

# Smart Grid School

MACRUC 15<sup>th</sup> Annual Education Conference

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Joe Miller - Smart Grid Implementation Strategy Team Lead  
June 28–29, 2010



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# Agenda

- **Role of the SGIS team at NETL**
- **What is the Smart Grid?**
- **Understanding the Smart Grid Value Proposition**
- **Q & A**





## **Role of SGIS Team at NETL**

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# Initial Role – Modern Grid Strategy

## ***Mission – Accelerate grid modernization in the U.S.***

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

*MGS Concepts form the foundation for the U.S. Smart Grid vision*



# Current Role – SG Implementation Strategy

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

- **Share, communicate, and educate stakeholders**
- **Support Implementation planning**
- **Support business case analysis**
- **Evaluate and communicate Smart Grid implementation results from a systems view perspective**
- **Federally managed team with broad industry experience**

*Continue to act as an “independent broker”*



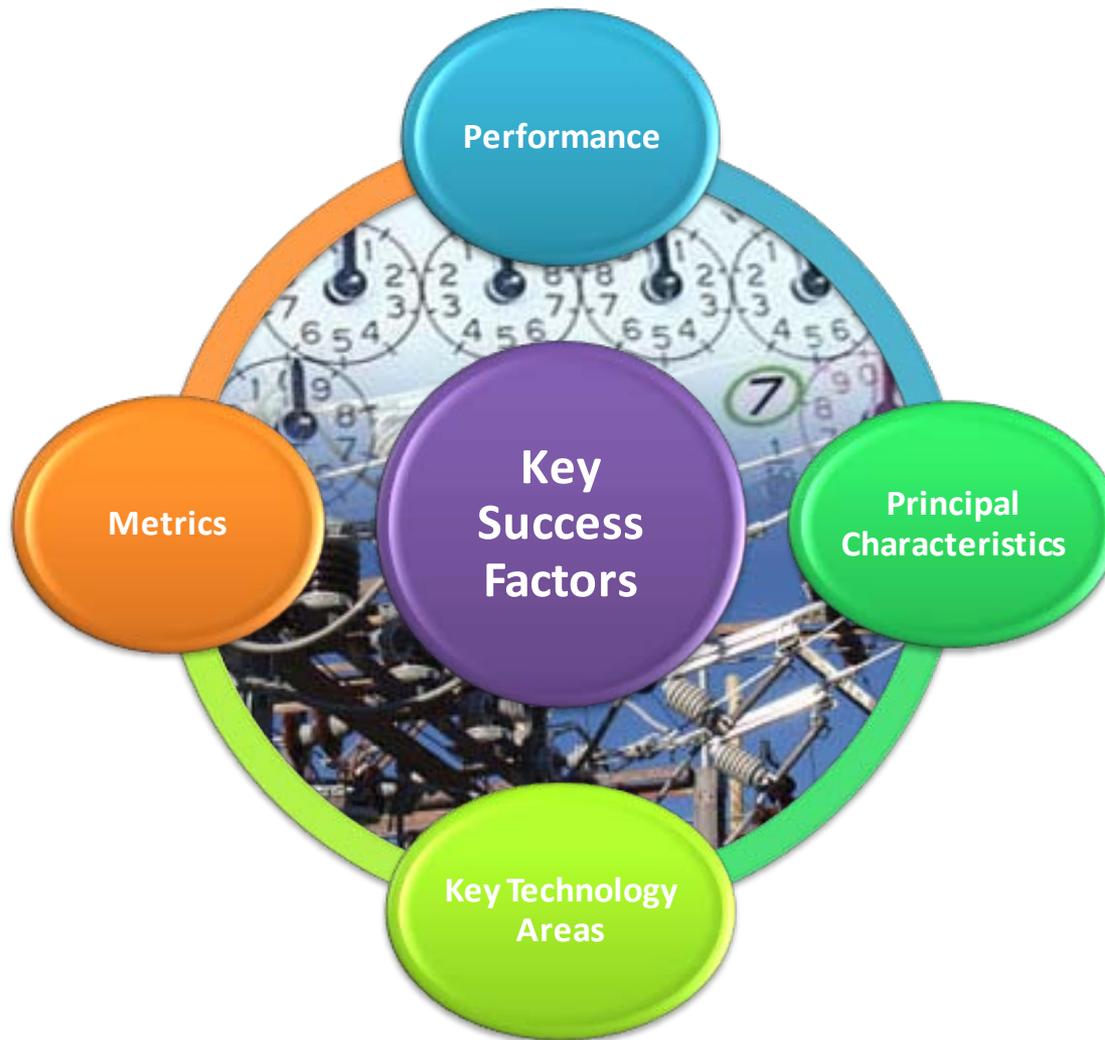


## **The Smart Grid—A Systems View**

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# U.S. Approach—A Systems View



# What's different with the Smart Grid?

- **Adds de-centralized supply and control**
- **Two-way power flow at the distribution level**
- **Two-way information flow**

*Creating the intelligence and capability to **optimize**:*

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

*...for all stakeholders*



# 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 (PHEV, HAN, EMS, smart appliances, etc.)
  - Sell resources for revenue or environmental stewardship
  - Provide incentives to participate (i.e. smart rates)
- **Grid operators have new resource options**
  - Reduce peak load and prices through demand response
  - Improve grid reliability
  - Access to 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”



# Smart Rates Can Work

Rate	Peak Time Pricing		Peak Time Rebate		8-Hour time of Use	
	Rate Alone	Rate w/Controlling Technology	Rate Alone	Rate w/Controlling Technology	Rate Alone	Rate w/Controlling Technology
Residential	-16.1%	-23.3%	-10.9%	-17.8%	- 3.1%	
Business	-2.8%	-7.2%	0.0%	-4.1%	0.0%	

*Connecticut L&P Plan-it Wise Results—Reduction in Peak Load*



# *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*

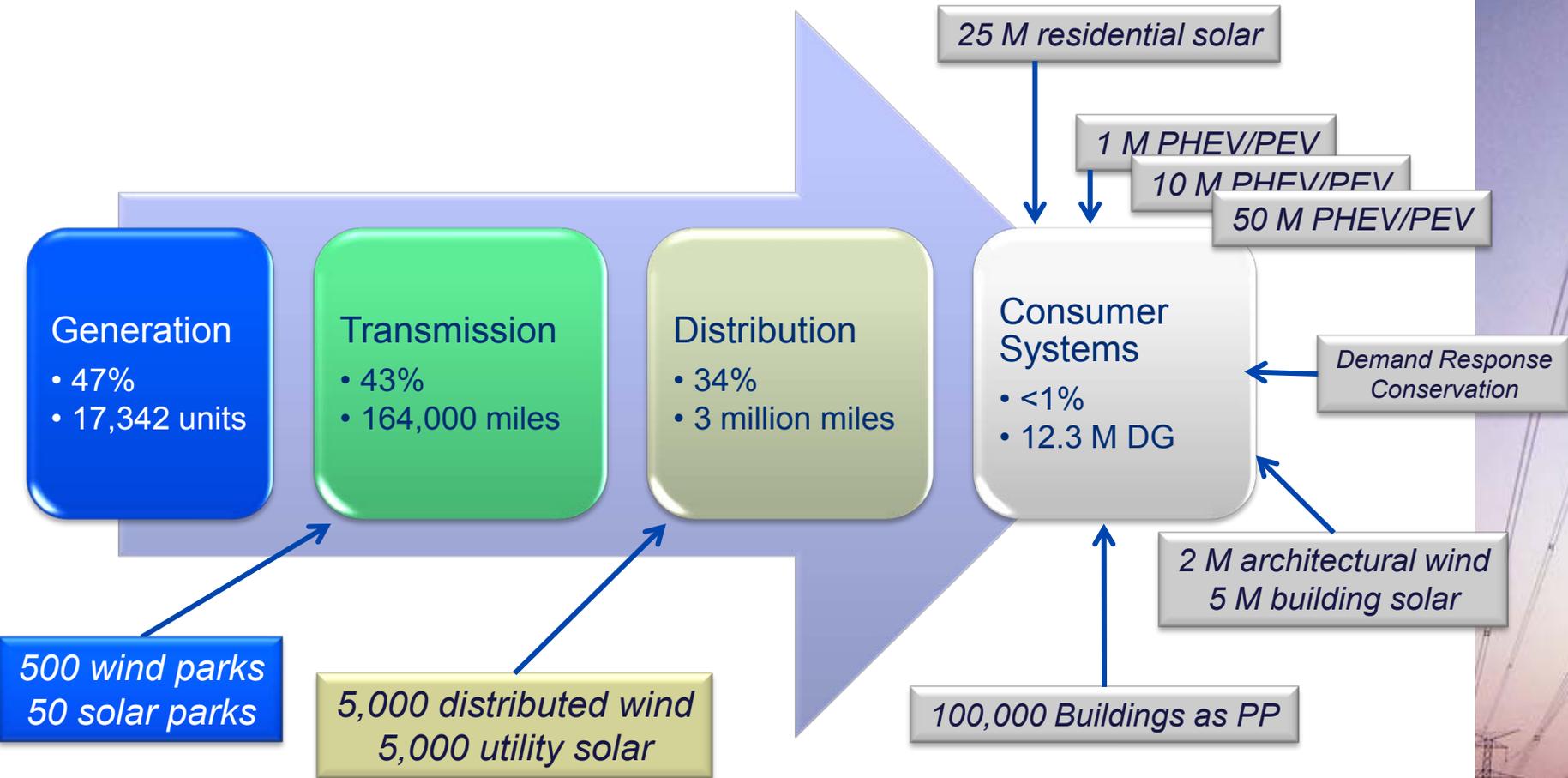
Dominated by central generation. Little DG, DR, storage, or renewables

## *Tomorrow*

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



# New stresses are on the way



# 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*



# *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 systems are resources for transmission, microgrids, growth of new secondary markets



# Smart Grid generates new ideas

## “Demand Dispatch” (DD)

- Demand Response (DR) is used relatively infrequently
- DD operates continuously
- Uses loads to “generation follow”
- For some loads, DD has little impact on end-user perception
- Aggregators could provide coordinated control over millions of DD compatible loads for ancillary services
- DD could play an increasingly important role in facilitating the growth of:
  - Variable resources
  - PHEV’s



