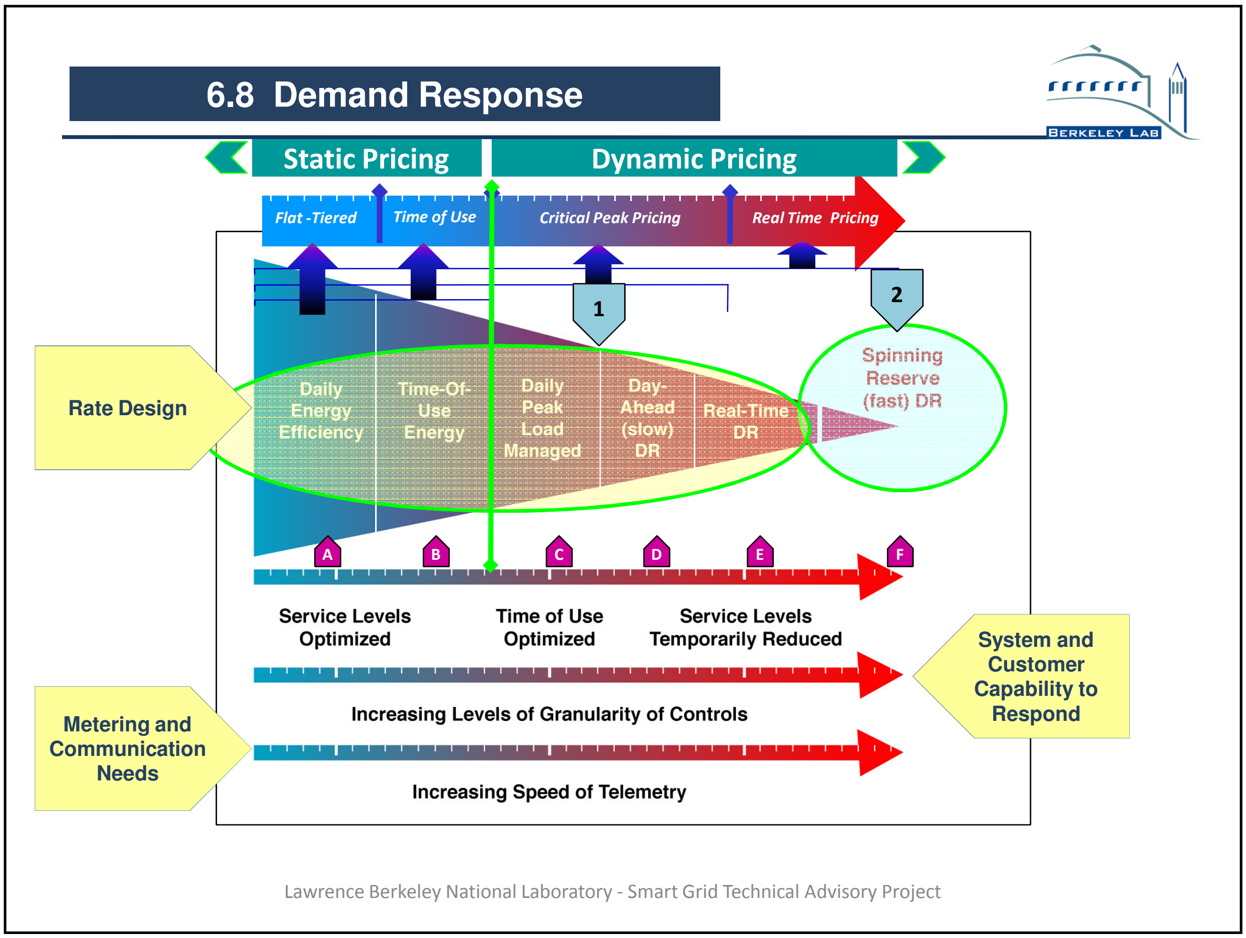

6.8 Demand Response
Berkeley Lab
Static Pricing
Dynamic Pricing
Flat -Tiered
Time of Use
Critical Peak Pricing
Real Time Pricing
1
2
Rate Design
Daily Energy Efficiency
Time-Of-Use Energy
Daily Peak Load Managed
Day-Ahead (slow) DR
Real-Time DR
Spinning Reserve (fast) DR
A
B
C
D
E
F
Service Levels Optimized
Time of Use Optimized
Service Levels Temporarily Reduced
System and Customer Capability to Respond
Increasing Levels of Granularity of Controls
Metering and Communication Needs
Increasing Speed of Telemetry
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6.9 Demand Response

