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# The Benefits and Challenges of Data-Based Management in Power Systems

## Lessons Learned from Three U.S. Case Studies

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March 13, 2012

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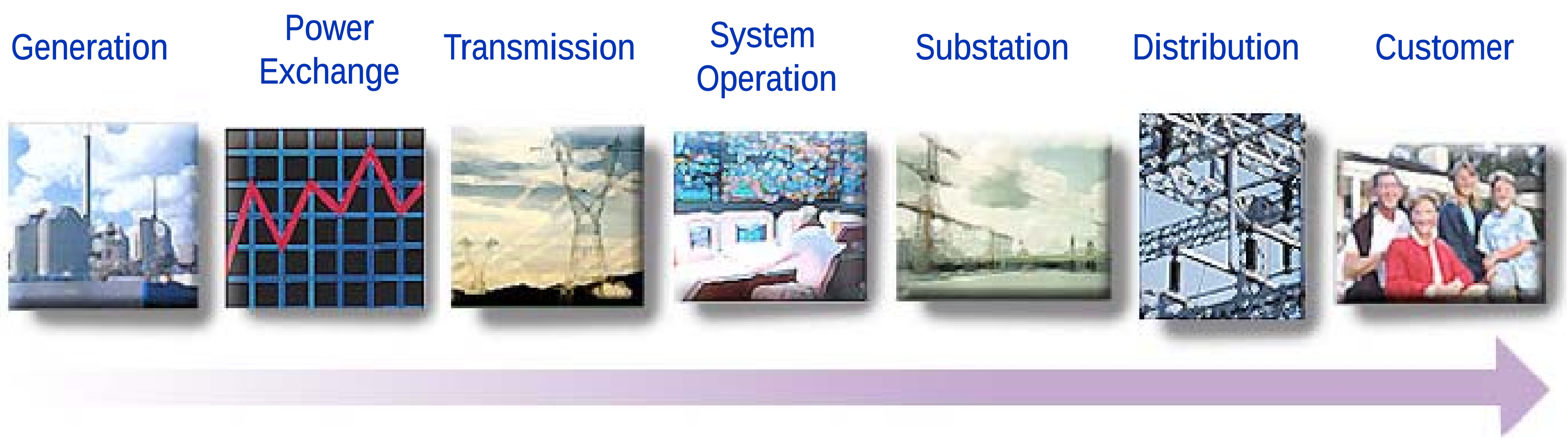


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# Topics

Benefits & Challenges of Data-Based Power Systems Management

Introduction

Integration of Demand Response into the Wholesale Markets

Voltage Conservation

Visibility & Control of Distributed Energy Resources

Conclusions & Recommendations

# Introduction

- Three case studies examine the role of data in advanced energy resources
  1) ***Demand Response***: integration with the wholesale markets
  2) ***Voltage Conservation***: program implementation and savings measurement & verification
  3) ***Distributed Energy Resources***: visibility and control of distributed supply (PV); load resources (DR); energy storage; and combination (microgrid, electric vehicle, combined heat and power)
- This presentation highlights potential benefits and liabilities in each case…
  - Benefits: energy savings, increased reliability and emissions reductions.
  - Liabilities: supply-demand imbalances & reduced power quality
  - Proper integration can emphasize benefits over liabilities
- And what role power system data might play in facilitating successful integration
  - Improved monitoring and better access to grid data allows operators to more readily identify and respond to or even prevent system events.
- Findings highlight the fact that data can play an important supporting role in both electricity grid and market operations and indicate the need for additional research.

# Smart Grid Investment & Deployment


*Source: SmartGrid.gov*

Smart grid deployment across the U.S. is developing capability throughout all portions of the electricity grid.


*LEGEND*
AMI = Advanced Metering Infrastructure
CS = Customer Systems
DS = Distribution Systems
EM = Equipment Manufacturing
IS = Integrated Systems
TS = Transmission Systems
RD = Regional Demonstration
SD = Storage Demonstration

*Source: Smart Grid Information Clearinghouse*

# "Markets 3.0"

Wholesale energy markets have evolved that strive to optimize the economics and competition around supply and demand. These markets are characterized by the following trends:

- *Need to manage new products* such as Demand Response, Energy Storage, and Variable Energy Resources

- *Penetration of and coupling with retail resources* –use of DG and smart load resources from the industrial, commercial and residential sectors

**Markets 3.0** ***2011-2020***
- Dynamic retail pricing
- DR for ancillary services
- Capacity markets for firming & DR
- Intra-hr scheduling of renewables
- Storage as a resource

**Markets 2.0** ***2001-2010***
- Co-optimized energy & ancillary services
- Congestion pricing
- Nodal real time dispatch
- Capacity markets for DR

**Markets 1.0** ***1995 - 2003***
- Wholesale day ahead energy on hourly schedules
- Ancillary services
- Balancing and regulation
- Transmission rights

# Voltage Conservation Timeline

**1976** — California PUC: Utilities directed to modify service voltages to 120-114V where cost effective.

**1981-1984** — EPRI evaluates Conservation Voltage Reduction

**1987** — BPA Study : Assessment of Conservation Voltage Reduction in the BPA Service Area

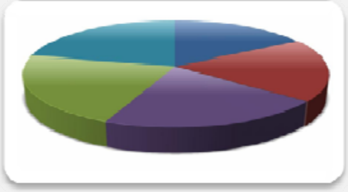
**2003-2007** — BPA & NEEA – Distribution Efficiency Initiative: Confirmed and validated costs, benefits, & implementation options & tools

**2009** — EPRI Green Grid Initiative: Confirmed the NEEA DEI Study results of 1 to 3 percent energy savings.

**2010** — BPA formed the Distribution Efficiency Technical Workgroup (TWG). Approved simplified protocol May 2010

*Source: Based on PECO 2010*

# Project Overview: Demand Response Market Integration

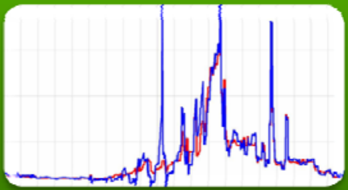


## Estimate Demand Response Potentials by Type

Identify potential penetrations of dispatchable demand response (DDR) and dynamic pricing demand response (DP) on NYISO's system by 2020.


