

# Smart Grid Technologies

## Professional Development Course

*ASME-IEEE-FSU CAPS-USF PCUE*

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# Agenda

- **What is a Smart Grid?**
- **How does it fit together?**
- **Is it worth it?**
- **Will we ever get there?**
- **What are the next steps?**
- **Q&A**



# Initial Role – Modern Grid Strategy

## *Mission – Accelerate grid modernization in the US*

- Develop a vision for the Smart Grid
- Reach out to stakeholders to get input and consensus
- Assist in the identification and resolution issues
- Act as an “independent broker”
- Promote testing of integrated suites of technologies
- Communicate concepts to assist interested stakeholders
- Began in January 2005

*MGS Concepts form the foundation for the US Smart Grid vision*



# New Role – Smart Grid Implementation Strategy

*Mission – To accelerate the transition to a smart grid through the development of implementation strategies and tools*

- **Create a national interest in “Performance Feedback”**
- **Continue to communicate and educate stakeholders on fundamental SG concepts**
- **Develop SGI case studies on key topical areas**
- **Provide technical support to industry groups as requested**

*Continue to act as an “independent broker”*





## **What is a Smart Grid?**

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# How it Started — A Systems View





# What's different with the Smart Grid?

- De-centralized supply and control
- Two-way power flow
- Two-way information flow

*Creating the intelligence and capability to  
optimize:*

- *Reliability*
- *Security*
- *Economics*
- *Efficiency*
- *Environment*
- *Safety*

*...for all Stakeholders*

*Smart Grid is a Vision and a System*





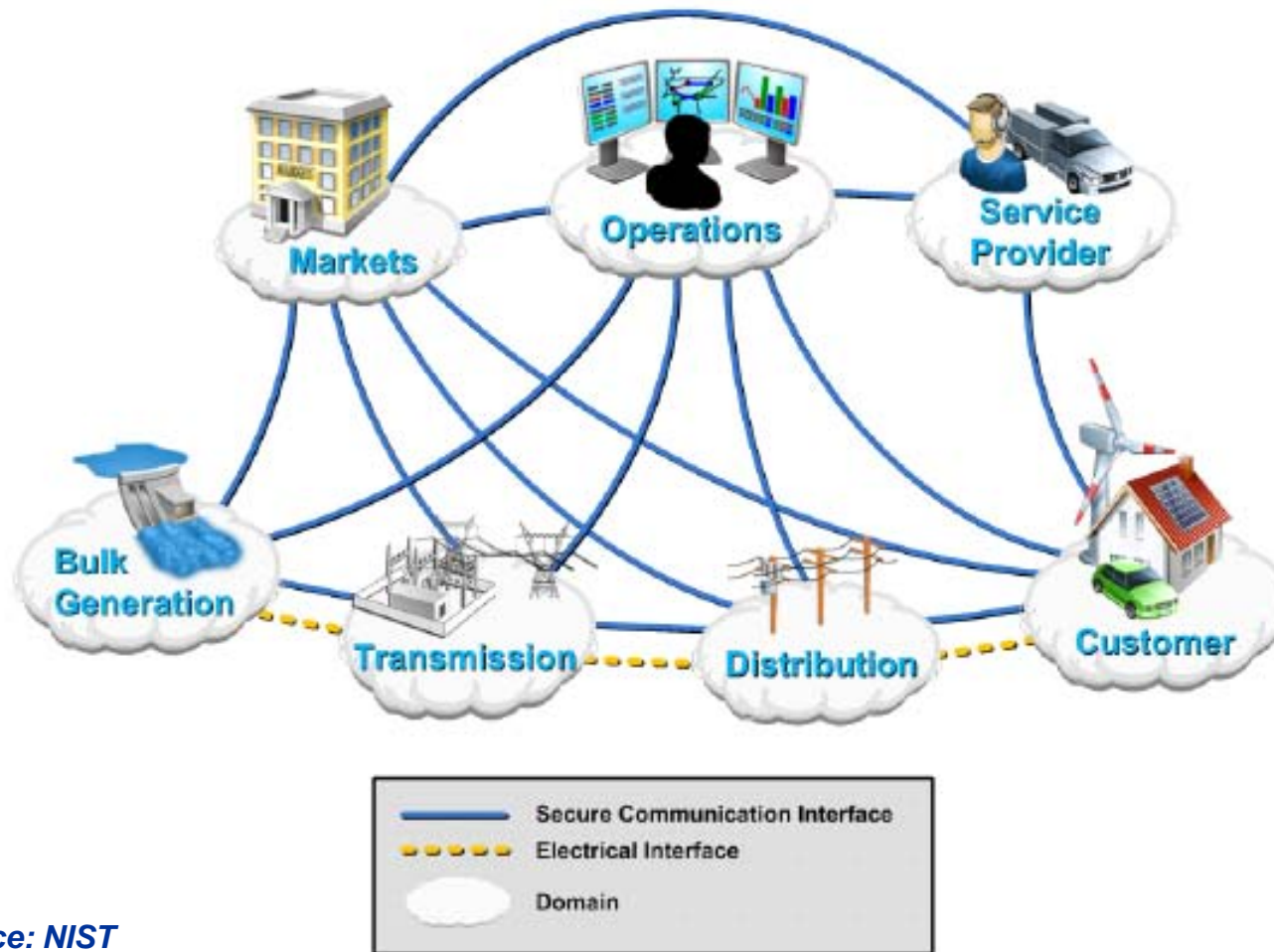
# What it isn't

- **Gadgets and Gizmos**
- **Electric Vehicles**
- **Wind Turbines**
- **Time of Use rates**
- **PMU's**
- **Renewable Portfolio Standards**
- **Internet**
- **GIS**

*It's not about the pieces—its about the system!*



# Smart Grid Conceptual Model



Source: NIST

# Smart Grid Characteristics

## ***The Smart Grid is “transactive” and will:***

- *Enable* active participation by consumers
- *Accommodate* all generation and storage options
- *Enable* new products, services, and markets
- *Provide* power quality for the digital economy
- *Optimize* asset utilization and operate efficiently
- *Anticipate & respond* to system disturbances (self-heal)
- *Operate* resiliently against attack and natural disaster

***...the enabler***



# *It will “Enable active participation by consumers”*

- **Consumers have access to new information, control and options to engage in electricity markets**
  - Reduce consumption and energy bill
  - Enable new technologies (PEVs, HAN, EMS, smart appliances, etc.)
  - Sell resources for revenue or environmental stewardship
  - Incentives to participate (i.e. smart rates)
- **Grid operators have new resource options**
  - Reduce peak load and prices through demand response
  - Improve grid reliability
  - Ancillary services

## *Today*

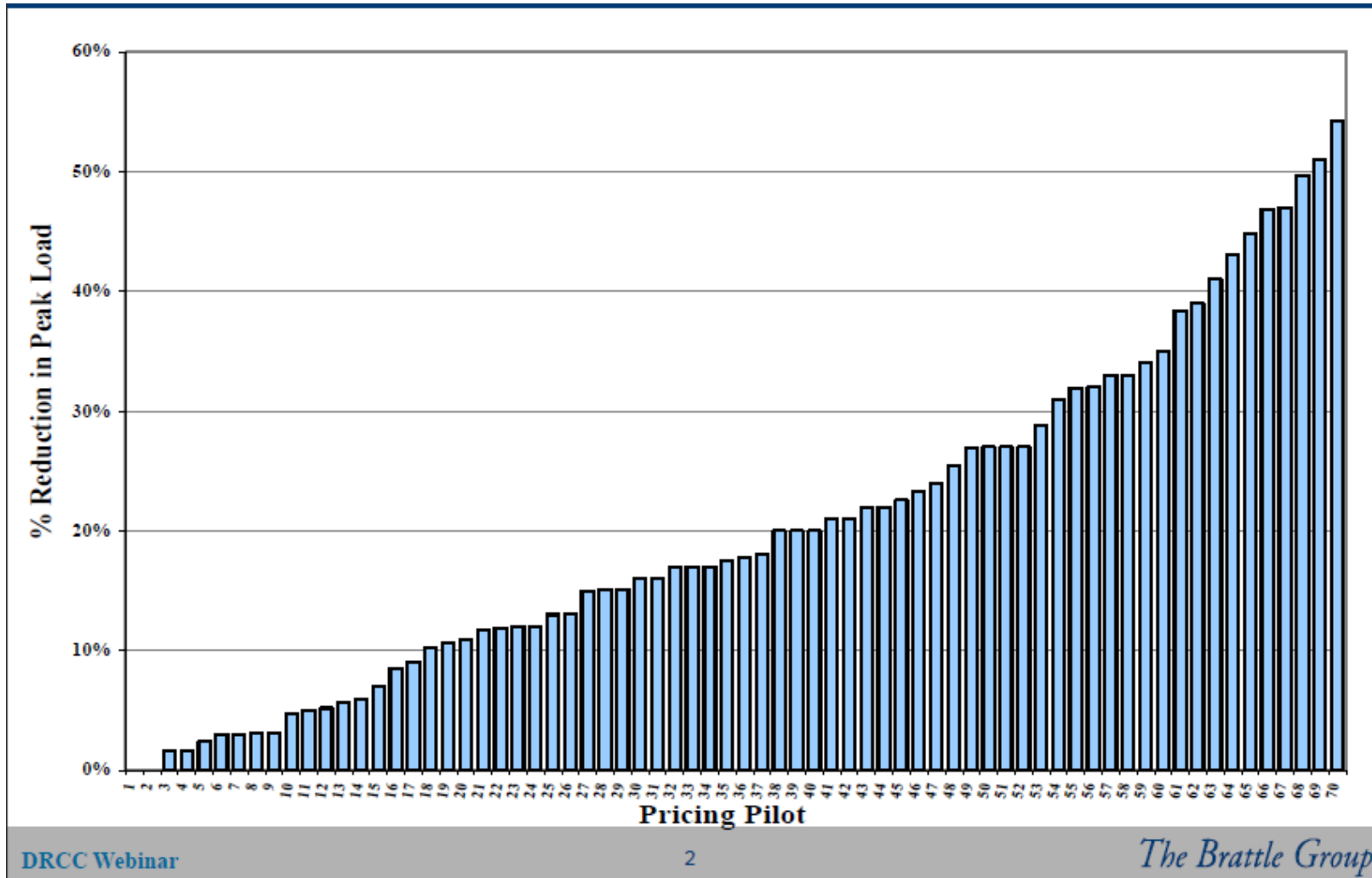
Little or no info, limited use of smart pricing, few choices

