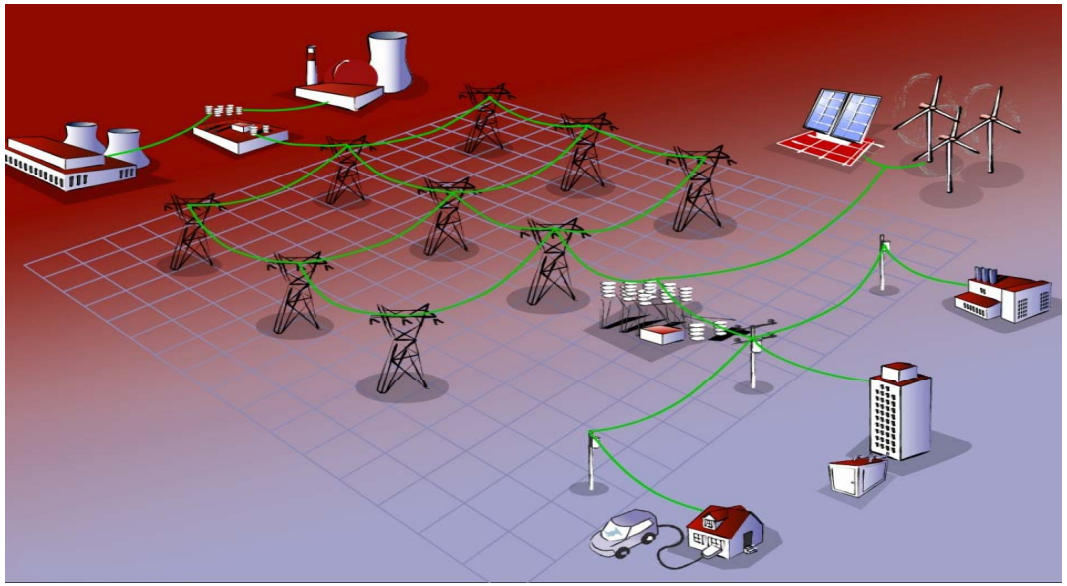
NATIONAL ENERGY TECHNOLOGY LABORATORY



The Smart Grid ??

AEE – National Capital Chapter

Keith Dodrill

US Dept of Energy

National Energy Technology Laboratory

May 25, 2010

Topics

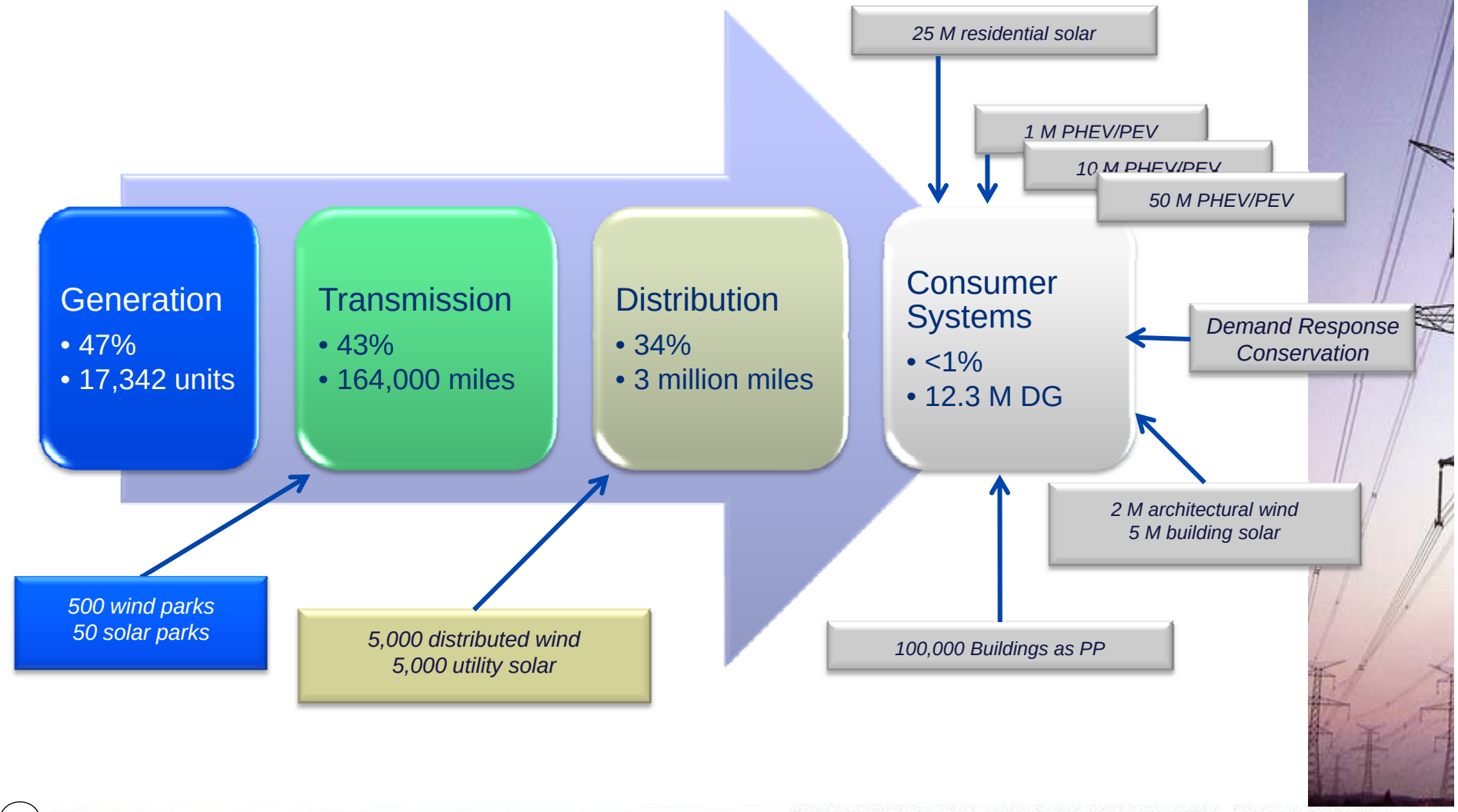
- The "Case for Action”
- What is the Smart Grid?
- Key Technology Areas
- The Smart Grid business case
- Challenges and Barriers
- Current Activities
- Summary