## Develop Model to Assess Market Integration

- Examine real time energy markets
- Explore dynamics by capturing timing of clearing and dispatch



## Identify Impacts and Implications

- Determine impacts on market prices and supply dispatch
- Examine successful ways for integrating DP and DDR resources

# Demand Response: DDR versus DP[1]

- Dispatchable Demand Response (DDR):

"*Dispatchable demand response" refers to planned changes in consumption that the customer agrees to make in response to direction from someone other than the customer. It includes direct load control of customer appliances such as those for air conditioning and water heating, directed reductions…and a variety of wholesale programs offered by RTOs/ISOs that compensate participants who reduce demand when directed for either reliability or economic reasons…"*

- Dynamic Pricing (DP) response:

*A "customer decides whether and when to reduce consumption based on a retail rate design that changes over time. This is sometimes called retail price-responsive demand and includes dynamic pricing programs that charge higher prices during high-demand hours and lower prices at other times…"*

[1] Source: FERC's National Action Plan for Demand Response, June 2010 @ http://www.ferc.gov/legal/staff-reports/06-17-10-demand-response.pdf

# Market Models

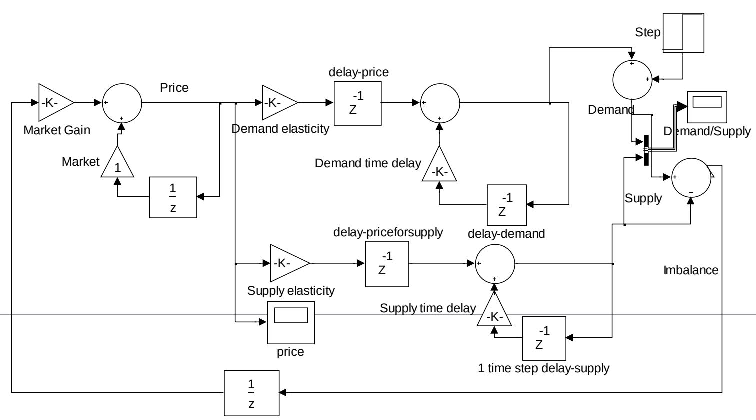
Theory

Simulation

## Process Control Model

***Simple market model based on control theory - captures generation & demand time dynamics***

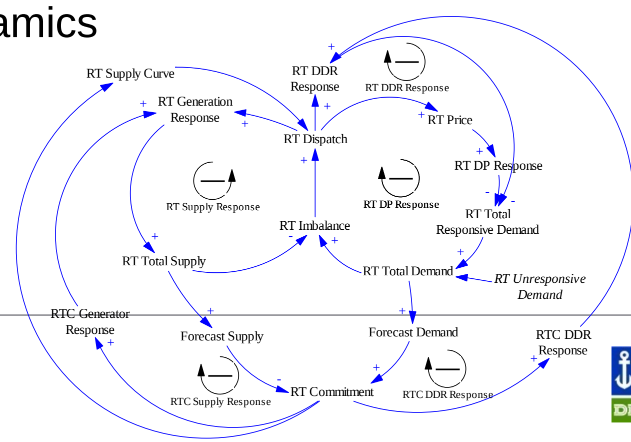
- Supply-demand imbalance is input to clearing function which adjusts price according to supply & demand elasticities.
- Feedback gain is inverse of sum of supply & demand elasticities. Delay equals periodicity of market clearing function.
- Critical parameters: price elasticity ratios, time delay ratios ; demand  elasticity error




## System Dynamics Model

***Detailed dynamic model of an ISO market operation using system dynamics***

- Non-linear supply curves representative of a real market & non-linear demand curves based on published research.
- Integrates day ahead, hour ahead, and real time energy market processes.
- Includes residential and commercial end-uses (HVAC, lighting, water heating, refrigeration).
- Does not predict price but captures market dynamics



# Resource Benefits & Liabilities

- **Benefits:** Widespread source of an economic, low-emissions power resource
- **Liabilities:** Deviations between expected and actual and present-day difficulty in forecasting voluntary response

***A. Some regimes of demand side integration into the markets can result in unstable or undesirable market behavior.***

Modeling considered dynamics of generation, demand, and market operation interactions. Scenarios of different relative supply and demand elasticities, and of different demand elasticity forecast errors demonstrates that there are regions where the system will not be stable.