# Other New Markets

- **Aggregators**
- **Energy Service Providers**
- **Financial Systems (PHEV transactions)**
- **PHEV's (kwh fuel, V2G, charging stations)**
- **Smart Appliances**
- **In-home Networks**
- **Home Energy Management Systems**
- **Microgrids**

*Others we can't yet imagine!*



# *It will “Provide power quality for the digital economy”*

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

*Today*

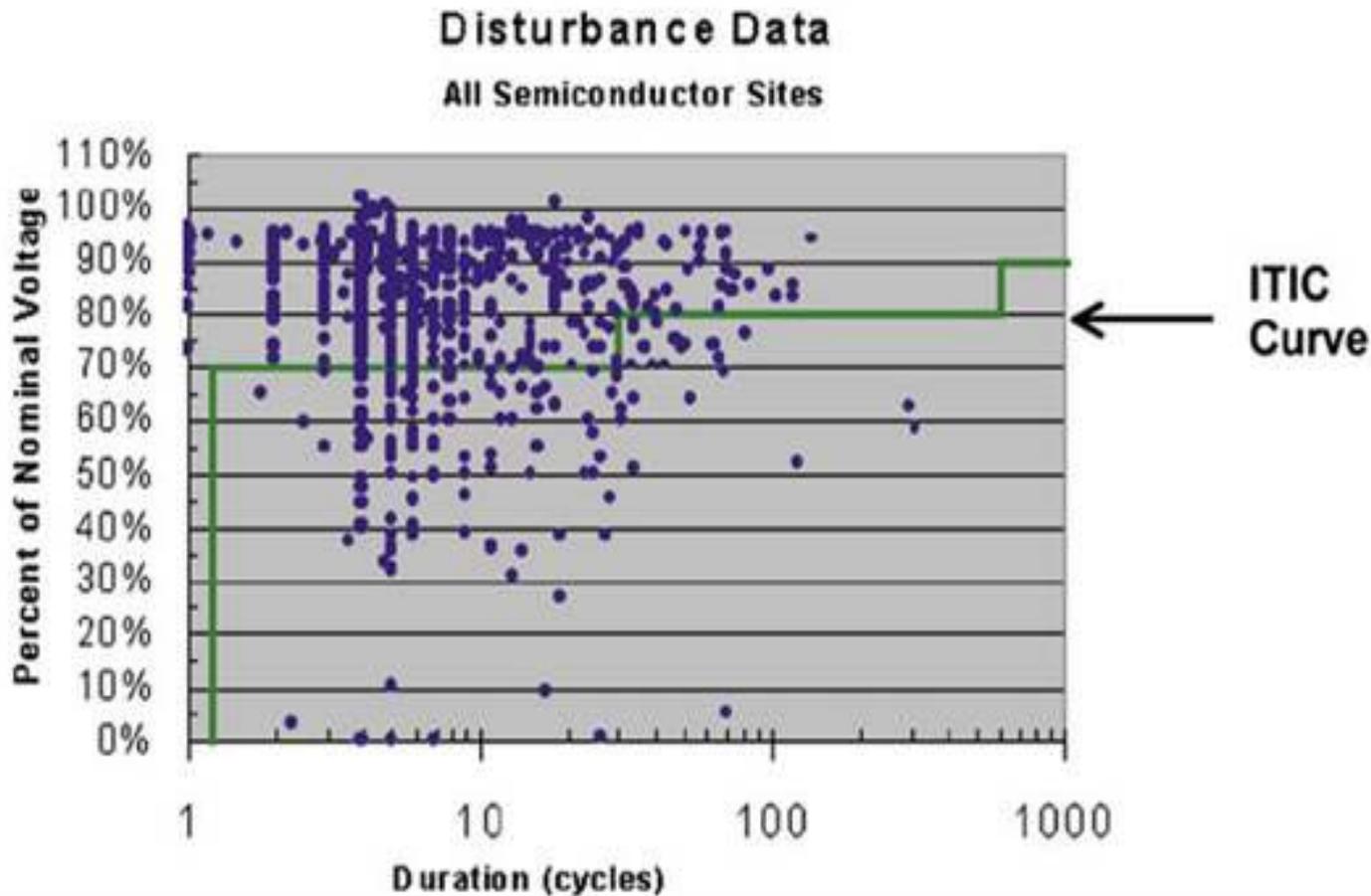
Focus on outages not PQ

*Tomorrow*

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



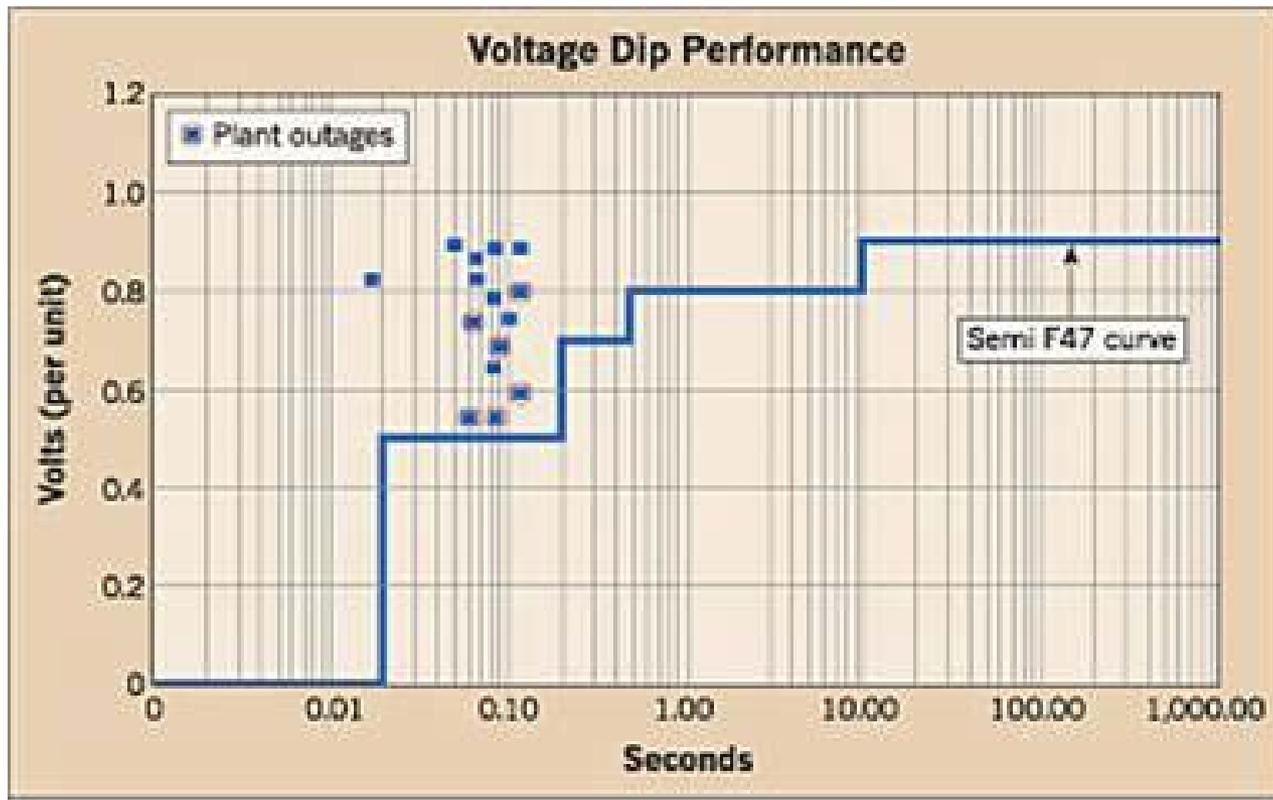
# System PQ “Performance”



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



# Consumer's PQ “Performance”



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

*Note: Some plant outages occur even when voltage sag does not exceed industry standard*

# *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**
  - 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*

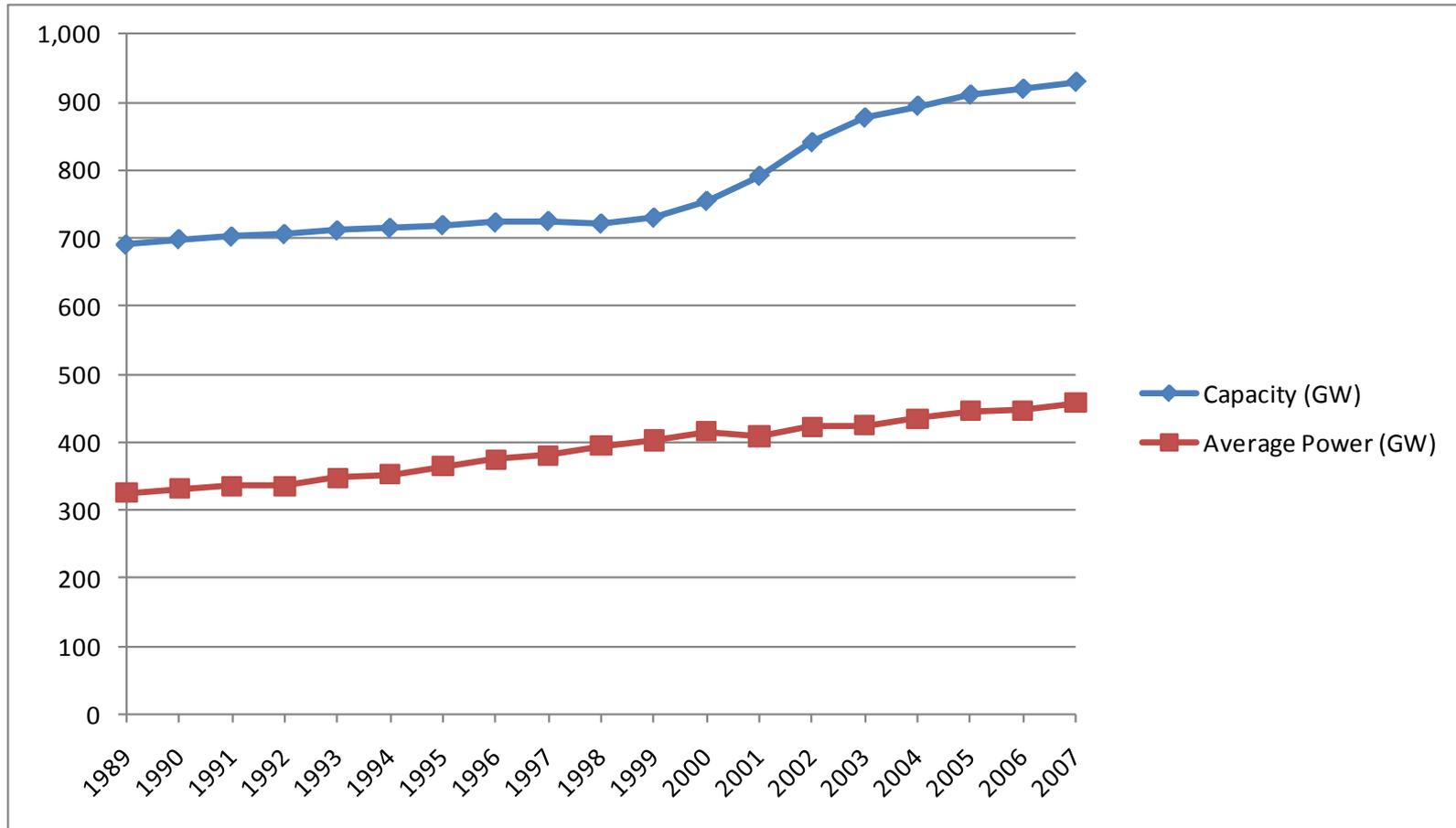
Limited grid information & minimal integration with asset management