## *Tomorrow*

Full price info, choose from many plans, prices and options, buy and sell, “E-Bay”



# Lessons Learned From Pricing Experiments



# *It will “Accommodate all generation and storage options”*

- **Seamlessly integrates all types and sizes of electrical generation and storage systems**
- **“Plug-and-play” convenience**
  - Simplified interconnection processes
  - Universal interoperability standards
- **“Moves the needle”– shifts to a more decentralized model**
- **Large central power plants will continue to play a major role.**

## *Today*

Dominated by central generation. Little DG, DR, storage, or renewables

## *Tomorrow*

Many “plug and play” distributed energy resources complement central generation



# PHEV's Need the Smart Grid

- **Energy transactions**
- **Financial transactions**
- **Peak load management**
- **Smart Charging**
- **Mobile resource issues**
- **Vehicle to grid support**

*“Put 1 million Plug-In Hybrid cars – cars that can get up to 150 miles per gallon – on the road by 2015, cars that we will work to make sure are built here in America”.*

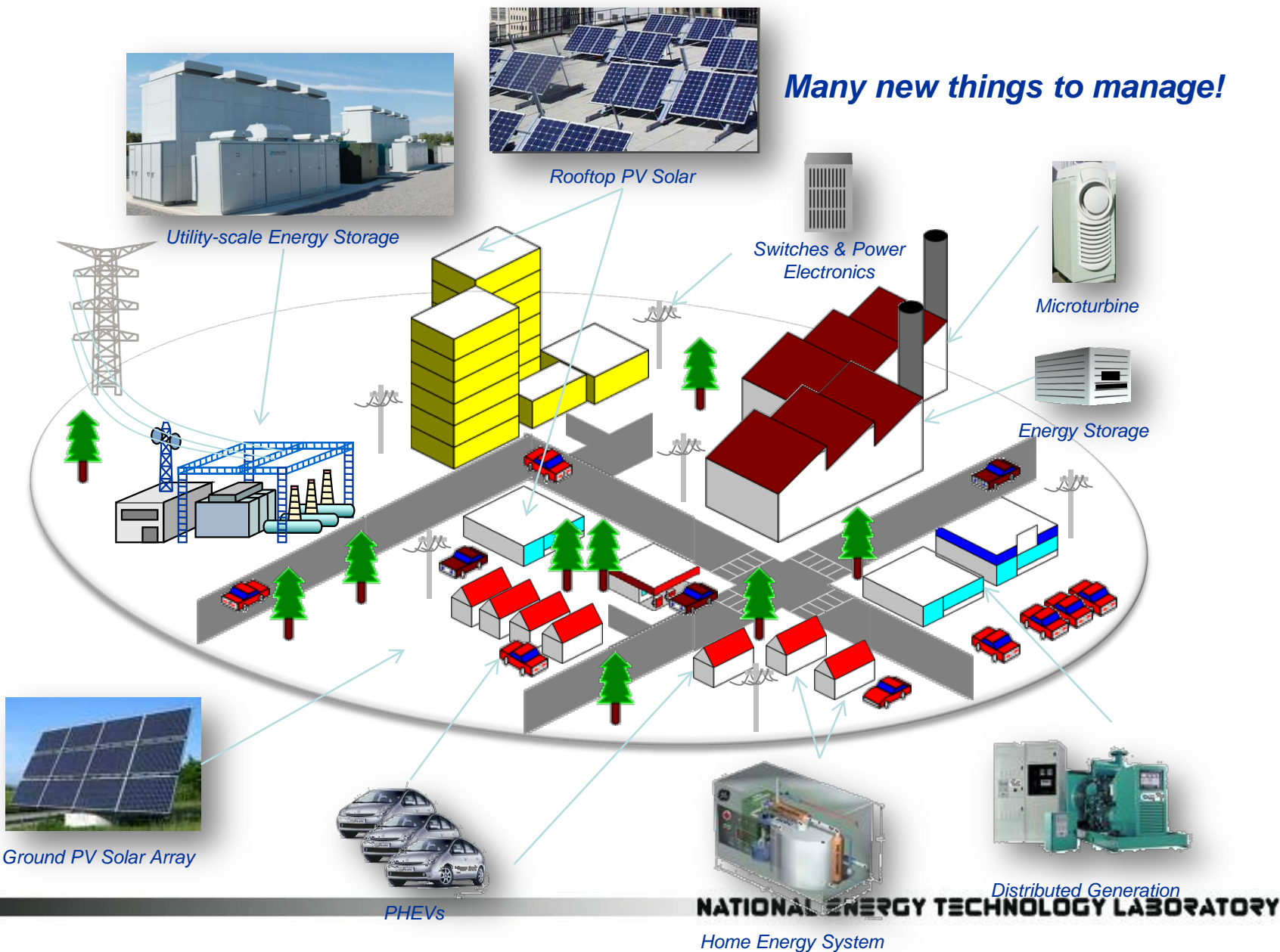
*The Obama-Biden Comprehensive New Energy for America Plan*





# Community Microgrid

*Many new things to manage!*



# *It will “Enable new products, services and markets”*

- **Links buyers and sellers – consumer to RTO**
- **Supports the creation of new electricity markets**
  - Demand Response
  - Energy, Capacity, Ancillary Services
  - Brokers, integrators, aggregators, etc.
  - In-home devices and applications
- **Provides for consistent market operation across regions**

## *Today*

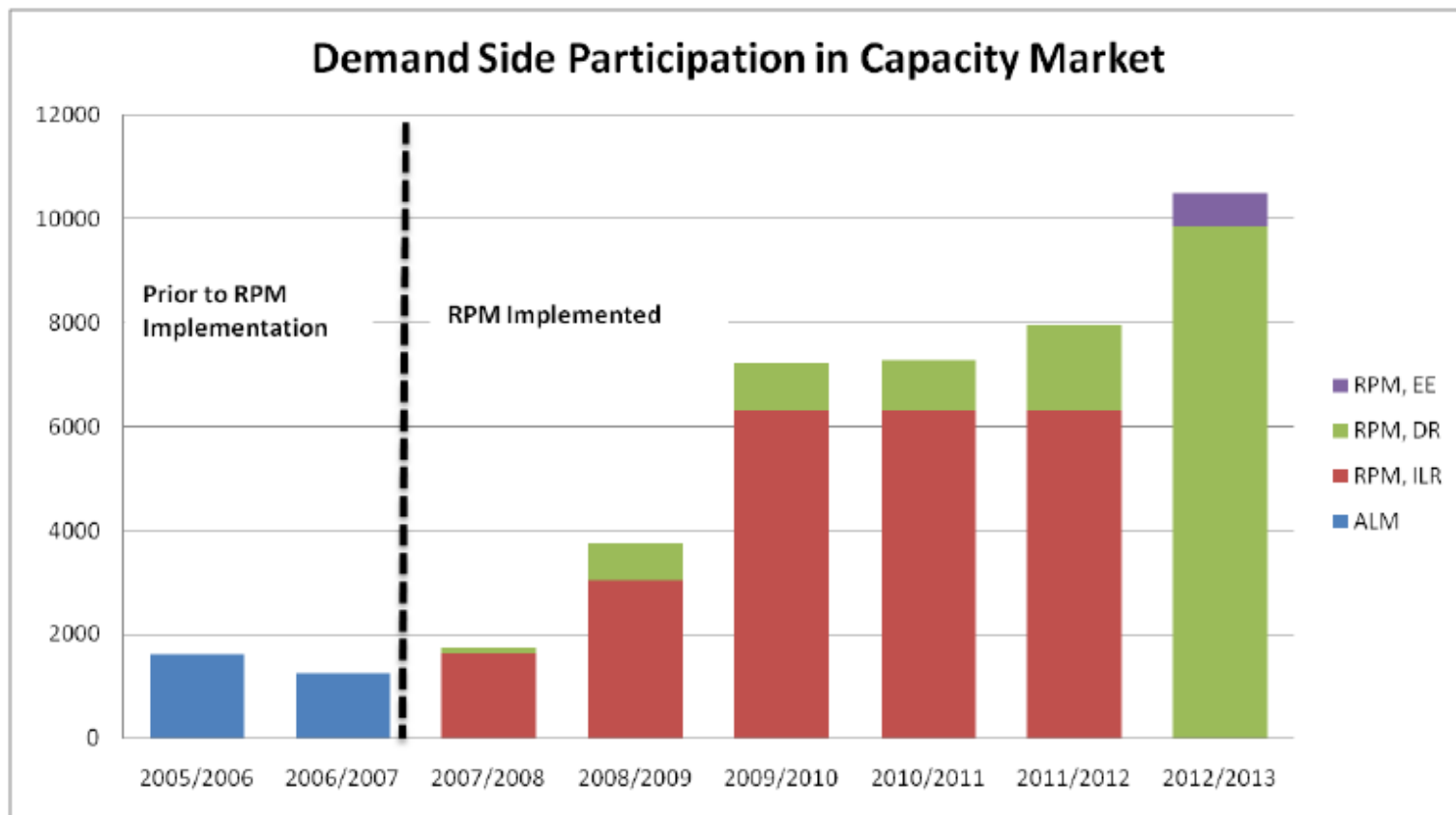
**Near-zero market interaction at distribution level**

## *Tomorrow*

**Distribution assets and consumers act as resources for transmission, growth of new secondary markets**



# Demand Side Markets



## *Demand Side Participation in the PJM Capacity Market*

# Other New Markets

- **Aggregators**
- **Energy Service Providers**
- **Financial Systems (PEV transactions)**
- **PEV's (kwh fuel, V2G, charging stations)**
- **Smart Appliances**
- **In-home Networks**
- **Home Energy Management Systems**
- **Others not yet known**



# *It will "Provide power quality for the digital economy"*

- **Monitors, diagnoses and responds to PQ issues**
- **Supplies various grades of power quality at different pricing levels**
- **Greatly reduces consumer losses due to PQ (~\$25B/year)**
- **Quality Control for the grid**

