# Demand Response and Variable Generation Integration
# 需求响应与波动性电源并网

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# A Role for Demand Response to Mitigate Variable Generation Integration Issues
# 需求响应在解决波动性电源并网中的作用

- **Large scale deployment of certain renewable energy resources, because of its variable and often times unpredictable production characteristics, poses integration challenges for bulk power system operators**

**由于其发电具有可变性，有时甚至具有不可预测性，可再生能源的大规模应用对大电力系统运营商提出了挑战。**

- **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**

**目前，大电力系统运营商依靠现有火电资源和不断改进的可再生能源发电功率预测来应对这些并网问题。**

- **Demand response (DR) is an alternative option for mitigating many VG integration issues**

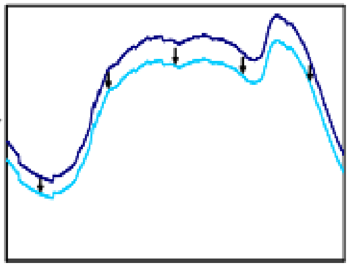
**需求响应也是减少波动性电源并网问题的措施之一。**

*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

# Demand Response: Change in Load Relative to Baseline in Response to System Needs需求响应：负荷根据系统需要做出偏离基准线的变化

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

   能效项目既可减少总用电量，也能削减尖峰负荷

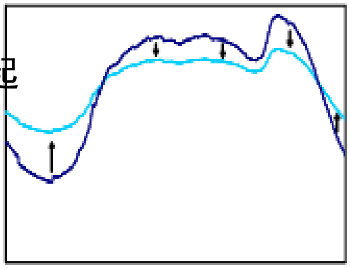


2. **Price Response** programs move consumption from day to night (real time pricing or time of use) – *immediately useful for variable generation integration*

   价格响应将部分用电量从白天转移到夜晚（实时或分时电价）–对缓解并网问题起到立竿见影的效果

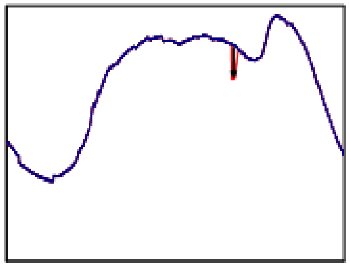
3. **Peak Shaving** programs require more response during peak hours and focus on reducing peaks every high-load day – *adaptable for variable generation integration*

   削峰项目要求负荷在尖峰时段根据系统需要做出更积极的响应，它关注每个高负荷日的削峰需求–可用于缓解并网问题



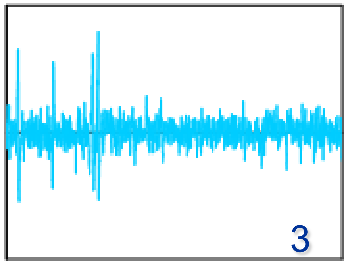
4. **Reliability Response** (contingency response) requires the fastest, shortest duration response. Response is only required during power system "events" – *this is new and slowly developing, adaptable for variable generation integration*

   可靠性响应（应急响应）是仅在系统事故发生时最快最短时间响应–发展中



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*

   调节响应是持续跟踪系统的分钟级需求来实现系统平衡-- 刚开始发展



*Source:* Milligan and Kirby (2010)

# DR and VG Literature Tends to Focus on Limited Subset of all Opportunities 关于需求响应和波动性电源的研究往往仅着眼于某些机会，而不是全部机会

## Ability of DR Resources to mitigate VG integration issues 需求响应缓解波动性电源并网问题的能力

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

# Presentation Overview 演讲大纲

- Objectives and Approach
- **Variable Generation Resources and the Bulk Power System 波动性电源和大电力系统**
- Demand Response Opportunities
- Opportunities for Demand Response Resources to mitigate issues that arise in integrating Variable Generation Resources in the Bulk Power System
- Comparison of Demand Response to Alternative Strategies to Integrate Variable Generation
- Conclusions

