Mass Market Demand Response and Variable Generation Integration Issues: A Scoping Study

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Report Summary

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Presentation Overview

- Objectives and Approach
- Variable Generation Resources and the Bulk Power System
- Demand Response Opportunities
- Demand Response as a Strategy to Integrate Variable Generation Resources
- Comparison of Various Strategies to Integrate Variable Generation
- Conclusions

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A Role for Demand Response to Mitigate Variable Generation Integration Issues

- **Large scale deployment of wind and solar energy resources, because of its variable and often times unpredictable production characteristics, poses integration challenges for bulk power system operators**
- **To date, bulk power system operators have relied on existing thermal generation resources and improved variable renewable electricity production forecasts to manage these integration issues**
- **Demand response (DR), however, has been readily identified by NERC and others as a viable means for managing many VG integration issues due to its ability to provide bulk power system services**

Source: NERC 2009. "Accommodating High Levels of Variable Generation. Special Report." North American Electric Reliability Council. Available at http://www.nerc.com/files/IVGTF_Report_041609.pdf

What Role Can the Smart Grid and Mass Market Customers Play in this Effort?

- **Greatest overall potential for increasing the size and scope of DR opportunities in the U.S. is with residential and small commercial (i.e., mass market) customers, but to do so will require massive investments in interval meters and/or control/automation technology**
- **By 2020, the electric power sector is expected to add ~65 million advanced meters (which would reach ~47% of U.S. households) as part of smart grid and AMI deployments.**

In the near-term, what role can the smart grid and mass market customers play in helping to integrate greater penetration of variable generation resources?

Literature Review Suggests Limited Information Exists to Set Realistic Expectations

Ability of DR Resources to mitigate VG integration issues

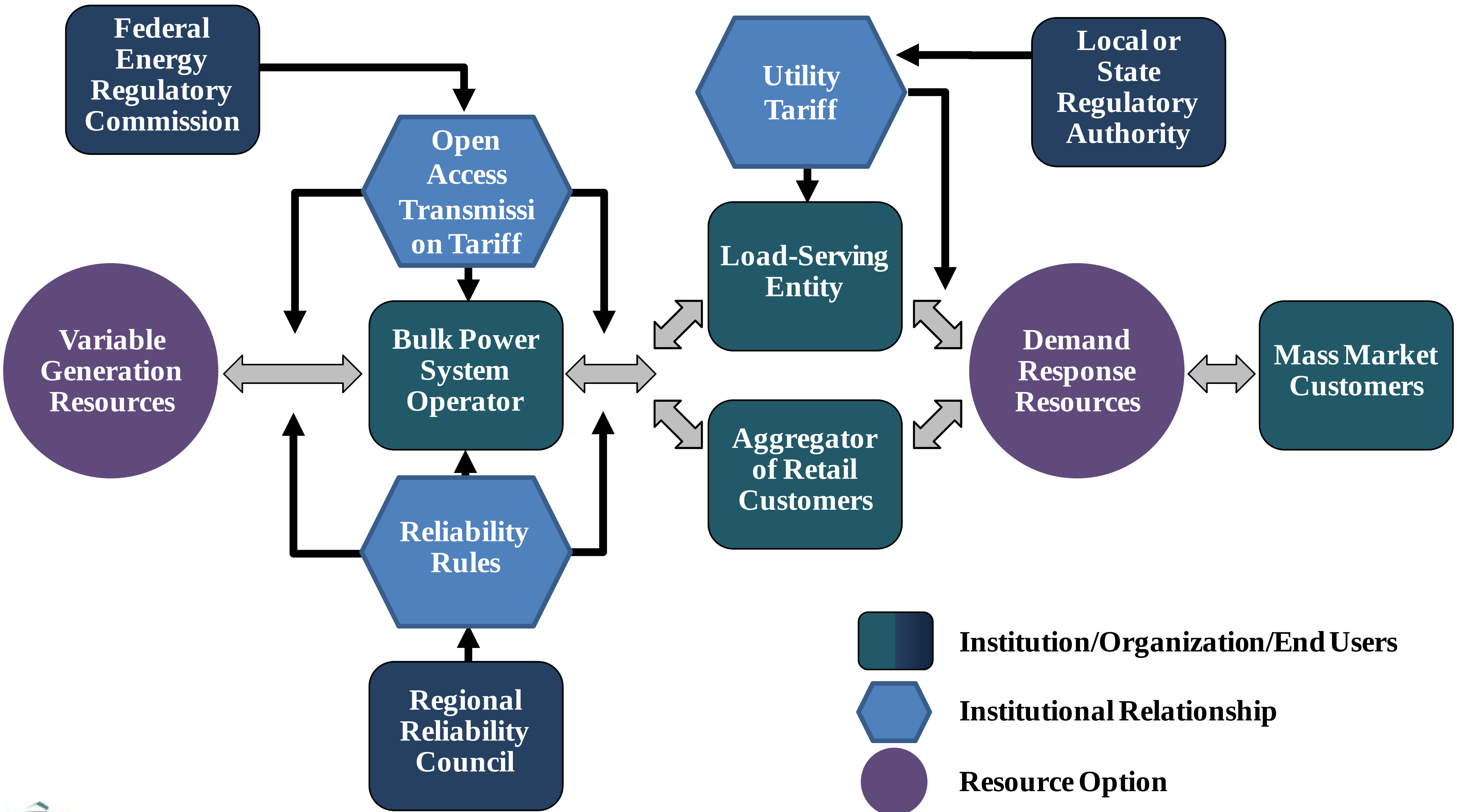
	Demand Response Opportunity			
Variable Generation Integration Issue	**Ancillary Services**	**DLC**	**DA-RTP**	**RT-RTP**
1 Min. to 5 – 10 Min. Variability	**1,6**	**9**		
<2 hr Forecast Error	**1**	**9**		**5**
Large Multi-hour Ramps	**1**	**8**		**5, 11**
> 24 hr Forecast Error	**3**			**5, 11**
Variation from Avg. Daily Energy Profile		**4, 7**	**2, 8, 10**	**11, 12**
Avg. Daily Energy Profile by Season		**4, 7**	**2, 8, 10**	**11, 12**