	1 2 Through the Meter Two-way Narrowband [ZigBee-HomePlug, OpenADR]	3 Public or Private Two-way Broadband [Internet via DSL, cable, fiber, etc.]	4 Radio Broadcast One-way Narrowband [RBDS/RDS, Satellite, Pager to the devices]
Technologies to Send Signals • Price • Reliability • DR Events • Information	**NIST#14, #15 SEP 2.0** • Requirements doc to be released soon • Specification doc to be ready May 2010 • Testing to begin 2011	**NIST#13 OpenADR** • Server available today • Open source in 2010 • Open to Aggregators	**NIST#13 OpenADR** • OpenADR bridge client to RBDS/RDS tested • Proprietary Paging
Technologies to Receive and Act on Signals • Energy Managers • Thermostats • Smart Appliances • Third-party services	**NIST #14, #15 ZigBee-HomePlug** • Not tested with IP (network/transport) • Products use older incompatible stack	**Commercial/Industrial** • ~50 EMCS, BAS, etc., products already have OpenADR clients • 7 years of field testing	**Small Commercial & Residential Thermostats** • U-SNAP TX interface • Proprietary devices

* Source: "Requirements Engineering for the Advance Metering Infrastructure and the Home Automation Network (AMI-HAN) interface", California Energy Commission, February 2008.

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6.91 Demand Response

Rights	Obligations	Comments
1. CUSTOMER CHOICE: • the right to receive price and reliability signals without enrolling in utility programs • without registering their equipment with their utility.	Utilities are obligated to broadcast price and reliability signals which can be received by customer equipment that is neither registered with the utility nor used in a utility program.	• Broadcasting price and reliability signals creates "operational" information. • Broadcasting price and reliability signals encourages open market response and equipment options.
2. CUSTOMER CHOICE: the right to choose if and how they will program their communicating devices to respond to price and reliability signals.	Vendors of programmable communicating devices are obligated to provide a means of setting the device to not respond to signals, and a means of overriding programming.	• Customer choice promotes participation, eliminates dropouts, and increases DR effectiveness. • Open market vendors as well as utilities should provide equipment and services to support DR. • DR systems and equipment should support a minimum required set of common functions.
3. CUSTOMER CHOICE: the right to purchase, rent or otherwise select any vendor, devices, and services used for energy management or other purposes in their premise.	Utilities are obligated to provide open communication protocols that do not restrict customer DR equipment or service choices.	• Common, open communication protocols promote competitive markets for DR, features and services customized to customer needs, lower costs and more rapid, widespread implementation.

* Source: "Requirements Engineering for the Advance Metering Infrastructure and the Home Automation Network (AMI-HAN) interface", California Energy Commission, February 2008.

6.92 Demand Response

Rights	Obligations	Comments
4. <u>OPEN MARKET FOR DR</u>: Vendors have the right to compete in an open market to sell HAN related systems, devices and services to all utility customers.	Utilities are obligated to not restrict customers enrolled in utility programs, to equipment that uses the AMI communication protocol.	• Open market vendors as well as utilities should provide equipment and services to support DR. • Common, open communication protocols promote competitive markets for DR, features and services customized to customer needs, lower costs and more rapid, widespread implementation. • Customer choice promotes participation, eliminates dropouts, and increases DR effectiveness.
5. <u>OPEN MARKET FOR DR:</u> Utilities have the right to offer DR and energy management services to customers which utilize the information and communication capabilities of their AMI system.	Customers are obligated to maintain their equipment used in utility programs, in good working order, and to provide any communications translation device if needed.	
6. <u>OPEN MARKET FOR DR</u>: Customers have the right to participate in utility sponsored programs and at the same time, use equipment, not involved in the utility program, to receive price and reliability signals.	Utilities have an obligation to provide price and reliability signals through their AMI two-way signal system and through a one-way signal system.	

