Exploring the Limits of Demand Response: A Duke Energy Case Study

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Demand Response Questions

- How much DR is enough?
- What value can DR provide?
- What type of parameters are needed?
  - Number of Hours and Events
  - Time of Day
  - Reason for Implementation
- What customers can provide the parameters needed?
  - And how much will it cost for
    - Incentives
    - Technology
- Is the portfolio sustainable?

Demand Response Answer

- IT DEPENDS ON…
  - Regulatory environment
  - Revenue recovery mechanism
  - Customer composition
  - Technology strategy
  - Current supply position & DR portfolio
  - Future supply position

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Multiple Analysis Frameworks

- Three approaches that could be connected
  1. Loss of Load Expectation: Reliability focused study that can shed light on how often DR resources are needed and when.
     - Load / weather
     - Supply stack & DR portfolio
       – Current and future
     - Purchase Power availability
     - T&D Constraints
     - Peak day exposure…beyond

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Multiple Analysis Frameworks

- Three approaches that could be connected
  2. Peak Day Implementation Review: how much load can be reduced on peak days.
     - Hourly load shapes
     - Program parameters…current and projected
     - Rebound implications

Multiple Analysis Frameworks

- Three approaches that could be connected
  3. Program Cohesion Review: how do programs work together throughout the year.
     - Given additional insights about your customers, new technologies, and DR programs designed for implementation beyond peak days, how well do the programs and their parameters fit together with each other across the time periods needed or desired
     - Depending on results and current supply and DR portfolios, what type of programs and program parameters are needed if the intention is to add more demand response?

t4

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DEMAND RESPONSE SATURATION ANALYSIS

Slide 7

t4 Since you are presenting, i would put Duke's name first.
t19793, 12/10/2012

How much is enough?

- Fundamentally, the electric system needs enough capacity to meet the forecast coincident peak demand plus the mandated reserve margin based on the target reliability criteria selected
- Often referred to as Resource Adequacy (RA), the DR contribution often depends on RA "counting rules"
- But, the correct answer (viewed ex-post) depends on a lot of uncertainty and risk

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How much is enough?

- The optimal amount of DR can be measured from several perspectives including cost-effectiveness, marginal revenue requirements and effective coincident peak coverage, among others.
- The suggestion is that effective limits exist and become more important to address as more and more DR is added to the portfolio.
- The physical limit to the amount of usable DR on a given utility system is essentially driven by the shape of the utilities peak day load curve.