# Production Characteristics of Fleet of Variable Generation Resources 波动性电源的发电特性

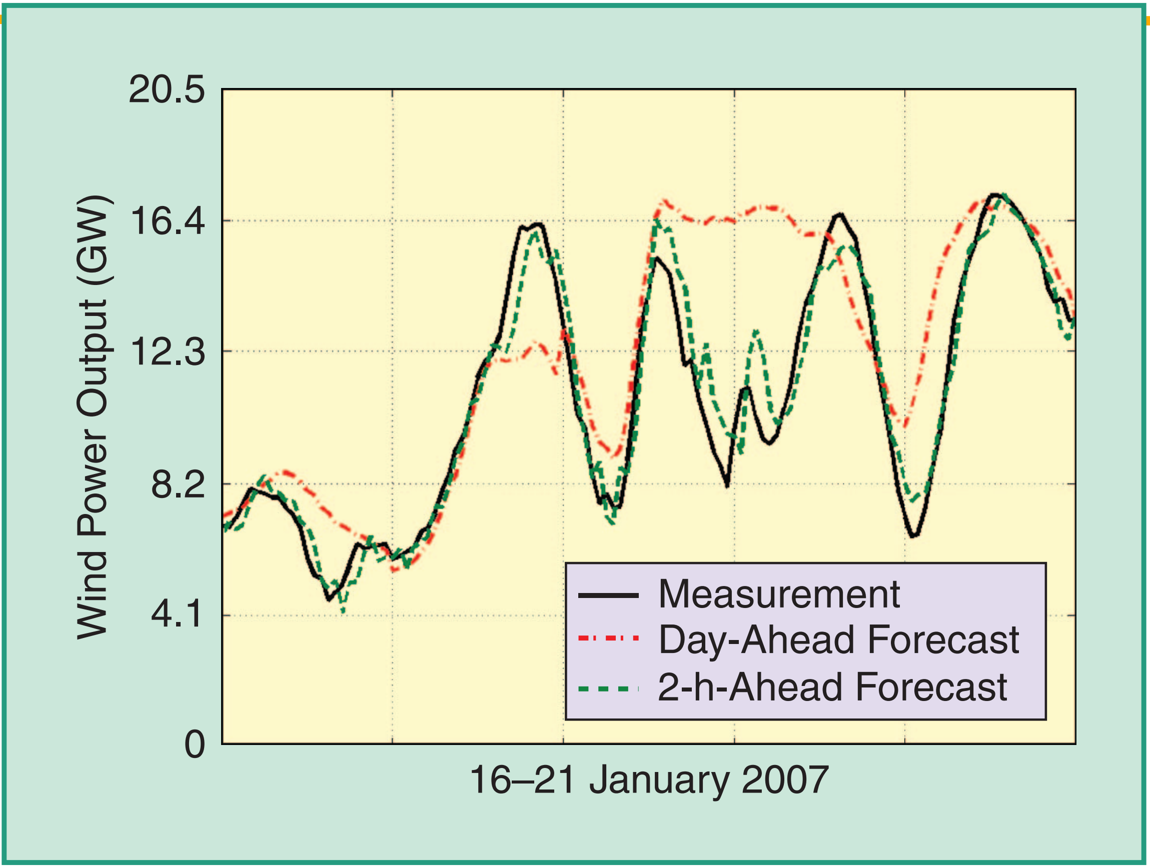
| Variable Generation Production Characteristics | Abbreviated Name | Example of Wind Variability (% of Nameplate Capacity) |
|---|---|---|
| Changes in output over very short time scales | <1-minute variability | 0.1%-0.2% |
| Changes in output over short time scales | 1 minute to 5-10 minute variability | 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 generation is larger over a time period of 1-12 hours than over a sub-hourly time period**