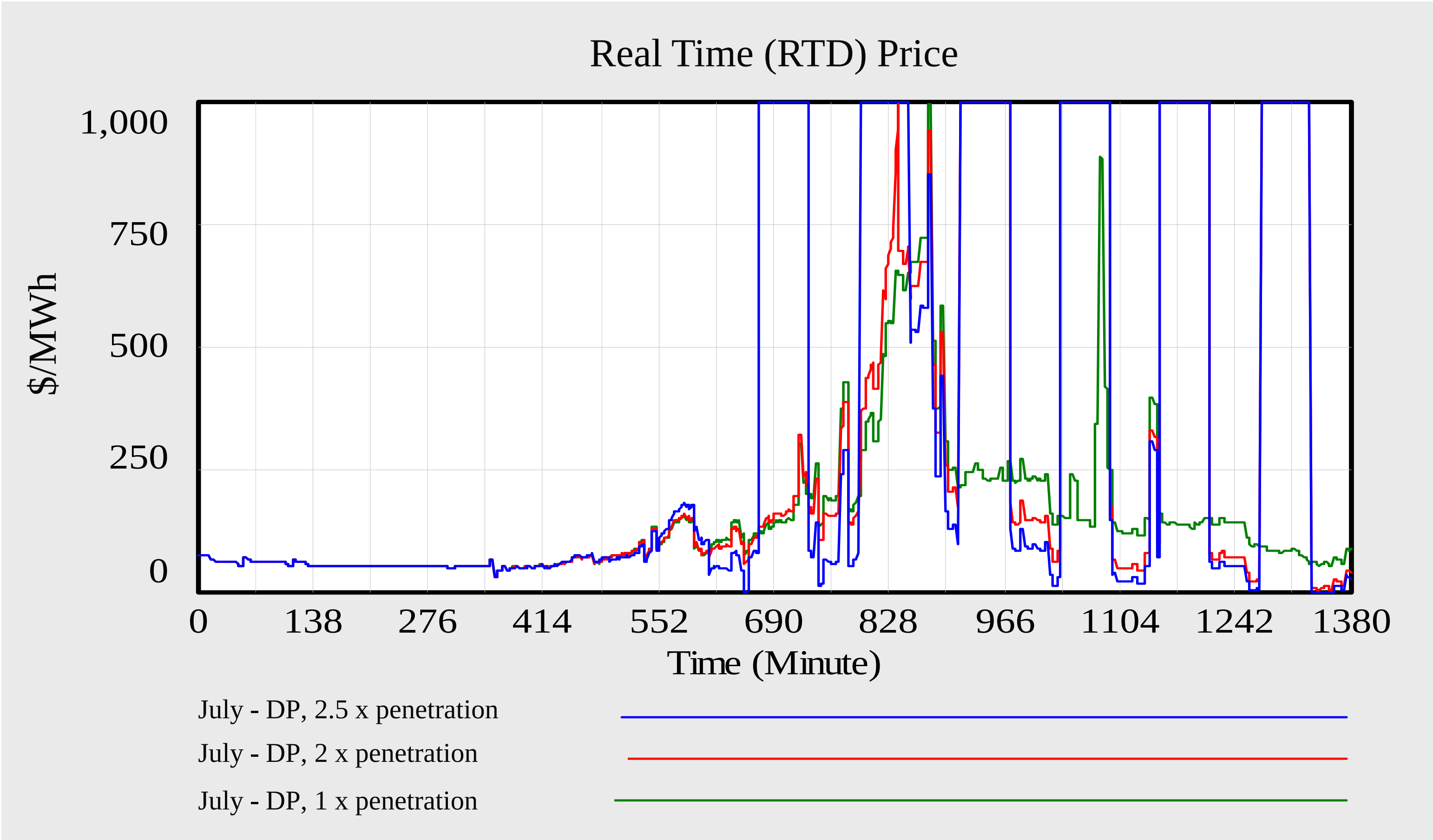
***B. Alignment of demand side resources with market products in terms of technical performance is critical to stable market behavior.***

If the generation is “slower” than the load response then instability can occur.

- If generation is faster than demand & the market, the system is always stable.
- If that condition is not met, then for some ratios of generation & demand elasticity the system will become unstable.
- If the market is “aware” of demand elasticity & factors this into the clearing, then the system is stable. The market stability is sensitive to the magnitude of error in estimating demand elasticity.

# Modeling Results (cont'd)

- DP impacts are very sensitive to DP penetration, demand elasticity, and the accuracy of  estimated demand elasticity in the market clearing algorithms.




*As the amount of DP in the market increases, price potentially increases and can grow to be volatile.*

# Study Conclusions

- Markets should explore how to **integrate demand elasticity into market clearing algorithms and load forecasting**, and how to estimate demand elasticity on an ongoing basis.
- **Aligning the duration and delays of DDR & DP resources with the frequency of market clearing** & dispatches is an essential aspect of integrating these resources into wholesale markets and operations.
- **Market clearing algorithms should include actual DDR response** and its duration (compared to expected response) in the load forecasting process
- The role of **self-optimizing customers** (SOCs) with grid-connection should be examined closely. Initial research shows that their behavior is unique and that without proper consideration, their loads **can lead to unstable behavior**.
- **Factoring SOCs into the market clearing will become critical**, either via a bid offer process that leads to known schedules or via a cross-elasticity process integrated with load and production forecasting. Either one requires the markets to have more information of SOC behavior.