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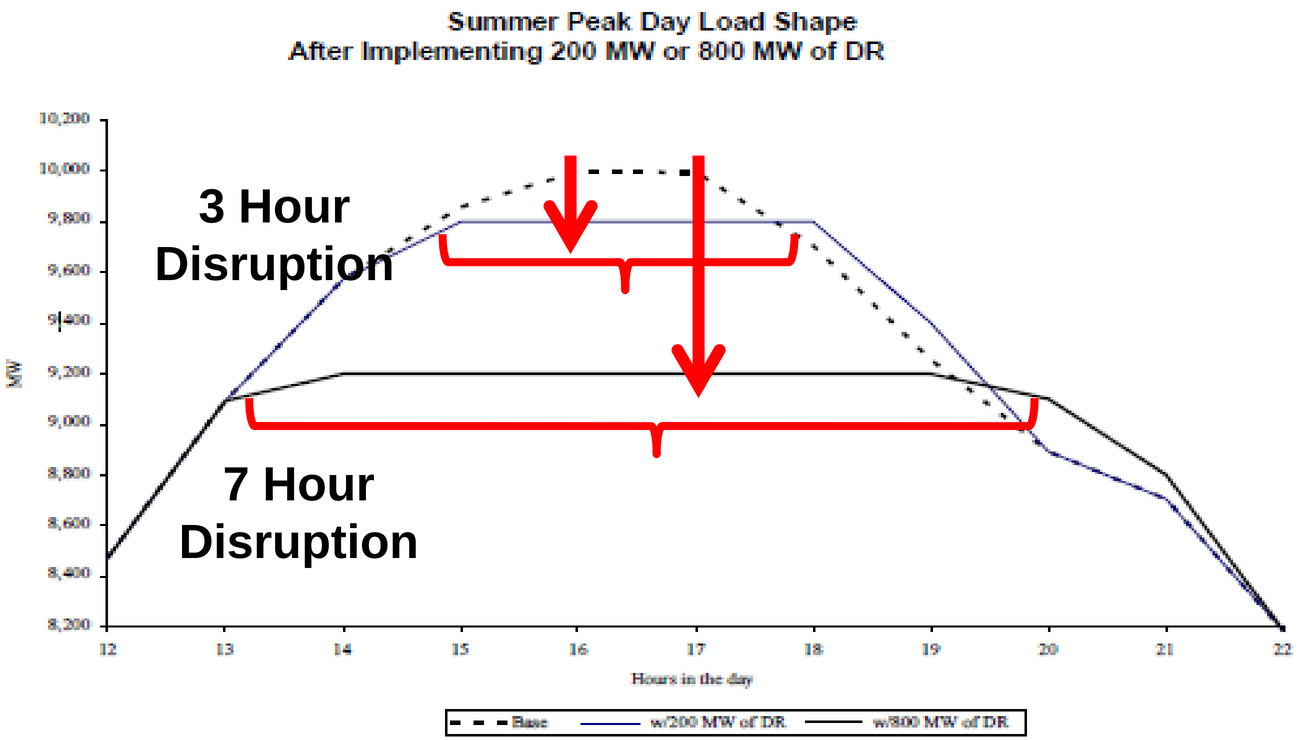
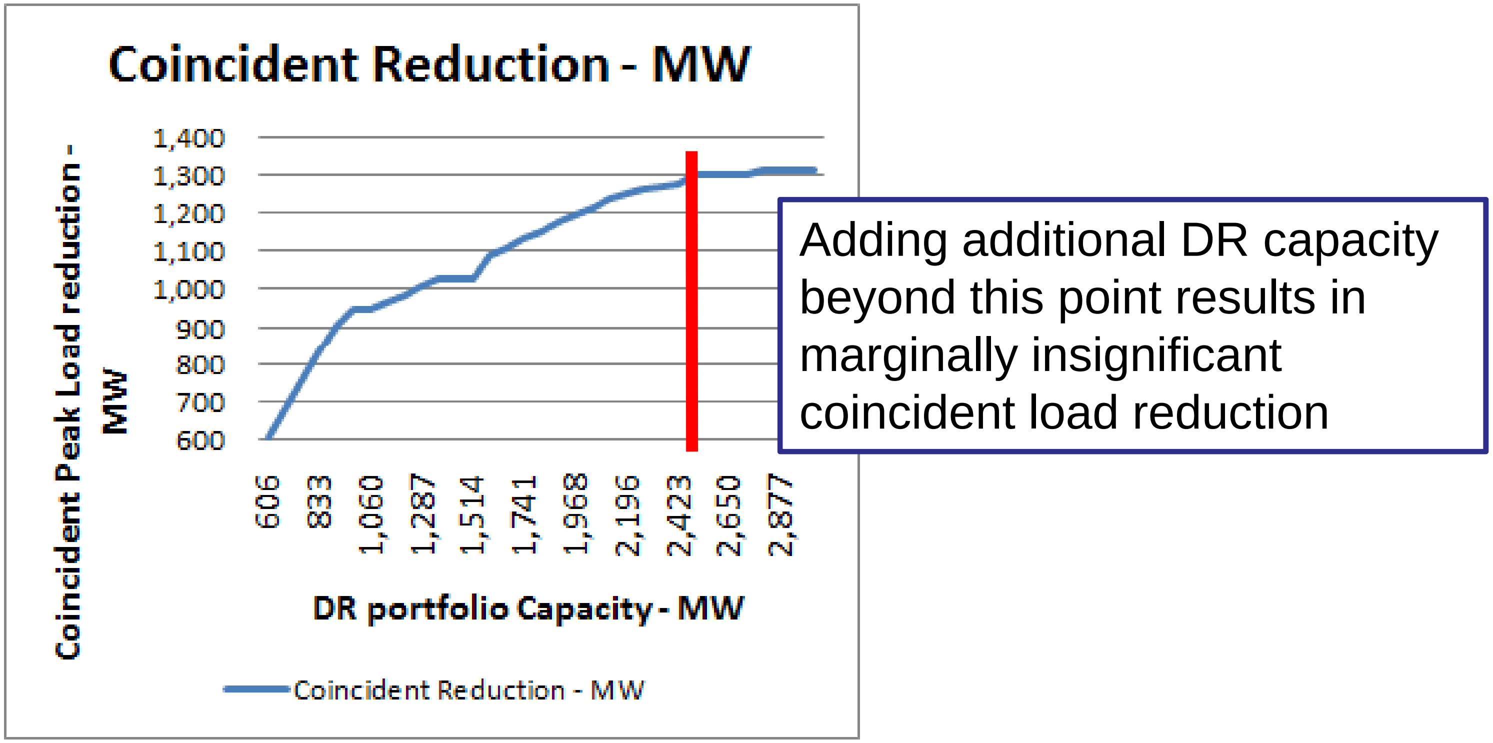
How much is enough?