*Tomorrow*

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



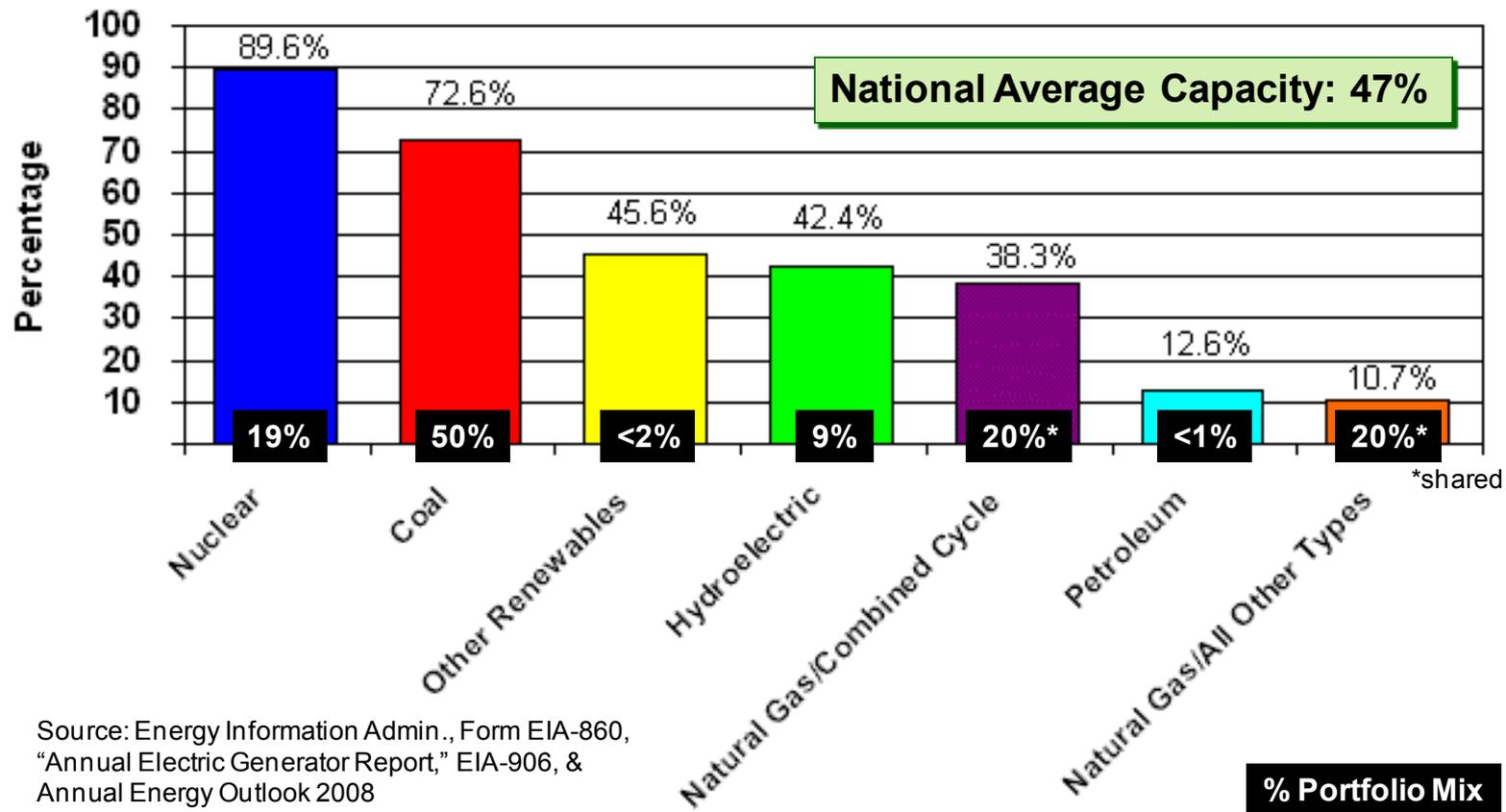
# Addressing the Peak



*U.S. Power Capacity versus Actual Average Power (Energy Information Administration, 2009)*



# U.S. Generation Portfolio Capacity Factors



Source: Energy Information Admin., Form EIA-860, "Annual Electric Generator Report," EIA-906, & Annual Energy Outlook 2008

# Dynamic Ratings for Transmission Lines



*Source: Promethean Devices*  
*Dynamic Ratings allow lines to operate up to, but not above, their real-time maximum transfer limit*

# *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*

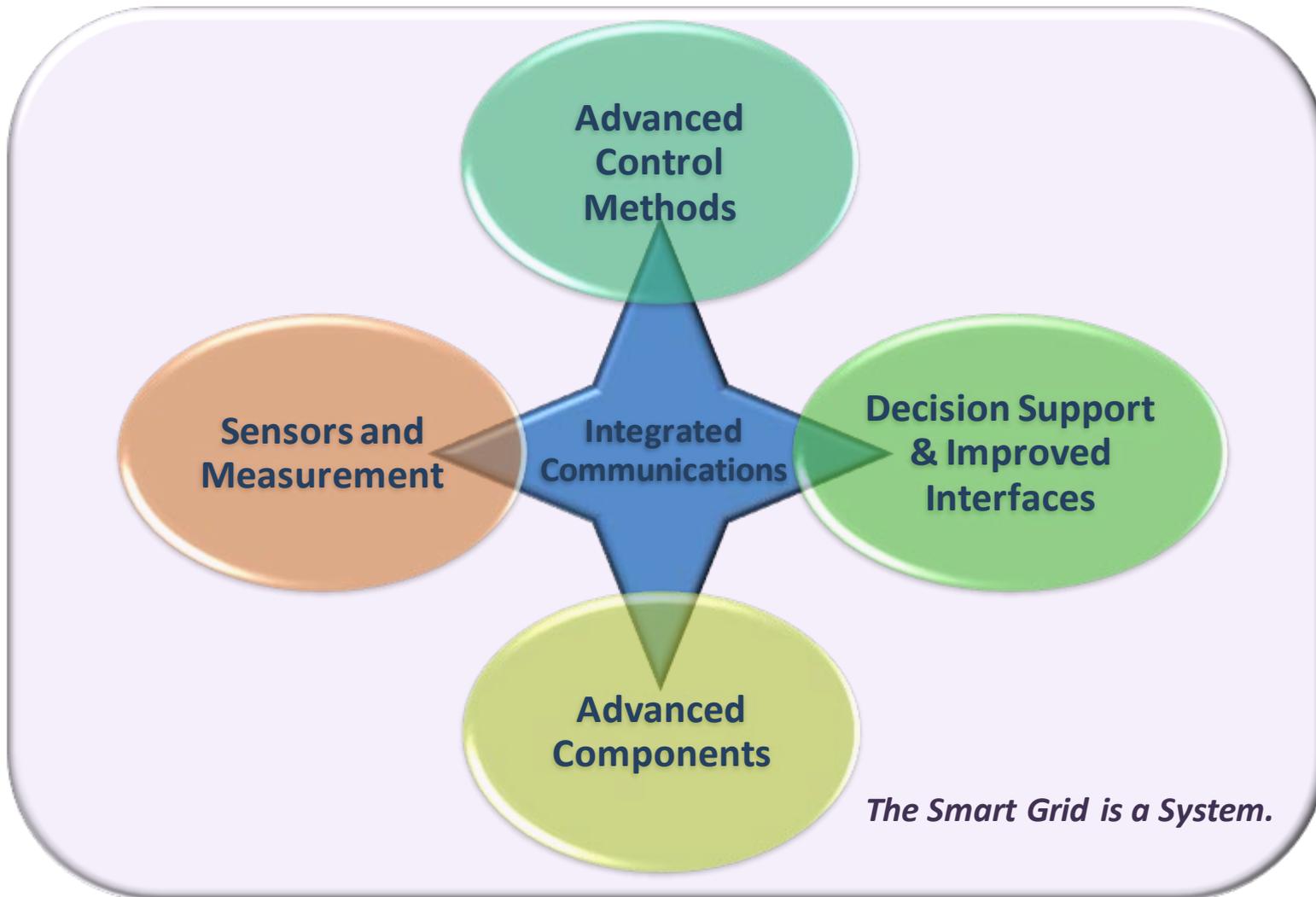
**Protects assets following disruption  
(e.g., trip relay)**

## *Tomorrow*

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

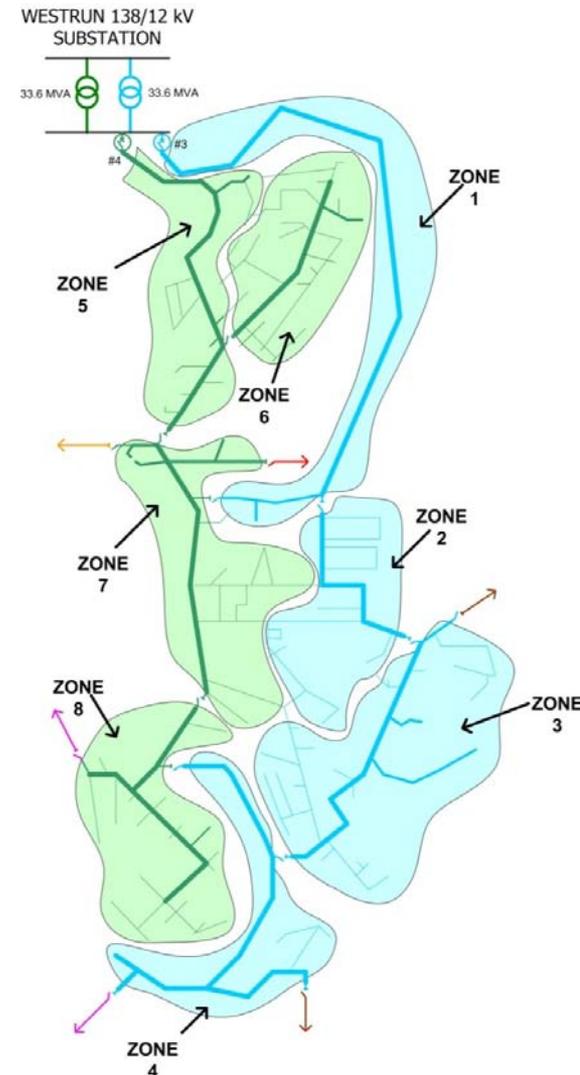


# Smart Grid Key Technology Areas



# A Self Healing Example

- **Fault Location, Isolation, and Restoration**
  - Restoration based on real-time loadings
  - Intelligence at the substation
  - Back-to-normal topology with one click
  - Open architecture



# *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**
- **PHEV-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 do we get there?