  **风力发电在1-12小时时间段的波动性比在一小时以内时间段的波动性大。**

# Actual Wind Forecast Errors in Germany
# 德国风电实际预测偏差

风电出力（GW）

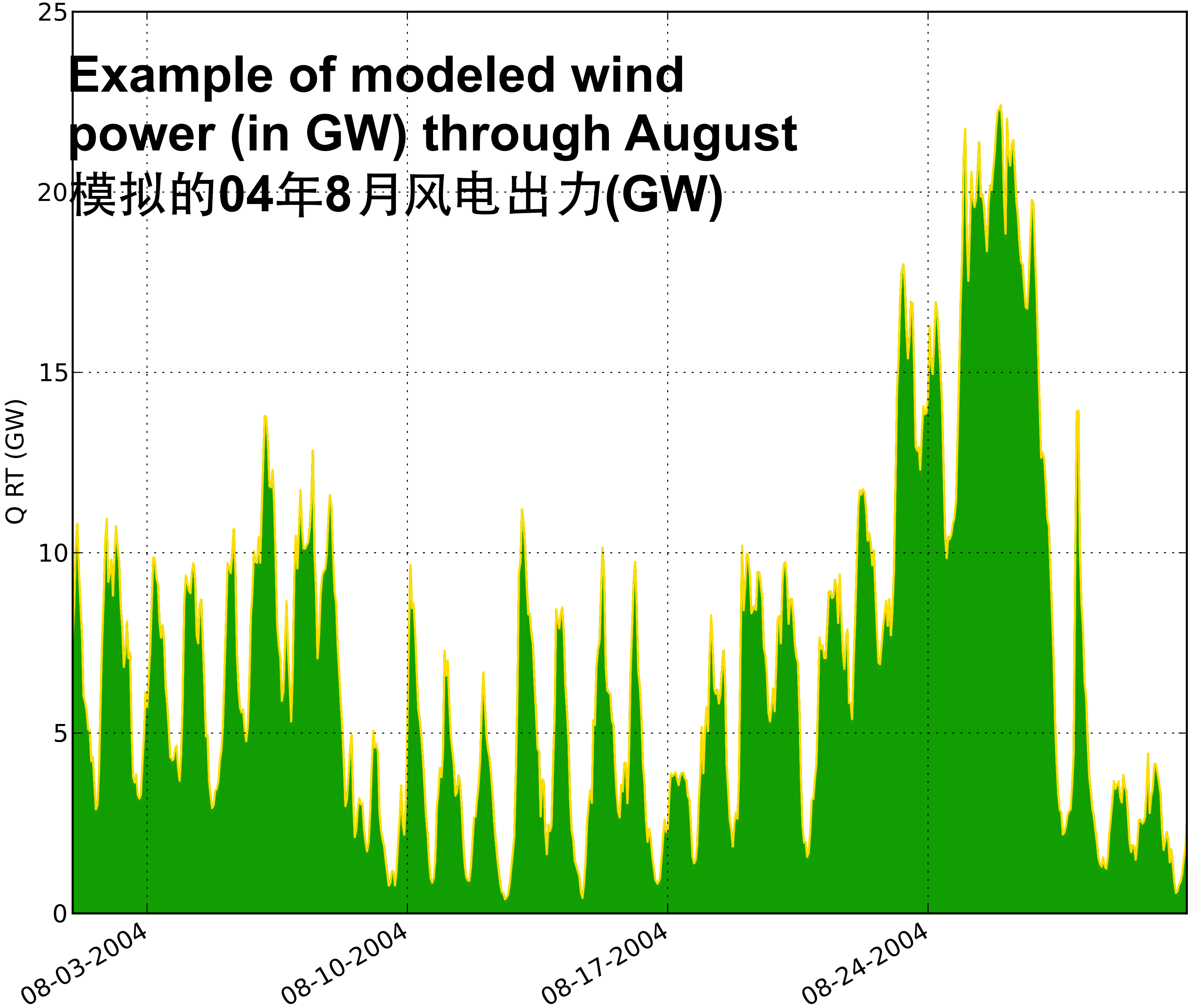



*Source:*
Holttinen et al. 2011 (IEEE PES Special Issue on Wind Integration)

**figure 10.** A large forecast error in the day-ahead forecast during the severe storm Kyrill in Germany in 2007. The forecast was off by as much as 8 GW.