- As the utility signs up more and more DR load reduction capability, each incremental participant must respond for longer and longer periods.



Results

- Viewed from the perspective of coincident peak reduction, which is different than peak day, we found that effective limits do exist.



- As the portfolio we tested is scaled up, coincident peak reduction is limited.

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Results

- The limit is highly dependent on the characteristics of the DR programs.
  - Number of curtailable hours per day, week, season, etc.
  - Number of permissible events
  - Control technology
  - Opt out assumptions, etc.
- As we reduce peak load, more and more days/hours start to compete for the limited DR resource as the new post-DR coincident peak shifts to other hours/days.

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Stretching the Limits

- Although we too find limits, we additionally find that limits can be "stretched" by planning for <u>uncertainty of supply and demand; and by investments in new "smart grid" technologies.</u>

  – Uncertainty *necessitates* additional DR

  – Technology *enables* additional DR

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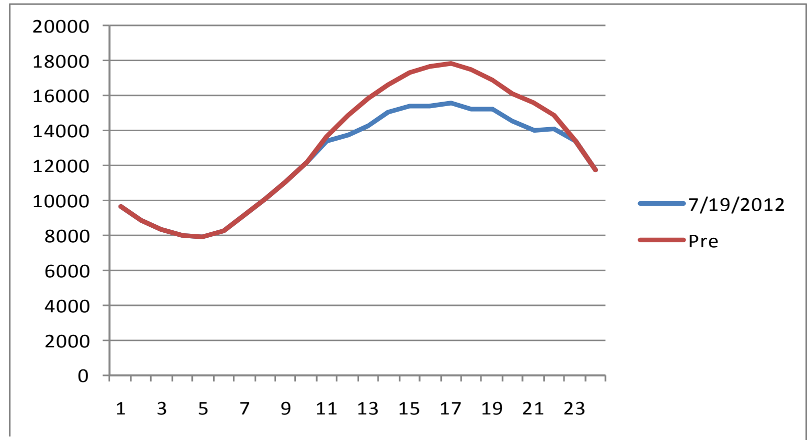
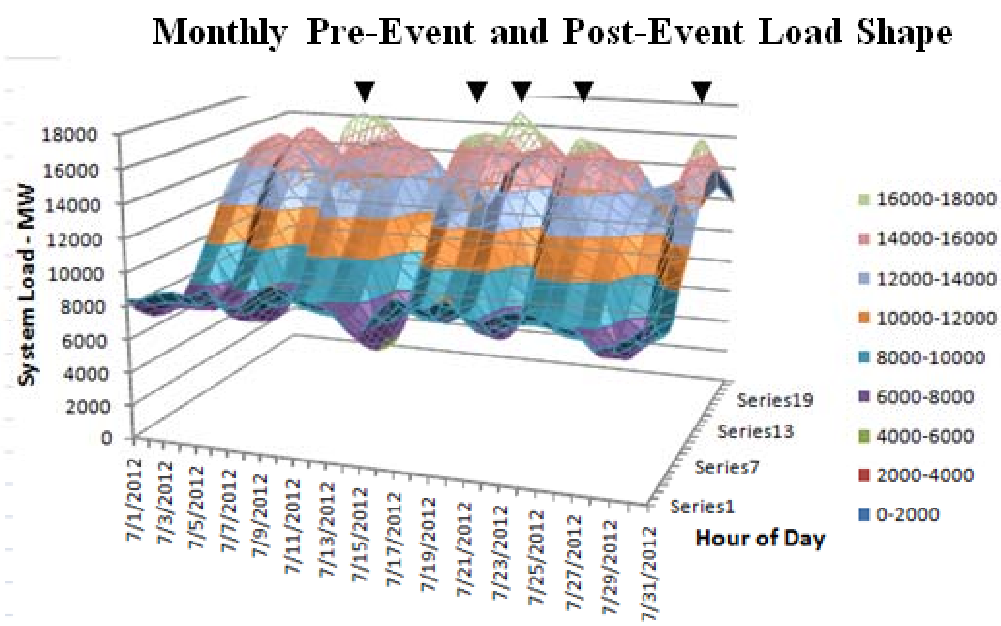
Stretching the Limits