## Smart Grid “Building Blocks”

- **Consumer Enablement (CE)**
- **Advanced Distribution Operations (ADO)**
- **Advanced Transmission Operations (ATO)**
- **Advanced Asset Management (AAM)**

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



# Consumer Enablement Solutions

- **Smart Meters & 2–way communications**
- **Meter Data Management**
- **Consumer Portal / Home Area Network**
- **Innovative and dynamic Rates**
- **Customer Information System**
- **IT upgrades**
- **Customer Education**
- **Demand Response, DG and Storage**
- **Community microgrids**

*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)**
- **Distributed generation and storage**
- **Advanced protection and control**
- **Advanced grid components for distribution**

*Advanced Distribution enables “Self Healing”*



# Advanced Transmission Solutions

- **Wide Area Measurement System (WAMS)**
- **Substation Automation**
- **Advanced regional operating applications (RTO)**
- **Integration with distribution operations**
- **Advance materials and power electronics**
- **Modeling, simulation and visualization tools**
- **Advanced digital protection**
- **Dynamic ratings**

*Deeply integrated with CE and AD to optimize overall grid operations*



# Advanced Asset Management Solutions

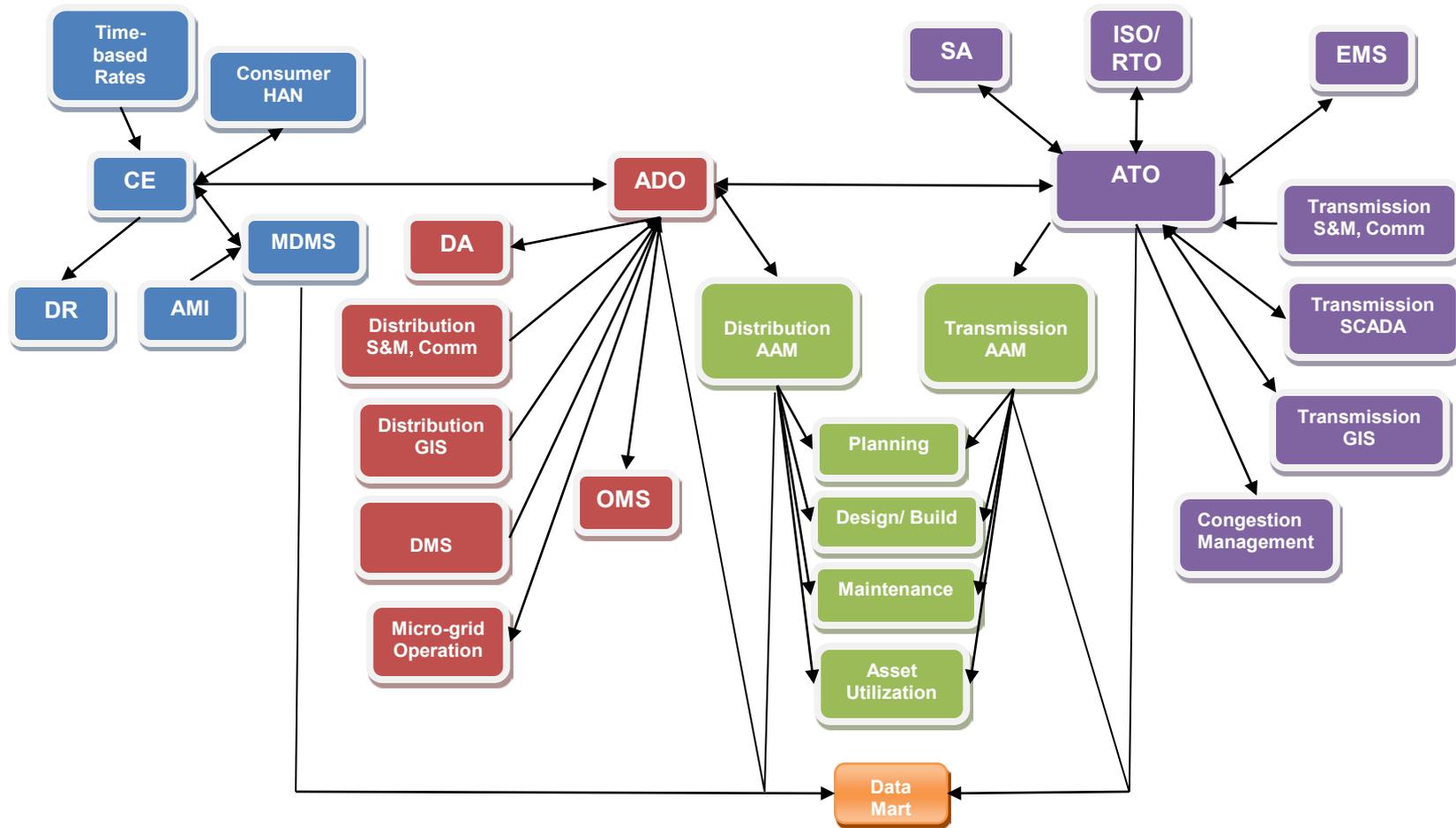
## Advanced sensors

- 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

*Integration of CD, AD, and AT with asset management processes will dramatically improve grid operations and efficiency*



# The “Big Picture”



# A Microgrid Definition

- **Clusters of resources**
  - Distributed generation
  - Storage
  - Dispatchable loads
- **Smartly connected**
- **Operable in parallel with grid or isolated**
- **Meeting the needs of its “members”**



# Why Microgrids?

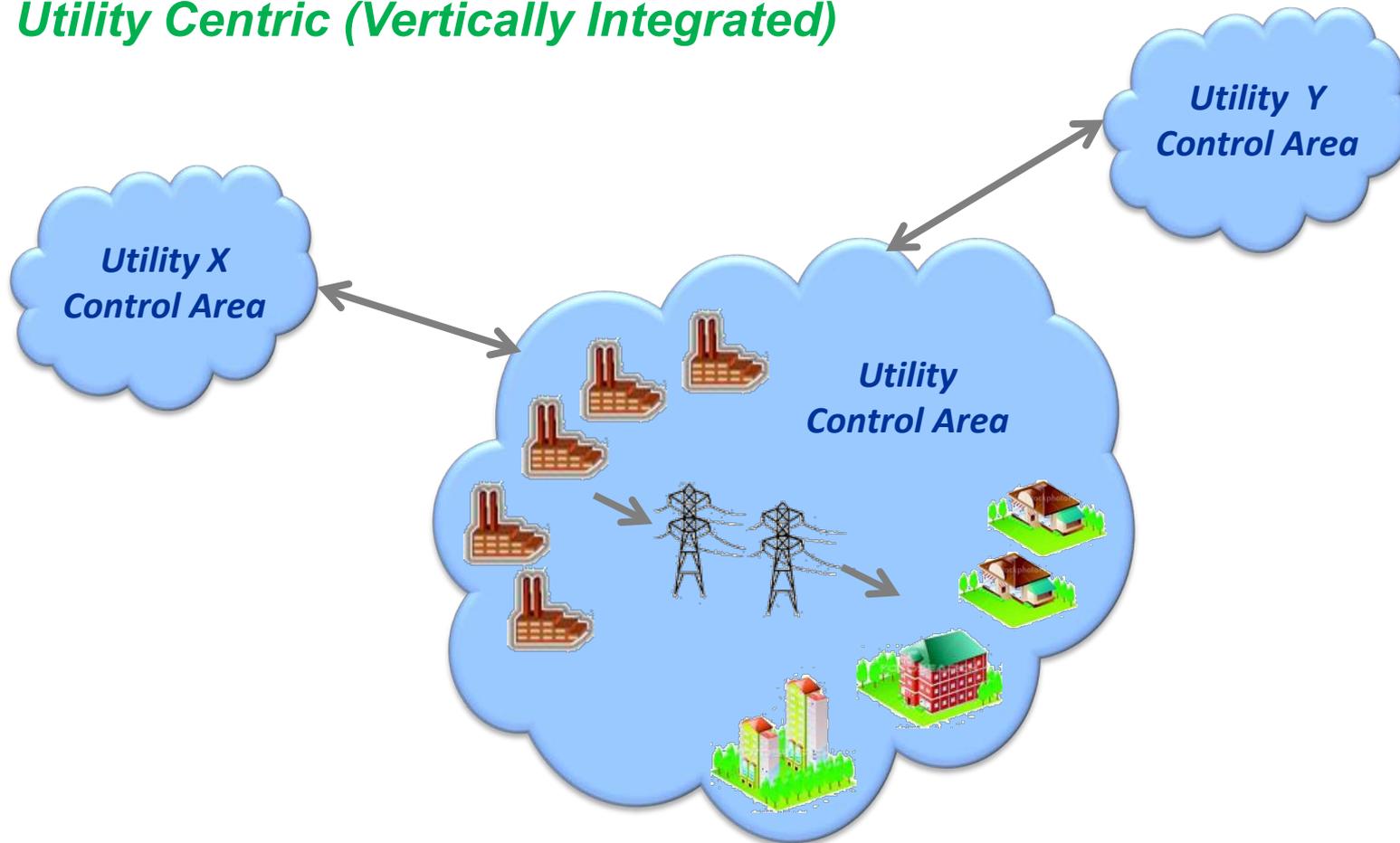
*“...the current system has become incapable of meeting the growing needs of twenty-first century consumers. One solution to this problem is to **expand the role of smart microgrids** that interact with the bulk power grid but can also operate independently of it in case of an outage or other disturbance.” **The Galvin Electricity Initiative***