2007年，德国遭遇强烈Kyrill风暴期间，日前预测误差极大，达到8GW。

# Example of modeled wind power (in GW) through August
# 模拟的04年8月风电出力(GW)



# System Requirements for Bulk Power System Operations 大电力系统运行要求

| 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 |

60
GW

**Generation (GW)**
**发电量**

30
GW

0
GW

$250/
MWh

**System Marginal Cost**
**系统边际成本**
**($/MWh)**

$0/
MWh

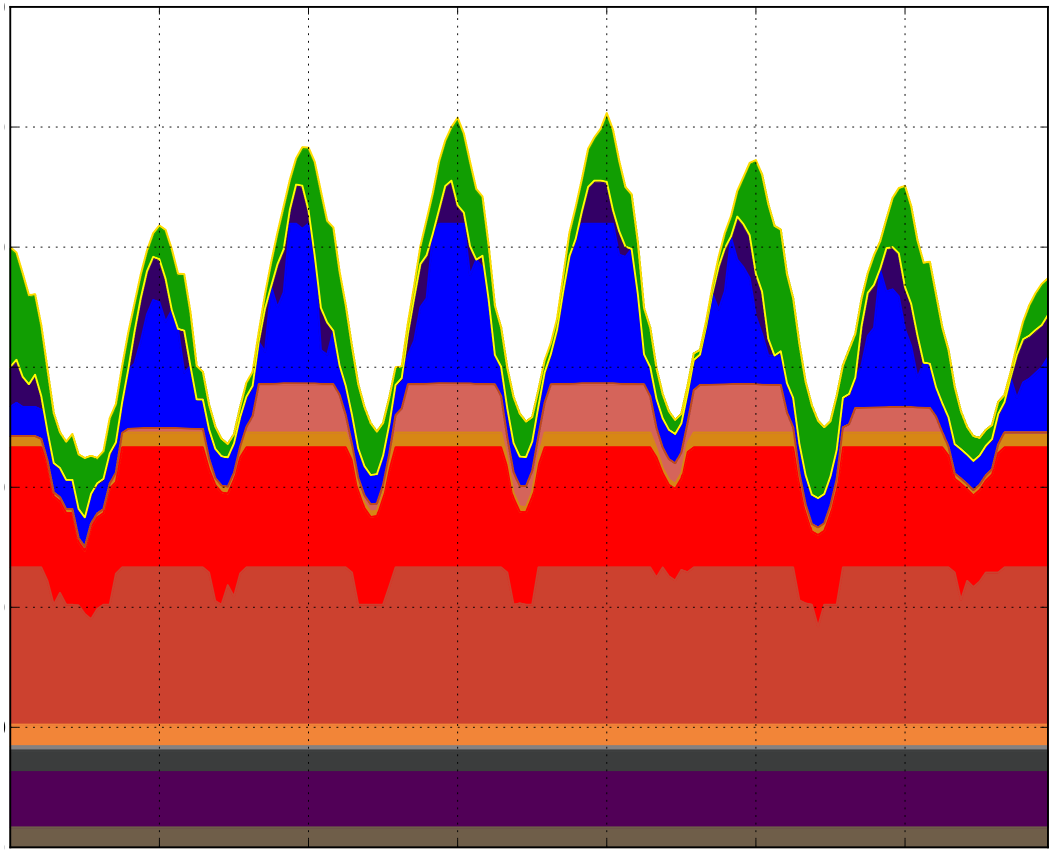

Example modeled dispatch and system marginal costs in August
模拟的04年8月电力调度和系统边际成本

60 GW

30 GW

0 GW

Generation
发电量 (GW)

