Demand Response as a Power Sector Resource

Richard Cowart
Director, European Programmes

Energy Savings Coalition
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RAP is a global, non-profit team of experts providing technical and policy assistance to government officials on energy and environmental issues.

RAP has advised governments in more than 30 countries and 50+ provinces and states, and now has major programmes in the US, China, India and Europe. Our European offices and staff are in Brussels, Berlin, Warsaw, and the UK.

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Major points today

1. **What** is Demand Response (DR)? Types of DR resources
2. **Why** DR? Multiple values of efficiency and flexible resources
3. **New challenge** -- Integrating growing fractions of renewables
4. **New opportunity**?: Smart Grids, Dynamic Pricing, and DR
5. **How** to capture DR? Market options and regulatory reforms that can tap DR resources
(1) What Is Demand Response?
Much more than traditional peak load management
Traditional DR: Peak Shaving

Source: www.ienko.com
Demand Response – Definitions evolve

• Changes in electric usage by end-use customers from their normal consumption patterns in response to changes in the price of electricity over time, or to incentive payments designed to induce lower electricity use at times of high wholesale market prices or when system reliability is jeopardized.
  – US FERC 2008 Demand Response Assessment

• “Demand response” -- Customer loads that can be modulated up or down in real time in response to wholesale market conditions, expressed either in wholesale prices, via frequency or voltage fluctuations, or through arrangements allowing direct control by the system operator or third party aggregator.
  -- RAP, “Beyond Capacity Markets” 2012
Using Demand Response to Shape Load

Source: http://www.cp.tatapower.com
Demand Response: Change in Load Relative to Baseline in Response to System Needs

1. **Energy Efficiency** programs reduce electricity consumption and usually reduce peak demand

2. **Price Response** programs move consumption from day to night (real time pricing or time of use) – *immediately useful for variable generation integration*

3. **Peak Shaving** programs require more response during peak hours and focus on reducing peaks every high-load day – *adaptable for variable generation integration*

4. **Reliability Response** (contingency response) requires the fastest, shortest duration response. Response is only required during power system “events” – *this is new and slowly developing, adaptable for variable generation integration*

5. **Regulation Response** continuously follows the power system’s minute-to-minute commands to balance the aggregate system – *Just beginning, adaptable for variable generation integration*
How is DR actually delivered?

- Vcharge Inc. controlling ETS units in 30 homes
  - Stroudsburg, PA
- Could save each household 6 – 9 cents/kWh if controlled for energy purchasing and Regulation
- 14,000 units deployed in PPL in 1980’s
Electric Heat Pumps as DR

Demand response with thermal storage is an untapped resource for flexible response

- Can quickly absorb unexpected changes in load and renewable energy generation
- Commercially available technologies exist that add communication and control capability to enable and disable electric water and space heaters for fast response
- Requires high-speed, two-way communication infrastructure
Industrial DSM now over 27,000 MW

US Data: Pike Research 2013
EV costs $.76 per “gallon” at average power rates in PJM and $.60 if charged off-peak
Uncontrolled EV charging: no price signals or automated control technology

Controlled EV charging: price signal plus automated control technology
(2) Why DR? Multiple Values of Efficiency and Flexible Resources
Efficiency and DR Have Many Power System Benefits

- Production Energy
- Production Capacity
- Avoided Emissions
- Transmission Capacity
- Distribution Capacity
- Line Loss Reduction
- Avoided Reserves

Plus “Non-Energy” Benefits including:
- Add’l resource benefits (water), building durability, health & safety

* Note: numbers presented in graph are Illustrative
Different views of the absence of demand

50% Air
50% Water

Technically, the glass is completely full.
Efficiency and Load Management
Walking hand-in-hand

Figure 5: Peak Load Reductions from Efficiency and Load Management
Benefits of Demand Response: Emergency Reserves

Demand response can provide ancillary services that include various reserve services, dynamic system regulation, and load-following capabilities that can deliver value to the grid during any hour of the year.

Demand Response Deployment of Emergency Reserves in Texas on August 4, 2011

Benefits of DR: Managing peak power costs
(in this case, 16% of annual costs arise in 1% of the hours of the year)
DR lowers power prices for everyone
Demand Response via Thermal Storage

Electric resistance water heater demonstrates low-cost water heating using day-ahead LMP while responding to the PJM frequency regulation signal.

Operational Details
• 105 gallon, dual element electric resistance
• “Power” 4.5 kW, Energy 26 kWh
Low-Tech Storage: Water Heaters Can Provide Rapid Response Frequency Regulation

PJM pilot water heater -- January 14, 2011; Midnight to 3:00 a.m.