*Today*

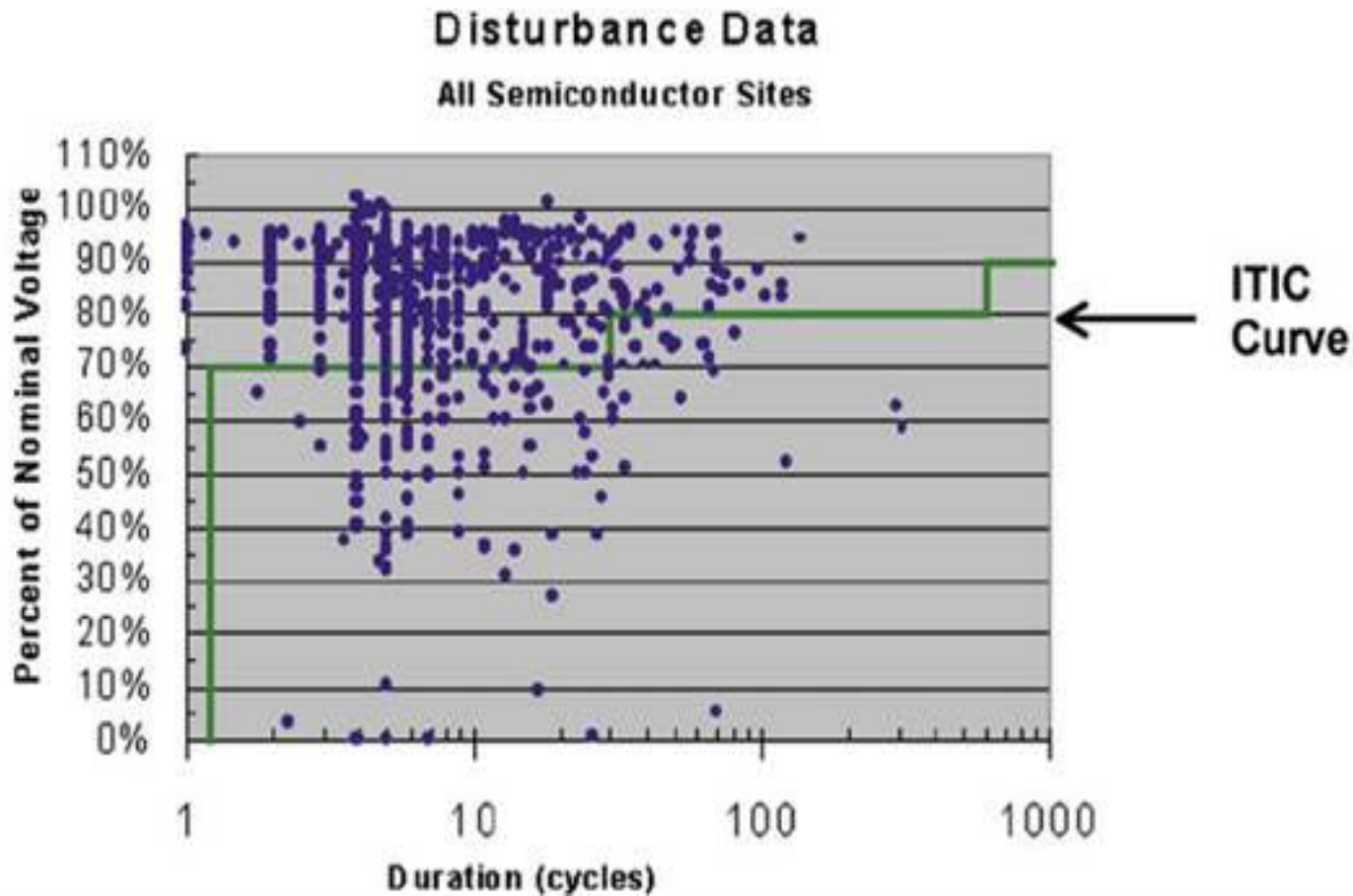
Focus on outages not power quality

*Tomorrow*

PQ a priority with variety of price/quality options based on needs



# System PQ “Performance”

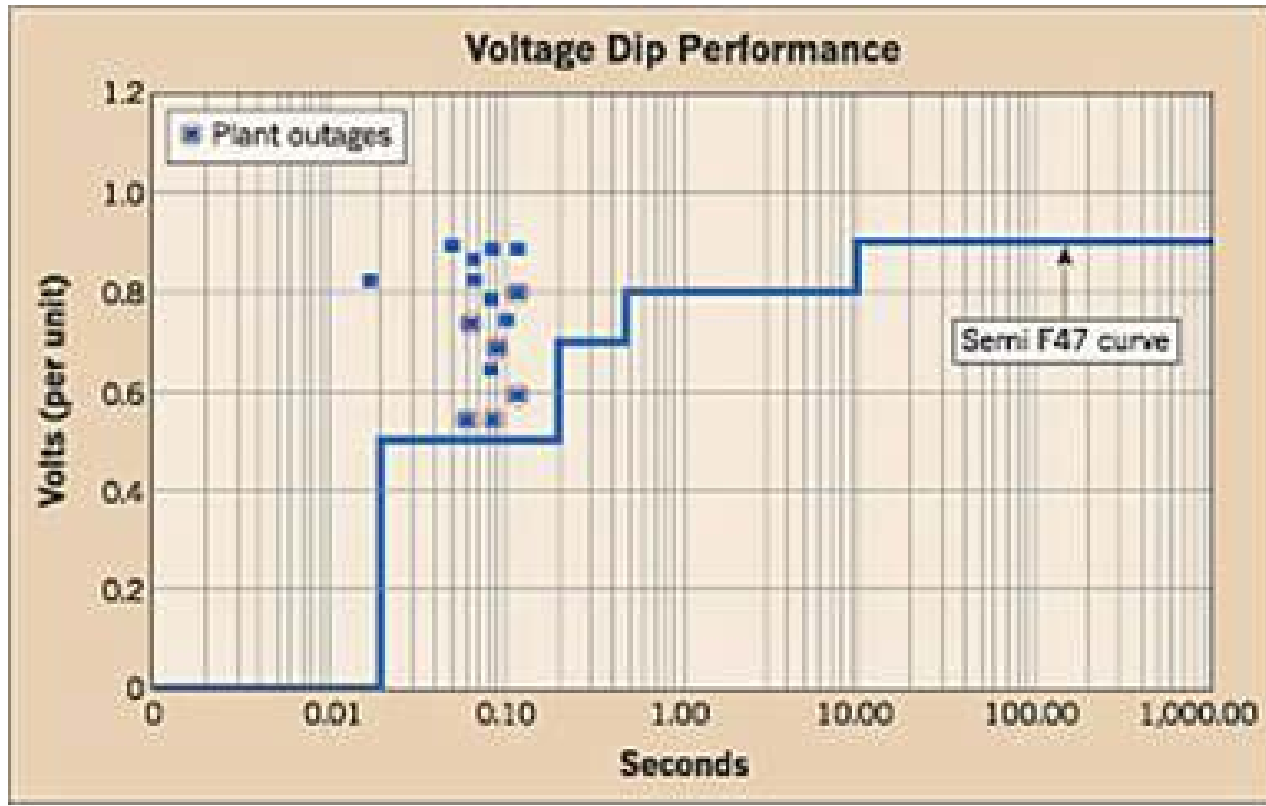


*Sag monitoring data from 15 semiconductor sites—source EPRI*





# Consumer's PQ "Performance"



*Voltage Sag Events at one facility—source: EPRI*





# *It will “Optimize asset utilization and operate efficiently”*

- **Operational improvements**
  - Improved load factors and lower system losses
  - Integrated outage management
  - Risk assessment
- **Asset Management improvements**
  - The knowledge to build only what we need
  - Improved maintenance processes
  - Improved resource management processes
  - More power through existing assets
- **Reduction in utility costs (O&M and Capital)**

*Today*

Limited grid information & minimal integration with asset management

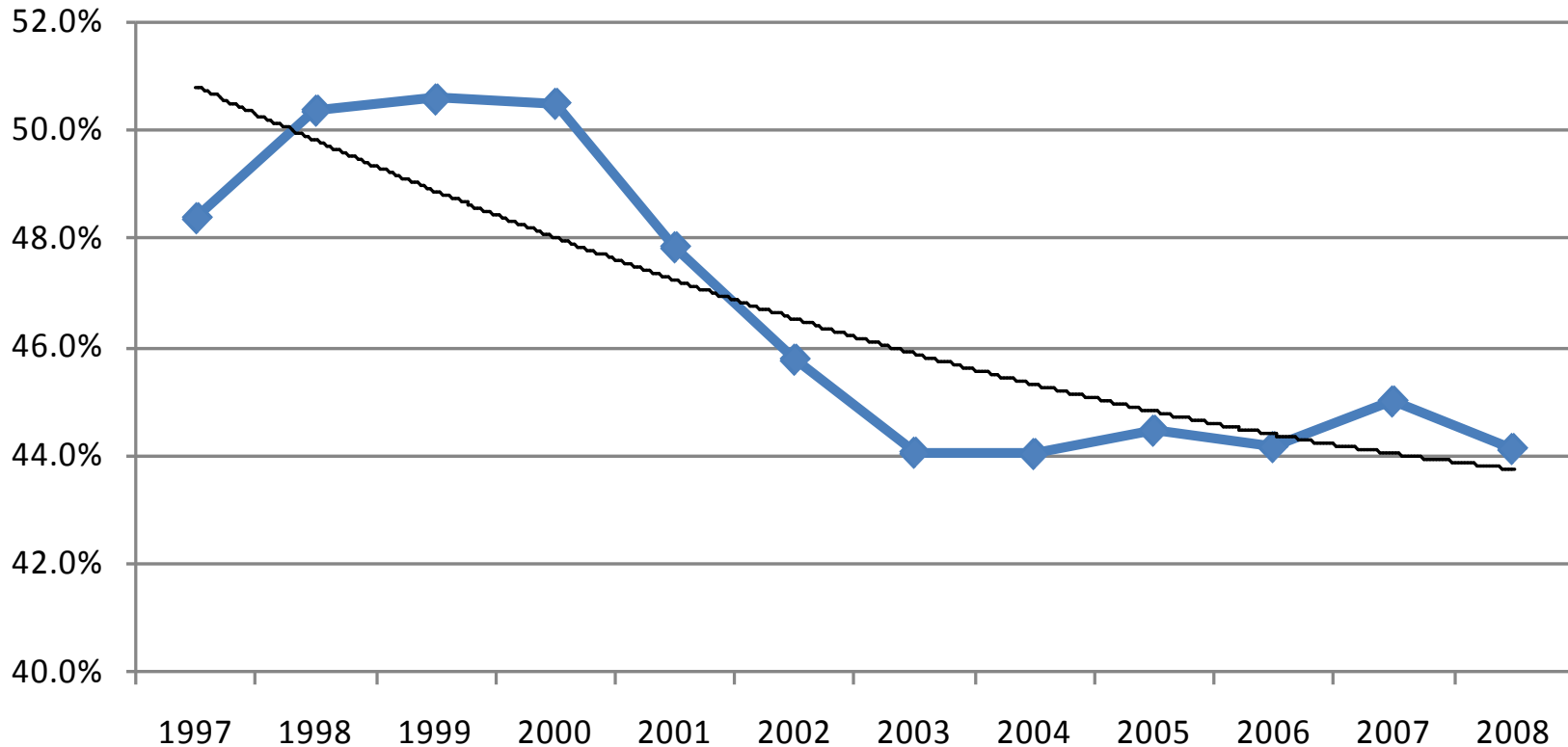
*Tomorrow*

Deep integration of grid intelligence enabling reduction in O&M and CapEx



# Trend in Central-Station Generation

## Average Generation Asset Utilization Factor



Source: EIA Electric Power Annual 2008

*Why would we think this will work tomorrow?*

# Dynamic Ratings for Transmission Lines



*Source: Promethean Devices*

# *It will “Anticipate & respond to system disturbances”*

- **Performs continuous self-assessments**
- **Detects, analyzes, responds to, and restores grid components or network sections**
- **Handles problems too large or too fast-moving for human intervention**
- **Self heals - acts as the grid’s “immune system”**
- **Supports grid reliability, security, and power quality**