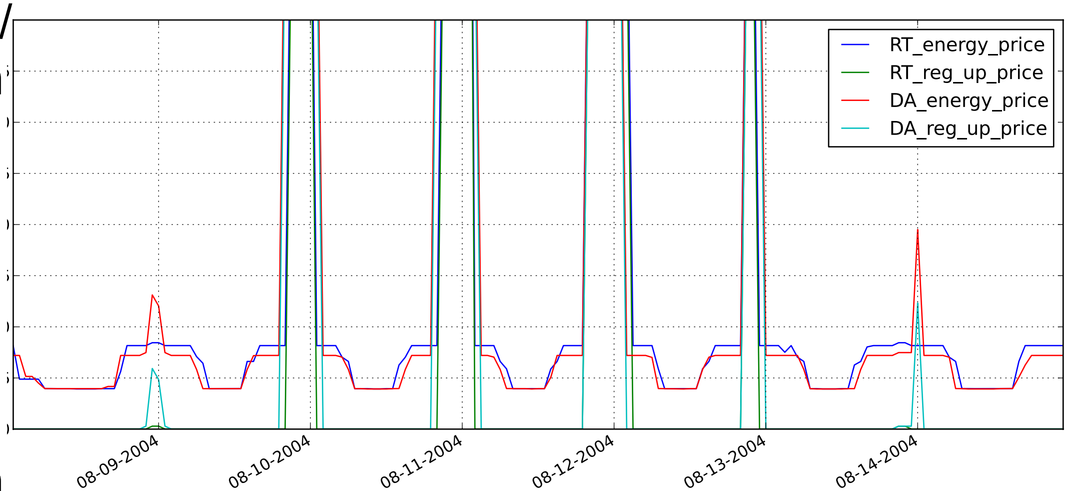


High Load Period
高负荷时期

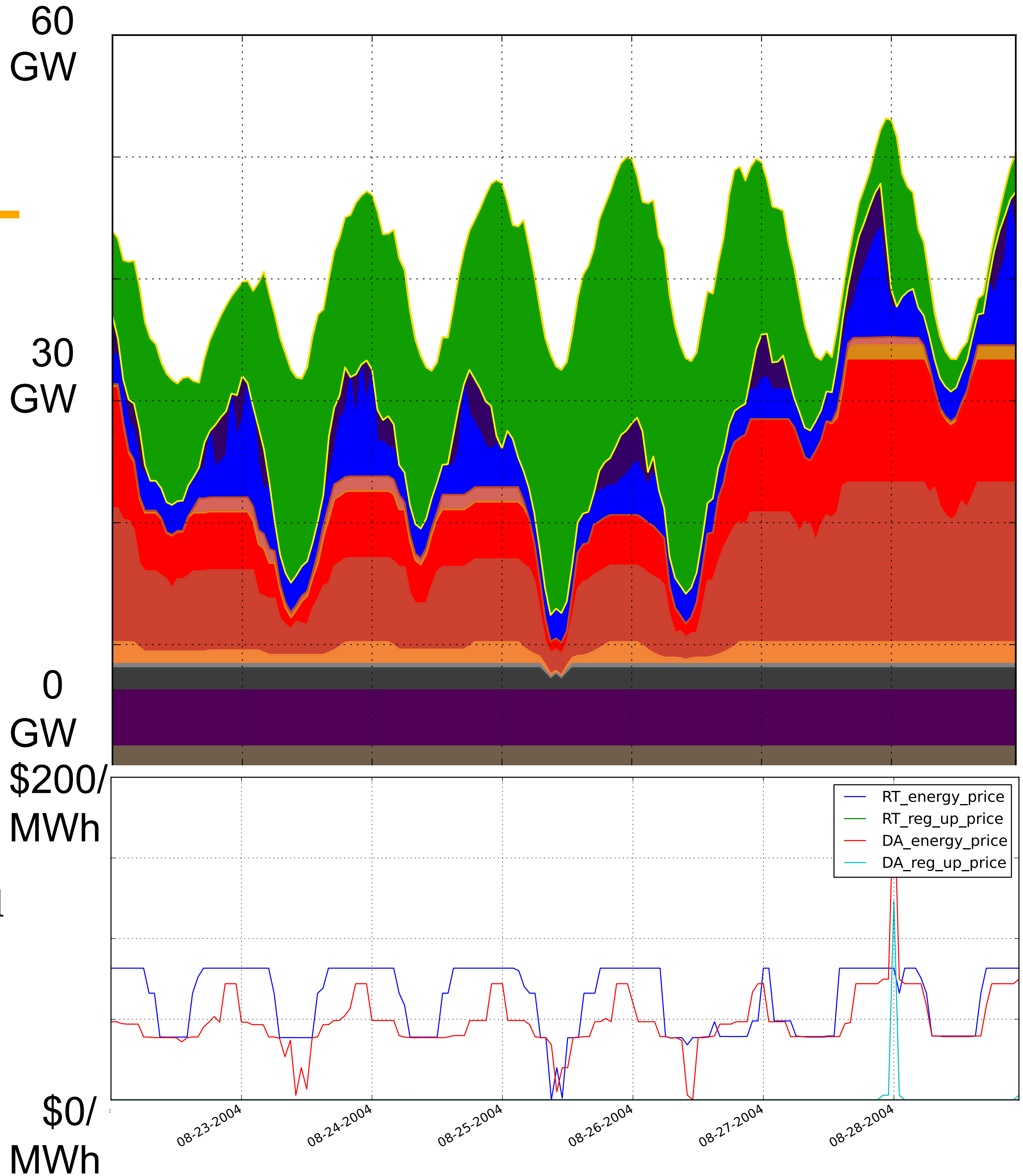
$400/MWh

$0/MWh

System Marginal Cost 系统边际成本 ($/MWh)



Generation (GW) 发电量




System Marginal Cost系统边际成本 ($/MWh)

High Wind Period 高风力时期

# Bulk Power System Operations in Support of Variable Generation Resources
# 支持波动性电源的大电力系统运行

| 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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- Variable Generation Resources and the Bulk Power System
- **Demand Response Opportunities 需求响应措施**
- Opportunities for Demand Response Resources to mitigate issues that arise in integrating Variable Generation Resources in the Bulk Power System
- Comparison of Demand Response to Alternative Strategies to Integrate Variable Generation
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# Typical Demand Response Opportunities
# 典型的需求响应措施

- **DR customers alter electricity consumption over some time period based on DR Signal provided by utility** **需求响应用户根据电力公司提供的需求响应信号在一定时间段改变电力消费行为**
- **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** **基于时间的零售价格发出价格信号以引导电力用户增加或减少消费；基于激励的需求响应项目则利用需求响应信号来引导用户减少用电**

| **Time-Based Retail Rates**<br>***DR Signal: Price Level*** | **Incentive-Based DR Programs**<br>***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
# 需求响应的特征

| 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 Typical DR Opportunities to Impact the Bulk Power System Is Limited
# 典型需求响应措施对大电力系统的影响有限