*“The evidence is growing that privately owned, consumer-driven, small-scale, geographically distributed renewables could deliver a 100% green-energy future faster and cheaper than big power projects alone. Companies like GE and IBM are talking in terms of up to half of American homes generating their own electricity, renewably, within a decade. But distributed power -- **call it the "microgrid" -- poses an existential threat to the business model the utilities have happily depended on for more than a century..**” Anya Kamenetz, *Fast Company*, July 2009*



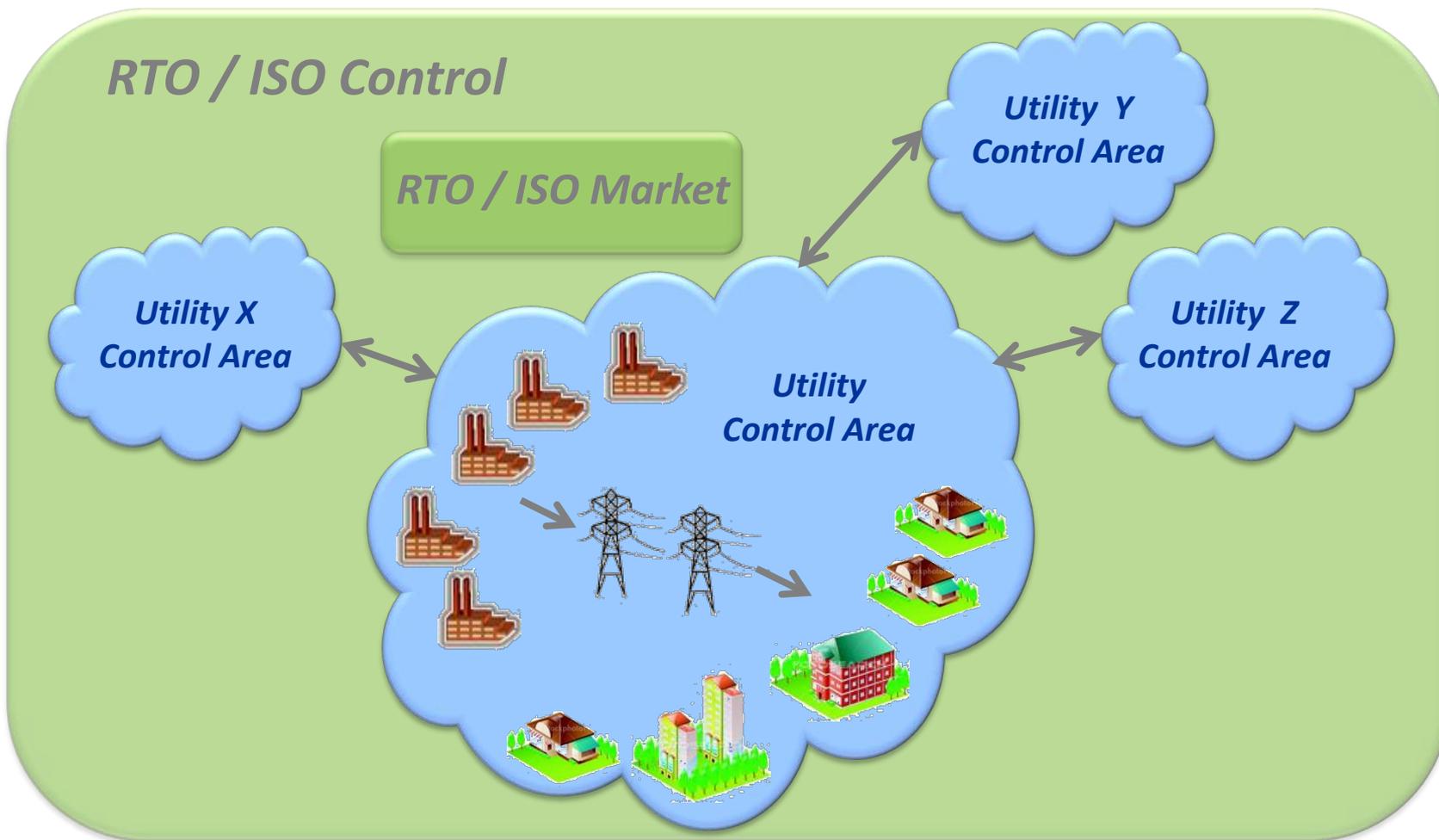
# Grid Operations - Past

## Utility Centric (Vertically Integrated)



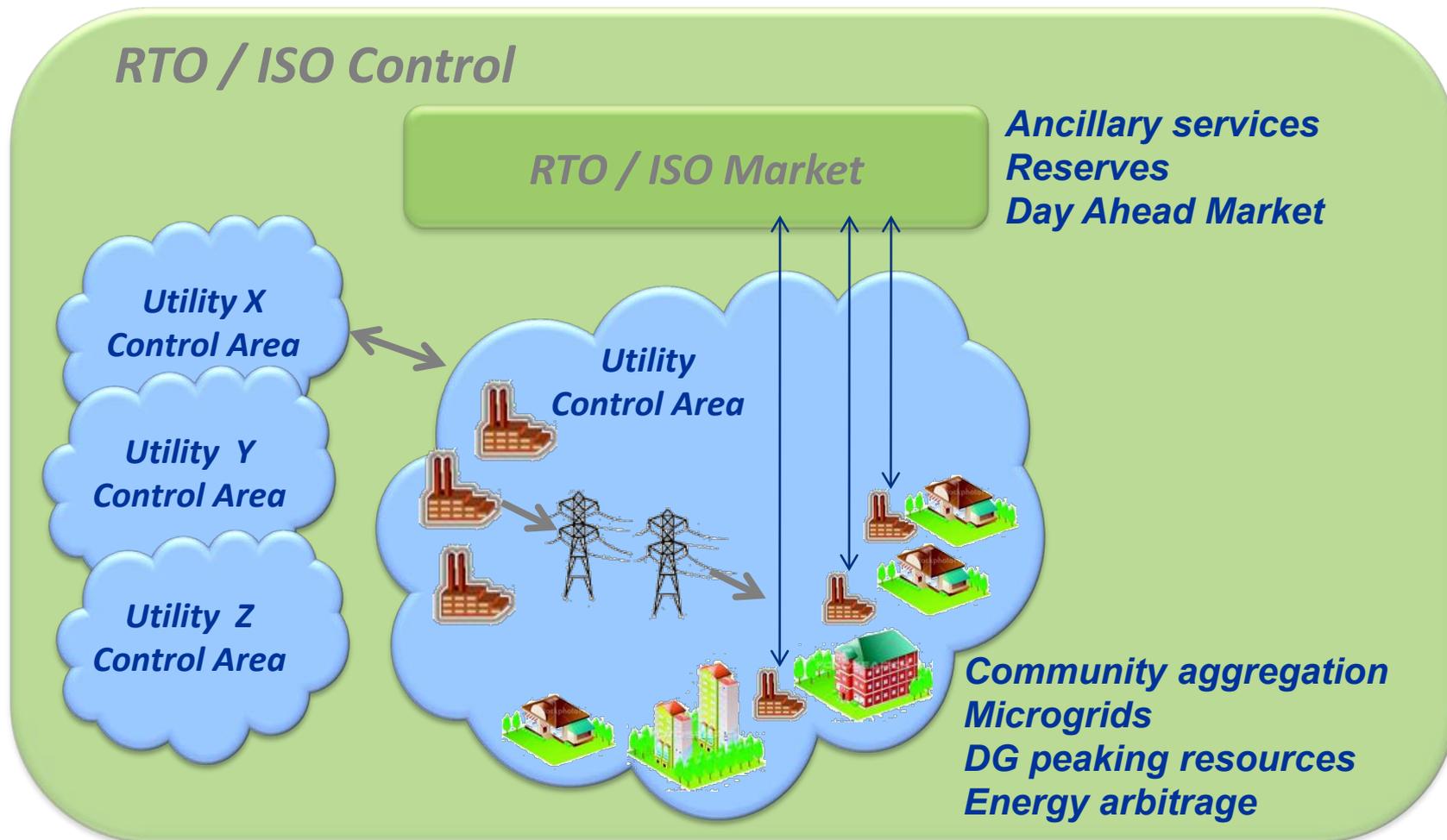
# Grid Operations - Present

## *RTO/ISO Centric – Security-Constrained Economic Dispatch*



# Grid Operations – Possible Future

## Consumer Centric – Economic / Reliability / Environ (ERE) Dispatch



# What is a Microgrid?

## Utility Network Management

**Microgrid  
Master Controller**

**SCADA System**

### Microgrid Objectives

Take action to improve reliability  
Take action to improve economics  
Take action to manage renewables

### Distributed Energy Resources

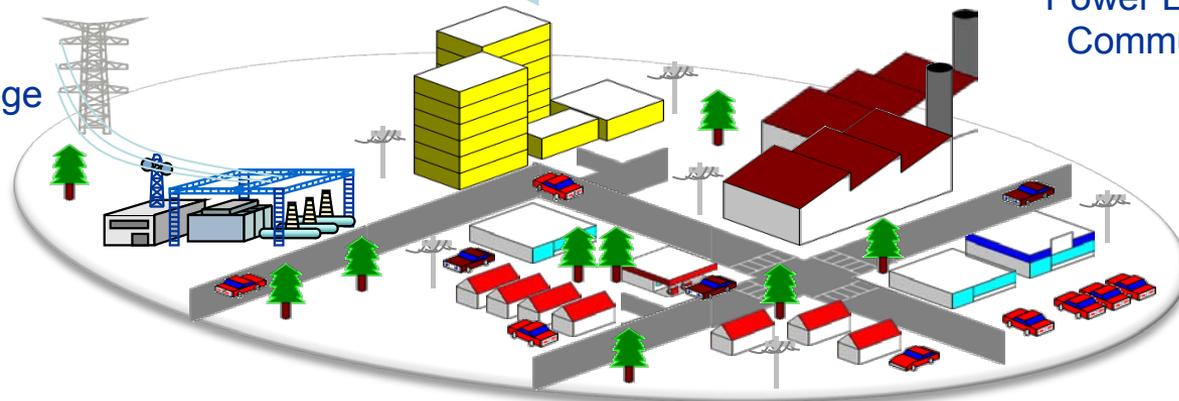
Utility-scale Energy Storage  
Rooftop PV Solar  
Micro-turbines  
Building Energy Storage  
Community Energy Storage  
Distributed Generation  
Home Energy System  
PHEVs  
Ground PV Solar Array