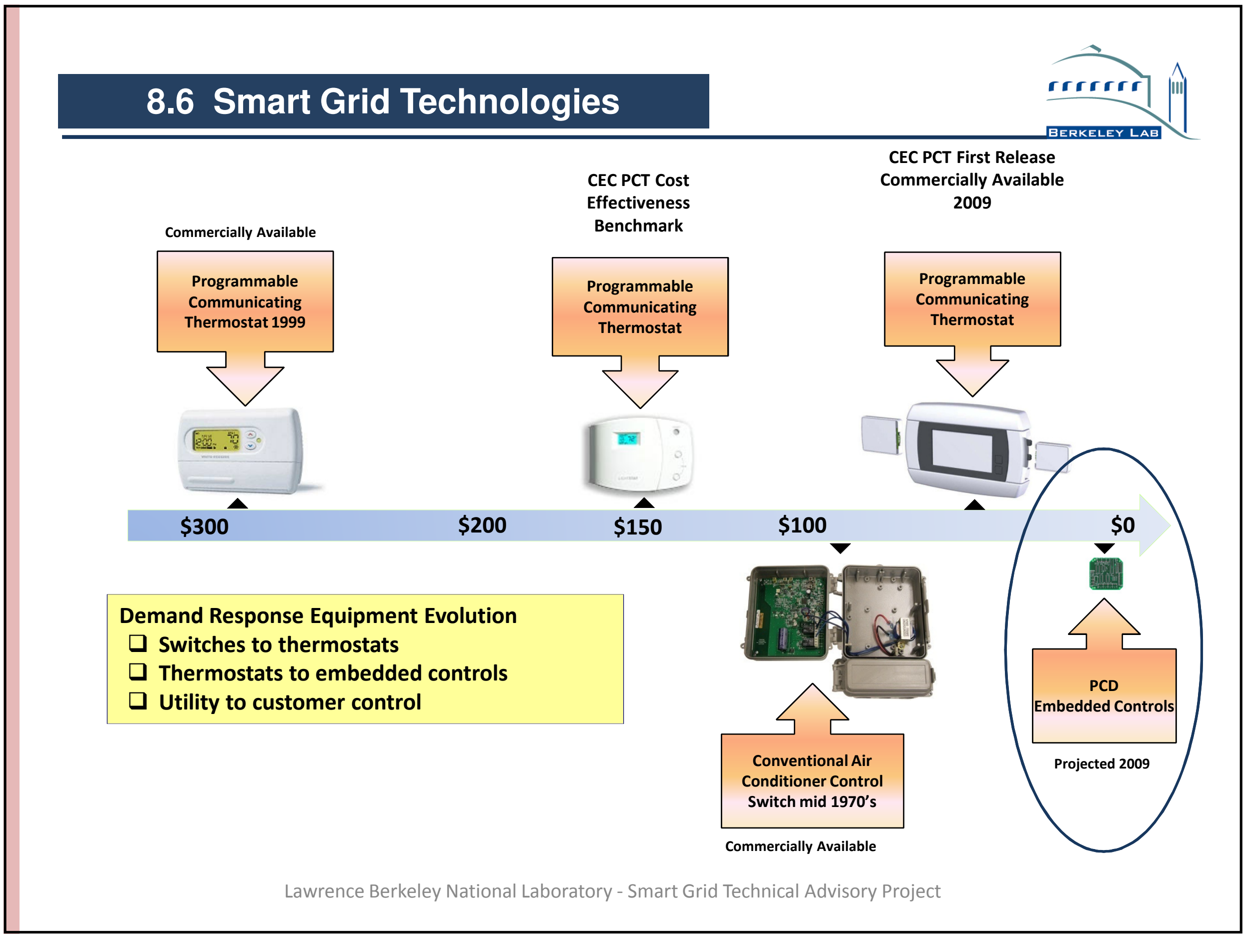
* Source: "Requirements Engineering for the Advance Metering Infrastructure and the Home Automation Network (AMI-HAN) interface", California Energy Commission, February 2008.

8.0 Smart Grid Technologies

8.1 Smart Grid Technologies

Issues and Opportunities

A. Microgrids
B. Solar Photovoltaic
C. Wind
D. PHEV's
E. Consumer Controls and Appliances
   a) Programmable Controllable Thermostats
   b) Smart Appliances
   c) In Home Displays
   d) Interoperability