1	Callaway 2009	7	Lund and Kempton 2008
2	Denholm and Margolis 2007	8	Moura and de Almeida 2010
3	GE Energy 2010	9	Papavasiliou and Oren 2009
4	Hughes 2010	10	Roscoe and Ault 2010
5	Klobasa 2010	11	Sioshansi and Short 2009
6	Kondoh 2010	12	Stadler 2008

Motivation of Scoping Study

- Growing interest in potential of AMI-enabled demand response to manage issues with integrating large-scale variable generation resources into the bulk power system
  - Grid operators
  - Resource planners
  - Regulators/stakeholders/smart grid advocates
- Existing studies that assess DR potential to integrate VG often have:
  - Limited subset of bulk power operations
  - Limited assessment of DR programs
  - Unrealistic view of how VG and DR will be integrated into bulk power system in the near term (5-10 years)
- In scoping study, we assess extent to which demand side resources could be used to better integrate wind and solar resources; identify barriers that currently limit use of demand side strategies, and provide a qualitative comparison of demand side and other existing and proposed strategies to manage variable generation integration issues

Entities & Institutions that Influence Relationship between VG and DR Resources



Overview of Scoping Study

- Identify key issues associated with integrating large amounts of variable generation into the bulk power system

- Identify DR opportunities made more readily available to mass market customers through widespread deployment of AMI systems and how they can affect the bulk power system

- Assess the extent to which these mass market DR opportunities can manage VG integration issues in the near-term and what electricity market structures and regulatory practices could be changed to further expand the ability for DR to manage VG integration issues over the long term

- Provide a qualitative comparison of existing strategies to manage VG integration issues relative to DR opportunities

