Smart/Modern Grid Overview

WV Energy Summit

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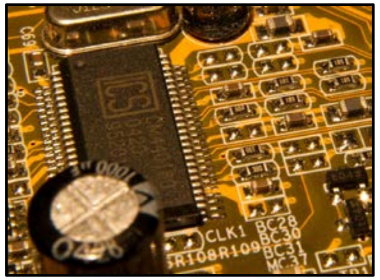
Topics

- Modern Grid Vision
- Modern Grid Deployments
- Case for WV Grid Modernization
- Some Challenges and Risks
- Questions

Modern Grid Vision

The Modern Grid

includes Smart Grid enhancements and more



Attributes of Smart Grid

Senses
Protects
Controls
Automates
Transforms Power

+

Enhanced Functionality

Generation
Storage
Load

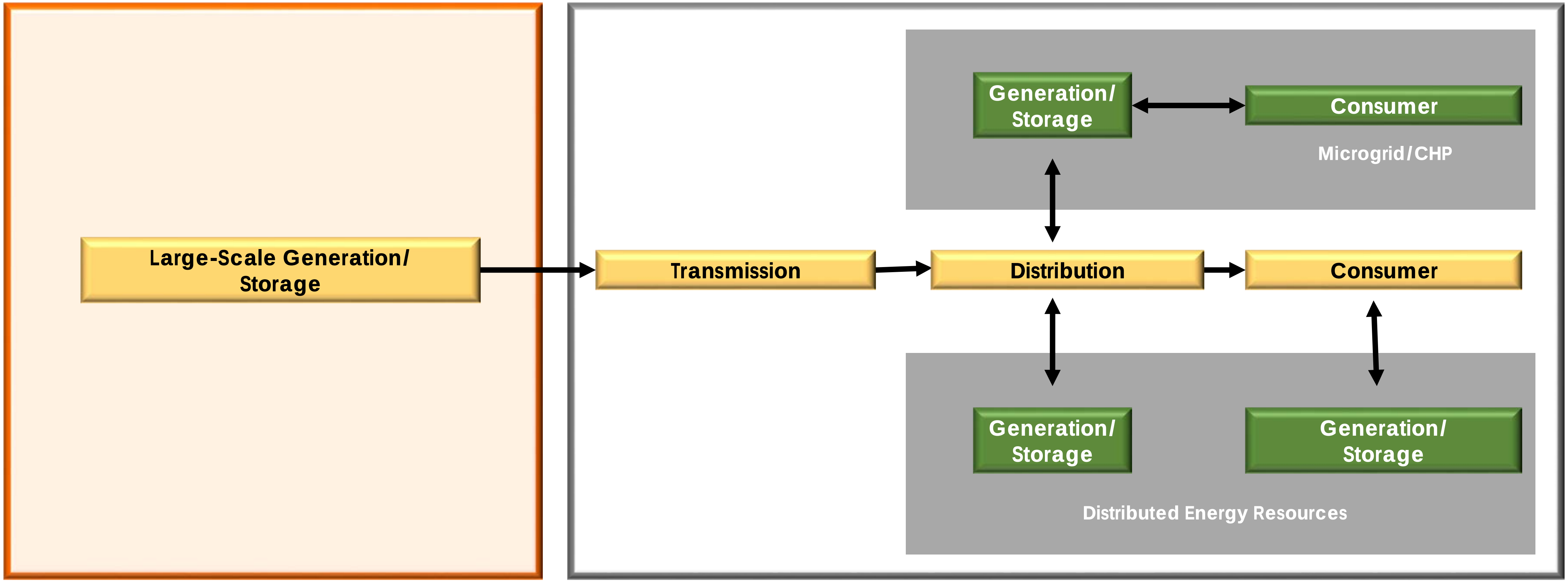
=

Modern Grid

Communication

The Modern System

will have changes in all of these elements, some more than others



Who are the Beneficiaries?

Utilities (What's in it for my shareholders?)

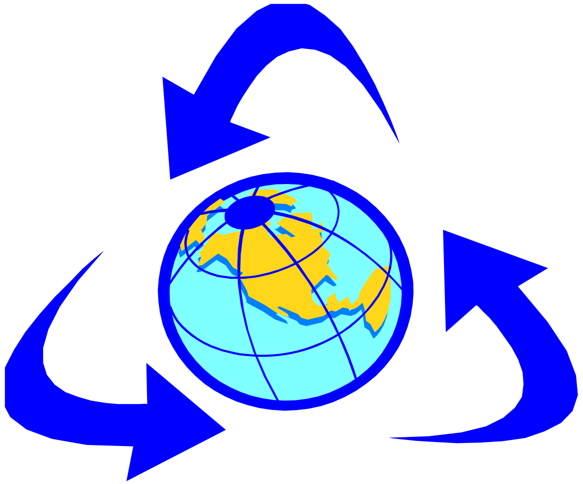
- Outage restoration
- Billing
- Operations and maintenance
- Asset utilization

Consumers (What's in it for me?)

- Improved reliability
- Manage electric power usage
- Energy bill savings (power & transportation)

Society (What's in it for us?)