# The Role of Customer Data

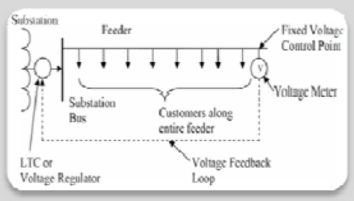
**Customer data provides a means for assessing or forecasting the response of demand resources**

- Customer data can assist DDR implementation by monitoring actual performance (size and duration) so actual response can be included it in the market clearing process.
  - *"Market clearing algorithms should include actual DDR response and its duration (compared to expected response) in the load forecasting process"*
- Customer data can also assist with load elasticity forecasting by providing a basis for estimating demand response based on prices, season, time of day, etc.
  - *"Markets should think about how they will integrate demand elasticity into market clearing algorithms and load forecasting, and how they will estimate demand elasticity on an ongoing basis."*
- Information on self-optimizing customers will facilitate understanding and integrating these unique profiles into the markets.
  - *"The role of self-optimizing customers with grid-connection should be examined closely. Initial research shows that their behavior is unique and that without proper consideration, their loads can lead to unstable behavior."*

# Project Overview: Voltage Conservation EM&V

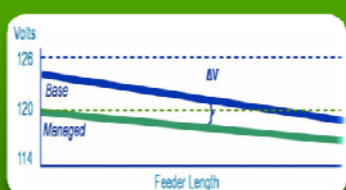
## Identify Analysis Methods and Time Periods of Analysis

Identify available data and define evaluation controls / baselines




## Create a Framework to Assess

- Develop statistical or engineering models to analyze differences between controls/baselines and active program




## Evaluate, Measure and Verify Program Savings

- Estimate energy savings (system and customer)
- Identify any process improvements to facilitate future program implementation and evaluations

# Three Voltage Regulation Techniques

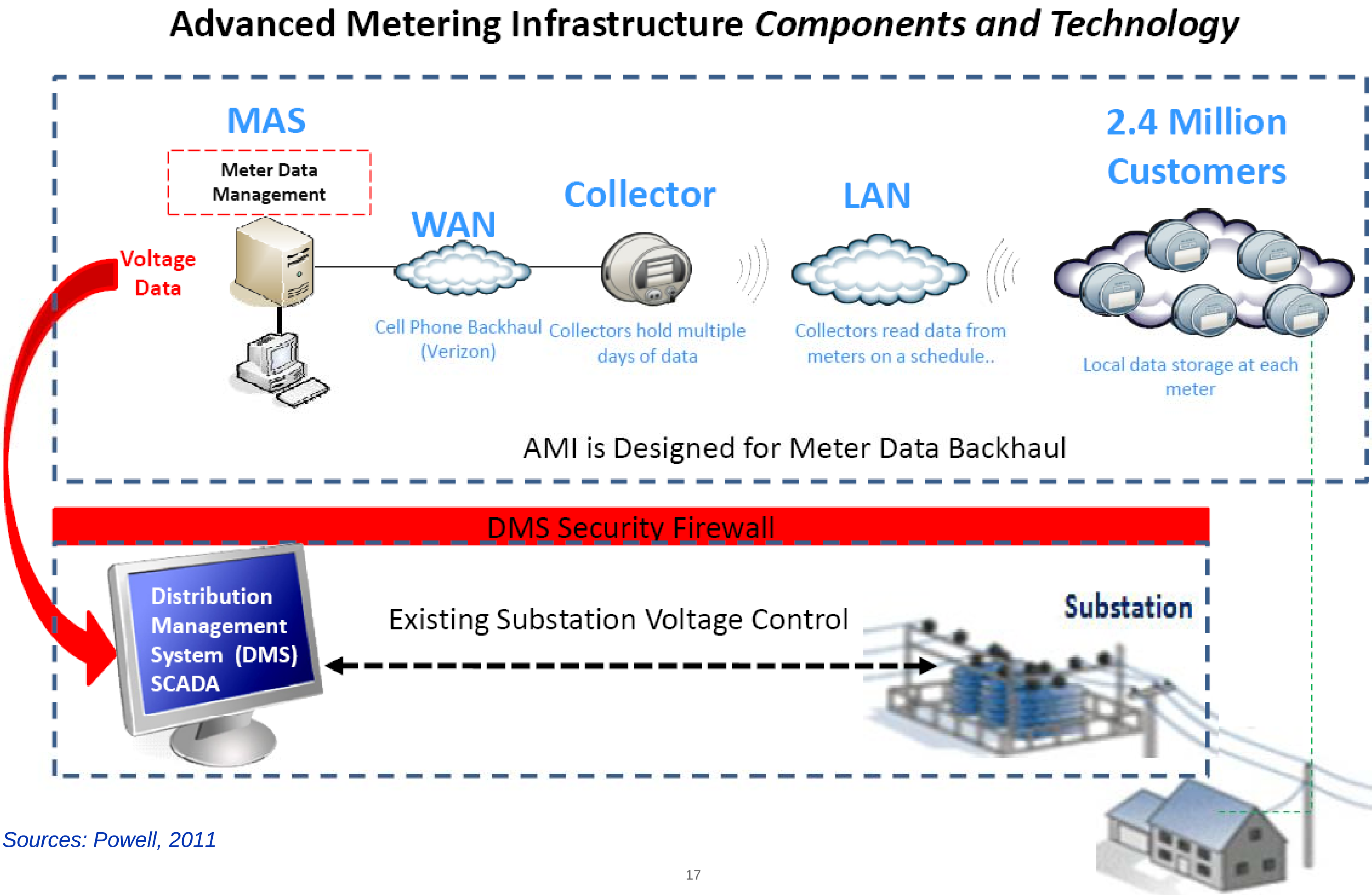
1. Voltage Fixed Reduction (VFR)
   - Fixes the voltage level at the substation source and the voltage level at the end of the feeder varies with load
2. Line Drop Compensation (LDC)
   - Fixes the voltage level at the end of the feeder and the voltage level varies at the substation source with load
3. Automatic Voltage Feedback Control (AVFC)
   - Fixes the voltage level at the substation source based on real-time voltage feedback sign from the end of the feeder