- Uncertainty of Supply and Demand
  - Viewed using average or expected values, or viewed using coincident-day load, will give a very different result than viewed from a supply and demand balance or LOLP (loss of load probability) perspective

Many days compete for the finite DR resource

- **Peak Day Load Reduction**
  - **One Day**
- **July Portfolio Coverage**
  - **Many Days**

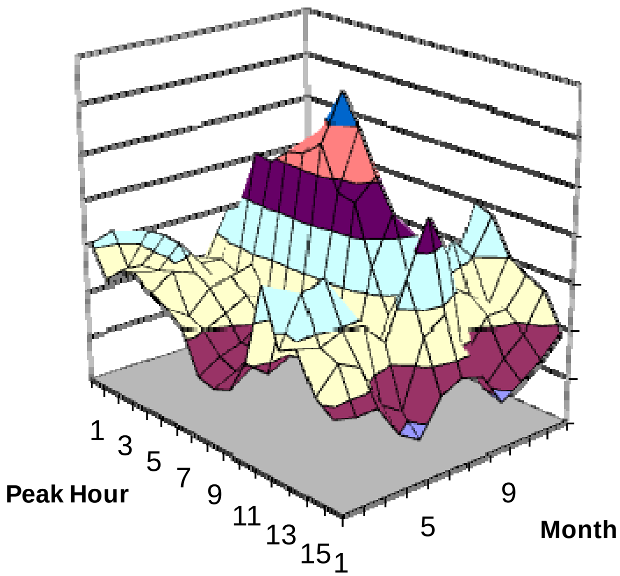


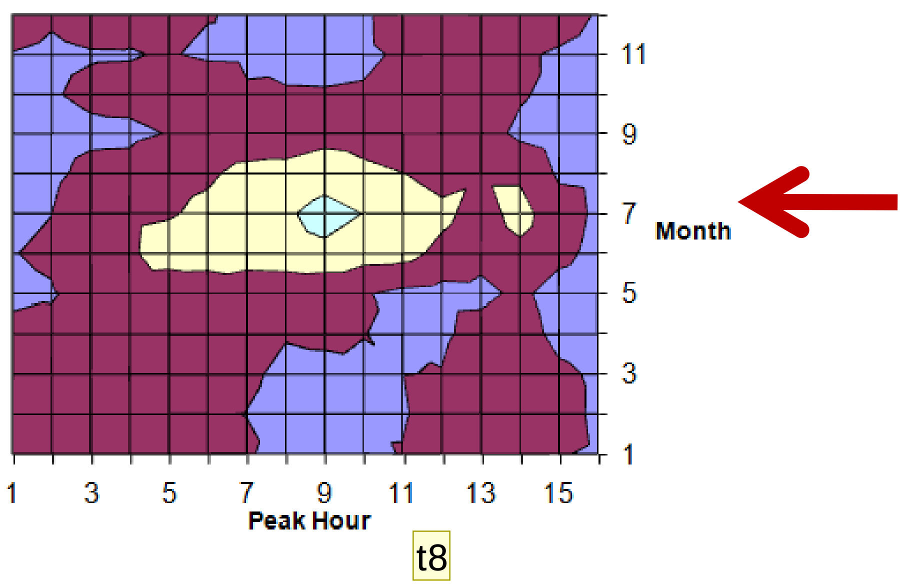


Key Takeaway: Peak day uncertainty necessitates additional DR capacity be available <u>to respond to variation in seasonal peaks</u>

Uncertainty of Supply and Demand

- For example, using historic data, the expected coincident system peak impact occurs at 5 pm in July