## *Today*

**Protects assets following disruption  
(e.g., trip relay)**

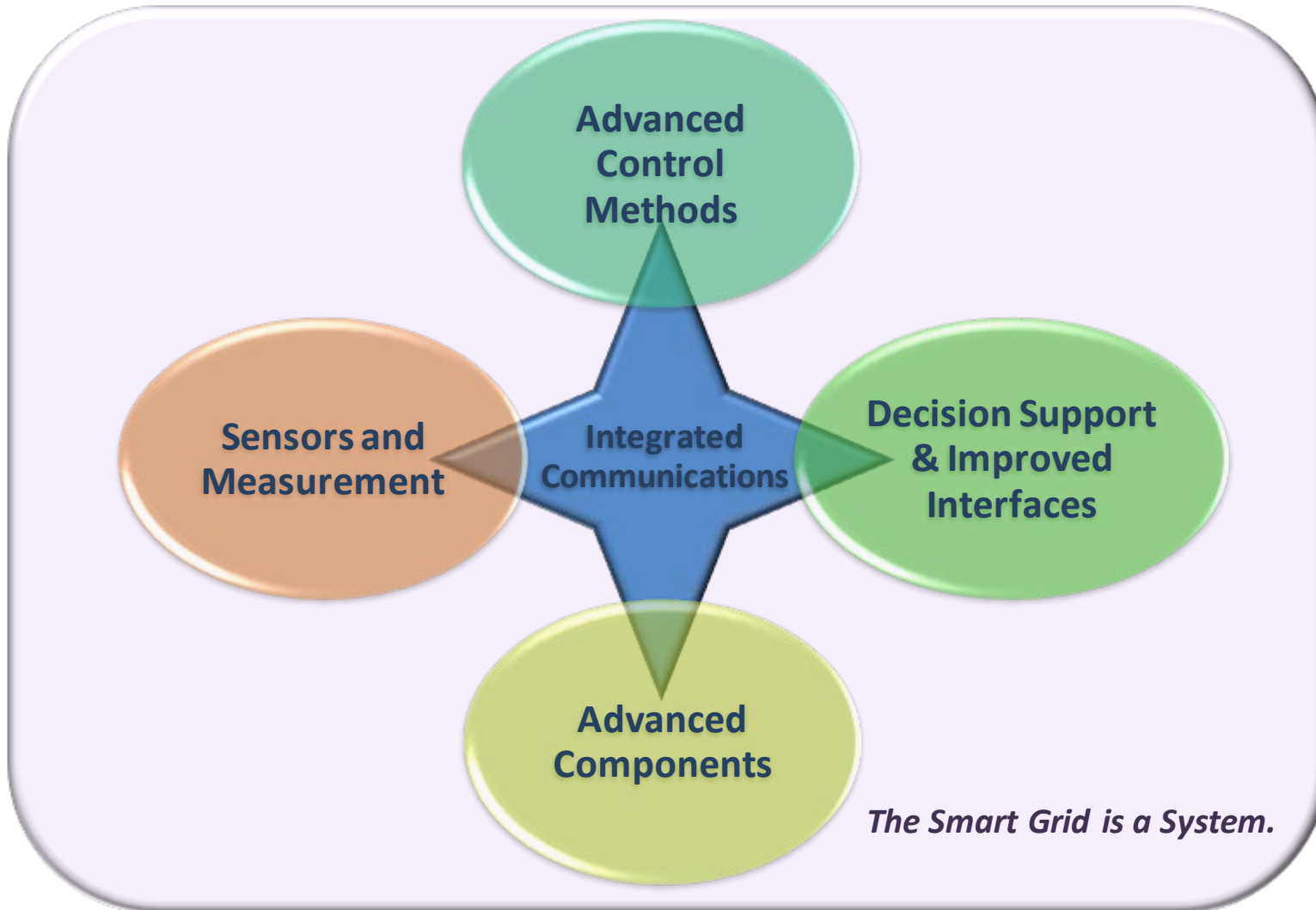
## *Tomorrow*

**Prevents disruptions, minimizes  
impact, restores rapidly**

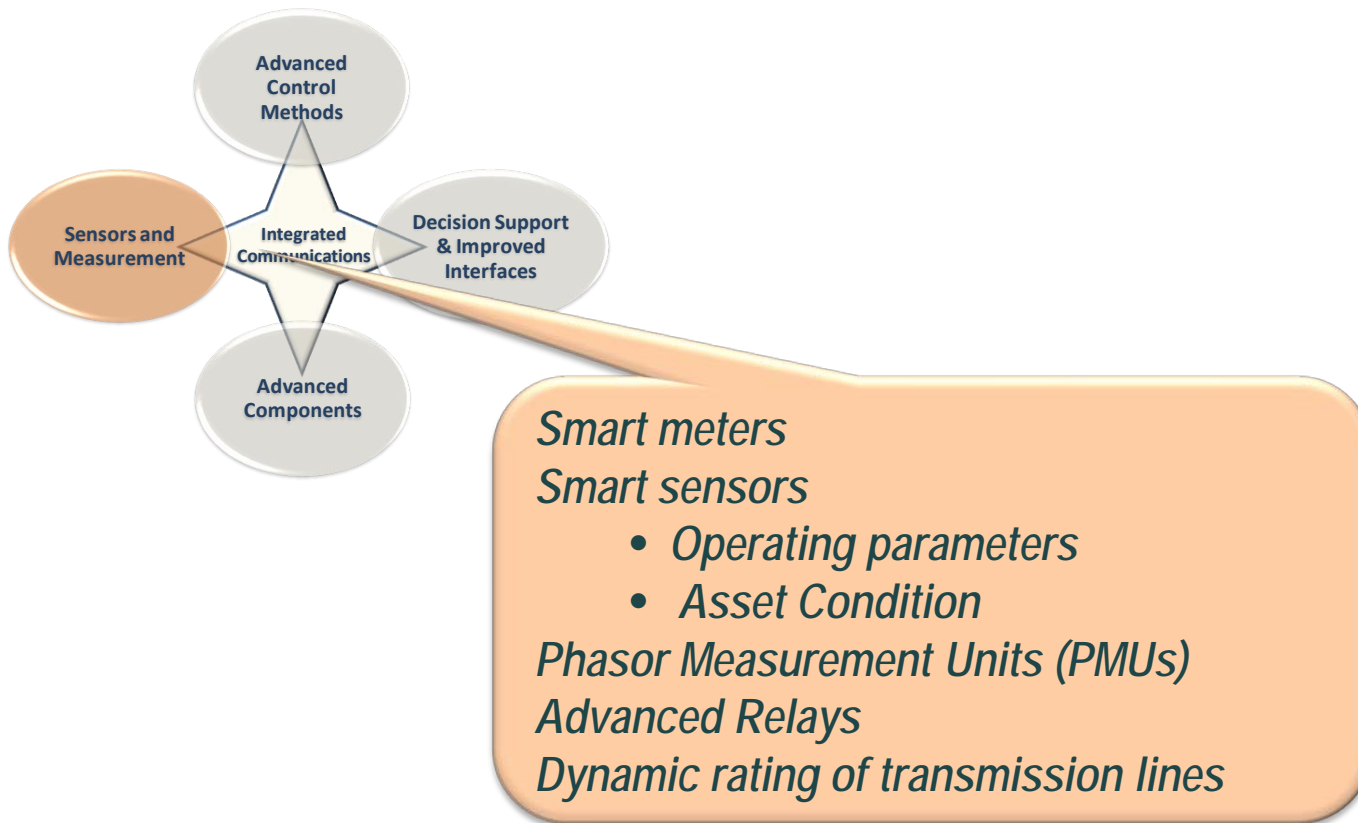




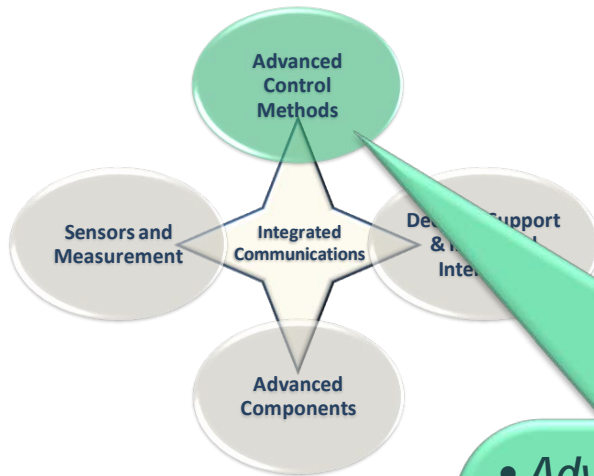
# Smart Grid Key Technology Areas



# Sensors and Measurement



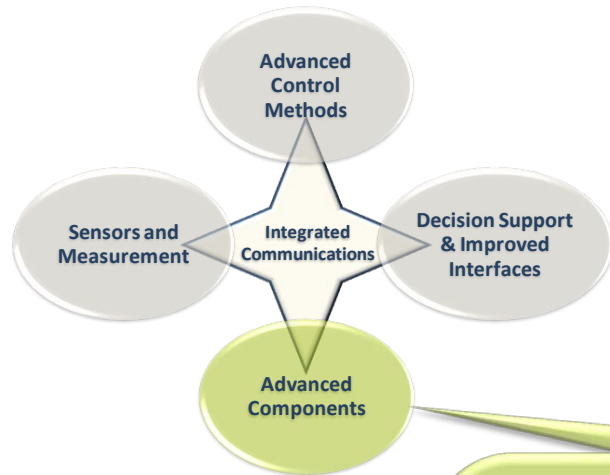
# Advanced Control Methods



- *Advanced Metering Infrastructure*
- *Advanced Outage Management*
- *Distribution Management*
- *Distribution Automation*
- *Microgrid Operation*
- *Modeling and Simulation*
- *Advanced Protection and Control*
- *Integration with enterprise-wide technologies*