- **Is DR allowed to provide bulk power system services? 是否允许需求响应为大电力系统提供服务?**
- **Is the DR signal based on local system needs or is it directly integrated into bulk power system operations? 需求响应信号是基于本地系统需要，还是直接与大电力系统运行相结合?**
- **The following is an assessment of the capabilities of typical DR opportunities to provide bulk power system services now and in near future (5-10 years)以下是对目前和近期（5-10年）典型需求响应措施为大电力系统提供服务的能力评估**

# Opportunities for Incentive-Based DR to Provide Bulk Power System Services
# 基于激励的需求响应为大电力系统提供服务的机遇

| 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.**
  **如果广大消费者愿意参与短期和频繁需求响应，需求响应为大电力系统提供服务的潜力巨大。**

# Opportunities for Time-Based Retail Rates to Provide Bulk Power System Services
# 基于时间的需求响应为大电力系统提供服务的机遇

| 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
- 在基于时间的价格机制中，实时价格配合消费者控制最具潜力
- Rates like CPP/CPR currently have more regulatory and stakeholder support but have very limited potential to provide bulk power system services CPP/CPR
  CPP/CPR等价格机制比较受监管者和相关方欢迎，但在服务大电力系统方面潜力非常有限

# Key Activities that will Influence Near-term Penetration of Demand Response
# 影响近期需求响应发展的关键活动

- **Advanced Metering Infrastructure Deployment 先进电表设施的应用**
  - Scope of deployment of advanced meters with two-way communication capabilities 双向沟通电表的应用范围
- **Stakeholder Acceptance of Time-Based Rates 利益相关方对基于时间的电价政策的接受程度**
  - Willingness of regulators to allow time-based retail rates as well as degree of customer acceptance 监管机构采用分时电价的意愿，及消费者的接受程度
- **Customer Acceptance of Automation/Control Technology 消费者对自动/控制技术的接受程度**
  - Are customers willing to accept these technologies? Will adding these technologies provide value to the customer? 消费者是否接受这些技术？使用这些技术是否能为消费者带来附加值

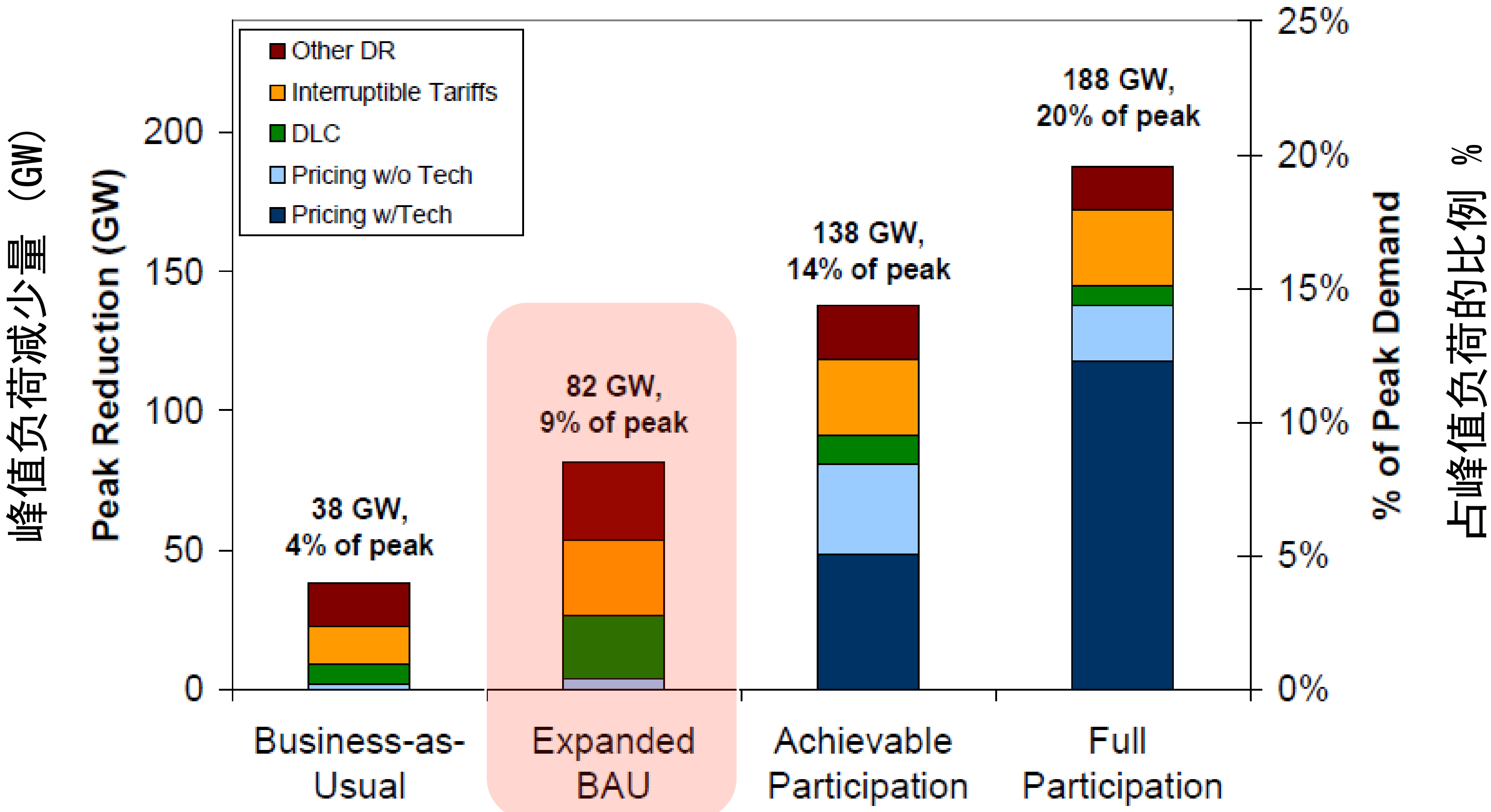
# Assessing the Potential for Future DR Opportunities among Customers 未来需求响应措施的潜力评估