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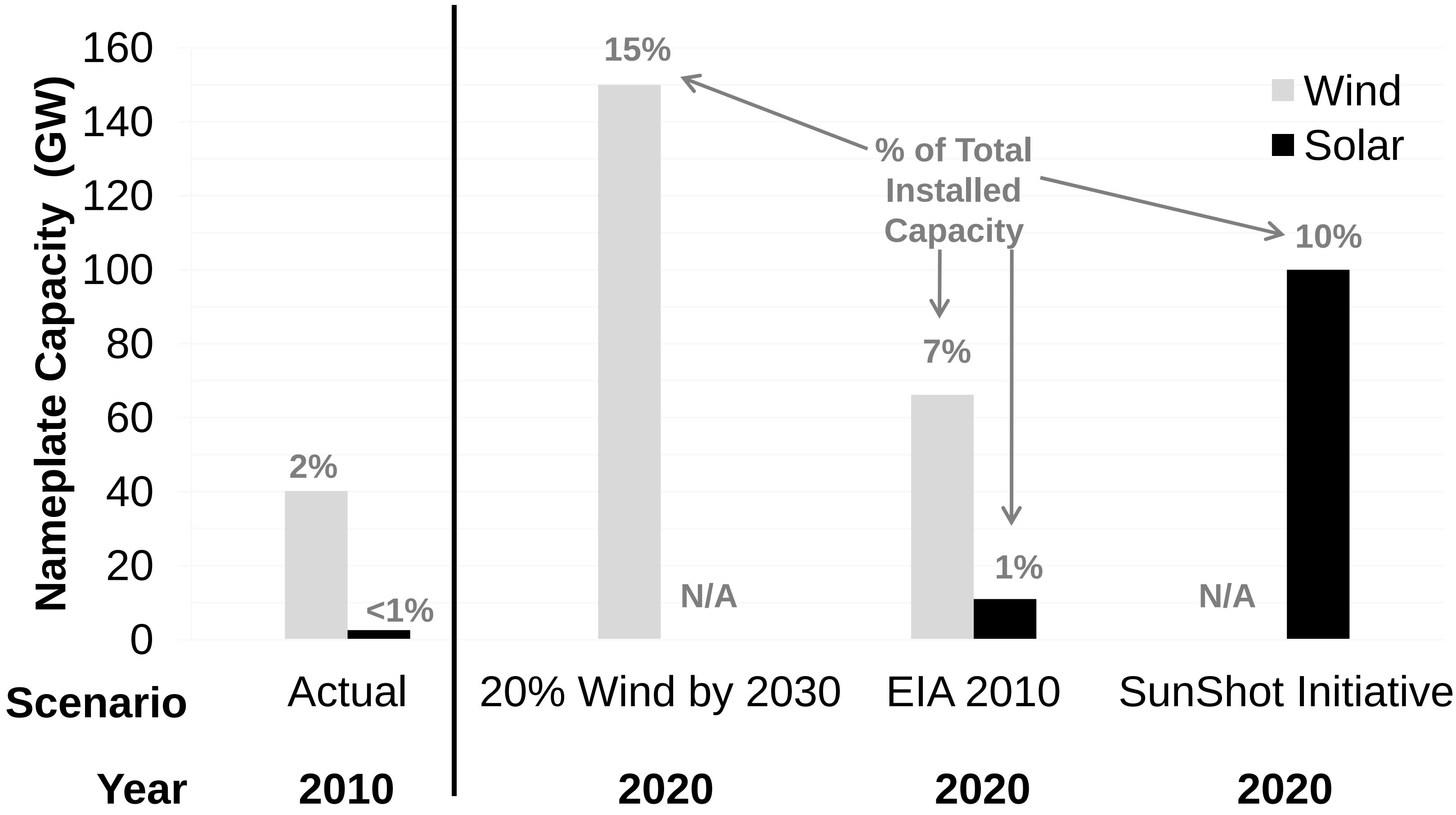
Forecasts of Variable Generation Resources in the U.S. by 2020



Production Characteristics of Fleet of Variable Generation Resources

Variable Generation Production Characteristics	Abbreviated Name	Example of Wind Variability (% of Nameplate Capacity)
Changes in output over very short time scales	<1-minute variability	0.1%-0.2%
Changes in output over short time scales	1 minute to 5-10 minute variability	3-14%
Imperfect ability to forecast generation output for time horizon of 10-120 minutes	< 2 hour forecast error	3-25%
Changes in a single direction for multiple hour periods	Large multiple hour ramps	50-85%
Imperfect ability to forecast generation output for time horizon of multiple hours to days ahead	> 24 hour forecast error	6-30%
Deviations from the average daily generation profile in actual day to day generation	Variation from average daily energy profile	25-60%
Average daily energy profile generation characteristics depending on the season	Average daily energy profile by season	30-50%

- **Variability in aggregate wind and solar generation is larger over a time period of 1-12 hours than over a sub-hourly time period**

System Requirements for Bulk Power System Operations

Bulk Power System Operations	Time Scale				
	Procurement or Schedule	Control Signal	Advance Notice of Deployment	Duration of Response	Frequency of Response
Spinning Reserves	Days ahead	<1-min	~1-min	~30-min	~ 20-200 times per year
Supplemental Reserves	Days ahead	<10-min	~10-30 min	~ Multiple hours	~ 20-200 times per year
Regulation Reserves	Days ahead	~1-min to 10 min	Automatic	< 10-min in one direction	Continuous
Load Following/ Imbalance Energy	5-min to 1-hr	5-min to 1-hr	5-min to 1-hr	5-min to 1-hr	Depends on position in bid stack
Hour-ahead Energy	1-2 hour	5-min to 1-hr	1-2 hour	>1 hr	Depends on position in bid stack
Multi-hour Ramping Capability	None	5-min to 1-hr	Days ahead to 30 min	1-4 hrs	As frequent as daily
Day-ahead Energy	24-36 hours	1-hr	24-36 hours	>1 hr	Depends on position in bid stack
Over-generation	None	1-hr	Day to multiple hours ahead	1 to multiple hrs	Seasonal
Resource Adequacy	Years	1-hr	Day ahead	Multiple hrs	Seasonal