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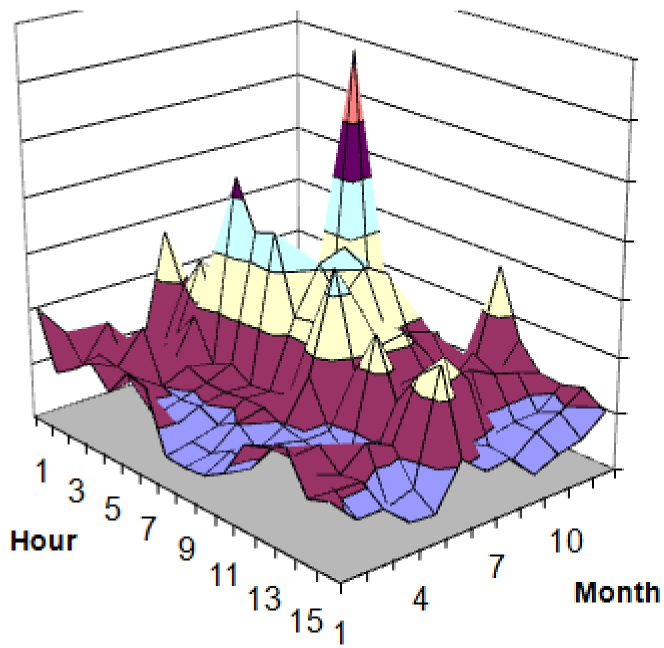
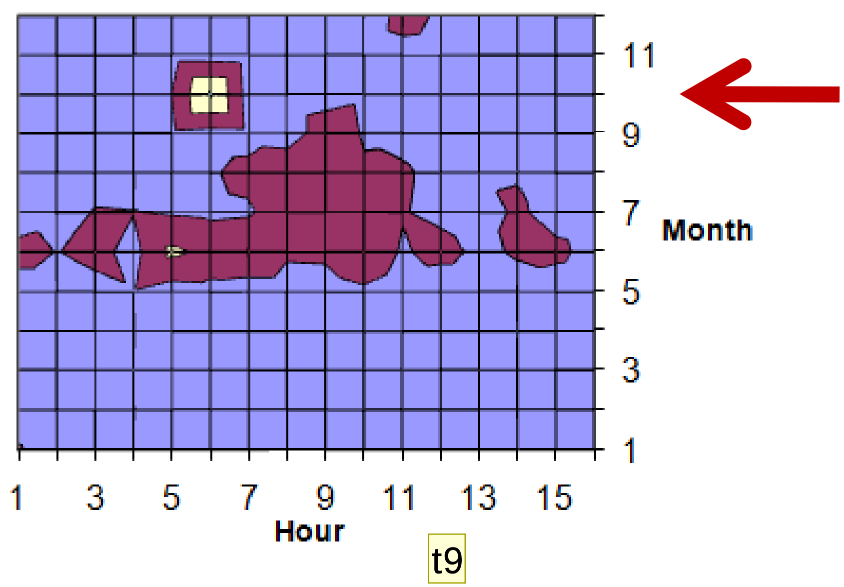
t8 These labels are confusing. I think what you are saying is the peak occurs 9 hours into a 16 hour peak period that starts at 7:00 am but that is not clear from this chart. Also, is it "hour ending" or "hour beginning"? Looks like "hour beginning"

t19793, 12/10/2012

Uncertainty of Supply and Demand

- But the critical hour happens at the supply and demand imbalance extreme – peak hour 2 pm in October.





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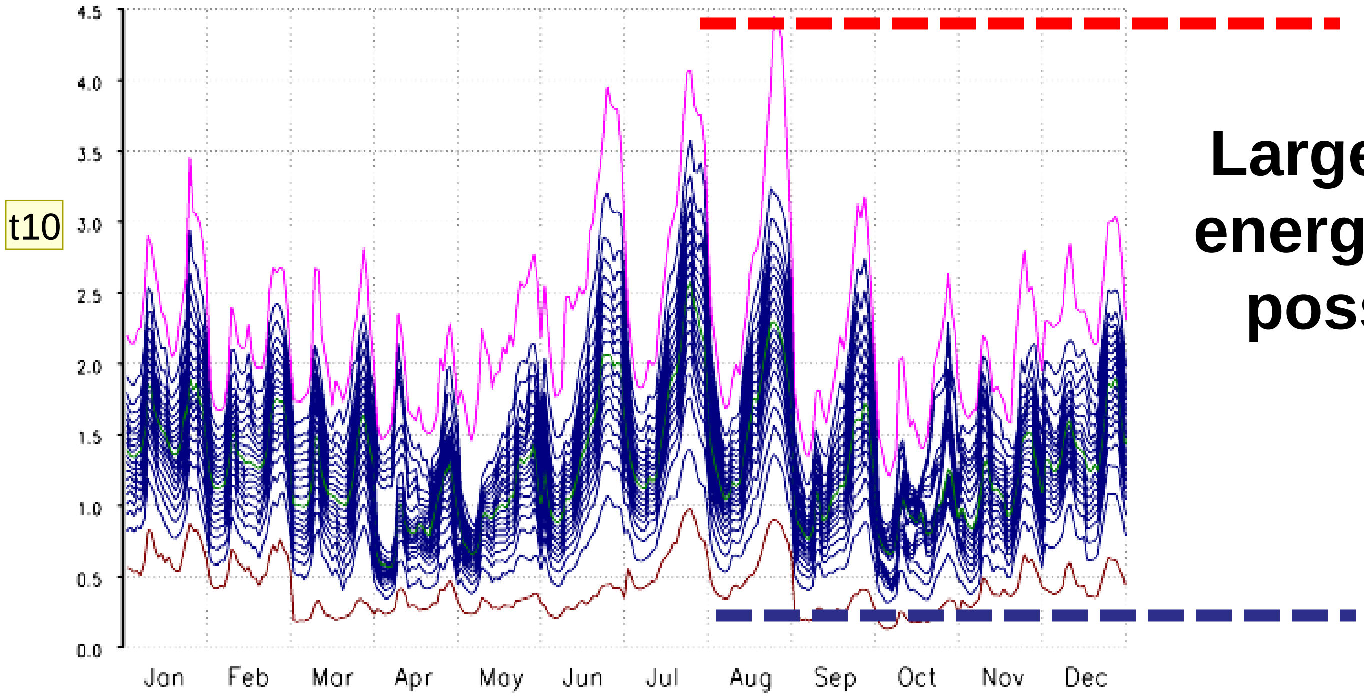
t9 Same comment about these labels.
t19793, 12/10/2012