| 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 联邦能源监管委员（FERC）需求响应潜力研究中的"扩大的基准情景"，与预期的监管机构和利益相关方近期对基于时间的价格政策的支持程度最为一致。**
- **FERC Achievable Participation case offers a more optimistic scenario for the long term (e.g. 2020-2025) FERC"可实现的参与情景"给出了一个对于远期（例如，2020-2025）更乐观的情形**

# FERC Estimates of U.S. DR Potential in 2019
# 联邦能源监管委员会估算的2019年美国需求响应潜力




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

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  **利用需求响应资源应对波动性电源并网问题：机遇**
- Comparison of Demand Response to Alternative Strategies to Integrate Variable Generation
- Conclusions

# Limited Ability for Time-Based Rates to Affect VG Integration Issues
# 基于时间的价格政策对影响波动性电源并网的能力有限

| 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) impact ability of dynamic pricing to mitigate VG integration issues 价格信号的精细化程度（小时级，多小时级）影响动态价格机制解决并网问题的能力**
- **Need regulator support for exposing customers to 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 需要监管机构支持，才能实施基于时间的价格政策（如实时电价）或至少是更灵活的价格机制（例如不同长度的CPP/CPR事件），并配合自动/控制技术来加强需求响应对波动性电源并网问题的作用**

# Portfolio of Incentive-Based DR Programs Can Mitigate Multiple VG Integration Issues 一系列基于激励的需求响应项目可以减少波动性电源并网问题

| 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 mitigate many variable generation integration issues if customers are willing to participate in programs whose designs feature short duration and frequent demand response events在消费者愿意参与短期和频繁需求响应的前提下，利用激励需求响应应对波动性电源并网问题的潜力巨大
- Customers‘ acceptance of the types of control technology required will dictate DRs ability to expand its role in mitigating VG issues 消费者对控制技术类型的选择会直接影响需求响应应对波动性电源并网问题的能力

# Potential Loads for Providing DR to help Integrate Variable Generation 能提供需求响应来帮助波动性电源并网的负荷类型

- Water pumping – 水泵
  - Irrigation 灌溉
  - Municipal: supply and treatment 市政：供水和水处理
- Thermal storage –热储存
  - Hot and cold 热和冷
  - Commercial and residential (water heaters, refrigerators) 商业和住宅 （热水器，电冰箱）
  - Space conditioning and cold storage 空调和冷储存
- Electrolysis 电解
- Electric vehicle charging 电动汽车充电
- Industrial processes with large thermal inertia 具有大量热惰性的工艺
  - Shale oil extraction 页岩油开采

*Source:* Milligan and Kirby (2010)