**Model:** **(+)** No infrastructure outlays or communications investments required
**(-)** Can be complex, can requirement maintenance

**Measure:** **(+)** Allows for feedback to control CVR in "real-time" based on activities
**(-)** May require communications / infrastructure upgrades

*Sources: BPA 2011; Brancaccio, 2011*

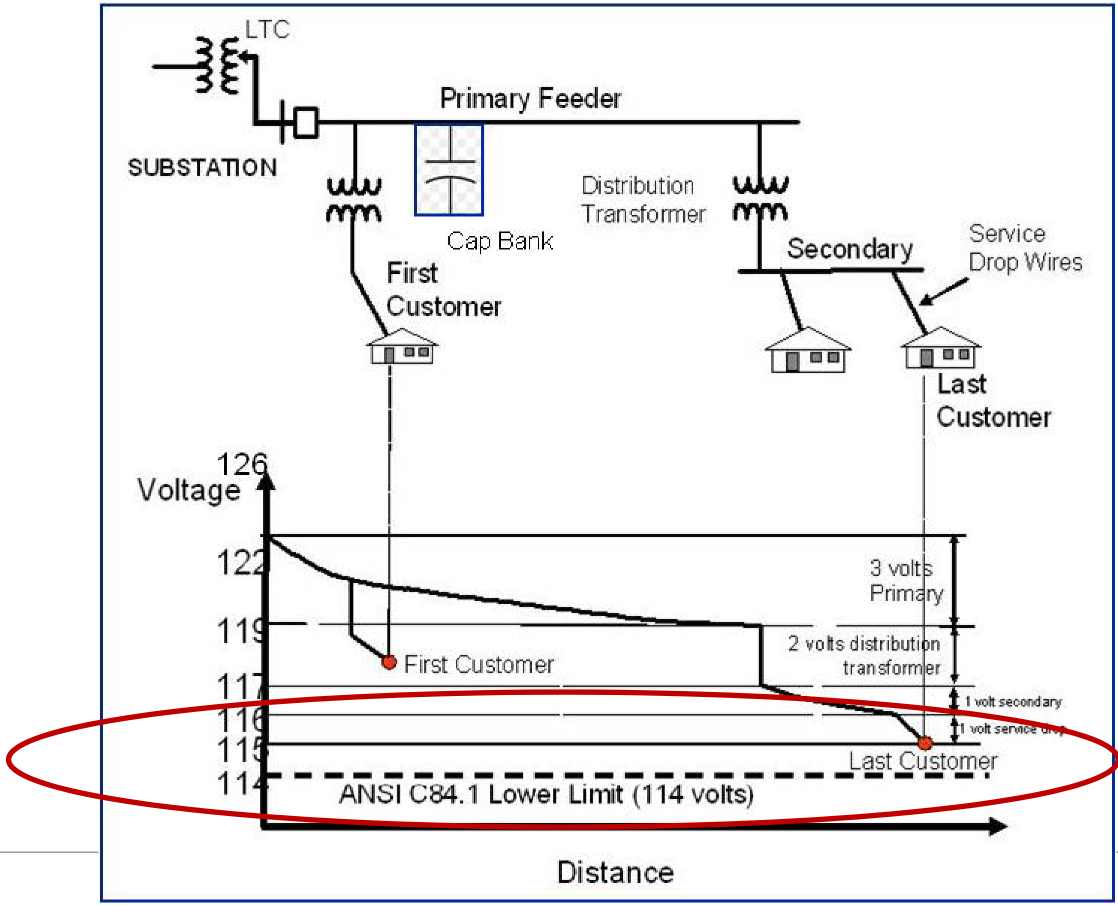
# Feedback Challenges




*Sources: Powell, 2011*

# Resource Benefits & Liabilities

- Benefits: Passive program for energy savings; potential for improved system performance
- Liabilities: Out of range operation for a set of customers, impacts to end-use performance




*Source: http://abbmvit.blogspot.com/2012/01/voltage-conservation-reduction-simple.html*

# Measurement & Verification

## BPA: Four Stages to Simplified VO M&V Protocol

1. Existing Performance Assessment and VO Implementation Plan

- Historical Load Data
- Distr _Line Modeling
- Load_Flow Analysis
- Threshold Analysis
- Determine end-use VO Factor
- Estimate Potential Savings
- Install VO and SI Improvements

2. System Improvements Baseline Pre-VO measurements

- 7-day measurements 'OFF'
- Veol, Vset, Esub
- Calculate Vpre-annual average

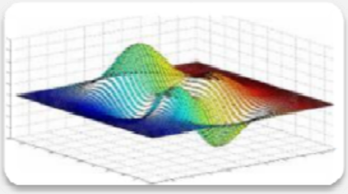
3. VO Implementation Post-VO Measurements and Verification

- 7-day measurements 'ON'
- Veol, Vset, Esub
- Calculate Vpost-annual average
- Determine Verified Savings

4. Persistence Measuremen

# Project Overview: CAISO DER

## Develop Forecasts and Identify Impacts



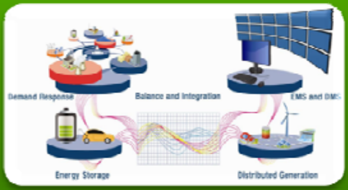
Identify penetration forecasts of Distributed Energy Resources (DER) on CA ISO's system by 2020, including:

- Distributed Utility & Customer Photovoltaic's
- Distributed Energy Storage
- Demand Response
- Combined Heat and Power (CHP)
- Self Optimizing Customer
- Plug In Electric Vehicles

## Create a Framework to Assess


- CA ISO current visibility of these Distributed Energy Resources
- Benefits of reduced uncertainty through monitoring
- Reduce variability through various control technologies

## Identify Implications



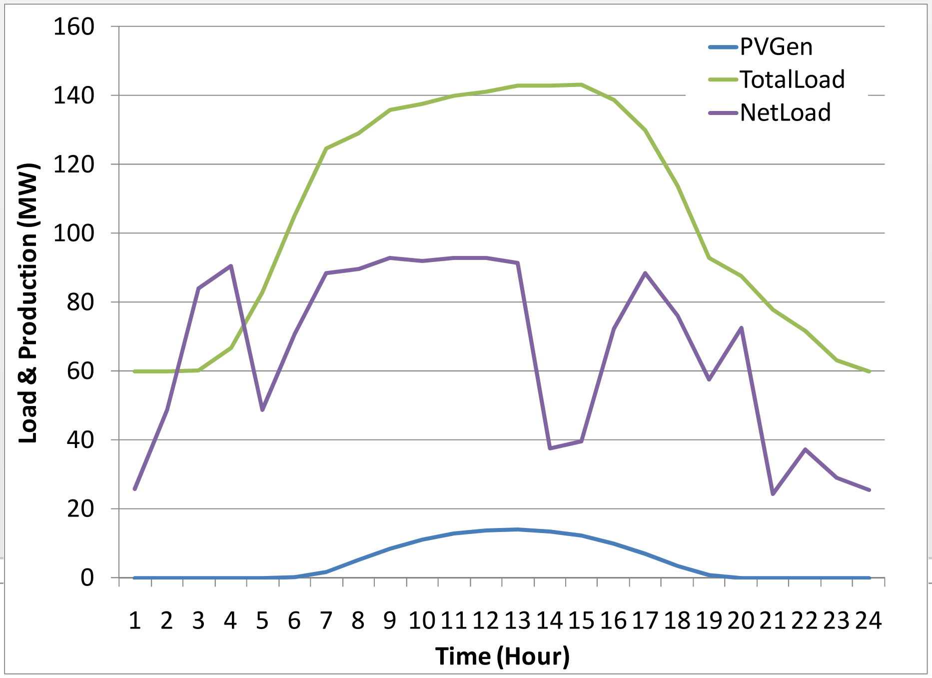

- Determine Benefit/Costs of DER visibility
- Determine Road Map for technology improvements to current visibility requirements

# Resource Benefits & Liabilities

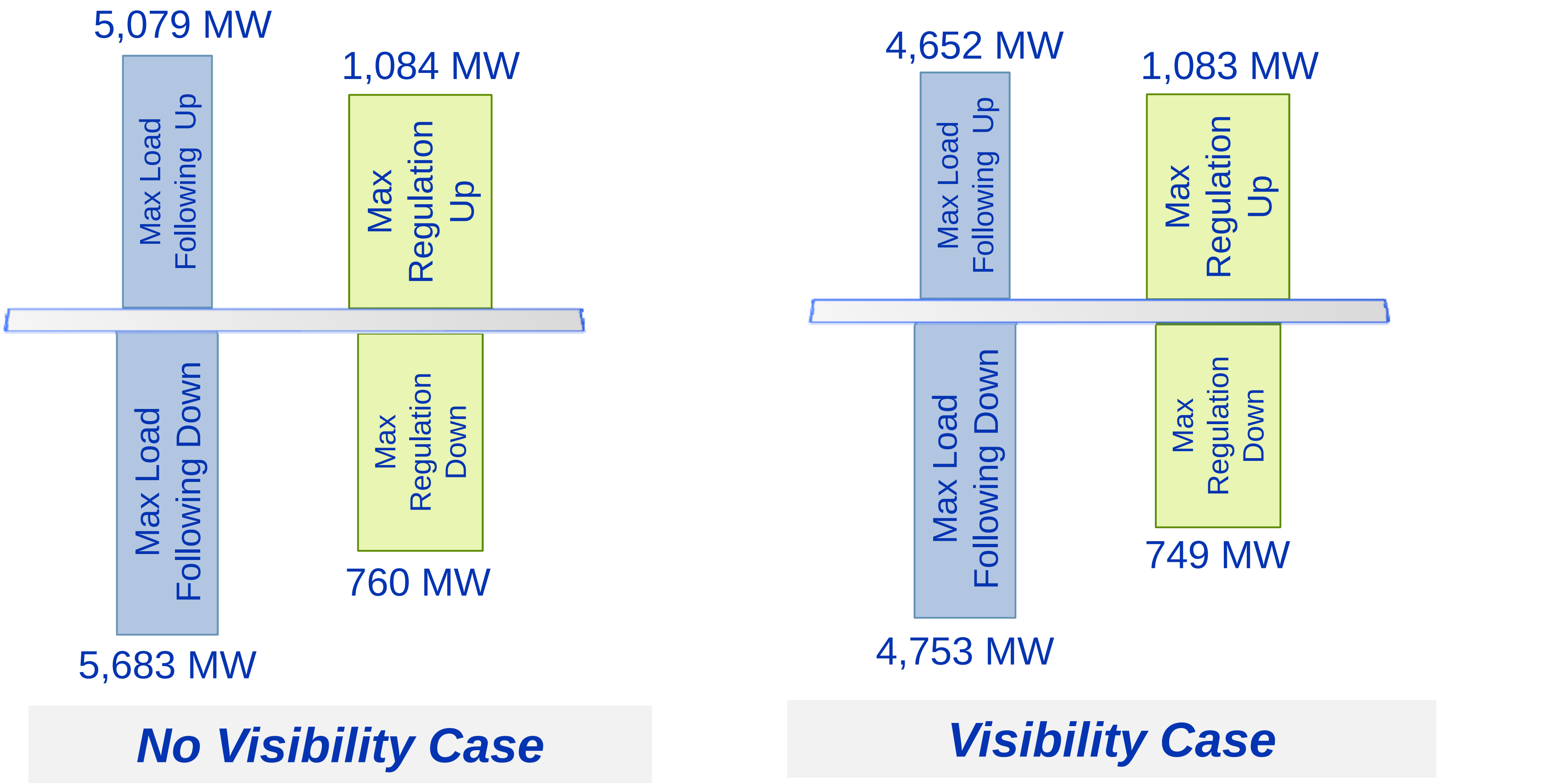
- Benefits: Harnessing local resource set; increase reliability; reduce emissions
- Liability:  Difficult to forecast net loads; de-centralized controls / reduced dispatch capability