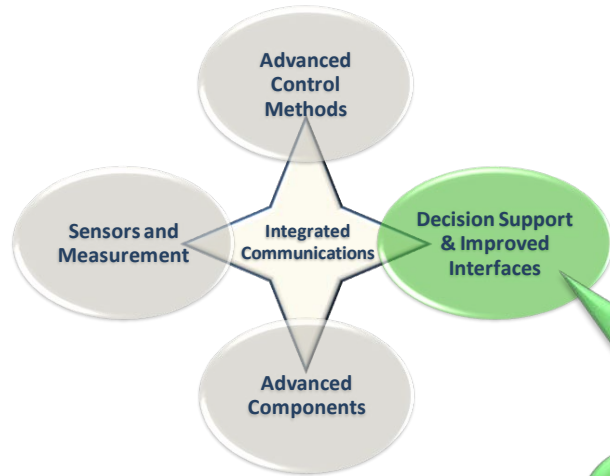


# Advanced Components



*Next generation FACTS/PQ devices*  
*Advanced distributed generation and energy storage*  
*PEV - V2G mode*  
*Fault current limiters*  
*Superconducting transmission cable & rotating machines*  
*Micro-grids*  
*Advanced switches and conductors*

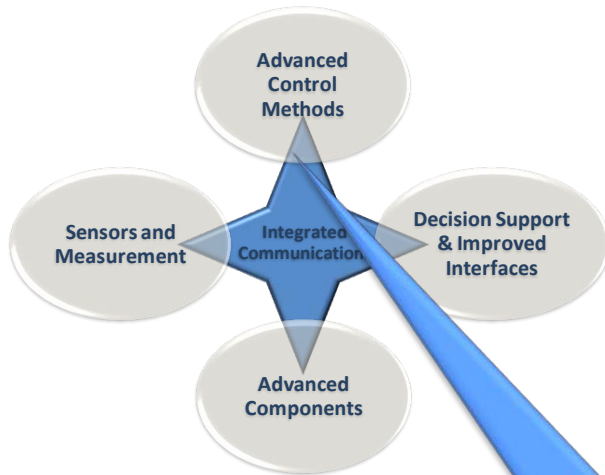
# Decision Support & Improved Interfaces



*Data reduction*  
*Data to information to action*  
*Visualization*  
*Speed of comprehension*  
*System operator training*



# Integrated Communications



*Consider all needs:*

- *Smart meters*
- *Smart sensors*
- *Demand Response*
- *DG dispatch*
- *Distribution automation*
- *Micro-grids*
- *Markets*
- *Work force management*
- *Mobile premises (PEV's)*



# *It will “Operate resiliently against attack and natural disaster”*

- **System-wide solution to physical and cyber security**
- **Reduces threat, vulnerability, consequences**
- **Deters, detects, mitigates, responds, and restores**
- **“Fort Knox” image**
- **Decentralization and self-healing enabled**

## *Today*

Vulnerable to terrorists and natural disasters

## *Tomorrow*

Deters, detects, mitigates, and restores rapidly and efficiently—“cyber proof”



# A Smart Grid is Resilient

- **Decentralized generation and storage**
- **Diversity in size and fuel type**
- **PEVs enabled providing millions of backup resources**
- **Consumers involved in grid operations and recovery**
- **Microgrid operation for isolation and recovery**
- **Video surveillance of key assets**
- **Self healing technologies**

*These features reduce the consequences of physical “attack”*





How does it fit together?

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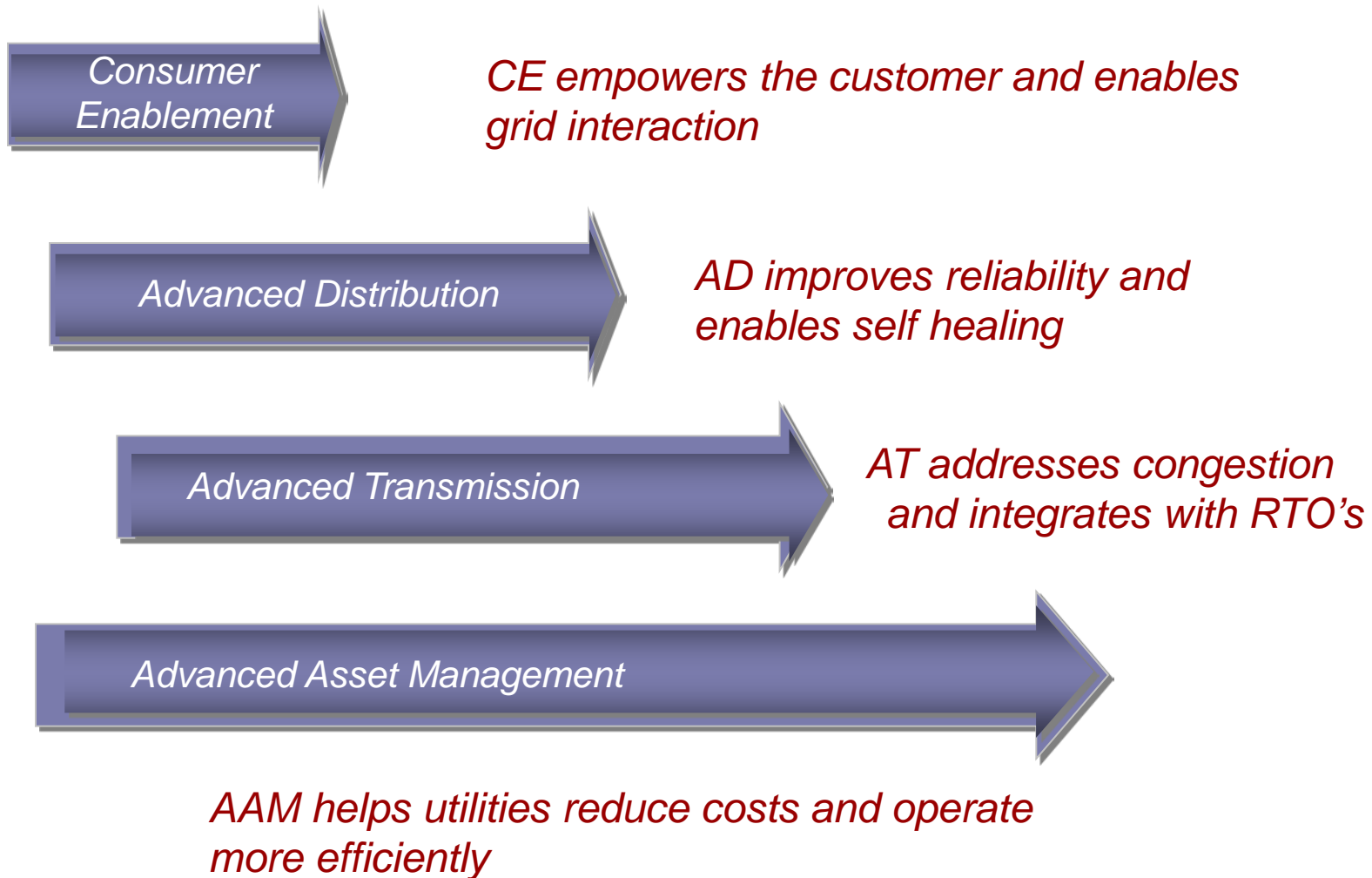
# Smart Grid Milestones

- **Consumer Enablement**
- **Advanced Distribution Operations**
- **Advanced Transmission Operations**
- **Advanced Asset Management**

*Each requires the deployment and integration of various technologies and applications*



# Sequence can vary



# Consumer Enablement Solutions

- **Smart Meters & 2-way communications**
- **Consumer Portal / Home area network**
- **Meter Data Management**
- **Time of Use Rates**
- **Customer Information System**
- **IT upgrades (SOA)**
- **Customer Education**
- **Demand Response and DER**

*CE empowers the customer and supports grid operations*



# Advanced Distribution Solutions

- **Smart sensors and control devices**
- **Distribution Management System**
- **Advanced Outage Management**
- **Distribution Automation**
- **Geographic Information System (GIS)**
- **DER and Micro-grid operations**
- **Advanced protection and control**

*Advanced Distribution enables “Self Healing”*



# Advanced Transmission Solutions

- **Substation Automation**
- **Advanced regional operating applications (RTO)**
- **Wide Area Measurement System (WAMS)**
- **Advance materials and power electronics**
- **Hi-speed information processing**
- **Modeling, simulation and visualization tools**
- **Advanced digital protection**

*Integrated with CE, AD and AAM – AT optimizes transmission operations*



# Advanced Asset Management Solutions

- **Advanced sensors**
  - System Parameters
  - Asset “health”
- **Integration of grid intelligence with other processes:**
  - Operations to optimize asset utilization
  - T&D planning
  - Condition based maintenance
  - Engineering, design and construction
  - Work and resource management
  - Customer service

*AAM processes will dramatically improve grid operations and efficiency*



# A “System of Systems”

<i>Characteristic</i>	<i>CE</i>	<i>ADO</i>	<i>ATO</i>	<i>AAM</i>
Enables Active Consumer Participation	✓	✓		
Accommodates All Generation & Storage Options	✓	✓	✓	
Enables New Products, Services and Markets	✓	✓	✓	
Provides PQ for Digital Economy	✓	✓	✓	✓
Optimizes Assets & Operates Efficiently	✓	✓	✓	✓
Anticipates and Responds to System Disturbances	✓	✓	✓	✓
Operates Resiliently Against Attack and Natural Disaster	✓	✓	✓	







**Is it worth it?**

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# Why invest in the Smart Grid?