8.6 Smart Grid Technologies
Berkeley Lab
Commercially Available
Programmable Communicating Thermostat 1999
CEC PCT Cost Effectiveness Benchmark
Programmable Communicating Thermostat
CEC PCT First Release Commercially Available 2009
Programmable Communicating Thermostat
$300
$200
$150
$100
$0
Demand Response Equipment Evolution
❑ Switches to thermostats
❑ Thermostats to embedded controls
❑ Utility to customer control
Conventional Air Conditioner Control Switch mid 1970's
Commercially Available
PCD Embedded Controls
Projected 2009
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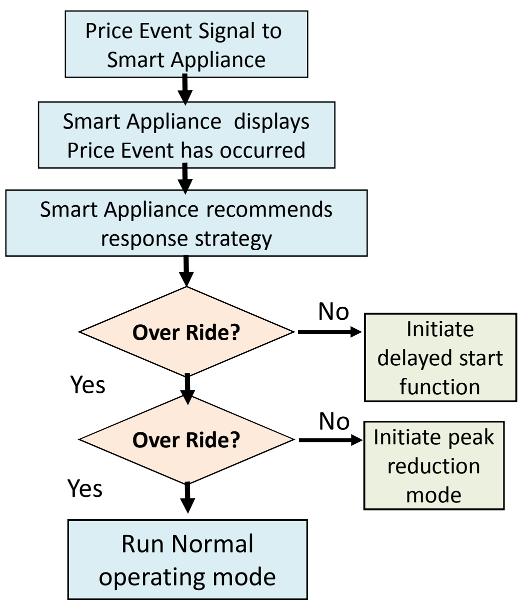
8.71 Smart Grid Technologies

Smart Appliances

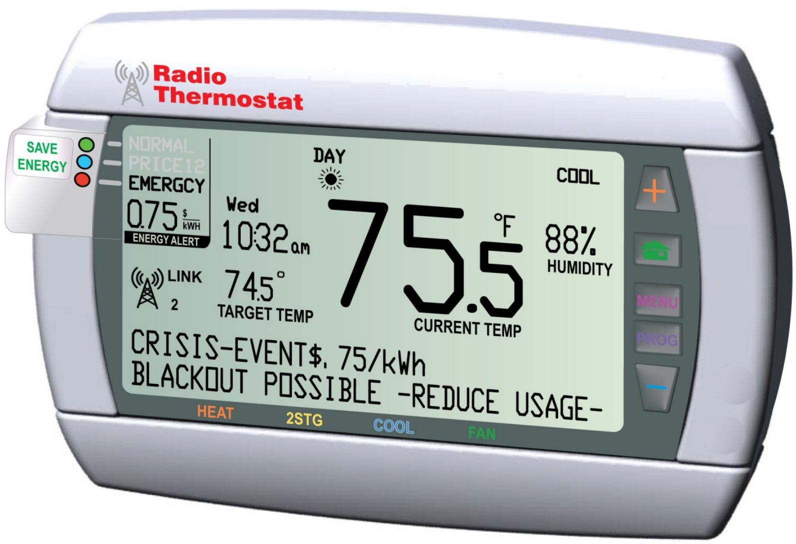


Demand Response Strategy

- Delay defrost
- Modify peak run time
- Reduced Peak features
- Energy saver mode
- temperature shift

8.72 Smart Grid Technologies

Programmable Controllable Thermostat



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8.8 Smart Grid Technologies

Utility Smart Network Access Port (Usnap)

- The **U-SNAP Alliance** is an open industry association developing de-facto standard for connecting energy aware consumer products with smart meters.
- The Alliance will create and publish a standard, establish testing and certification procedures for product conformance and educate consumers, utilities and vendors on the benefits of the standard.
- Alliance membership is comprised of utilities, manufacturers, consultants and other parties interested in developing or deploying the standard. For more information, or to find out how to join the Alliance, please visit www.usnap.org

8.91 Smart Grid Technologies

Technology Issues

- Low incremental costs with short payback (< 1 yr)
- Existing interfaces (e.g., i-Phone paradigm)
- Future proofing to avoid stranding investments
- End-to-end system integration, e.g., Internet
- Cyber-security, e.g., online banking, military, …
- Automation controlled by the consumer or proxy
- Open standards, common information model
- Product certification, similar to UL

8.92 Smart Grid Technologies

Policy Issues

- **Utility-owned vs. customer-owned equipment**
  - **Compatibility with IT, security, etc., networks**
  - **Equipment support and liability**
- **Utility-control vs. customer choice**
  - **Single function vs. multi-function devices**
- **Utility programs vs. open-market initiatives**
  - **Cost of Smart AC vs. retail thermostat**
  - **Deterministic vs. stochastic load reduction**