Bulk Power System Operations in Support of Variable Generation Resources

Bulk Power System Operations	Operational Characteristics of Variable Generation Resources					
	1 minute to 5-10 minute variability	< 2 hour forecast error	Large multiple hour ramps	> 24 hour forecast error	Variation from avg. daily energy profile	Avg. daily energy profile by season
Spinning Reserves	●	●				
Supplemental Reserves		●	●	●		
Regulation Reserves	●					
Imbalance Energy	●	●	●			
Hour-ahead Energy			●	●	●	
Multi-hour Ramping			●	●	●	
Day-ahead Energy			●		●	●
Over-generation				●	●	●
Resource Adequacy					●	●

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Typology of Existing Demand Response Opportunities

- **DR customers alter electricity consumption over some time period based on DR Signal provided by a Load Serving Entity (LSE) or Aggregator of Retail Customers (ARC)**
- **Time-Based Retail Rates send price signals intended to induce an increase/decrease in consumption; Incentive-Based DR Programs utilize DR signal to induce a reduction in electricity usage**

Time-Based Retail Rates ***DR Signal: Price Level***	**Incentive-Based DR Programs** ***DR Signal: System State***
Time-of-Use (TOU)	Direct Load Control (DLC)
Critical Peak Rebate (CPR)	Interruptible/Curtailable (IC)
Critical Peak Pricing (CPP)	Emergency DR Resource
Day-Ahead Real-Time Pricing (DA-RTP)	Capacity Resource
Real-Time Real-Time Pricing (RT-RTP)	Energy Resource
	Ancillary Services Resource

Demand Response Opportunities: Characteristic Features

Demand Response Opportunity	Time Scale		
	Advance Notice	Duration of Response	Frequency of Response
Time-Based Retail Rates			
TOU	>6 Months	Length of Peak Period (e.g., ~4-15 hours)	Daily, seasonal, etc.
CPR/CPP	2 – 24 Hours	Length of Critical Peak Period (e.g., ~2-8 hours)	Typically <100 Hours/year
DA-RTP	~24 Hours	Depends upon price level (e.g., ~2-8 hours)	Depends upon price level
RT-RTP	~5 min – 1 Hour After	Depends upon price level (e.g., ~2-8 hours)	Depends upon price level
Incentive-Based DR Programs			
Direct Load Control	None	5 – 60 Minutes	Sometimes limited in Tariff
Interruptible/Curtailable	30 - 60 Minutes	Depends on contract	Sometimes limited in Tariff
Emergency DR Resource	2 – 24 Hours	2 – 4 Hours minimum	Typically <100 Hours/year
Capacity Resource	2 – 24 Hours	2 – 4 Hours minimum	Typically <100 Hours/year
Energy Resource	~5 Minutes – 24 Hours	Depends upon price level	Depends upon price level
Ancillary Services Resource	~5 Seconds – 30 Minutes	10 Minutes – 2 Hours	Depends upon reliability level

Ability for DR Opportunities to Impact the Bulk Power System Is Limited

- **U.S. wholesale electricity market design and regional reliability rules increasingly encourage and allow DR to provide most bulk power system services**
- **In some jurisdictions, LSEs provide DR Signal based on their local system needs (not triggered or driven by input from bulk power system operators). In these cases, DR is not directly integrated into bulk power system operations**
- **The following characterization reflects LBNL's assessment of the capabilities of DR opportunities to provide bulk power system services now and in near future (5-10 years)**

Opportunities for Incentive-Based DR to Provide Bulk Power System Services

Bulk Power System Service	DLC	Emergency DR	Capacity	Energy	Ancillary Services
Spinning Reserves	○				○
Supplemental Reserves	○	○			○
Regulation Reserves					○
Imbalance Energy	◉			○	
Hour-ahead Energy	◉			○	
Multi-hour Ramping	○				
Day-ahead Energy	◉			○	
Over-generation	○				
Resource Adequacy	●		○		

	Currently not offered and unlikely to be offered in the future
○	Currently not offered or offered only on a very limited basis but could be offered more in the future
◉	Currently offered on a limited basis and could be expanded in the future
●	Currently offered on a wide-spread basis and likely to be continued in the future

- **Significant potential exists to provide bulk power system services if mass market customers are willing to participate in programs whose designs feature short duration and frequent demand response events.**

Opportunities for Time-Based Retail Rates to Provide Bulk Power System Services

Bulk Power System Service	TOU	CPR	CPP	DA-RTP	RT-RTP
Spinning Reserves					
Supplemental Reserves					
Regulation Reserves					
Imbalance Energy					○
Hour-ahead Energy					○
Multi-hour Ramping				○	○
Day-ahead Energy				○	○
Over-generation				○	○
Resource Adequacy	○	◉	◉	○	○