***A. High DER penetration leads to forecast uncertainty and increased production costs***

***B. The variability of DER assets make forecasting without visibility more uncertain***

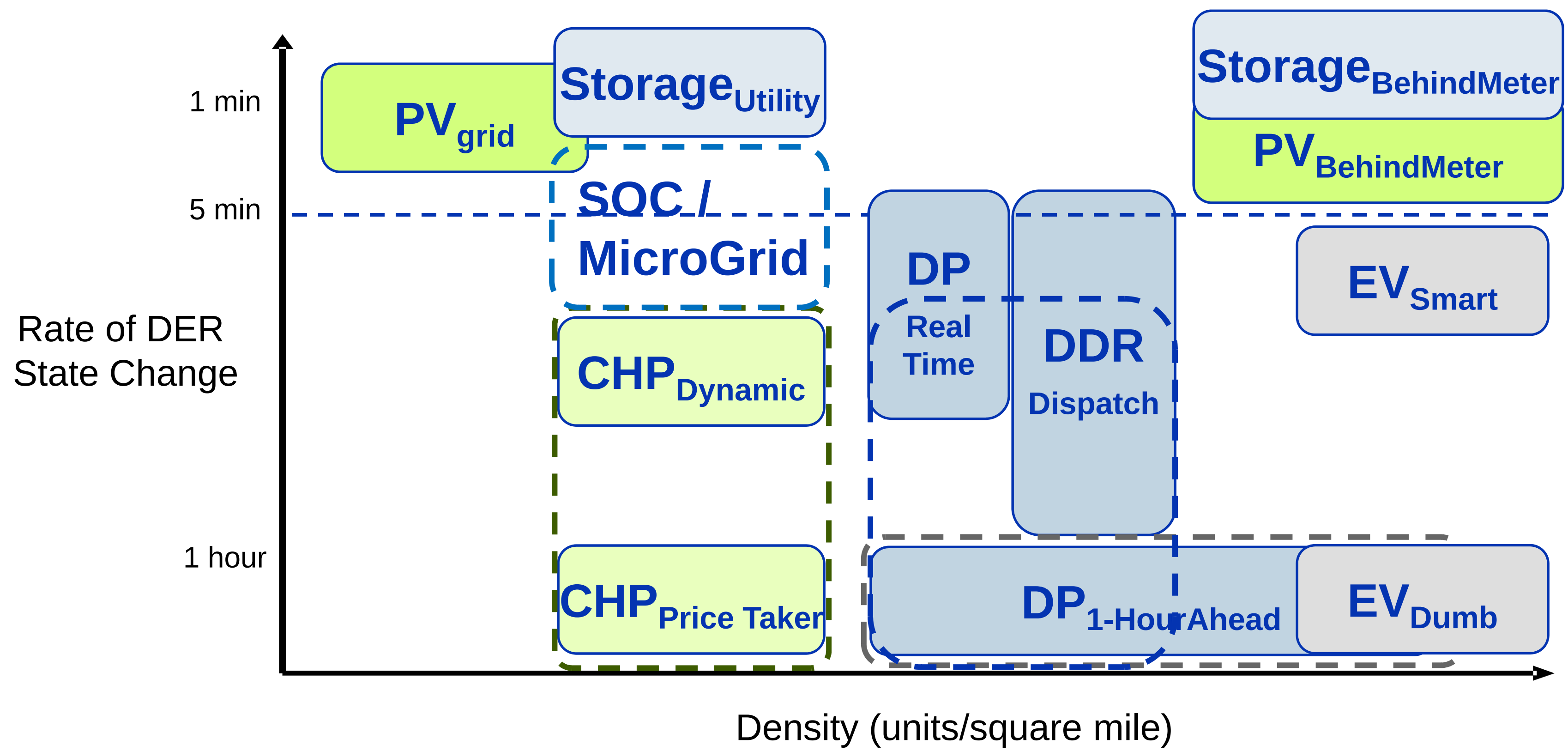


# Visibility Reduces Maximum Load Following Requirements




What impact will different penetrations of DER have on the ISO requirements for regulation and load following?