Case for Action

- 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
- Disturbing trends in prices, reliability, peak loads, transmission congestion, & asset utilization

But is it worth it?

The “Market” will create new stresses



What is the Smart Grid?

The Systems View

What's different with the Smart Grid?

- **Decentralized 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

In order to succeed, we must view the Smart Grid as a vision AND as a system…

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

Smart Grid Domains

Domain	Actors in the Domain
Customers	The end users of electricity. May also generate, store, and manage the use of energy. Traditionally, three customer types are discussed, each with its own domain: home, commercial/building, and industrial.
Markets	The operators and participants in electricity markets
Service Providers	The organizations providing services to electrical customers and utilities
Operations	The managers of the movement of electricity
Bulk Generation	The generators of electricity in bulk quantities. May also store energy for later distribution.
Transmission	The carriers of bulk electricity over long distances. May also store and generate electricity.
Distribution	The distributors of electricity to and from customers. May also store and generate electricity.

Source: NIST

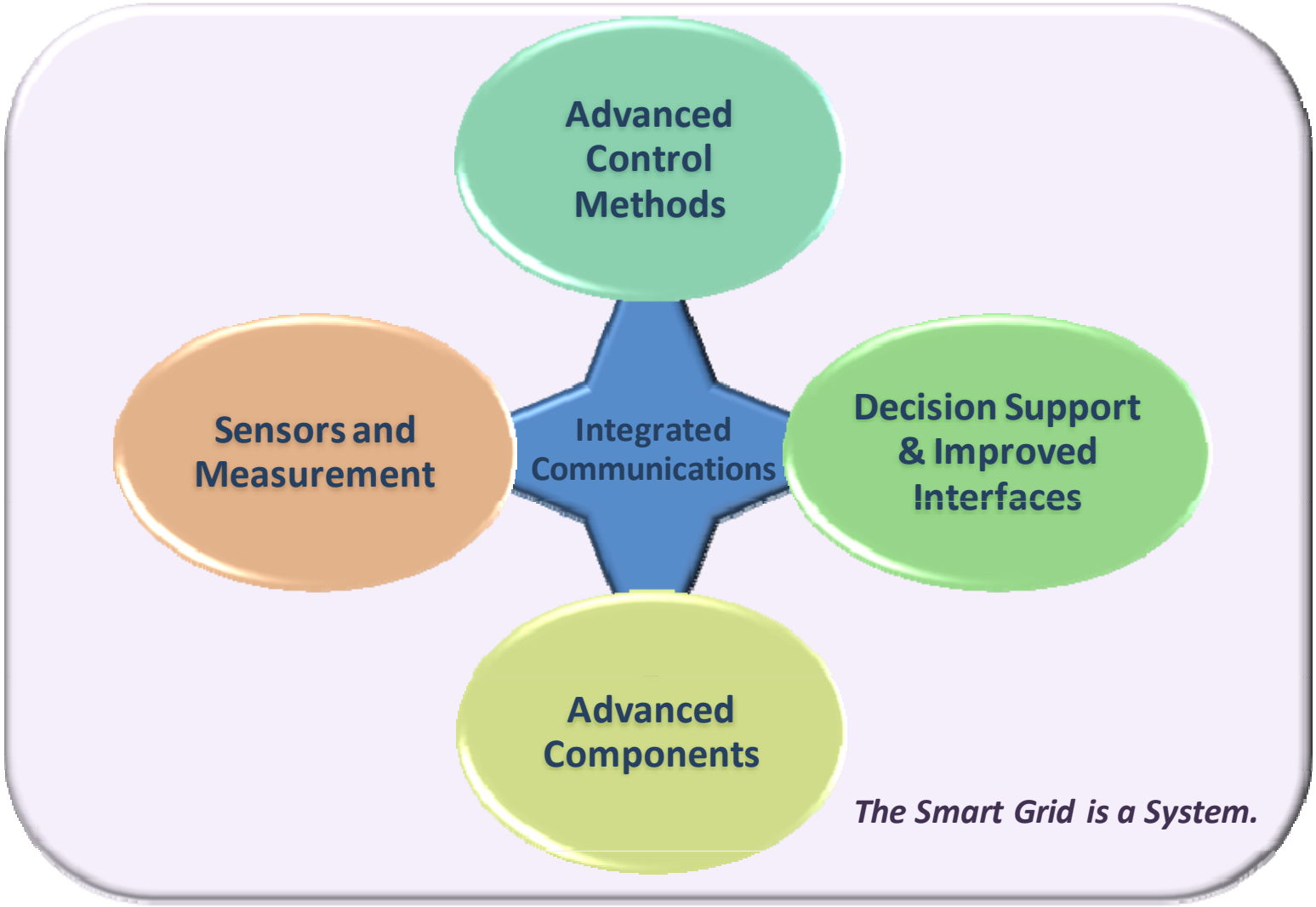
Smart Rates Can Work

Rate	Peak Time Pricing		Peak Time Rebate		8-Hour time of Use	
Customers	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%	3.7%	
Business	-2.8%	-7.2%	0.0%	-4.1%	0.0%	

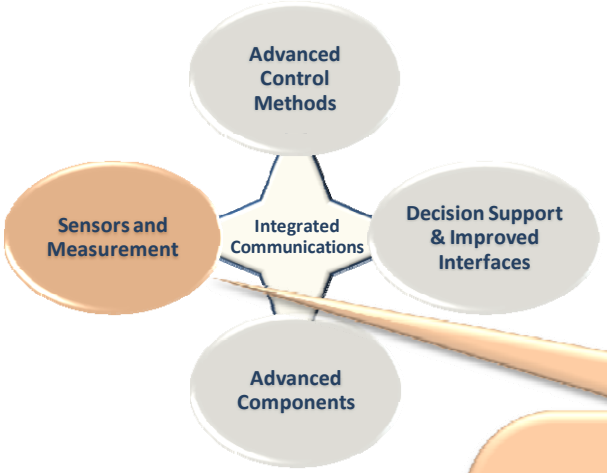
Connecticut L&P Plan-it Wise Results—Reduction in Peak Load

Key Technology Areas

Smart Grid Key Technology Areas



Sensors and Measurement



Smart meters

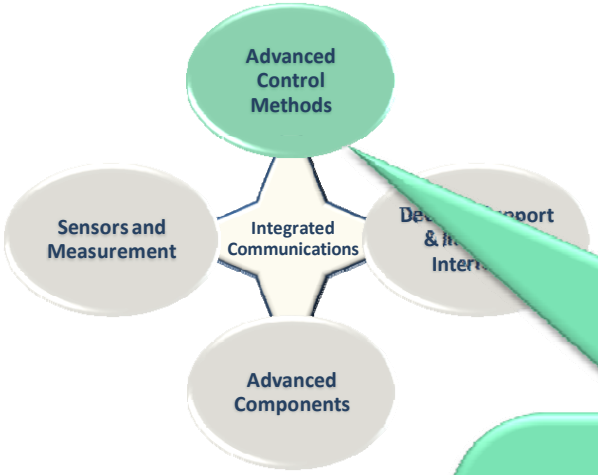
Smart sensors

- *Operating parameters*
- *Asset Condition*

Wide area monitoring systems (WAMS)