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- **RT-RTP with customer controls has most potential among time-based rates**
- **Rates like CPP/CPR currently have more regulatory and stakeholder support but have very limited potential to provide these bulk power system services**

Retail/Wholesale Market Environment Influences who Provides DR Opportunities

- Vertically integrated utilities outside of ISO/RTO footprint may offer both time-based retail rates and incentive-based DR programs; utilities may "outsource" their incentive-based DR programs to a third-party provider through contracts
- Vertically integrated utilities within ISO/RTO footprint may offer time-based retail rates but may or may not be the only entities providing incentive-based DR programs, depending upon state legislation and regulation
- Utilities within ISO/RTO footprint in states with retail competition are likely not the only entities offering time-based retail rates and incentive-based DR programs

Key Activities that will Influence Near-term Penetration of Demand Response

- **AMI Deployment**
  - **Scope of deployment of advanced meters with two-way communication capabilities**
- **Stakeholder Acceptance of Time-Based Rates**
  - **Willingness of regulators to allow utilities to offer time-based retail rates (on opt-in or opt-out basis) as well as degree of customer acceptance**
- **Customer Acceptance of Automation/Control Technology**
  - **Willingness of customers to accept these technologies will be based on alleviation of privacy concerns and development of value proposition**

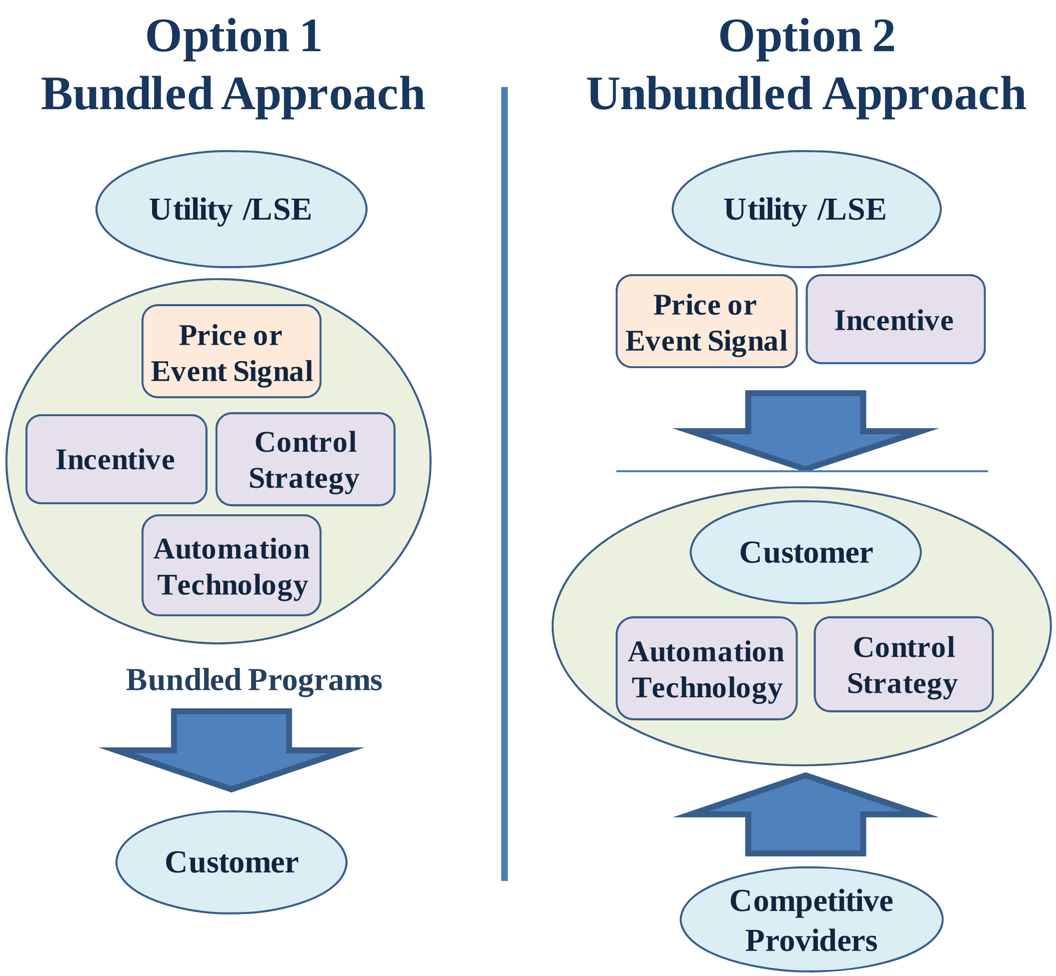
AMI Deployment

- **Current estimates indicate ~65 million advanced meters could be installed over the next decade (2011-2020)**
- **There have been several recent high-profile regulatory decisions which either allow customers in a individual utility (PGE) or all customers within a state (Maine) to opt-out of advanced meter installation at their homes for various reasons (e.g., health/safety concerns)**
- **Opt-out rates are not known at this time, but it is clear that not all U.S. homes will have the requisite metering deployed to participate in such DR opportunities**