- **Today's grid is aging and outmoded**
- **Unreliability is costing consumers billions of dollars**
- **Today's grid is vulnerable to attack and natural disaster**
- **An extended loss of today's grid could be catastrophic to our security, economy and quality of life**
- **Today's grid does not address the 21st century power supply challenges**
- **Missed opportunity to enjoy the benefits of a Smart Grid**

*There is a "case for action"*



# Smart Grid Value Areas

- **Reliability** — *by reducing the cost of interruptions and power quality disturbances and reducing the probability and consequences of widespread blackouts.*
- **Economics** — *by keeping downward prices on electricity prices, reducing the amount paid by consumers as compared to the “business as usual” (BAU) grid, creating new jobs and stimulating the U.S. GDP.*
- **Efficiency** — *by reducing the cost to produce, deliver, and consume electricity.*
- **Environmental** — *by reducing emissions when compared to BAU by enabling a larger penetration of renewables and improving efficiency of generation, delivery, and consumption.*
- **Security** — *by reducing dependence on imported energy as well as the probability and consequences of manmade attacks and natural disasters.*
- **Safety** — *by reducing injuries and loss of life from grid related events.*



# Who are the Smart Grid Beneficiaries?

- **Delivery Companies**
- **Generators**
- **Consumers (R, C, I)**
- **Society**

*The value of Smart Grid depends on who you ask!*



# What's in it for the Delivery Company?

- + **Happier customers (in theory)**
- + **Return “of and on” investment (regulated)**
- + **O&M Savings**
  - *Process improvement (metering, billing, work force, OM)*
  - *Reduced losses (energy)*
  - *Asset utilization and maintenance program*
- + **Capital Expense Savings**
  - *System planning (deferral of capital projects)*
  - *Asset management (e.g., life extension)*
- **Risk of cost recovery (regulated)**

*Is this compelling...many are moving forward?*



# What's in it for the Generators?

- + **Return “of and on” investment (regulated)**
- + **More reliable product delivery**
- + **New market opportunities**
  - *Renewables*
  - *Storage*
  - *Ancillary services*
- + **Increased value of baseload generation?**
- **Operational risk**
  - *Market uncertainty*
  - *Some peakers stranded as peak is reduced*

*Growth of renewables is occurring and will be enabled by SG*



# What's in it for the Residential Consumers?

- + **More reliable service**
- + **Potential bill savings**
- + **Transportation cost savings (PHEVs vs. conventional vehicles)**
- + **Information, control, and options for managing electricity (new devices and apps)**
- + **Option to sell consumer-owned generation and storage resources into the market**
- **Costs passed on to the consumer**

*Answers “What’s in it for my family and me?”*





# What's in it for C & I Customers?

- + **Opportunity to reduce energy and demand charges on bills**
- + **More reliable service resulting in a reduction in the costs of lost production and lost productivity**
- + **Option to sell consumer-owned generation and storage resources into the market**
- + **Information, control, and options for managing electricity**
- **Costs passed on to the consumer**
- **Many already have interval metering and energy management systems**

*Answers "What's in it for my business?"*



# What's in it for the U.S.?

## Societal Benefits

- *Reduced losses from outages and PQ*
- *Downward pressure on electricity prices*
- *Improved national security*
- *Improved environmental conditions*
- *Economic growth and opportunity*

*Hard to quantify but potentially a tipping point?*



## Reduced losses from power outages and power quality issues

- Reducing the probability of regional blackouts can prevent significant losses to society. The societal cost of the August 2003 blackout was \$8.6 billion.
- Reducing by even 20% the cost of outages and power quality issues, which are estimated to be at least \$100 billion annually, would save \$20 billion per year.



# Societal Benefits

## Downward pressure on electricity prices

- Eliminating or deferring large capital investments in generating plants, substations, and transmission and distribution lines, could reduce overall costs \$46–\$117 billion dollars over a 20-year period according to a 2003 PNNL report.
- Reducing O&M spending by 10% as a result of Smart Grid operational savings would save up to \$4 billion annually.
- Reducing T&D Losses, estimated at over \$25 billion per year, by even 10% would save \$2.5 billion/year.
- Reducing transmission congestion costs, which range from \$4.8 billion to as much as \$50 billion annually, by 10%, could save up to \$2 billion/year.



# Societal Benefits

## Improved National Security

- Reducing the U.S. dependence on foreign oil through the use of PHEVs could be up to 52% based on a recent PNNL report. This is an equivalent of reducing U.S. oil consumption by 6.5 million barrels per day. According to ORNL, the value of reducing this dependence is \$13.58 (2004 dollars) for every barrel of oil import reduced, creating a potential societal benefit of over \$30 billion/year.
- Reducing the probability (and consequences) of widespread and long-term outages due to terrorist activity could prevent significant societal costs that are immeasurable.



# Societal Benefits

## Improved Environmental Conditions

- Reduction in total emissions — Through conservation, demand response, and reduced T&D losses, the total U.S. electricity consumption could be reduced by 56 to 203 billion KWh's by 2030 (1.2–4.3%).
- Per PNNL, Smart Grid could reduce carbon emissions by 12% by 2030 (442 million metric tons).
- Deep penetration of electric vehicles – Smart Grid enabled – could reduce CO<sub>2</sub> emissions by 60 to 211 million metric tons by 2030.
- Improved public health — The impact of vehicle particulate emissions in urban areas can be reduced as the number of miles driven by CVs is offset by miles driven by electric vehicles.



# Societal Benefits

## Economic Growth and Opportunity

- Creation of new jobs — up to 280,000 to create a Smart Grid alone.
- Demand for new products and services created by Smart Grid related opportunities.
- Creation of new electricity markets enabling society to offer its electricity resources to the market (DR, DG, storage).
- Improved conditions for economic development — economic development depends on a reliable source of electric power.
- Reduced wholesale electricity prices compared with BAU – This reduction will be achieved through a reduction in peak loads and energy conservation.