Uncertainty of Supply and Demand

- Further, the magnitude of recognizing DR benefits in any given year depends on uncertain conditions.
  - In a weather mild year, DR programs may not be needed
  - In a weather extreme year, DR programs may be extremely important for system reliability
- Others have referred to this as the Option Value of Demand Response

Uncertainty of Supply and Demand

- Largely due to weather uncertainty, is there enough DR optionality to cover 1, 2, … etc. peak days?



Large range in energy demand possibilities

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t10 What are the units?

t19793, 12/10/2012

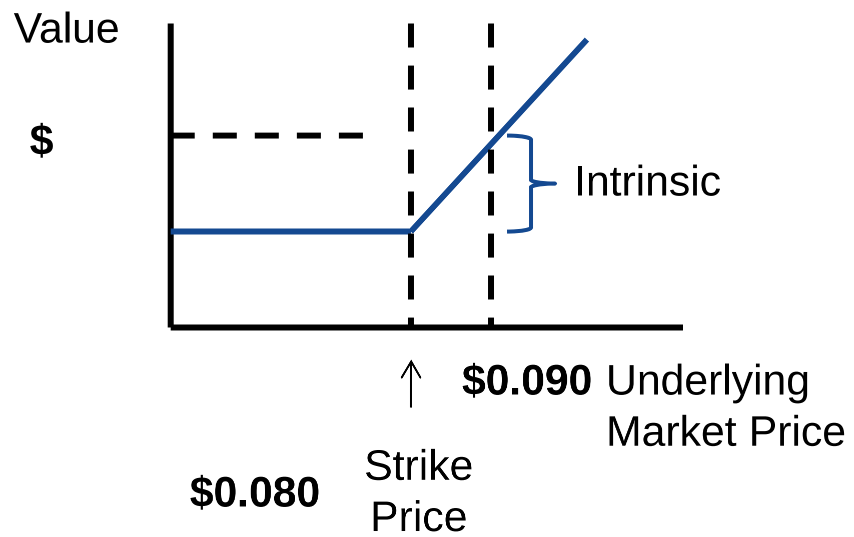
The Option Value of DR

- Analogous to an “insurance policy”, financial option hedging methods can be used to value and price the uncertainty of DR event days
- An insurance policy contains both an intrinsic and an extrinsic component.

The Option Value of DR

– If the underlying bilateral value of forward summer peak electricity is 9 cents per kWh, and the strike price is 8 cents per kWh, the option is “in-the-money” by one cent.
– Its intrinsic value is one cent.