Stakeholder Acceptance of Time-Based Retail Rates

- **Some state regulators are sensitive to exposing residential customers, especially at-risk groups (e.g., poor and elderly) to time-based retail rates on an opt-out or mandatory basis based in part on concerns raised by stakeholder groups**
- **Several recent studies have looked at the response of low-income customers to various types of dynamic rates, although more definitive and consistent evidence will likely be required from future studies to address concerns raised by these stakeholders**

Customer Acceptance of Automation/Control Technology



- **DR pilot results suggest that automation/control technology substantially increases customer response capability**
- **The challenges facing utilities (and policymakers) is to motivate large numbers of customers to accept these technologies into their homes and businesses**
- **Alternative methods for providing automation / control technology may influence acceptance**

Assessing the Potential for Future DR Opportunities among Mass Market Customers

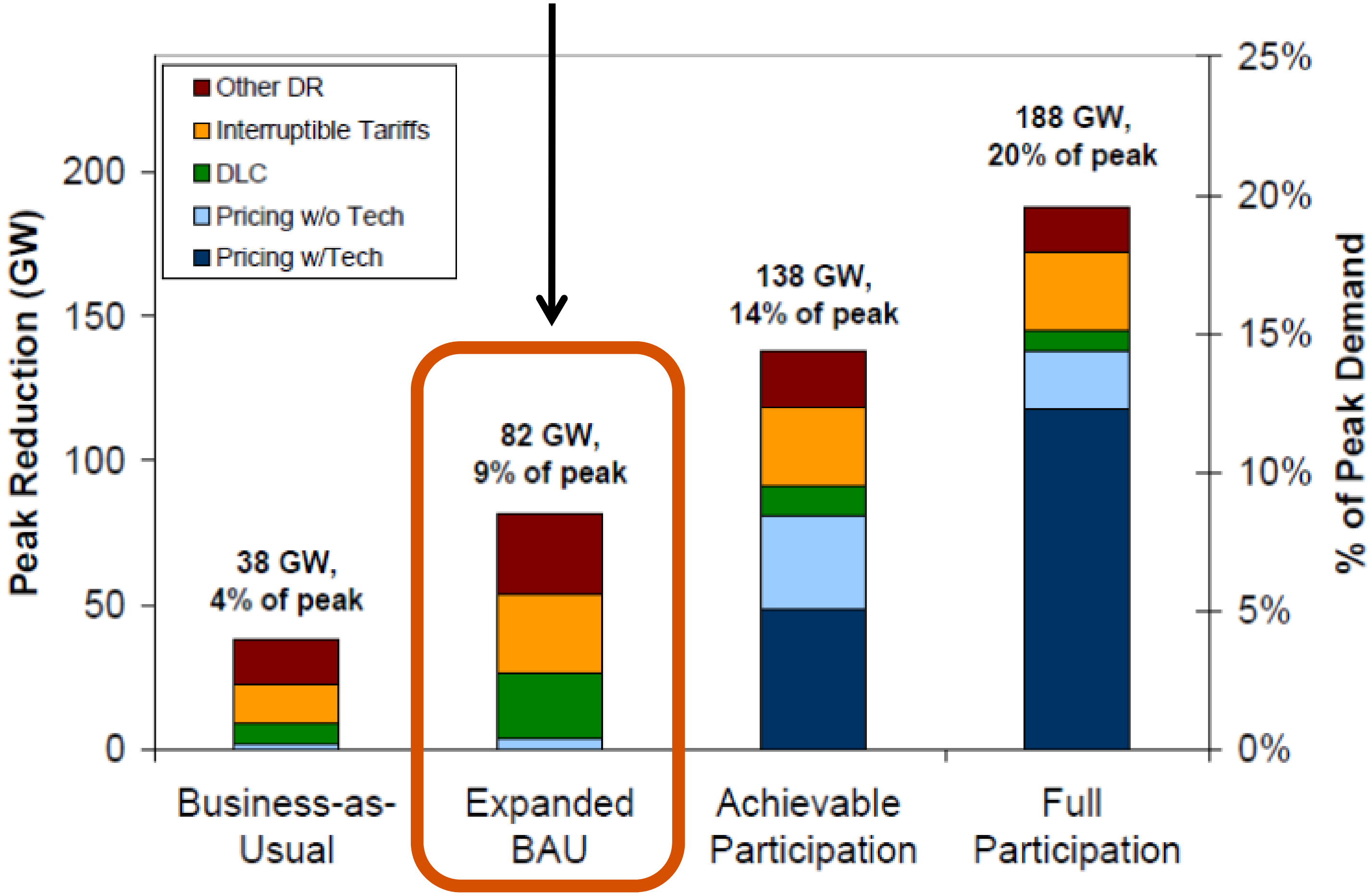
Assumption	Business-as-Usual	Expanded BAU	Achievable Participation	Full Participation
AMI Deployment	Partial Deployment	Partial Deployment	Full Deployment	Full Deployment
Dynamic pricing participation (of eligible)	Today's level	Voluntary (opt-in); 5%	Default (opt-out): 60% to 75%	Universal (mandatory): 100%
Eligible customers offered enabling tech	None	None	95%	100%
Eligible customers accepting enabling tech	None	None	60%	100%
Basis for non-pricing participation rate	Today's level	"Best practices" estimate	"Best practices" estimate	"Best practices" estimate