### Information

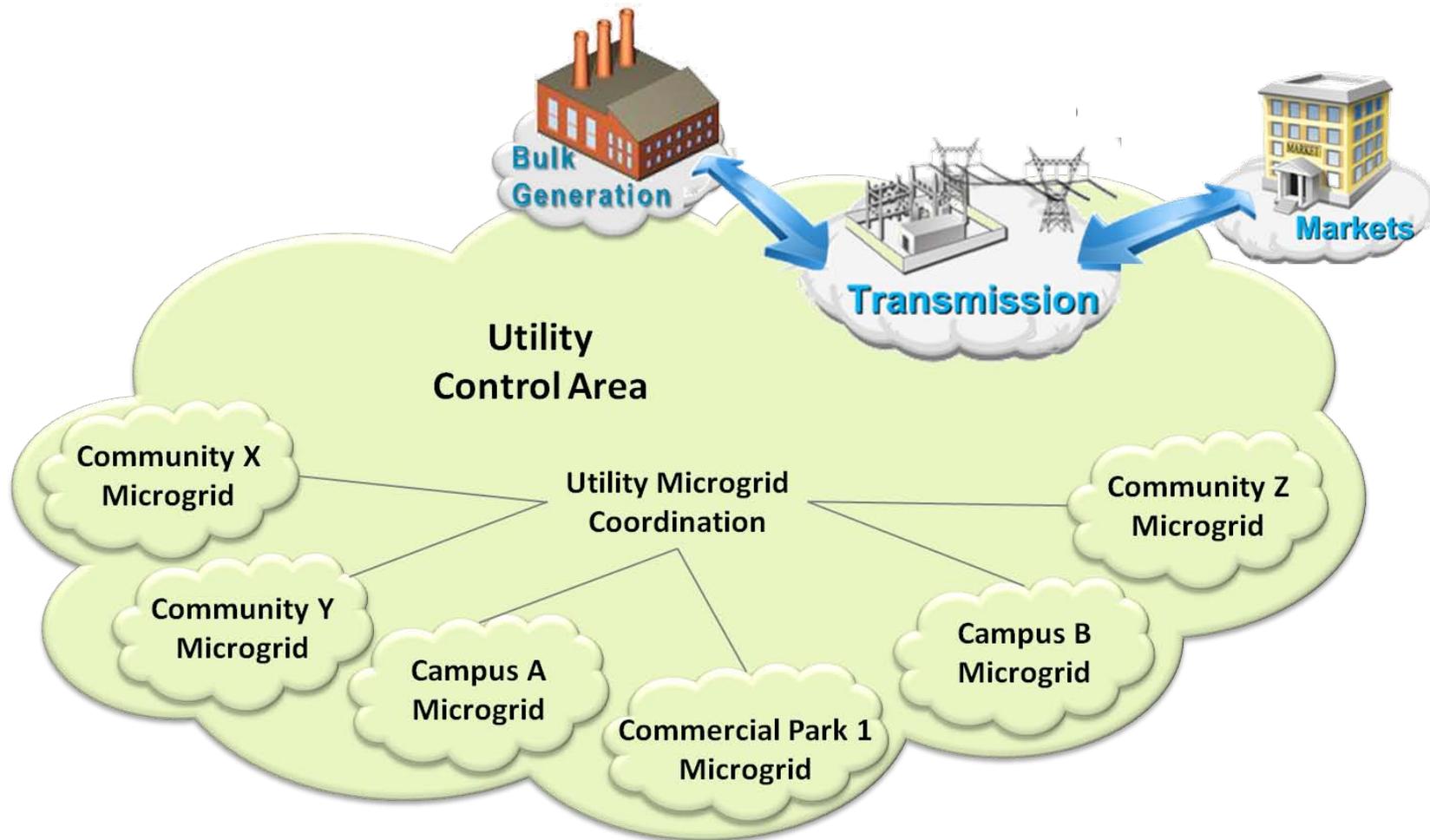
Electricity Pricing  
DER status  
Demand Response Programs  
Network status  
Community Objectives  
Load and Resource Profiles

### Grid Resources

Capacitor Banks  
Voltage Regulators  
Automated Switches  
Power Electronics  
Communications



# A Possible Future Architecture



# Role of Microgrids

- **Address local reliability challenges**
- **Address local economic issues**
- **Enable deeper deployment of renewables**
- **Enable energy arbitrage**
- **Aggregate control of multiple sources**
- **Increase grid security**
- **Aggregated operation of multiple microgrids (virtual power plant )**



# Some Beneficiaries

- **University Campuses**
- **Military Facilities**
- **Commercial Parks**
- **Industrial Complexes**
- **Municipalities**
- **Utilities**
- **“Communities”**

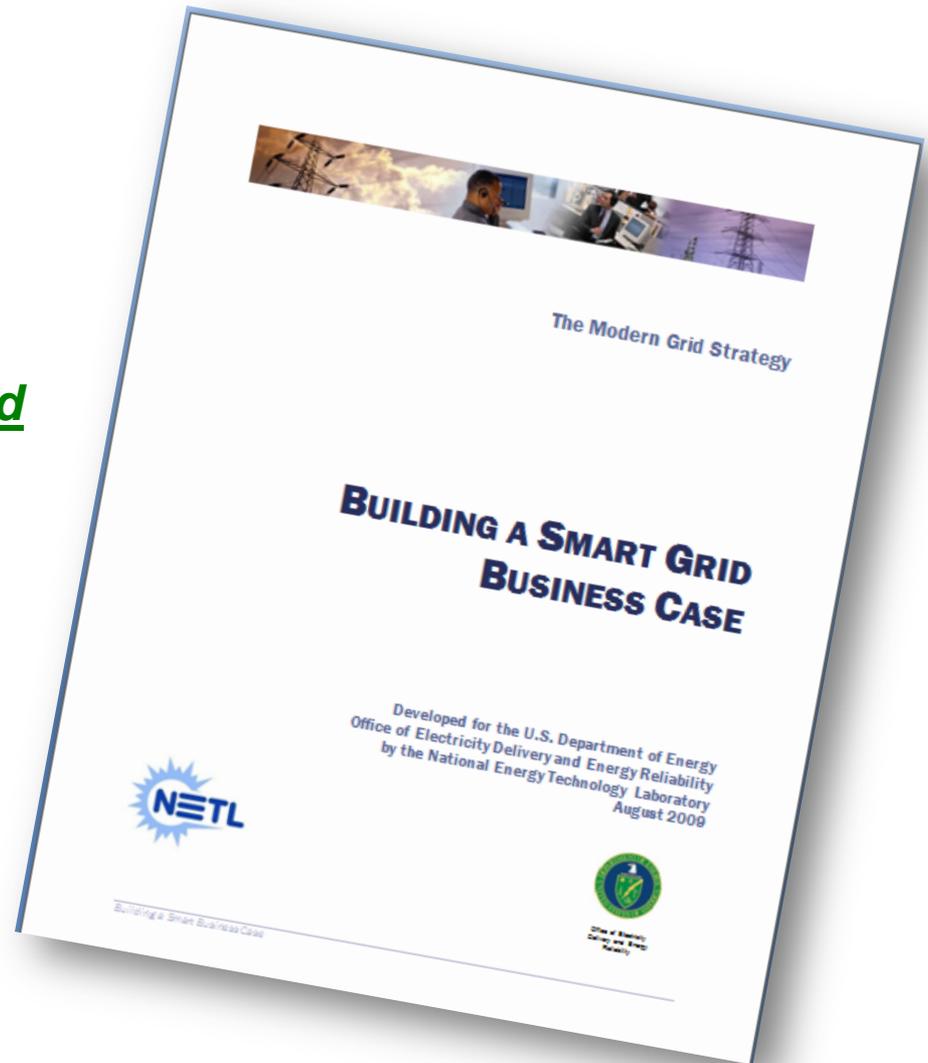
*The microgrid model is just one example of how dramatically the power system might change in the 21<sup>st</sup> century as we implement the Smart Grid*



# For More Information

*For additional Information:*

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



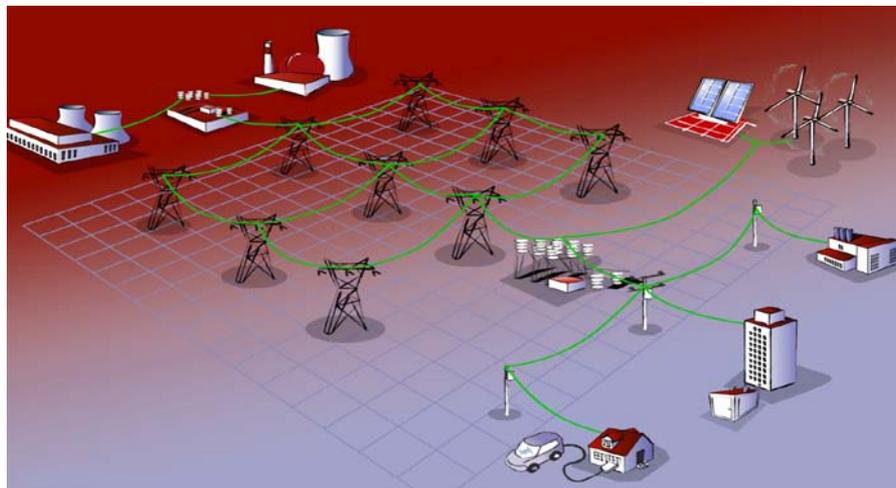


**NATIONAL ENERGY TECHNOLOGY LABORATORY**

**Questions?**

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## **Understanding the Smart Grid Value Proposition**

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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.*



# How does the Smart Grid Generate Benefits?

## Technology Solutions

- Advanced Metering Infrastructure (AMI)
- Customer Side Systems (CS)
- Demand Response (DR)
- Distribution Management System/Distribution Automation (DMS/DA)
- Transmission Enhancement Applications (TA)
- Asset / System Optimization (AO)
- Distributed Energy Resources (DER)
- Information and Communications Integration (ICT)