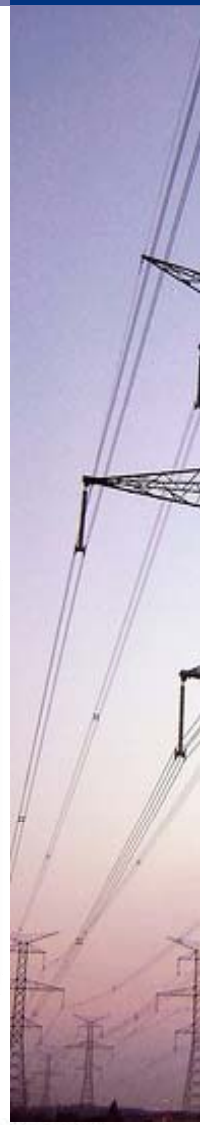
Dynamic rating of transmission lines

Advanced Control Methods

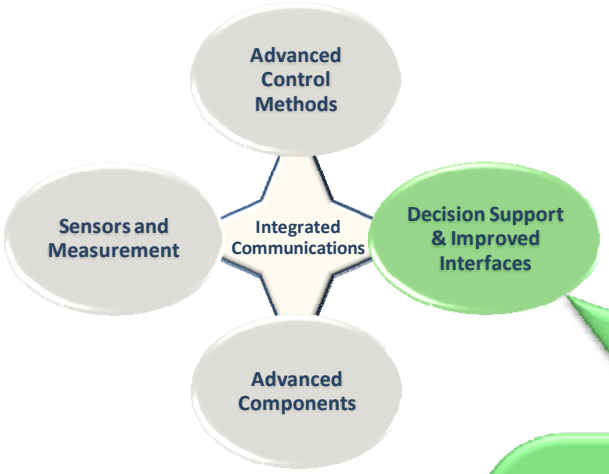


Applications that:

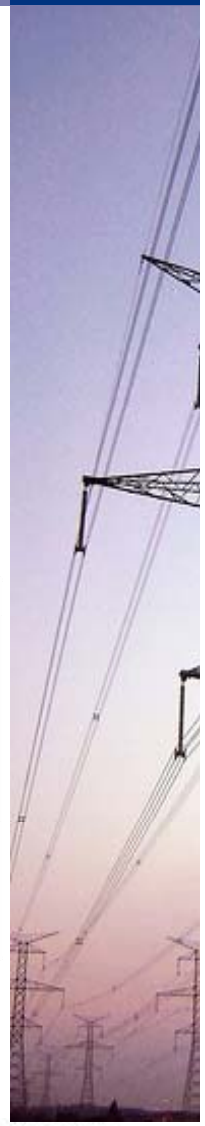
- *Monitor and collect data from sensors*
- *Analyze data to diagnose and provide solutions*
- *Real time and predictive*
- *Determine and take action autonomously or via operators*
- *Provide information and solutions to operators*
- *Integrate with enterprise-wide processes and technologies*