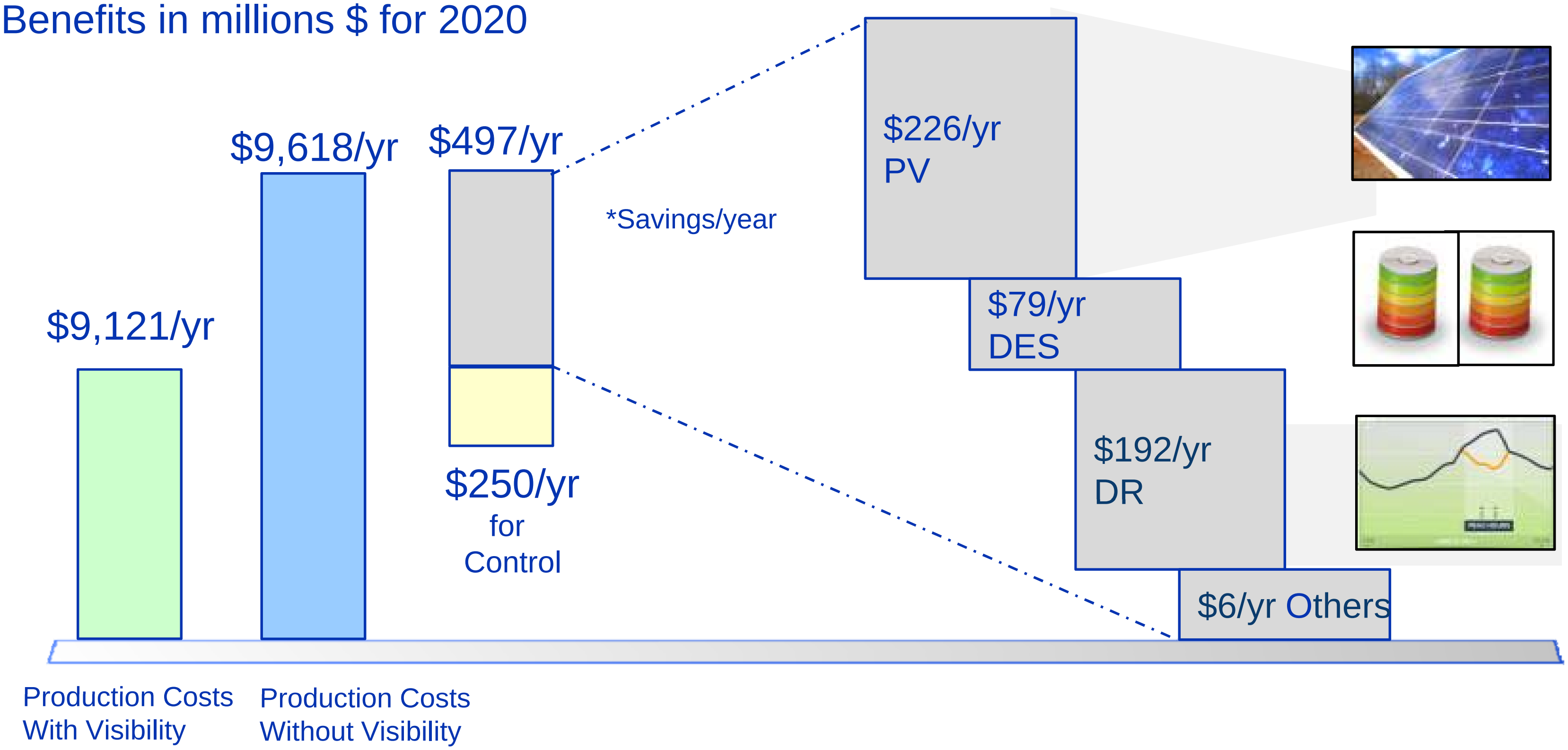
# Drivers for Communications Technology and Costs




Device density and rate of change are the drivers for communications technology and costs.

# Visibility Impacts by Resource Type

Benefits in millions $ for 2020




Visibility of PV, Distributed Storage and Demand Response can be expected to reduce production costs by more effective use of load following & regulating reserves

# Critical Policy and Standards Issues

- Visibility as part of DER Interconnection Standards and for Access to Real Time Pricing
- Smart Inverter Communications I/O Standard
  - Wireless technology life cycles are 2-3 x faster than DER asset lives. Adoption of any common carrier wireless services saves costs at the risk of early obsolescence. An open I/O standard is a risk mitigation that allows adoption of widely available low cost communications
- Models for how socialized market benefits are used to cover DER visibility costs that are borne by DER owners / aggregators.
  - Control costs will be part of the overall economics of DR – market payments for DR have to cover the convenience and technology costs
- Ongoing review of NIST standards to ensure DER visibility is adequately addressed
- Provisions for collection and maintenance of DER data – size, location, etc.

# The Role of System Data

- **Customer and distribution system data can assist with implementation of novel energy approaches**
  - Real-time feedback can assist operations
    - ‘Real-time’ CVR controls
    - Visibility to assist with forecasting
  - Archives can assist measurement & evaluation , guiding future implementation
- **Challenges remain**
  - Difficulties exist in aligning data systems (e.g., internal firewalls)
  - Investments are required to facilitate
    - The incentive to invest must exist (revenue losses, no requirement to invest, etc.)
    - In some cases, regulators must see value  to approve expenditures
  - Rules must be developed to coordinate technologies
  - The ‘right’ data must be collected
    - Data overload can bog down analyses
    - Sampling can help with measurement and verification but approaches must be defined
    - Data needs to be collected in a way that helps address the question at hand  (e.g., demand elasticity needs more than just load data)

# Thank you

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