# It gets complicated—fast

## Technology Solution vs. Value Area

AMI	Reliability
CN	Economics
DR	Efficiency
DMS	Environmental
AO	Safety
TA	Security
DER	
ITC	



# Do benefits have “dimensions”?

## Direct Benefits

- “Feels good” now without additional effort
- “Get what you pay for”
- Example—a good deal on purchase of land

## Optional Benefits

- Must do something to enjoy the benefit
- “On my nickel”
- Example—build a pole barn for antique car collection

## Conditional Benefits

- “Build it and they will come”
- Example—area prospers and property values rise

*Are these dimensions valued differently?*



# 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**
- + **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?”*



# An Example

## *Potential Bill Savings*

Estimated residential bill/year	\$1,200
Expected reduction from EE/DR	10% – 15%
Potential savings/year	\$120 – \$180
Assumed bill increase to pay for smart grid/year	\$60 – \$120
Net consumer value/year	\$0 – \$120

*Positive value but not very compelling!*



# Another Example

## *Potential Transportation Cost Savings*

Assumed miles driven/year	10,000
Fuel cost (gas)/mile	\$0.10 – 0.15
Fuel cost (PHEV)/mile	\$0.03 – 0.05
Annual fuel cost (gas)	\$1,000 – \$1,500
Annual fuel cost (PHEV)	\$300 – \$500
Potential fuel cost savings/year	\$500 – \$1,200
Premium to purchase PHEV over gas	\$4,000 – \$10,000

*More compelling but is it enough?*



# 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. and us?

## 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*





**What are some of the challenges?**

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# 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)**



# 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?”*



# Answering Consumers' Questions

- Why do we need to pursue the consumer side (smart meters) before smart grid upgrades are made to the delivery system?
- Why can't many of the benefits that Smart Grid provides be done with existing technologies, e.g., existing demand response technologies?
- All consumers will pay for Smart Grid investments, but only some will (can) take the initiative to achieve the benefits. Is that fair?
- Will consumers have to purchase additional devices to participate with the Smart Grid and enjoy its benefits, e.g., home area networks, in-home displays?
- Will Smart Grid technologies increase the risk of cyber security events resulting in a less secure grid?



# So is the Smart Grid worth it?

## My Score Card

- + Delivery companies (but cost recovery a concern)
- ? Generators (new risks but new opportunities)
- ? Residential consumers (risk/reward and other concerns)
- ± C&I consumers (some yes, some no)
- ✓ Society (hard to quantify, will they happen?)

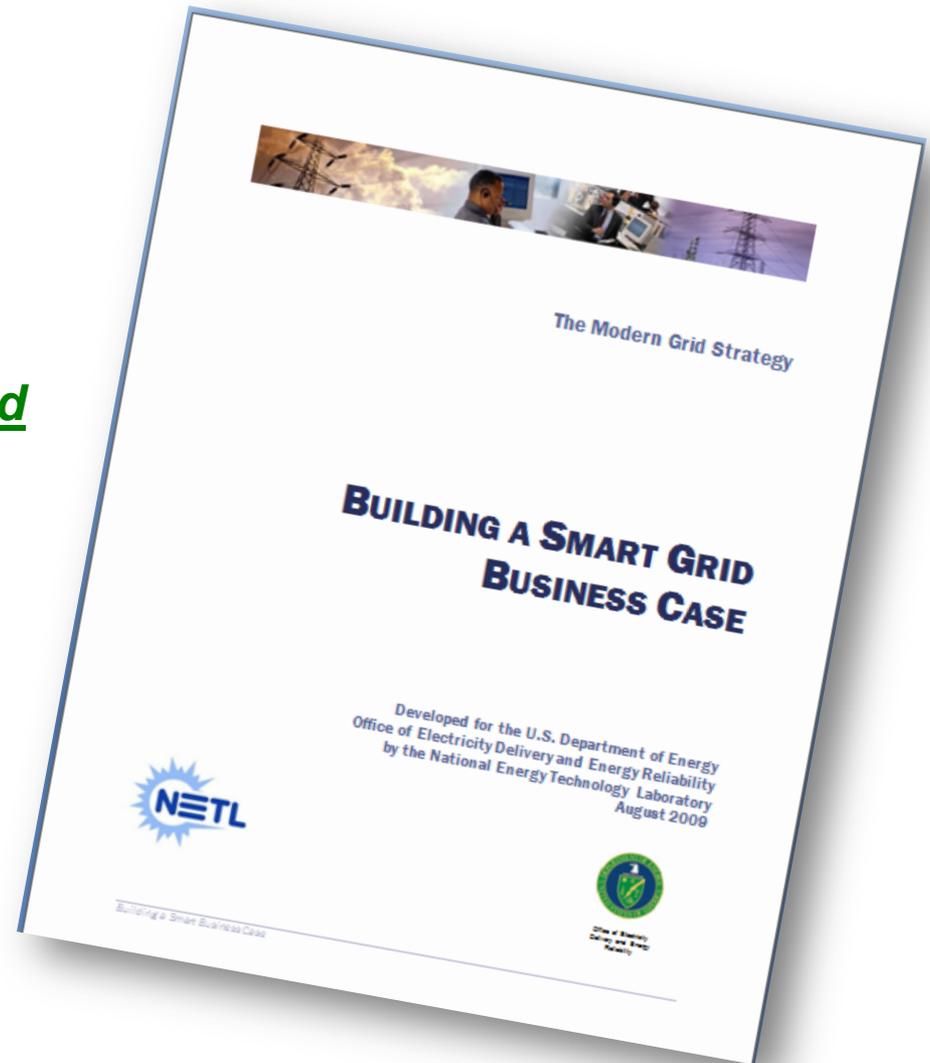
**What's yours?**



# For More Information

*For additional Information:*

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





**NATIONAL ENERGY TECHNOLOGY LABORATORY**

**Questions?**

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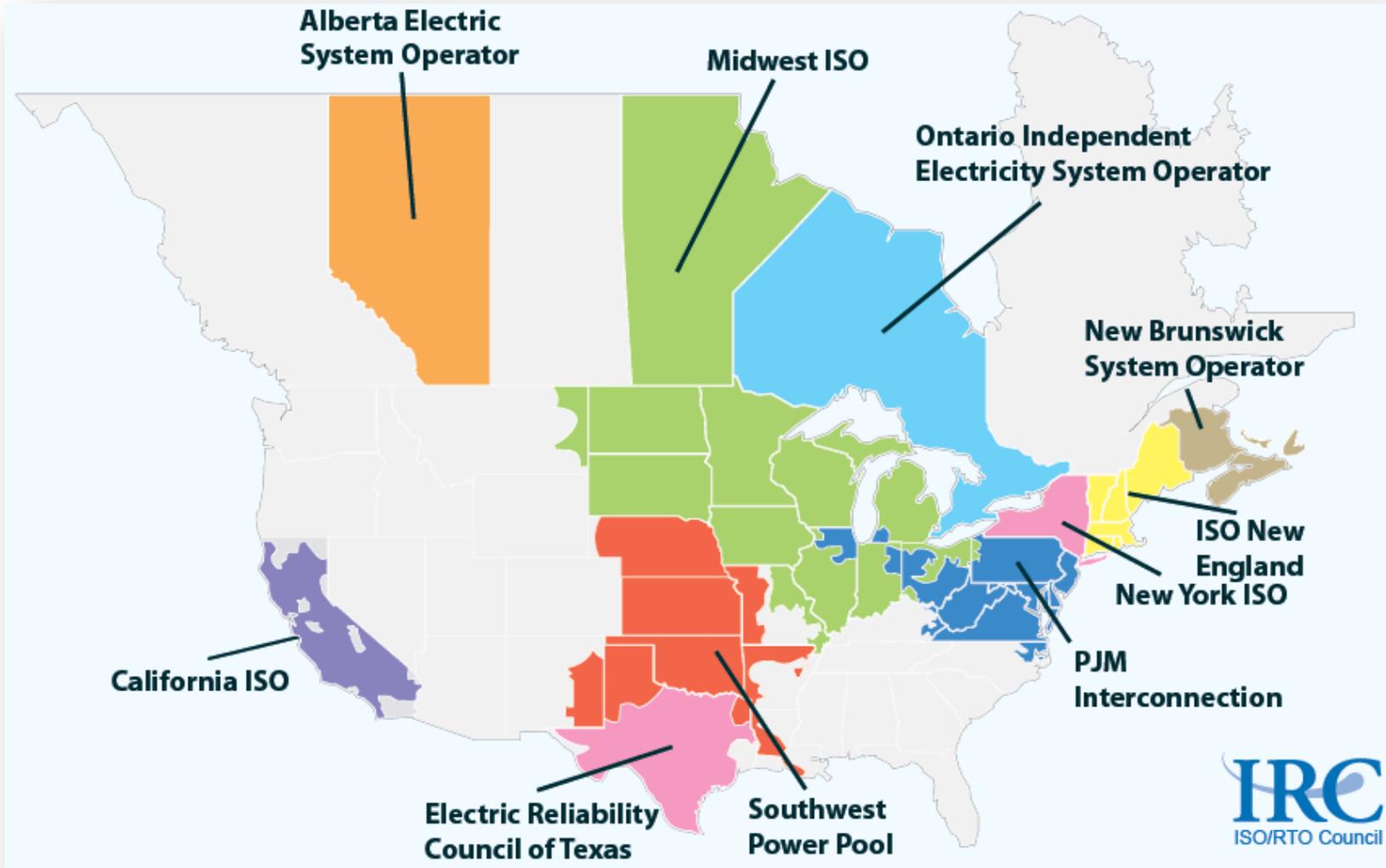


## **Backup Slides**

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# ISO / RTO Map



# PC View

- **Enables active participation by consumers:** Consumer choices and increased interaction with the grid bring tangible benefits to both the grid and the environment, while reducing the cost of delivered electricity.
- **Accommodates all generation and storage options:** Diverse resources with “plug-and-play” connections multiply the options for electrical generation and storage including new opportunities for more efficient, cleaner power production.
- **Enables new products, services, and markets:** The grid’s open-access market reveals waste and inefficiency and helps drive them out of the system while offering new consumer choices such as green power products and a new generation of electric vehicles. And reduced transmission congestion leads to more efficient electricity markets.