- PJM Frequency Regulation Signal
- Water heater power consumption +/- 2.25 Kw base point
Benefits of Demand Response: Avoiding T&D Upgrades

Con Edison in New York City

• Seeking local distribution peak reductions
• Goal was to eliminate 149 MW across several areas by 2012
• Decided to use demand resources - estimated to be less expensive and would avoid major disruptions in city (e.g., digging up streets)
• Employed EE, DG, thermal storage, fuel-switching
• Used competitive bidding by ESCOs to deliver
• Extensive M&V
• Costs born by all customers thru regulated (e.g., distribution network operator) tariffs
• Utility reports savings of over $1 Billion!
Benefits of Demand Response

Demand Response Can Reduce Grid Investments and Minimize Curtailment of Low-Carbon Resources

<table>
<thead>
<tr>
<th>Pathways</th>
<th>DSM</th>
<th>Transmission</th>
<th>Back-up and balancing</th>
<th>Renewables Curtailment</th>
</tr>
</thead>
<tbody>
<tr>
<td>80% RES 10% CCS 10% nuclear</td>
<td>0%</td>
<td>166</td>
<td>255</td>
<td>3%</td>
</tr>
<tr>
<td></td>
<td>20%</td>
<td>127</td>
<td>160</td>
<td>2%</td>
</tr>
<tr>
<td>60% RES 20% CCS 20% nuclear</td>
<td>0%</td>
<td>103</td>
<td>205</td>
<td>2%</td>
</tr>
<tr>
<td></td>
<td>20%</td>
<td>87</td>
<td>140</td>
<td>1%</td>
</tr>
<tr>
<td>40% RES 30% CCS 30% nuclear</td>
<td>0%</td>
<td>56</td>
<td>150</td>
<td>2%</td>
</tr>
<tr>
<td></td>
<td>20%</td>
<td>55</td>
<td>110</td>
<td>2%</td>
</tr>
</tbody>
</table>

EU transmission and additional generation requirements by 2050 (GW) to reduce greenhouse gas emissions to 80% below 1990 levels

Source: European Climate Foundation, Roadmap 2050
(3) New Challenge: Integrating Variable Renewables

Theme: DR and EE are essential partners with RES for a low-emissions, affordable power sector
The Declining Market Value of Variable Renewable Energy with Penetration:
Why Current Discussions on Integration Costs Are Incomplete

Ryan H. Wiser

Regulatory Assistance Project
June 19, 2013
Investment and dispatch decisions with increasing PV penetration

<table>
<thead>
<tr>
<th>PV Penetration</th>
<th>Incremental Reduction in Non-PV Capacity (GW)</th>
<th>Incremental Increase in Nameplate PV (GW)</th>
<th>Effective Marginal Capacity Credit (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0% -&gt; 5%</td>
<td>2.8</td>
<td>5.8</td>
<td>48%</td>
</tr>
<tr>
<td>15% -&gt; 20%</td>
<td>0.4</td>
<td>5.9</td>
<td>7%</td>
</tr>
</tbody>
</table>
Marginal value of variable generation varies with technology and penetration.
Marginal value of PV is high at low penetration due to high capacity value

<table>
<thead>
<tr>
<th>Component ($/MWh)</th>
<th>0% PV</th>
<th>2.5% PV</th>
<th>5% PV</th>
<th>10% PV</th>
<th>15% PV</th>
<th>20% PV</th>
<th>30% PV</th>
</tr>
</thead>
<tbody>
<tr>
<td>+ Capacity Value</td>
<td>+37</td>
<td>+34</td>
<td>+27</td>
<td>+13</td>
<td>+8</td>
<td>+4</td>
<td>+1</td>
</tr>
<tr>
<td>(Capacity Value in $/kW-yr)</td>
<td>(120)</td>
<td>(110)</td>
<td>(82)</td>
<td>(39)</td>
<td>(24)</td>
<td>(11)</td>
<td>(4)</td>
</tr>
<tr>
<td>+ Energy Value</td>
<td>+54</td>
<td>+53</td>
<td>+52</td>
<td>+49</td>
<td>+45</td>
<td>+41</td>
<td>+27</td>
</tr>
<tr>
<td>+ DA Forecast Error</td>
<td>-0.4</td>
<td>-5</td>
<td>-4</td>
<td>-6</td>
<td>-5</td>
<td>-4</td>
<td>-3</td>
</tr>
<tr>
<td>+ Ancillary Services</td>
<td>-0.9</td>
<td>-0.8</td>
<td>-0.7</td>
<td>-0.4</td>
<td>-0.2</td>
<td>-0.1</td>
<td>-0.0</td>
</tr>
</tbody>
</table>