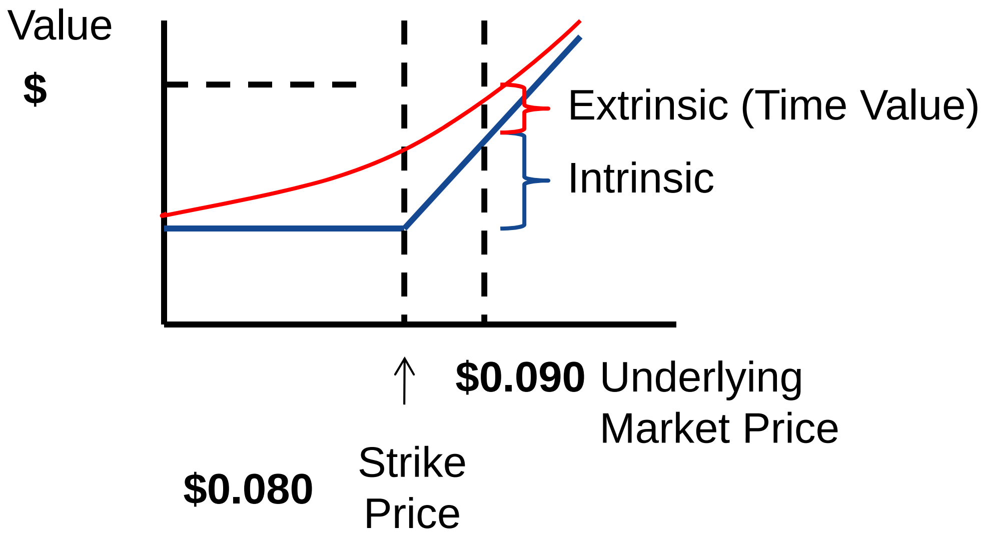
Option Value Payoff Diagram



The Option Value of DR

– The extrinsic value depends on the market volatility, time to expiration, etc., and measures the probability of prices exceeding 9 cents on the expiration date of the option.

Option Value Payoff Diagram



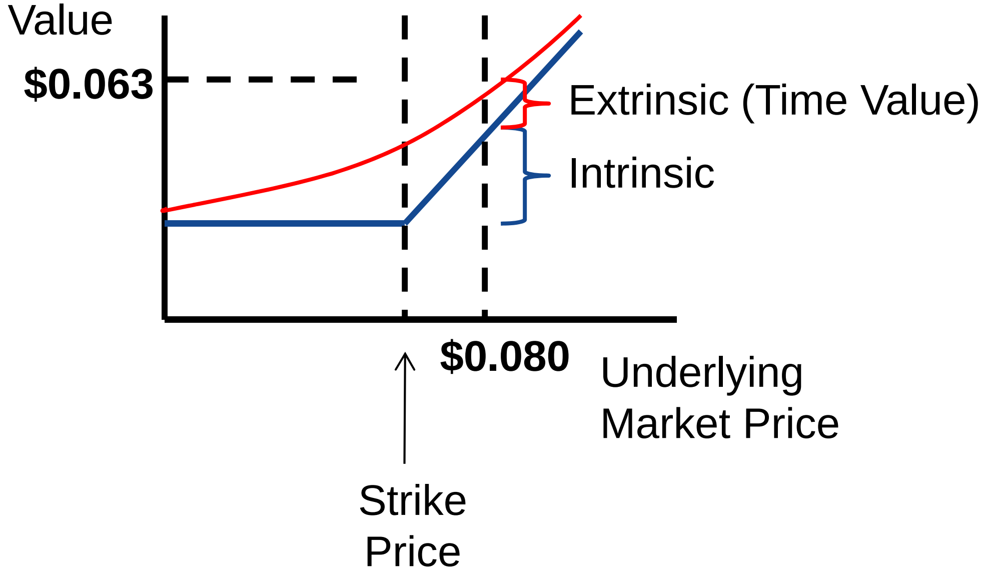
The Option Value of DR

– The total value of the DR program is equal to the sum of the intrinsic and extrinsic option value.

Example 1 - Strike Price is "In the Money"