# PC View

- **Provides power quality for the digital economy:** Digital grade power quality for those who need it avoids production and productivity losses, especially in digital device environments.
- **Optimizes asset utilization and operates efficiently:** Desired functionality at minimum cost guides operations and allows fuller utilization of assets. More targeted and efficient grid maintenance programs result in fewer equipment failures and safer operations.
- **Anticipates and responds to system disturbances (self-heals):** The smart grid will perform continuous self-assessments to detect, analyze, respond to, and as needed, restore grid components or network sections.
- **Operates resiliently against attack and natural disaster:** The grid deters or withstands physical or cyber attack and improves public safety.



# Societal Value Proposition

## Benefits

- Energy independence
  - Deep penetration of electric vehicles –Smart Grid enabled – **could reduce oil imports by 52%.**
  - Smart Grid supports conservation, demand response, and reduces T&D losses **reducing total U.S. electricity consumption by 1-4% by 2030.**
- National security
  - Smart Grid increases the decentralization of supply, greatly **reducing its vulnerability to attack.**
  - 2-way flow of power and information enables the grid to anticipate and respond to problems (self-heals) dramatically **reducing the impact and duration of disturbances.**



# Societal Value Proposition

## Benefits

- Downward pressure on electricity prices – *through* improved operating and market efficiencies, consumer involvement, deferral of capital projects.
- Improved environment
  - ***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 in 2030.***
  - New storage technologies—including EV’s— ***will enable a much deeper penetration of intermittent renewables.***
  - Smart Grid ***will reduce T&D losses*** thereby reducing the amount of generation needed to serve a given load.



# Societal Value Proposition

## Benefits

- Growing the U.S. economy
  - New jobs—**280K new, 140K sustained**— to support the planning, design, construction, operation and maintenance of the Smart Grid.
  - Economic development for new products and services demanded by Smart Grid consumers.
- Improved reliability – **leading to reduction in consumer losses (~\$135B)**

## Additional Costs

- None



# 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*



# Other Potential Risks

- **PHEV's without a price signal could result in making peak demand worse.**
- **Early deployments of AMI without interoperability and cyber security standards in place could create financial risk to retrofit and increase the vulnerability of the grid.**
- **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.**



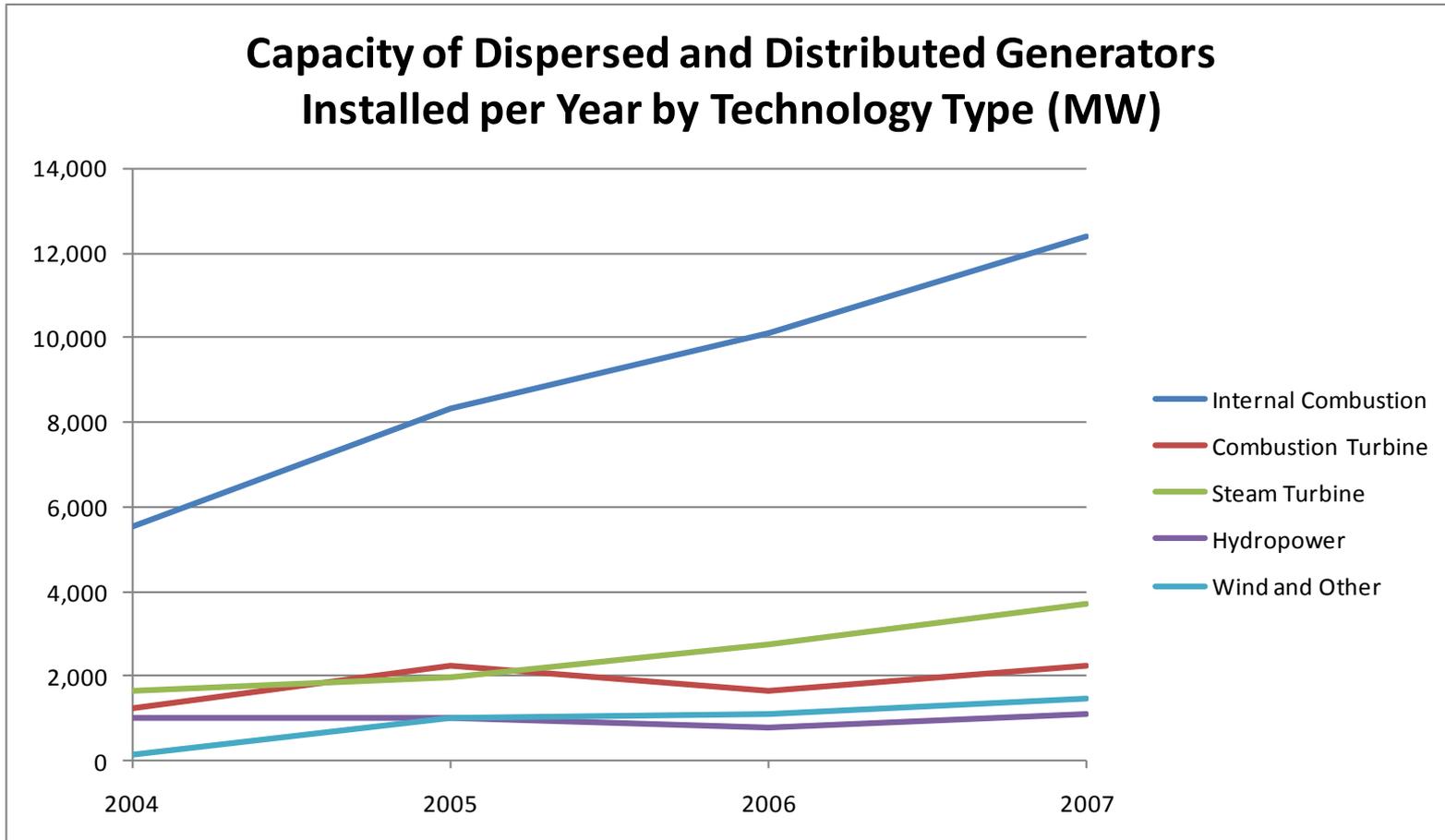
# Residential Consumer Acceptance

## **A significant change management effort is needed:**

- Why do we need to change?
- What is the vision?
- What is the value proposition?
- 300 million consumers affected
- Consumer education, alignment and motivation is critical
- Metrics needed for accountability and to monitor progress
- Active leadership by stakeholder groups needed



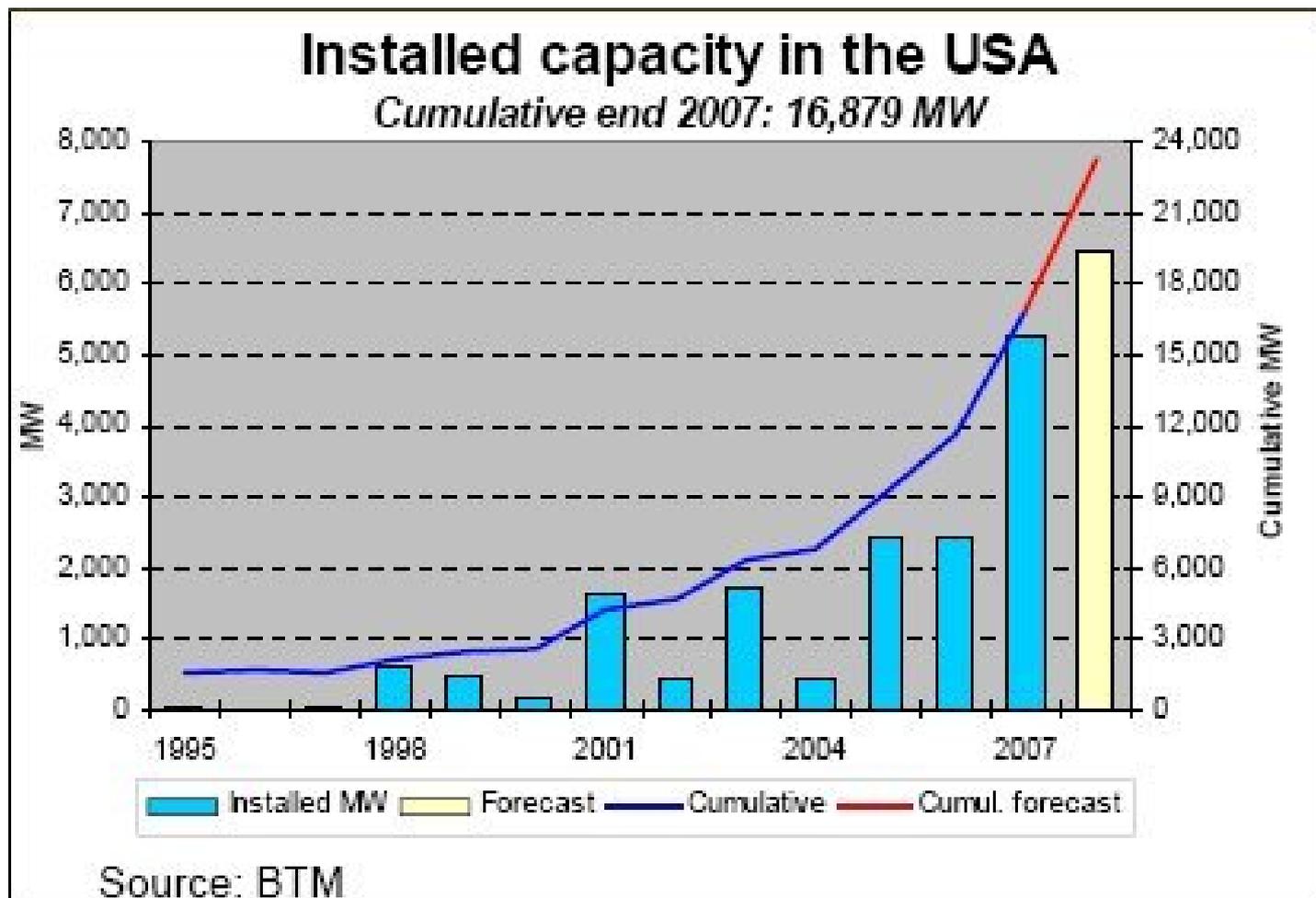
# Distributed Generation Trends



*Capacity of Distributed Generation Installed per Year by Technology Type (EIA, 2009)*



# Growth of Wind



# Characteristic – Milestone Map

<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	✓	✓	✓	