*Societal Benefits come with little incremental cost*





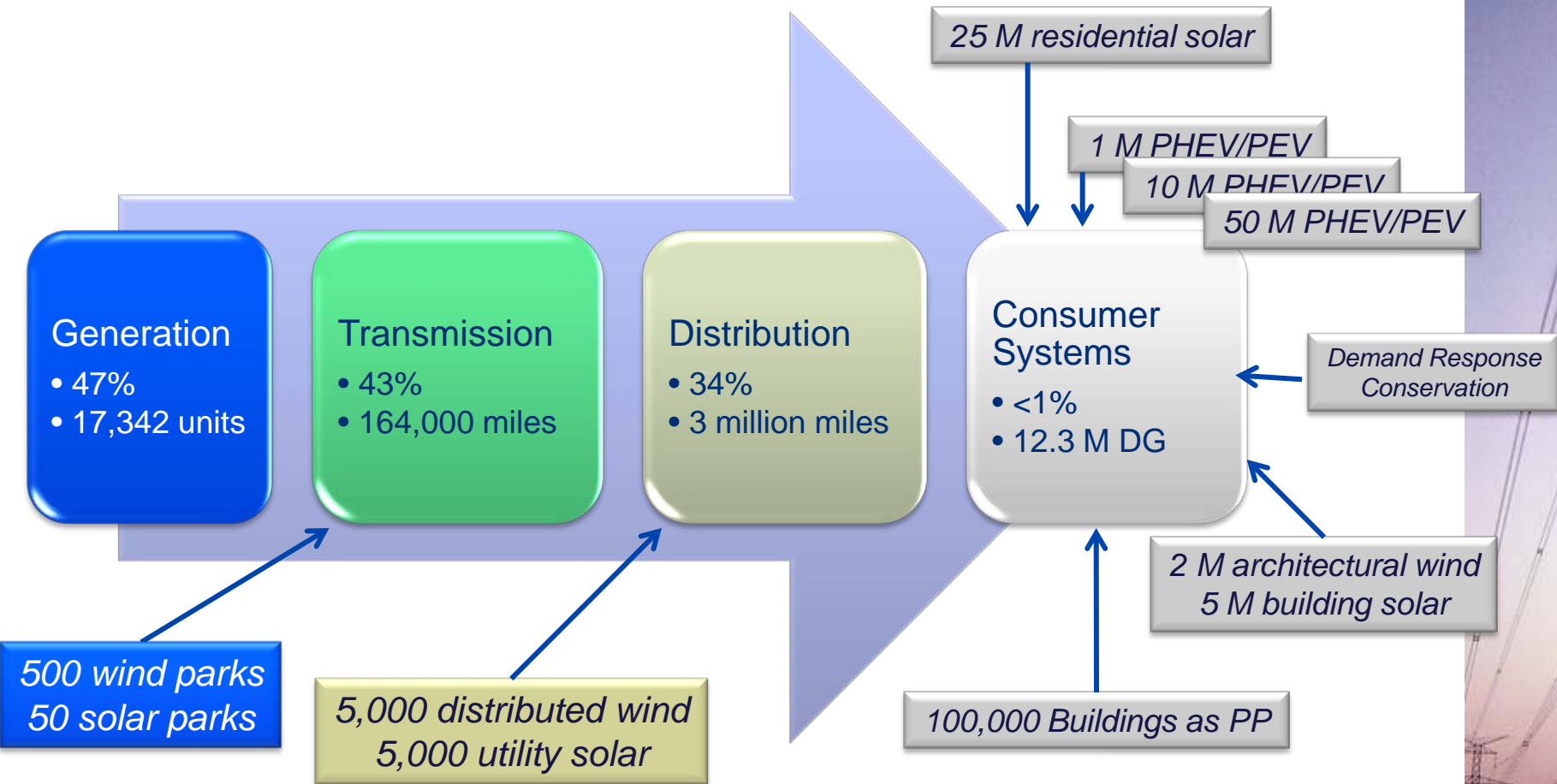


**Will we ever get there?**

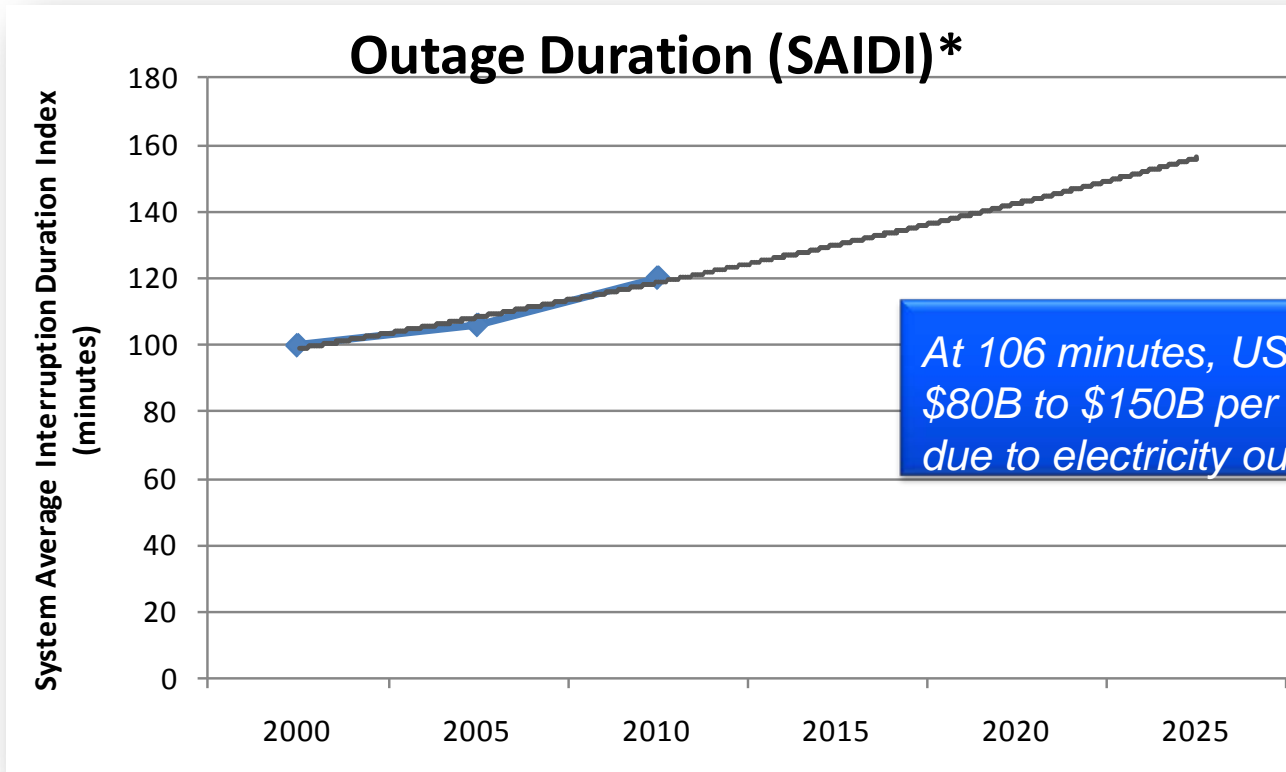
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# Some Drivers for a Smart Grid



# Electric System Reliability

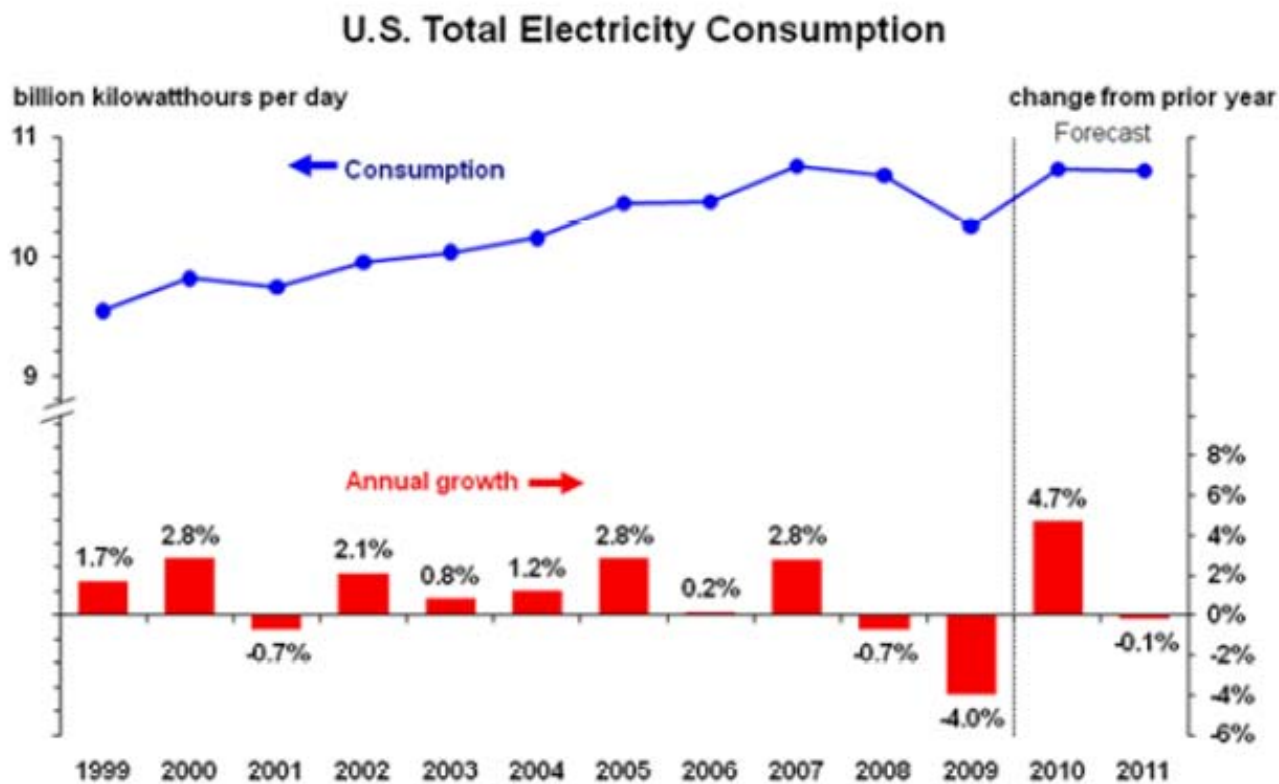


*\*Reports on previous year's data*

Sources: Lawrence Berkeley National Lab, IEEE 1366, EIA data, EPRI



# Load Growth Flat



Source: Short-Term Energy Outlook, December 2010

Source: U.S. Energy Information Administration, 2010



# Externalities

- **Renewable Portfolio Standards**
- **Global Warming**
- **Global Economic Competition**
- **Consumer Interest**
- **Others?**

*Many drivers but many challenges!*



# Many Challenges to Address

- **Regulatory Policy**
- **Standards**
- **Engineering**
- **System Planning**
- **Operations**
- **Consumer Acceptance**
- **Managing the Change**



# Regulatory Policy

- **Consumer education and alignment**
- **Time based rates** – incentives for consumers to become actively involved
- **Policy changes that provide incentives and remove disincentives to utilities** – investment in a Smart Grid should make business sense
- **Clear cost recovery policies** – uncertain cost recovery increases investment risk
- **Barriers to community microgrids**
- **Societal benefits** – quantified and included in business cases
- **Different regulatory models** (51 PUC's and FERC)





# What about Technical Standards?

- **NIST leading a national effort**
  - Interoperability
  - Cyber Security
- **What about other technical standards?**
  - Real-time operations (AMI, DER, DMS, micro-grids, markets, PHEV interface, etc.)
  - Maintenance (condition monitoring devices, etc.)
  - Design
  - Construction
  - Testing and commissioning





# Engineering Challenges

- **Large numbers of small sources and storage**
- **Incorporating 2-way power flow into operations**
- **Micro-grids and dynamic islanding**
- **Adaptive protective “relaying”**
- **Getting the communications system right**
- **“Future proofing” the technologies**
- **Integration of new power electronics**
- **Cyber Security**
- **Keeping the end in mind**
- **Loss of skills and experience**

*The design approach will change dramatically*



# Planning Challenges

- **Load forecasting**
  - Smart loads are now sources
  - Impact of renewables at the C&I and residential levels
  - PEV penetration rate
- **Integration of transmission and distribution studies**
  - Reliability and markets
  - Level of detail (PHEV to nuke)
  - 2-way power flows on distribution system
  - Large numbers of small sources and storage
- **Advanced contingency analyses**
  - Economics at the distribution level
  - Risk, carbon, etc.

*More sophisticated planning tools and hi power computing will be needed*



# Operating Challenges

- **Modeling, simulation, and visualization tools**
  - Faster than real time
  - Use of PMU's
  - Probabilistic Risk Assessment (“risk meter”)
  - Data analytics
- **Optimization**
  - Loss reduction
  - Operating margins (component, circuit, system levels)
  - Reliability and risk
  - Markets (energy, capacity, ancillary services, carbon, retail, wholesale, etc.)
- **Autonomous decision making by agents vs. operator**

*“Data” to “information” to “action”*



# How do we engage the consumers?

## ***Three Step Process***

- ***Create Understanding*** of Smart Grid concepts and issues through effective communication, education, and debate
- ***Create Alignment*** using a collaborative approach and by allowing consumers to impact the direction of the Smart Grid transition in their respective areas or regions
- ***Motivate*** :
  - *Value in moving forward*
  - *Cost/penalties of doing nothing*
  - *Address their questions and concerns*