= Marginal Economic Value  
90  81  73  55  47  41  25

Single-axis PV and CSP without TES have similar relative magnitude of different components and similar changes in value of components with increasing penetration.
These effects are not an artifact of this specific study’s modeling approach.
The Challenge of Renewables’ Variability

*Net demand*: gross demand minus demand effectively served by low-marginal-cost, uncontrollable supply.
Net demand: more volatile than overall demand, lacking a repeatable pattern. Demand and availability of variable renewables can be moving in opposite directions 24/7/365

A challenging week for West Connect, USA, assuming 35% wind penetration
Net Demand Projected for Germany, 24th calendar week in 2020

Renewable generation and power demand, 2020, 24th calendar week
Leistung (GW) = Output  Wochentag = week day

Source: Deutsche Umwelthilfe
(4) New Opportunity: Smart Grids, Dynamic Pricing, and Demand Response
Smart grid introduces new pricing possibilities and more opportunity for DR

Flat energy rates
Rates do not vary by time or wholesale market cost and include an insurance premium to protect customers from volatility (supplier bears price risk in absence of FAC).

Tiered rates (inclining or declining blocks)
The cost per unit of electricity increases/decreases at defined consumption thresholds

Time of use (TOU) rates (time of day, seasonal).
Divides the period (day) into time periods and provides a schedule of rates for each period (e.g., peak, off-peak, shoulder).

Critical peak pricing (CPP)
Typically an overlay on TOU pricing. During times of system stress or high cost (i.e., critical peak [CP] events), price rises to a very high level (either administratively set or market-determined) to reflect the very high but short-term cost of generating or purchasing electricity at times of shortage or peak demand. Customers are notified in advance of a CP event and the number of events per year is typically capped.

Peak-time rebate (PTR, also critical peak rebate or CPR)
Participants are paid for load reductions (relative to what they would have otherwise used) during critical peak events.

Real-time pricing (RTP) rates
Prices may change as often as hourly. Price signal is provided to the user in advance (or at the beginning) of the period to which it applies, and it reflects the actual time- and circumstance-dependent cost of generating or purchasing electricity.
Variable peak pricing (VPP) is a combination of TOU and RTP, wherein periods and the off-peak price are set, but the peak period price varies with the (day-ahead) market.
France -- EDF Tempo Tariff

- Customers are told day-ahead what “color” tomorrow’s rates will be (note peak period is 6am to 10 pm; focus is winter heating period)
- Since 1996, now 400,000 customers
- Total reduction 450MW (45% reduction on “red” days, 10% “white” days)
- On average enrolled customers save 10%
- Customer options for automatic controls on some appliances
## Smart Grid Opens the Door to New DR Options

<table>
<thead>
<tr>
<th>Traditional DR</th>
<th>Smart Grid DR</th>
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<tbody>
<tr>
<td>- Primarily utility control</td>
<td>- Customer control</td>
</tr>
<tr>
<td>- Focuses on a few end uses</td>
<td>- All end uses</td>
</tr>
<tr>
<td>- Limited customer options</td>
<td>- Unlimited options</td>
</tr>
<tr>
<td>- Participation incentives required</td>
<td>- Advanced meters enable dynamic pricing for all</td>
</tr>
<tr>
<td>- Primary focus on retail markets</td>
<td>- Wholesale and retail markets linked</td>
</tr>
</tbody>
</table>

*Adapted from Roger Levy, Charles Goldman and Rich Sedano*
Risk-Reward Trade-Off

Conceptual Representation of the Risk-Reward Tradeoff in Time-Varying Rates

# Traditional vs. Smart Grid Demand Response

<table>
<thead>
<tr>
<th>Participation</th>
<th>Conventional DR</th>
<th>Smart Grid DR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Targeted, Limited to Large C/I &amp; Residential</td>
<td>All Customers</td>
</tr>
<tr>
<td>Who Controls</td>
<td>Utility</td>
<td>Customer</td>
</tr>
</tbody>
</table>
| 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     |
| DR Products            | Generally limited to Reliability |
| DR, EE, Renewable      | No              | Yes           |
| Integration            |                 |               |

Lawrence Berkeley National Laboratory - Smart Grid Technical Advisory Project
California

Some Lessons Learned from Pilots

- Enabling technology enhances the beneficial impacts of time-varying rates
- Peak savings in some pilots persisted for several years
- Low-income customers can respond to price signals, although not necessarily to the degree or in the numbers that other customer classes can
(4) Capturing the value of DR: market options and regulatory reforms
## Types of DR Programs