Source: FERC. A National Assessment of Demand Response Potential. 2009.

- **Expanded BAU case in FERC DR Potential Study is most consistent with expected near-term regulatory and stakeholder support for time-based pricing**
- **FERC Achievable Participation case offers a more optimistic scenario for the long term (e.g. 2020-2025)**

FERC Estimates of U.S. DR Potential in 2019

Estimated DR potential is 2-4 times greater than existing DR resources



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Potential Exists for DR to Mitigate Variable Generation Integration Issues

- **Recent studies have examined the potential role of DR to address VG integration issues**
  - **Applications of both pricing and incentive-based demand response opportunities have been widely assessed**
  - **Studies tend to assume that DR is generally able to deal with integration issues that have shorter advance notification periods, reasonably lengthy durations and relatively frequent events**
- **Applicability of results to current generation of DR opportunities is questionable as studies typically assume ambitious acceptance rates and/or impose highly optimistic customer behavioral response**
- **However, various field tests are exploring these issues in greater depth (e.g., BPA-Mason County PUD #3, Infotility project in Marin County, CA)**

Limited Ability for Time-Based Rates to Affect VG Integration Issues

Variable Generation Integration Issue	TOU	CPR	CPP	DA-RTP	RT-RTP
1 min. to 5 – 10 min. variability					
<2 hr. forecast error					○
Large multiple hour ramps					○
>24 hr. forecast error					○
Variation from avg. daily energy profile		◉	◉	○	○
Avg. daily energy profile by season	◉			○	○

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- **Granularity of pricing signals (e.g., hourly, multiple-hourly) will dictate the efficacy and ability of dynamic pricing to manage VG integration issues**
- **Need political support for exposing mass market customers to greatest time-differentiation in pricing (e.g. RTP) or at least to more flexible rate designs (e.g., variable length CPP/CPR events) coupled with automation/control technology in order to enhance ability of DR to affect VG integration issues**

Portfolio of Incentive-Based DR Programs Can Manage Multiple VG Integration Issues

Variable Generation Integration Issue	DLC	Emergency	Capacity	Energy	Ancillary Services
1 Min. to 5 – 10 Min. Variability	○				○
<2 hr Forecast Error	◉	○		○	○
Large Multi-hour Ramps	◉			○	
>24 hr Forecast Error	○			○	
Variation from Avg. Daily Energy Profile		○	○	○	
Avg. Daily Energy Profile by Season					

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- **Incentive-based DR programs have significant potential to manage many variable generation integration issues if residential customers are willing to participate in programs whose designs feature short duration and frequent demand response events**
- **Mass market customers' acceptance of the types of control technology required will dictate DRs ability to expand its role in mitigating VG issues**

Can the Smart Grid Harness the Diversity and Flexibility of Mass Market DR?

- **Research has demonstrated how DR targeted to mass market customers can reliably provide bulk power system services as a fleet of distributed resources**
  - **Two-way communications capabilities of smart grid provide an opportunity to expand this "fleet" concept**
- **Current situation: PUC-approved DR tariffs of many electric utilities (LSEs) place severe restrictions on differentially and selectively dispatching end-use or equipment-targeted load reductions from customers as a portfolio of DR resources**
- **Aggregators of Retail Customers (ARCs) are not bound by same limitations**
  - **ARC business model allows for aggregation, selective dispatching, and can limit customer exposure to non-performance penalties**