Strike	$0.058
Extrensic	$0.041
Intrensic	$0.022
Total (Option) Value	**$0.063**

68% Volatility, $0.080 Underlying



Option Value Payoff Diagram

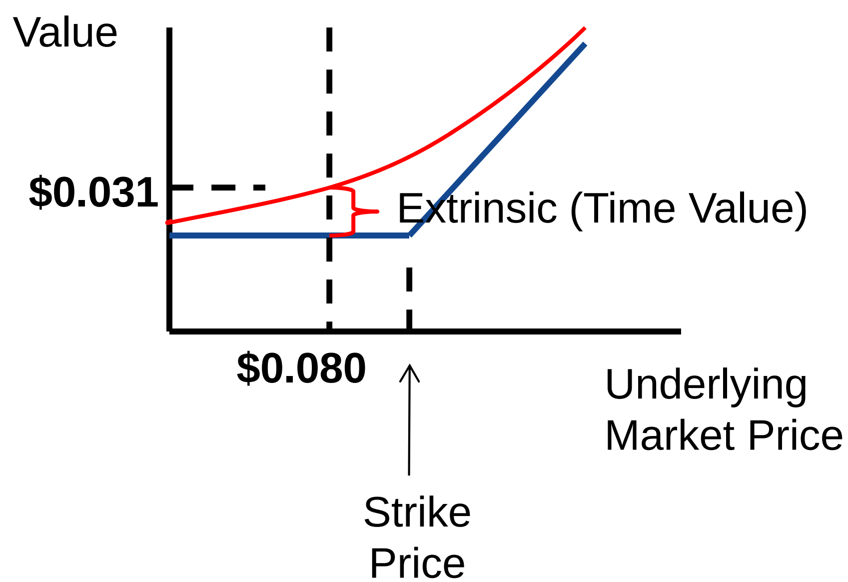
The Option Value of DR

– Program characteristics impact the program value – for example the "strike price" can be set so high as to eliminate any intrinsic value.

Example 2 - Strike Price is "Out of the Money"

Strike	$0.090
Extrensic	$0.031
Intrensic	
Total (Option) Value	**$0.031**

68% Volatility, $0.080 Underlying



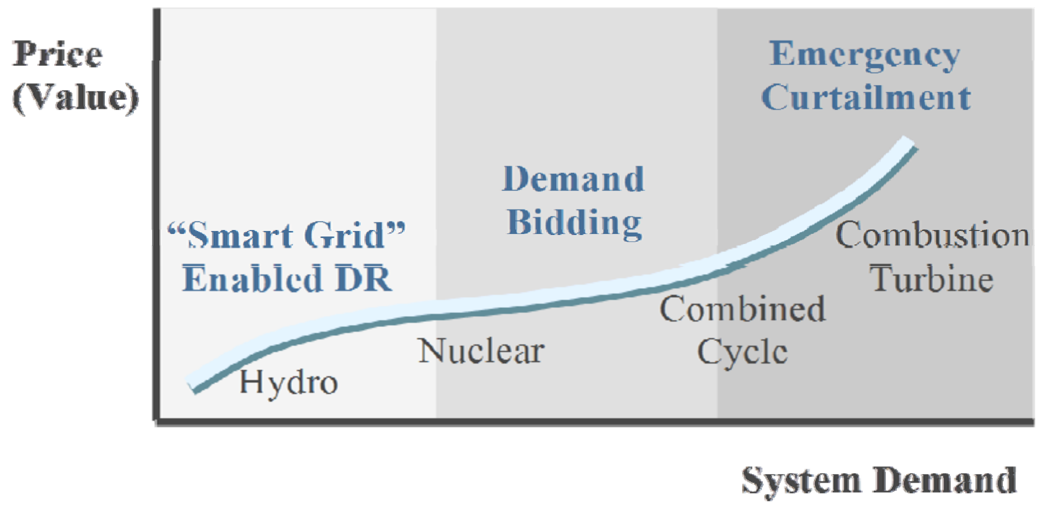
Option Value Payoff Diagram

Smart Technology Investments

- Smart Grid Technology
  - The benefits of DR can extend to all peak hours through demand bidding and “smart dispatch” in coordination with traditional supply resources
  - Smart technology enables dynamic dispatch (DD) and virtual power plant (VPP) applications

Smart Technology Investments

– The unique characteristics of different demand response programs allow direct comparison to unique fossil resources



– This approach can be used to measure DR program cost effectiveness and the appropriate incentive payments

Example Advanced AMI Study - Residential Results

Assumes average annual residential:

- bill = ~$1,758 ($147/mo)
- kWh consumption = 18,949 kWh (1,579 kWh/mo)
- peak kW = 4.93 kW

	Minimum	Maximum
% Annual kWh Savings	0%	28%
% Annual kW Savings	0%	47%
% Avoided Cost	6%	35%
% Customer Bill Reduction	3%	25%

NOTE: Assumes each home can only be independently optimized (e.g. no benefit provided by scheduling two or more homes together).

Conclusion

- As direct load control and demand response programs are increasingly added to long-term resource adequacy plans, the need to accurately measure the value and appropriate quantity of these benefits will intensify.
- Although limits exist, both the maximum attainable coincident savings and the value of the DR portfolio could potentially improve if programs are better designed to account for the uncertainty of supply and demand and the benefits of new smart grid technologies.

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