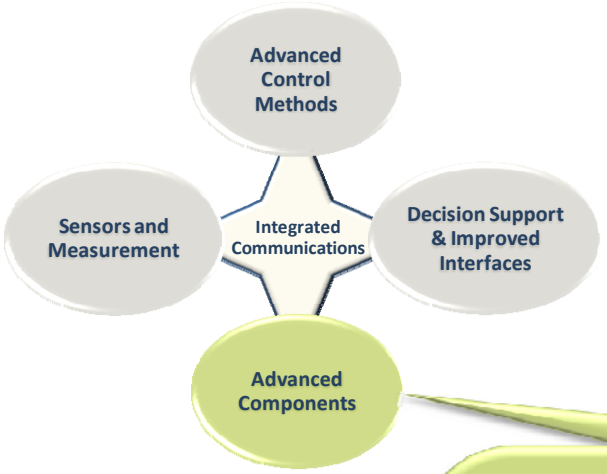
Decision Support & Improved Interfaces



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

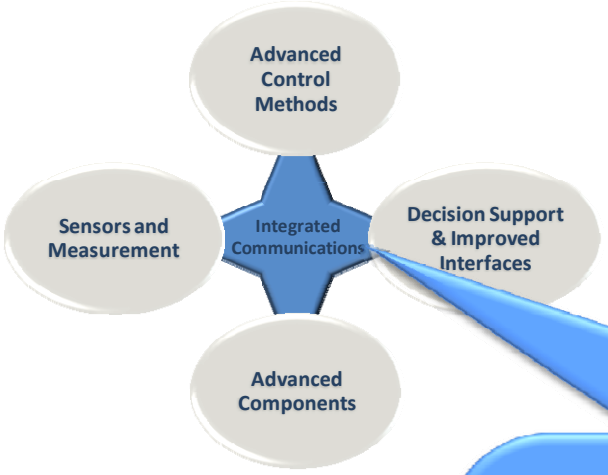


Advanced Components



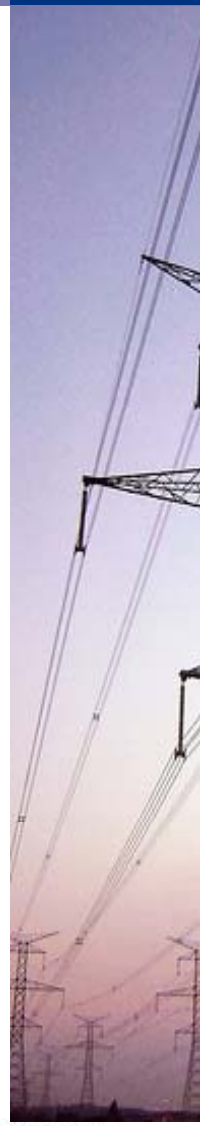
Next generation FACTS/PQ devices
Advanced distributed generation and energy storage
PHEV - V2G mode
Fault current limiters
Superconducting transmission cable & rotating machines
Micro-grids
Advanced switches and conductors

Integrated Communications



Consider all needs:

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



The SG Business Case

EPRI's Perspective on the Value Proposition

Cost to Modernize

- **$165B over 20 years**
  - $127B for Distribution
  - $38B for Transmission
- **~$8.3B per year (incremental to business-as-usual)**
- **Current annual investment - $18B**

EPRI 2004

Benefit of Modernization

- **$638B - $802B over 20 years**
- **Overall benefit to cost ratio is 4:1 to 5:1**

Thus, based on the underlying assumptions, this comparison shows that the benefits of the envisioned Future Power Delivery System significantly outweigh the costs. *(EPRI, 2004)*

WV Smart Grid Costs & Benefits

	PV 20-yr Cost and Benefits ($1000)	
Solution	**Cost**	**Benefits**
AMI	$399	$1,377
IT	$170	$1,025
DR	$22	$877
DMS	$454	$3,286
DER	$832	$3,671
Total	**$1,878**	**$10,236**

*Benefit to Cost Ratio for West Virginia – **5:1***
Benefit to Cost Ratio for San Diego – 6:1
Benefit to Cost Ratio for US (EPRI 2004) – 4:1 to 5:1