Expanding Customer Aggregation through Retail Market Regulatory Changes

- ARCs are pushing for expanded opportunities to provide bulk power system services by acting as third-party providers of DR programs, which may require regulatory approval
- State PUCs (and utilities) should consider new tariffs or modifying existing tariffs to allow the differential dispatching of DR resources
  - Would allow utility and any third-party provider greater flexibility in addressing such issues as variable generation integration
- Remains to be seen if utilities provided with such tariff changes will take advantage of this opportunity by:
  - Investing in the necessary infrastructure to dispatch their own DR resources as a portfolio; or
  - Partnering with third-party service providers that already have this capability

Expanding Customer Aggregation through Wholesale Market & Reliability Rule Changes

- Historically, rules for wholesale markets and reliability were designed under a "generator-only" paradigm
- Capturing full value of DR opportunities requires changes to reliability rules and access to wholesale power markets
  - Some ISO/RTOs and reliability councils have expanded product definitions and addressed necessary technical issues to allow DR resources to provide ancillary services
- Definitions of bulk power system services may have to be altered to access balancing services from demand response (along with other new resources like storage)
- Experience with DR must be sufficient for system operators to gain confidence that customer resources can perform well and/or predictably during times of need

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DR Is But One Way to Address these VG Integration Issues

- **Historically, fossil-based and large hydro generation resources provided majority of bulk power system services**
- **System operators and policymakers are considering various strategies to integrate large-scale variable generation in addition to demand response, including:**
  - **Improved forecasting tools to increase the accuracy of expected output from variable generators**
  - **Technology improvements in variable generation that enable them to provide some bulk power system services**
  - **Expanded transmission system capacity**
  - **Institutional changes in electricity market structure (e.g., larger balancing authorities) or market design (e.g., intra-hour markets in the West)**

Must Understand Perceived Risks, Benefits and Costs of Various Strategies

- **Adding VG resources requires increased operating reserves and management of day-ahead forecast errors**
  - **Recent study in the West estimated that benefits of using DR instead of thermal generators were $310-450/kW-yr, which needs to be compared to cost and risks of enrolling customers in a DR program to provide load reductions with little or no notice for 10-35 hrs/yr (on average) that could be called on any time**
- **Depending on the generation profile, VG may contribute little to resource adequacy**
  - **The low capacity credit of wind would be relatively less important if alternative sources of capacity become inexpensive (i.e., DR)**
- **Ramping capability can be increased with new flexible plants**
  - **DR opportunities that lessen the magnitude of ramps can offset these investments and increased operating costs, but is the response predictable and dependable?**

Supply-Side Costs Are Reasonably Well Understood, But Not So for DR Resources

- **Significant cost component of DR programs are LSE/ARC efforts to induce customer participation and response**
- **Time-based retail rates:**
  - **Eliciting initial participation may require LSE to offer enabling technology, develop extensive marketing and customer education plans**
  - **On-going education efforts may be required to maintain or improve performance over time**
- **Incentive-based DR programs:**
  - **LSE/ARC provides incentive payments to elicit customer participation and response**
  - **Direct utility control or high frequency DR signals will require additional customer control technology beyond AMI**
  - **How is cost allocated between customer and the retail entity?**

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Conclusions

- **Smart grid proponents assert that AMI and smart grid deployment will enable significantly more demand response from residential and small commercial (mass market)**
- **The penetration of renewable generation resources is expected to increase substantially over the next five to ten years (and beyond) in the United States due to various state and federal policies**
- **The largest variability and uncertainty in renewable electricity production is from wind and solar resources over time periods of 1-12 hours; time scales that are in sync with most DR opportunities**

Conclusions (2)

- **For the smart grid and AMI to facilitate the integration of variable generation resources, it will require:**
  - **Regulatory and stakeholder support for dynamic rates with the greatest potential to address VG integration issues (i.e., RTP)**
  - **Establishment of price/event response strategies at the customer level that may rely on automation/control technology and should likely precede actual DR rate or program participation**
  - **Ratepayer acceptance of end-use control technology that would be used frequently and be more directly integrated into end-uses**
  - **Consideration of regulatory/market framework: bundled utility DR program, technology and service offering vs. utility provision of DR incentives and price/event signals while competitive market provides controls technology and DR services**
  - **Addressing retail market restrictions, wholesale market designs, and reliability rules to access the diversity and flexibility of customer demand**

Conclusions (3)

- System operators and policymakers should systematically analyze the perceived risks, costs and benefits of the various strategies, including demand response, to facilitate the integration of large-scale VG resources
- Should DR be deemed a cost-effective solution to help manage VG integration issues, the value generated will likely be just one of many benefits streams used to justify the investment in AMI and smart grid technology
- The greater the number of opportunities for DR to provide value, the more likely it will be that utilities and end-users insist that policymakers adopt the necessary changes to facilitate an expansion in the offering and adoption of demand response opportunities