*Commissioner, “Where is my Smart Grid?”*

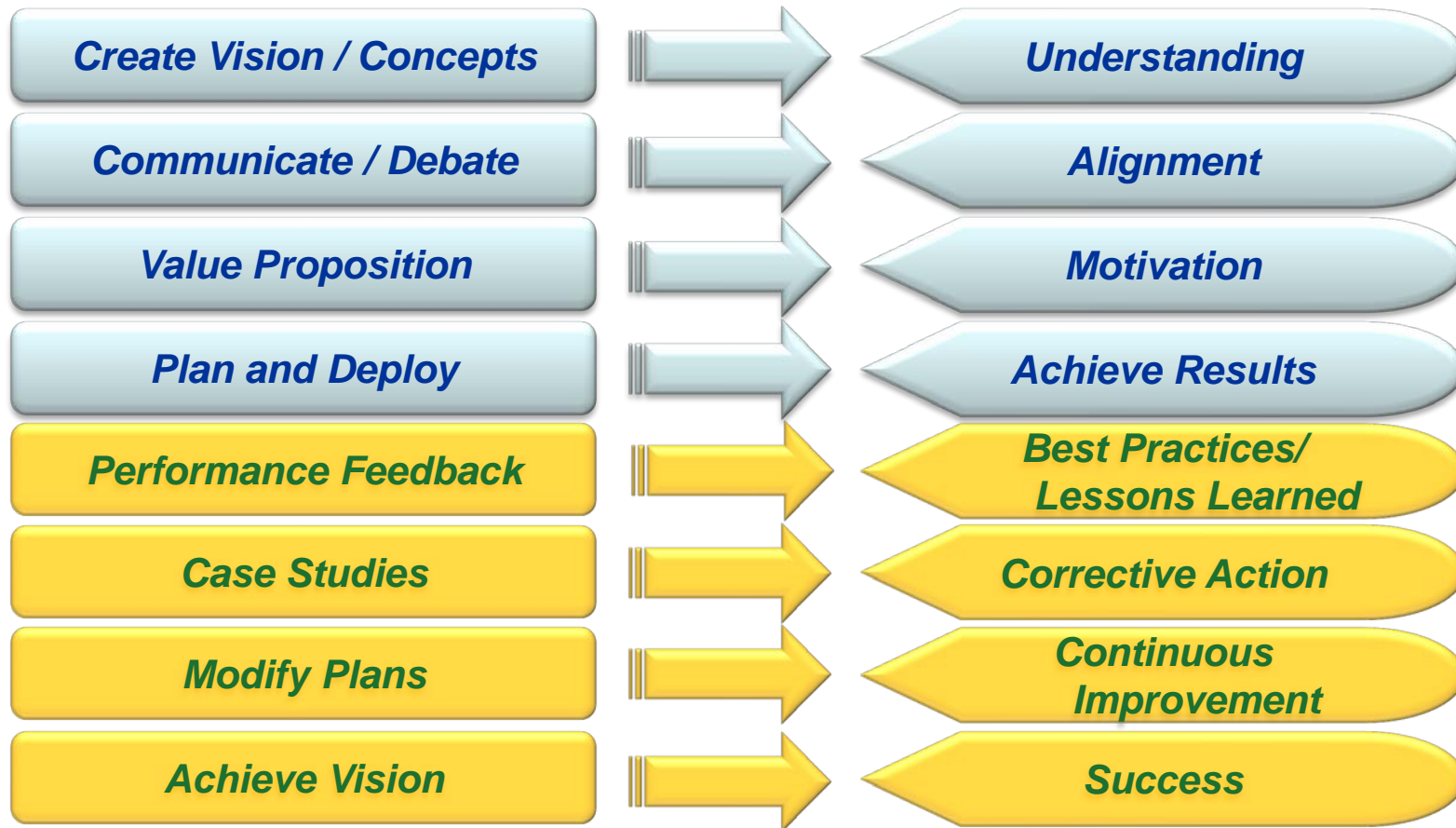


# Other Potential Risks

- **PHEV's without an effective price signal could result in making peak demand worse**
- **Deployment of a communications platform without considering the full range of Smart Grid requirements could result in future rework and additional costs.**
- **Widespread deployment of interconnected DG and storage without an advanced distribution management system to effectively operate them could challenge the reliability and safety of the grid**



# Managing the Change to the Smart Grid



*Two Ways to get there—Market and Mandate*







**What are the next steps?**

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# Achieving the Smart Grid Vision

## Phase 1

- Create Vision/Concepts
- Communicate/Debate
- Value Proposition
- Plan and Deploy

- Perform Feedback
- Case Studies
- Modify Plans
- Achieve Vision

**Understanding**  
**Alignment**  
**Motivation**  
**Achieve Initial Results**

*Phase 1 is “getting started” — Phase 2 is “getting done”*



# Progress won't be “smooth and easy”

## We can expect:

- Not all technologies will work as planned
- Software issues will arise
- “Myths and legends” will emerge that impede progress
- Unexpected events will occur
- Workforce training weaknesses will become apparent
- Progress may not be achieved at the expected rate
- Some benefits will not be realized as expected
- + Good ideas and practices will be identified

*Experience sharing can greatly improve the change process*



# Performance Feedback Program Vision

***“The Smart Grid Performance Feedback Program facilitates the sharing of Smart Grid experiences and learnings, thereby allowing stakeholders to continuously improve, avoid pitfalls, and build upon the best practices of others to more effectively, efficiently, and safely achieve their Smart Grid vision.”***

***NETL Smart Grid Implementation Team***



# PFP Fundamental Components

**Smart Grid  
Transition  
Activities**

**Performance  
Monitoring**

**Analysis**

**Results and  
Validation**

**Communication  
and Education**

**Benefits  
Realized**



# Value of the Smart Grid PFP

- **Improves the efficiency and efficacy of Smart Grid implementation**
- **Keeps implementation costs down**
- **Maintains Smart Grid implementation momentum**
- **Keeps “us” on track with plans and schedules**
- **Reduces the potential for repeating “missteps”**
- **Prevents “reinventing the wheel”**
- **Provides guidance for future codes and standards development**
- **Provide a means to communicate progress to the stakeholders to encourage their support and feedback**
- **Create “best-in-class” for various Smart Grid applications that will enable others to benchmark their projects**



# Performance Monitoring

- **Corrective Action**
- **Event Reporting**
- **Failure Monitoring**
- **Metrics Reporting**
- **Surveys**

**Provides the data & information streams that support Analysis**





# Analysis Methods

- **Trend Analysis**
- **Root Cause Analysis**
- **Benchmarking**
- **Self Assessments**
- **Peer Team Assessments**
- **Case Studies**

**Analysis yields “logic based” conclusions**



# Results and Validation

- ***Best Practices*** – proven processes demonstrating positive results that if implemented broadly would represent significant benefit for the industry
- ***Lessons Learned*** – unintended consequences that negatively impact the Smart Grid transition. Sharing these lessons learned can help prevent others from repeating the same “mistake”
- ***Issue Clarification or “Myth Busting”*** – unresolved issues or conflicting opinions on key Smart Grid transitional matters tend to paralyze progress. Resolution of these issues and opinions can reduce or eliminate uncertainties enabling progress to proceed.
- ***Validation of Results*** – critical to ensure that only good and accurate information is conveyed to the Smart Grid stakeholders community



# Communication and Education

## Methods

- **Presentations at conferences**
- **Workshops**
- **Articles in Smart Grid publications**
- **Website Postings**
- **Webcasts**
- **Social Media**
- **Blogs**

**Communication plan is essential for effectively sharing the results of the Smart Grid PFP**



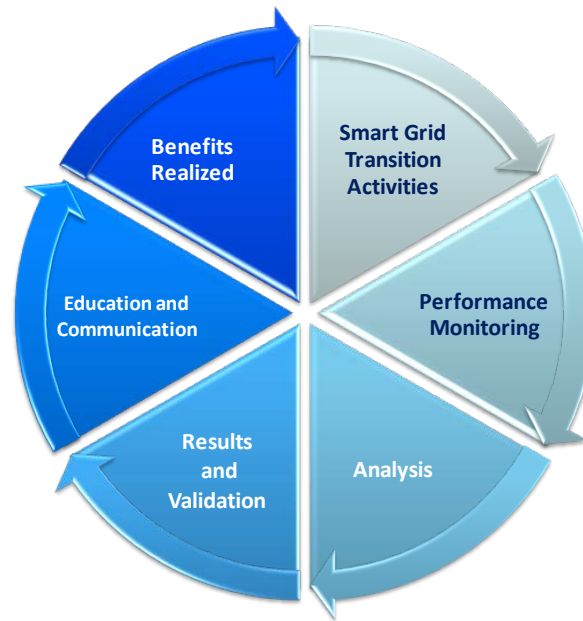
# Possible PFP Leaders

- **National Action Plan Coalition (NAP)**
- **GridWise Alliance (GWA)**
- **Smart Grid Consumer Collaborative (SGCC)**
- **Institute of Electrical and Electronics Engineers (IEEE)**
- **Edison Electric Institute (EEI)**
- **National Rural Electrification Cooperative Association (NRECA)**
- **Electric Power Research Institute (EPRI)**
- **Software Engineering Institute— Smart Grid Maturity Model (SEI)**
- **National Association of Regulatory Utility Commissioners (NARUC)**
- **American Public Power Association (APPA)**
- **NETL Smart Grid Implementation Team (SGI)**
- **University Research Consortia**



# Challenges

- Value not yet understood
- Reluctance to share experiences
- Program “ownership” not defined



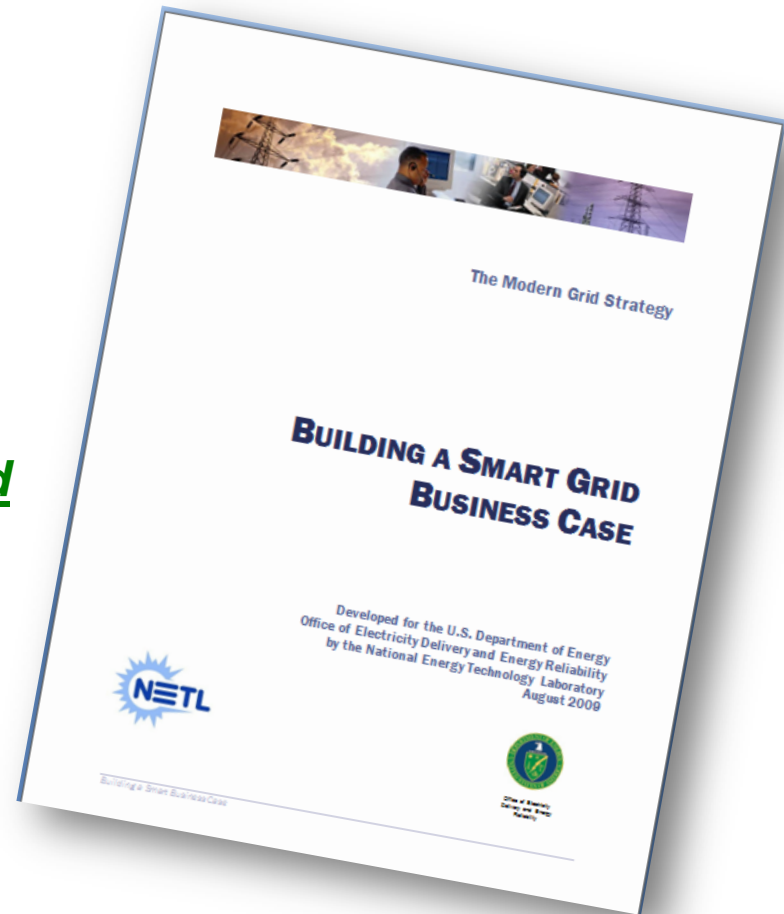
# For More Information

***“Those that fail to learn from history are doomed to repeat it.”***

***Winston Churchill***

***For additional Information:***

**<http://www.netl.doe.gov/smartgrid>**





**NATIONAL ENERGY TECHNOLOGY LABORATORY**

**Questions?**

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