WV Smart Grid Annual Benefits

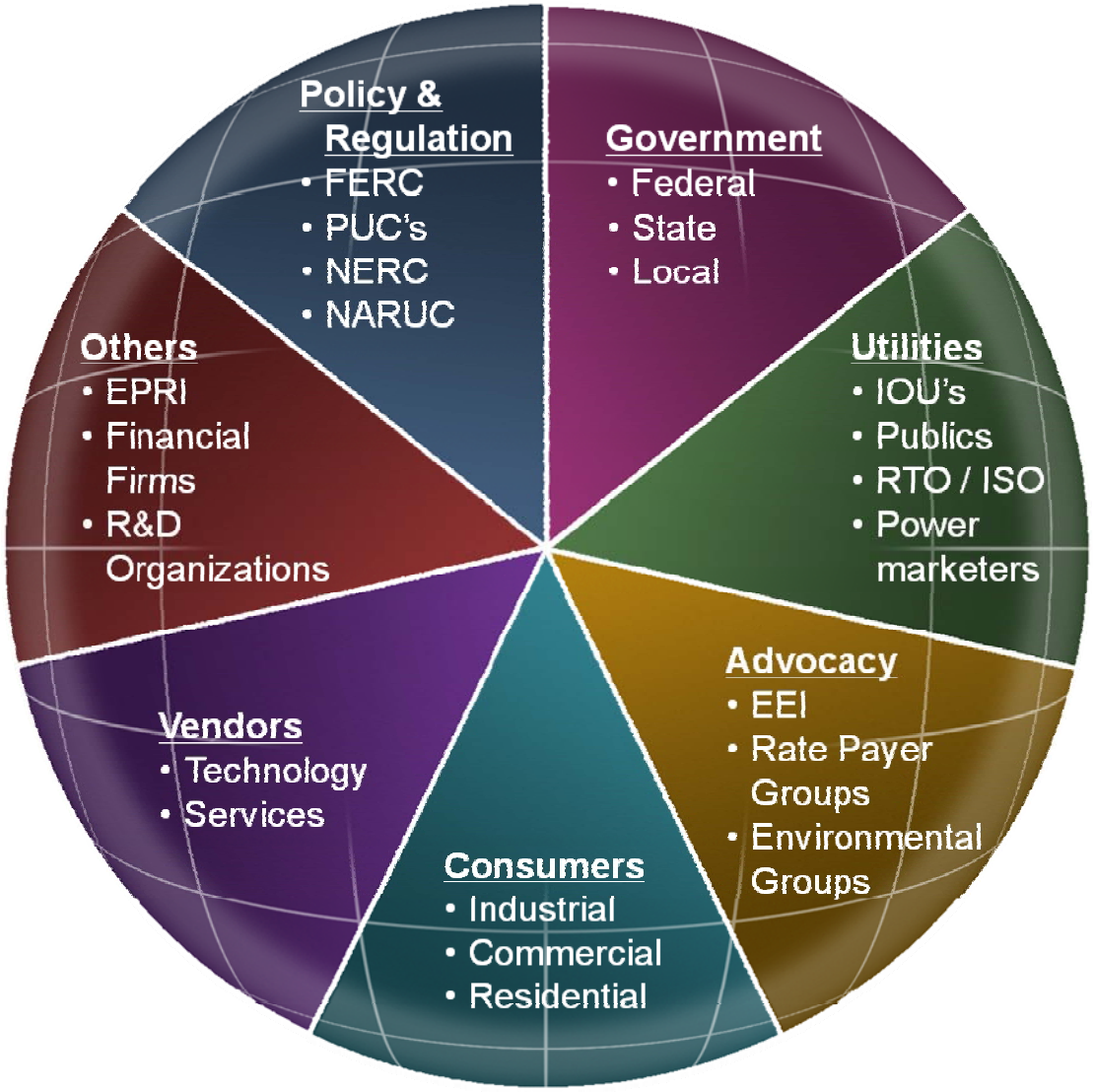
Key Success Factors	Benefits	Annual Benefits ($M) (All Beneficiaries)
Reliability	Reduced Consumer Losses	$898
	Reduce Power Quality Events	$131
Economic	Reduce Price of Electricity	$399
	Job Creation	$215
	Consumer Sales of DER Resources	$175
	Increased Energy Sales as Exports	$7
	Reduced Transmission Congestion	$1
	Increased Transportation Fuels Business	$5
	Consumer Conservation	$20
	Operational Savings	$194
Environmental	Reduced Emissions	$7
Security	Reduced Blackout Probability & Dependence on Foreign Oil	$13
Safety	Reduce Hazard Exposure	$1

Challenges and Barriers

Many Challenges to Address

- Consumer acceptance
- Culture and education
- Regulatory & policy
- Technical
- Engineering
- System planning
- Operations
- Workforce training and education