<table>
<thead>
<tr>
<th>Price Options</th>
<th>Incentive- or Event-Based Options</th>
</tr>
</thead>
</table>
| **TOU rates:** Rates with fixed price blocks that differ by time of day.
| **CPP:** Rates that include a pre-specified, extra-high rate that is triggered by the utility and is in effect for a limited number of hours. |
| **RTP:** Rates that vary continually (typically hourly) in response to wholesale market prices. | **Direct load control:** Customers receive incentive payments for allowing the utility a degree of control over certain equipment. |
|                        | **Demand bidding/buyback programs:** Customers offer bids to curtail load when wholesale market prices are high. |
|                        | **Emergency demand response programs:** Customers receive incentive payments for load reductions when needed to ensure reliability. |
|                        | **Capacity market programs:** Customers receive incentive payments for providing load reductions as substitutes for system capacity. |
|                        | **Interruptible/curtailable:** Customers receive a discounted rate for agreeing to reduce load on request. |
|                        | **Ancillary services market programs:** Customers receive payments from a grid operator for committing to curtail load when needed to support operation of the electric grid (i.e., ancillary services). |

CPP = critical peak pricing; RTP = real-time pricing; TOU = time of use.

*Source: National Action Plan for Energy Efficiency, 2010*
Examples of Regulatory Barriers to Demand Response across the EU
(Source: SEDC Snapshot 2011)

- A 24/7 resource availability requirement for peak consumption programs (Austria)
- A 16 hour load reduction duration requirement (Slovenia)
- Lack of regulation or applicability of load reduction measurements (most markets)
- Minimal single bid requirements ranging from 4 MW in Ireland to 25 MW or even 50 MW (France)
- Lack of appropriate base load measurement requirements (GB & other)
- Lack of clear payment and contract structures for demand reductions (most markets)
- Lack of information on intraday prices making it impossible to calculate the value of a Demand Response bid causing investment and payment uncertainty (Nordpool)
- Demand side resources barred from existing capacity markets (Poland, Greece)
- The aggregation of Commercial/Industrial loads is not allowed (Italy)
Markets that value what is needed

(1) Recognize the value of efficiency
– Allow energy efficiency to participate in capacity markets
– Standardize M&V procedures and capacity values for a menu of common EE measures
– Consider location-specific EE as a competitive alternative to transmission
Competitive example: EE & DR Bidding in Regional Capacity Markets

- **Issue**: Power system needs reliable capacity on a forwards basis (to avoid future capacity crisis)
- **Generator proposal**: Pay for Generator capacity in advance, for 10-year forward period
- **Better solution**: Let supply and demand-reduction also bid to meet growth needs
- First auction (New England ISO) 2007: demand resources including EE won 2/3rds of the bids for new capacity & lowered the clearing price
- PJM auction (for 2012/2013) DSM bids lowered the clearing price by 90% (from ~$179MW/day to $16.46 per MW/day)
- Demand-side winners include utilities, ESCOs and state programs
Growth of Demand Response Resources in New England

Offers of Demand-Side Resources as Capacity in PJM by Delivery Year

- Energy Efficiency
- RPM and FRR DR
- Interruptible Load for Reliability
- Active Load Management

As of 7/2011
Demand Resource in the Capacity Market-2014/2015

Demand Resources

14,118 MW or enough power for 5 million people or half the number of households in the state of Michigan

Energy Efficiency

822 MW or enough to power 149,000 households about the number of households in the city of Cleveland, Ohio
Markets that value what is needed

(2) Update system operations to unlock flexibility in the short term
– Upgrade scheduling, dispatch and weather forecasting processes
– Consolidate/integrate balancing areas
– Access dispatchability of renewable energy assets
– Employ day-ahead markets for current ancillary services;
– Expand the role of demand response
Markets that value what is needed

(3) Create investment incentives to ensure flexibility in the long term

- Develop tools to better forecast net demand and forward value of critical capabilities
- Adapt forward mechanisms to send investment signals that will capture the value of flexible resources (demand and supply)
- Encourage DR aggregators, flexible generation providers and similar new entrants wherever possible consistent with overall market structure
DR is Flexible and Fast – New Entrant Example

ENBALA Power Network Client Pool beginning to respond to ISO signal.
The aggregate response of each resource in the network is compiled to form a unified regulation response.
Questions?

See “Beyond Capacity Markets – Delivering Capability Resources to Europe’s Decarbonised Power System” (Gottstein and Skillings, RAP-2012)

Many other reports on DR, EE, and Power Market Design on the RAP website

Richard Cowart, Regulatory Assistance Project
Posted at www.raponline.org
Email questions to rcowart@raponline.com