# Presentation Overview　演讲大纲

- Objectives and Approach
- Variable Generation Resources and the Bulk Power System
- Demand Response Opportunities
- Opportunities for Demand Response Resources to Mitigate Issues that Arise in Integrating Variable Generation Resources in the Bulk Power System
- **Comparison of Demand Response to Alternative Strategies to Integrate Variable Generation**

  **需求响应与解决波动性电源并网问题的其他策略比较**

Conclusions

# DR Is But One Way to Address these VG Integration Issues
# 需求响应只是解决波动性电源并网问题的办法之一

- Historically, fossil-based and large hydro generation resources provided majority of bulk power system services
  历史上，大电力系统服务主要是由火电和大型水电来提供的
- System operators and policymakers are considering various strategies to integrate large-scale variable generation in addition to demand response, including:除需求响应之外，系统运营商和政策制定者还研究了多种应对大规模波动性电源并网的策略，包括：
  - Improved forecasting tools to increase the accuracy of expected output from variable generators
    改进预测工具来加强对波动性电源出力的预测
  - Technology improvements in variable generation that enable them to provide some bulk power system services
    波动性电源发电技术革新，使它们自己能够提供某些系统服务
  - Institutional changes in electricity market structure or design
    电力市场结构或设计的体制改革

# Must Understand Perceived Risks, Benefits and Costs of Alternative Mitigation Strategies 必须研究各种策略的预期风险、收益和成本

- Adding VG resources requires increased operating reserves and management of day-ahead forecast errors 波动性电源并网后，需要增加旋转备用，管理日前预测误差
  - Recent study in the Western U.S. 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

  美国西部近期的研究表明，利用需求响应替代火电服务的收益大概是每年$310-450/kW，这需要与实施需求响应（消费者每年有10-35小时需要随时被要求减少负荷）的成本和风险进行比较
- Depending on the generation profile, VG may contribute little to resource adequacy 根据出力曲线，波动性电源对资源充裕度贡献很小
  - The low capacity credit of wind would be relatively less important if alternative sources of capacity become inexpensive (i.e., DR)

  如果替代容量资源（如需求响应）的成本降低，风电容量置信度低的问题就不那么重要了
- Ramping capability can be increased with new flexible plants 增加灵活的发电机组可以提高系统爬坡能力
  - DR opportunities that lessen the magnitude of ramps can offset these investments and increased operating costs, but is the response predictable and dependable?

  需求响应可以通过减少爬坡需求来减少灵活机组投资和运营费用，但是这种需求响应是否是可预期的和可靠的？

# Supply-Side Costs Are Reasonably Well Understood, But Not So for DR Resources
# 供应侧的成本比较透明、好理解，需求侧则不然

- Significant cost component of DR programs are utility efforts to induce customer participation and response DR成本主要来自电力公司吸引消费者参与和实施回应的费用
- Time-based retail rates: 基于时间的零售电价政策：
  - Eliciting initial participation may require utility to offer enabling technology, develop extensive marketing and customer education plans

    电力公司为吸引用户参与，可能需要提供所需的技术，加强营销，以及对消费者进行培训
  - On-going education efforts may be required to maintain or improve performance over time 可能需要不断的培训来保持和改进实施效果
- Incentive-based DR programs: 基于激励的需求响应项目：
  - Utility provides incentive payments to elicit customer participation and response 电力公司提供激励资金，吸引消费者参与和实施响应
  - Direct utility control or high frequency DR signals will require additional customer control technology beyond AMI

    电力公司直接控制或高频率的DR信号除了AMI，还需要其他的消费者控制技术
  - How is cost allocated between customer and the utility?

    消费者和电力公司怎样分担成本？

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# Conclusions 总结

- The largest variability and uncertainty in VG integration issues is over time periods of 1-12 hours; time scales that can be in sync with DR opportunities

  波动性电源并网最大的可变性和不确定性发生在1-12小时的时间段，恰好与 需求响应时间一致

- Greatest match between DR option an VG integration need: 需求响应和波动性电源并网相配合，需要：
  - Direct load control 直接控制负荷
  - Portfolio of incentive based programs (i.e., energy, capacity, ancillary services,) 一系列激励项目（例如能源、容量、辅助服务）
  - Dynamic rates (i.e., RTP) 动态电价 （例如实时电价）
- Customers will need to establish response to price/event response 消费者需要建立对价格/事件的响应
  - May require automation/control technology 可能需要自动/控制技术
  - End-use control technology will be used frequently and be more directly integrated into customer end-uses 将频繁使用终端控制技术，并将更多地与用户终端用电直接集成