Many Stakeholders Involved

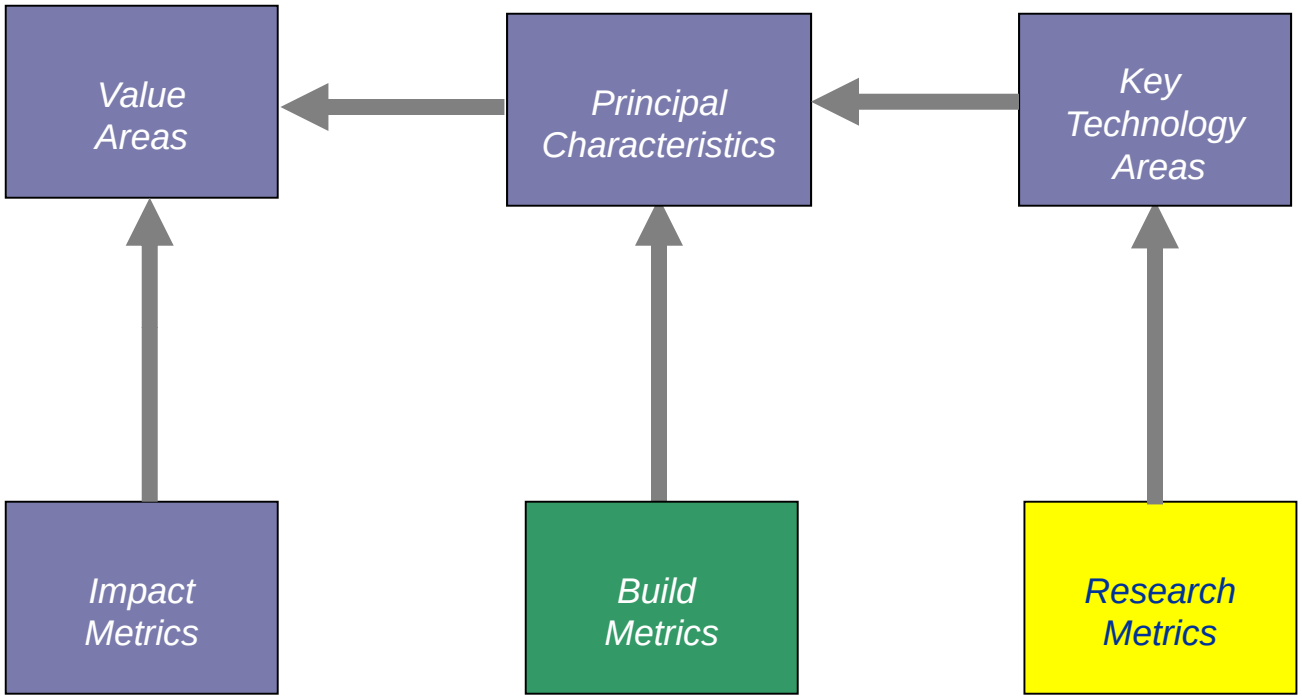


The Two Big Things…

- **Defining and understanding the business case**
  - Leads to logical implementation
  - Maximizes profitability
  - Minimizes impact to the consumer
- **Consumer education**
  - Needed understanding of the Smart Grid vision
    - consumer benefits
    - societal benefits
    - costs of doing nothing
    - address their concerns and questions

The consumer will pay for the Smart Grid…

Smart Grid Metric Map



If we do this right – we can all be winners

- *Suppliers*
- *Consumers*
- *Society*

Current Smart Grid Activities

- **Smart Grid Investment Grants (100 projects)**
  - $3.4 billion Federal; $4.7 billion private sector
  - 850 PMUs covering 100% of transmission
  - 200,000 smart transformers
  - 700 automated substations
  - 40 million smart meters
  - 1 million in-home displays
- **Smart Grid Demonstration Projects (32 projects)**
  - $620 million Federal; $1 billion private sector
  - 16 storage projects
  - 16 regional demonstrations

Summary

- Motivation to move toward national Smart Grid
- Common vision being established for Smart Grid
- Benefits accrue to utilities, consumers & society
- Business case shows 4:1 to 6:1 ROI
- Different approaches to implementing Smart Grid
- Technical, regulatory, consumer & cultural barriers
- DOE ARRA projects create momentum

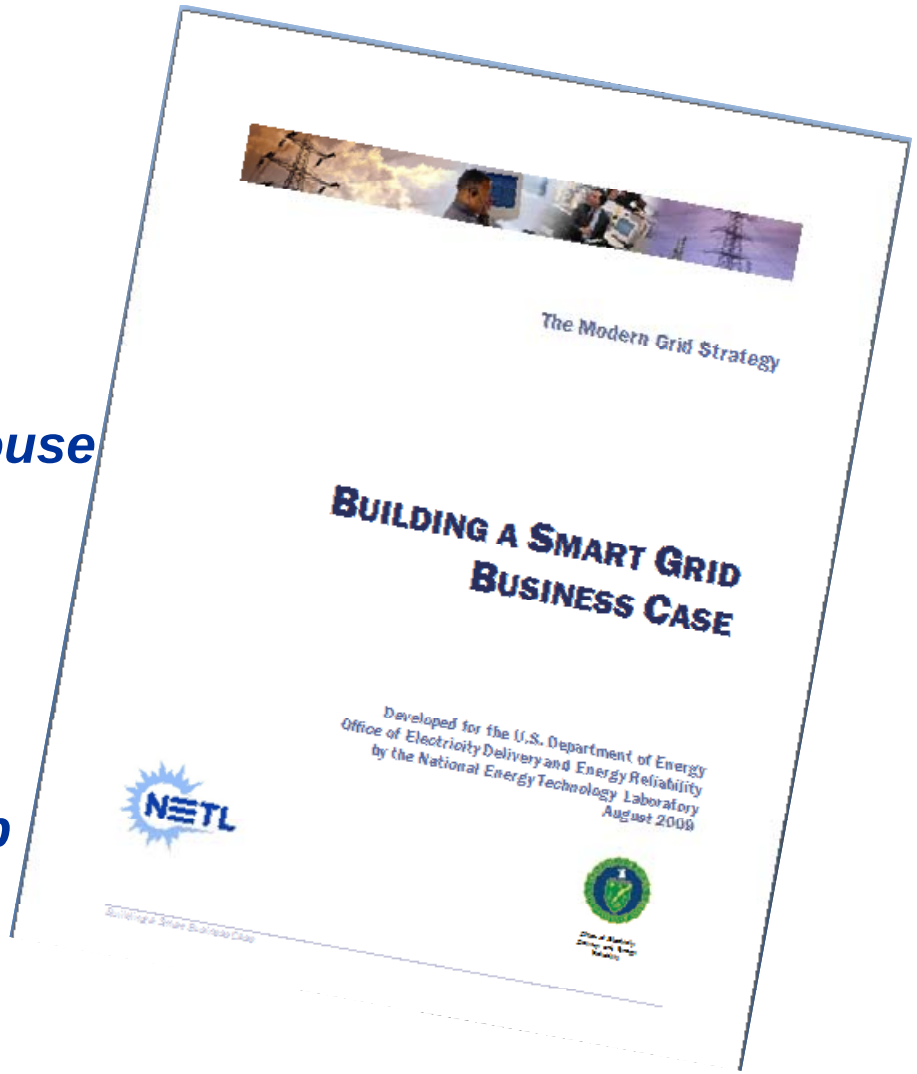
For More Information

For additional Information:
www.netl.doe.gov/smartgrid

Federal Smart Grid Website
www.smartgrid.gov

Smart Grid Information Clearinghouse
www.sgiclearinghouse.org

Steve Bossart
National Energy Technology Lab
304-285-4643
Steven.Bossart@netl.doe.gov



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
  - 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	*Tomorrow*
Little or no info, limited use of smart pricing, few choices	**Full price info, choose from many plans, prices and options, buy and sell, "E-Bay"**

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	*Tomorrow*
Dominated by central generation. Little DG, DR, storage, or renewables	**Many "plug and play" distributed energy resources complement central generation**

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	*Tomorrow*
Near-zero market interaction at distribution level	**Distribution assets and consumers act as resources for transmission, growth of new secondary markets**

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	*Tomorrow*
Focus on outages not power quality	**PQ a priority with variety of price/quality options based on needs**

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	*Tomorrow*
Limited grid information & minimal integration with asset management	**Deep integration of grid intelligence enabling reduction in O&M and CapEx**

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	*Tomorrow*
Protects assets following disruption (e.g., trip relay)	**Prevents disruptions, minimizes impact, restores rapidly**

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	*Tomorrow*
Vulnerable to terrorists and natural disasters	**Deters, detects, mitigates, and restores rapidly and efficiently—"cyber proof"**

Who are the Smart Grid Beneficiaries?

- **Utilities**
- **Consumers**
- **Society**

The value of Smart Grid depends on who you ask!

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 Fuel 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?

Societal Value Proposition

Benefits

- Energy independence
- National security
- Downward pressure on electricity prices
- Improved environment
- Growing U.S. economy
- Improved reliability

Implementation sequence can vary

Consumer Enablement

CE empowers the customer and enables grid interaction

Advanced Distribution

AD improves reliability and enables self healing

Advanced Transmission

AT addresses congestion and integrates with RTO's

Advanced Asset Management

AAM helps utilities reduce costs and operate more efficiently

Current Smart Grid Activities (cont.)

- **DOE Renewable & Distributed Systems Integration (9 projects)**
- **EPRI Smart Grid Demonstrations (6 projects)**
- **Excel's Smart Grid City, Boulder, CO**
- **Smart Grid System Report to Congress**
  - http://www.smartgrid.gov/resources