- Reduce emissions
- Energy independence



Value of Service from Improvements in Reliability

NATIONAL ENERGY TECHNOLOGY LABORATORY

1 project involving 230 automated feeder switches on 75 circuits in an urban area

From Apr 1 – Sep 30 2011

SAIDI improved 24%; average outage duration decreased from 72.3 to 54.6 minutes

Estimated Average Customer Interruption Costs US 2008$ by Customer Type and Duration

Customer Type	Interruption Cost Summer Weekday	Interruption Duration				
		Momentary	30 mins	1 hr	4 hr	8 hr
Large C&I	Cost Per Average kWh	$173	$38	$25	$18	$14
Small C&I	Cost Per Average kWh	$2,401	$556	$373	$307	$272
Residential	Cost Per Average kWh	$21.6	$4.4	$2.6	$1.3	$0.9

Estimated monetary value of this improvement in reliability based on value-of-service data is $21 million

Sullivan J, Michael, 2009 Estimated Value of Service Reliability for Electric Utility Customers in the US, xxi

Modern Grid Deployments

Modern Grid ARRA Activities

American Recovery and Reinvestment Act ($4.3B)

- **Smart Grid Investment Grants (99 projects)**
  - $3.4 billion Federal; $4.7 billion private sector
  - >800 PMUs covering almost 100% of transmission
  - 6500 distribution automation circuits
  - >15 million smart meters

- **Smart Grid Demonstration Projects (32 projects)**
  - $620 million Federal; $1 billion private sector
  - 16 storage projects
  - 16 regional demonstrations

AMI Improvements in Operational Efficiencies

NATIONAL ENERGY TECHNOLOGY LABORATORY

Results from 15 projects due to automation of metering service tasks and reductions in labor hours and truck rolls

Smart Meter Capabilities	O&M Savings	% Reduction
• Remote meter reading • Remote service connections/disconnections	Meter Operations Cost	13-77
	Vehicle Miles	12-59

Future SGIG examples to provide information on other benefits

Smart Meter Capabilities	Expected Benefits
• Tamper detection and notification	Enables potential recovery of ~1% of revenues that may be lost from meter tampering
• Outage detection and notification	Enables faster restoration (e.g., PECO avoided 6,000 truck rolls following Superstorm Sandy and accelerated restoration by 2-3 days)
• Voltage and power quality monitoring	Enables more effective management of voltages for conservation voltage reductions and other VVO applications

Reliability Improvements from Automated Feeder Switching

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4 Projects involving 1,250 feeders

April 1, 2011 through March 31, 2012

Index	Description	Weighted Average (Range)
SAIFI	**System Average Interruption Frequency Index (outages)**	**-22 %** (-11% to -49%)
MAIFI	**Momentary Average Interruption Frequency Index (interruptions)**	**-22 %** (-13% to -35%)
SAIDI	**System Average Interruption Duration Index (minutes)**	**-18 %** (+4% to -56%)
CAIDI	**Customer Average Interruption Duration Index (minutes)**	**+8 %** (+29% to -15%)

Weighted average based on numbers of feeders

City of Naperville
Empowering Consumers in Illinois

Key Activities

- Naperville's "Smart Grid Initiative" completes a decade long efforts to automate the city's entire electric distribution grid.
- Deploys smart meters city wide to all customers.
- Provides consumer education programs to engage public participation in shaping smart grid policies and programs.

Aims and Strategies

- Strengthen reliability and reduce the frequency and duration of power outages.
- Empower consumers to manage their own power consumption and costs to enhance energy efficiency, reduce peak, and reduce power purchase costs from wholesale suppliers.

Results and Benefits

- Distribution automation investments have improved System Average Interruption Duration Index each years since 1991 by from 15% to 55%.
- O&M costs from dispatching repair crews reduced by about 40%.
- Enacted Naperville Smart Grid Consumer Bill of Rights.
- Implemented Smart Grid Ambassadors Program

Consumer programs for smart grid-savvy customers

Residents provide feedback on Naperville's smart grid policies and programs.

Facts & Figures

Total Project Budget:
$21,988,220

Federal Share:
$10,994,110

Distribution Automation:
Remaining 6 of 117 circuits

Smart meters:
57,000

Time-based Rates:
1,500 customers targeted

Electric Power Board of Chattanooga
Improved System Restoration

NATIONAL ENERGY TECHNOLOGY LABORATORY

Key Activities

- EPB's Smart Grid Project covers 600 miles throughout 9 counties of Georgia and Tennessee affecting 170,000 customers.
- Installing automated feeder switches, automated circuits, advanced SCADA, AMI, in-home displays, and communications infrastructure.

Aims and Strategies

- Electric Distribution System Automation – installing automated feeder switches and sensor equipment for distribution circuits that can be used to detect faults and automatically switch to reroute power and restore all other customers.
- Communications Infrastructure – includes fiber optic systems that enable two-way communication between the meters, substations, and control office which provides EPB with expanded capabilities and functionality to optimize energy delivery, system reliability, and customer service options.

Results and Benefits

- During the April 2011 storms, three fourths of EPB customers – 129,000 residences and businesses – lost power.
  - Smart switches avoided thousands of hours of outage time due to the devices and automation already installed
  - EPB was able to avoid sending repair crews out 250 times

Integrating Smart Grid Applications

Smart switches help ensure grid reliability and power quality

Facts & Figures

Total Project Budget:
$226,707,562

Federal Share:
$111,567,606

Equipment Deployed:
Smart Switches: 1,500
AMI:170,000
Direct LC Devices: 5,000
HEMS: 5,000
Thermostats: 5,000
Automated Circuits:164

Case for WV Grid Modernization

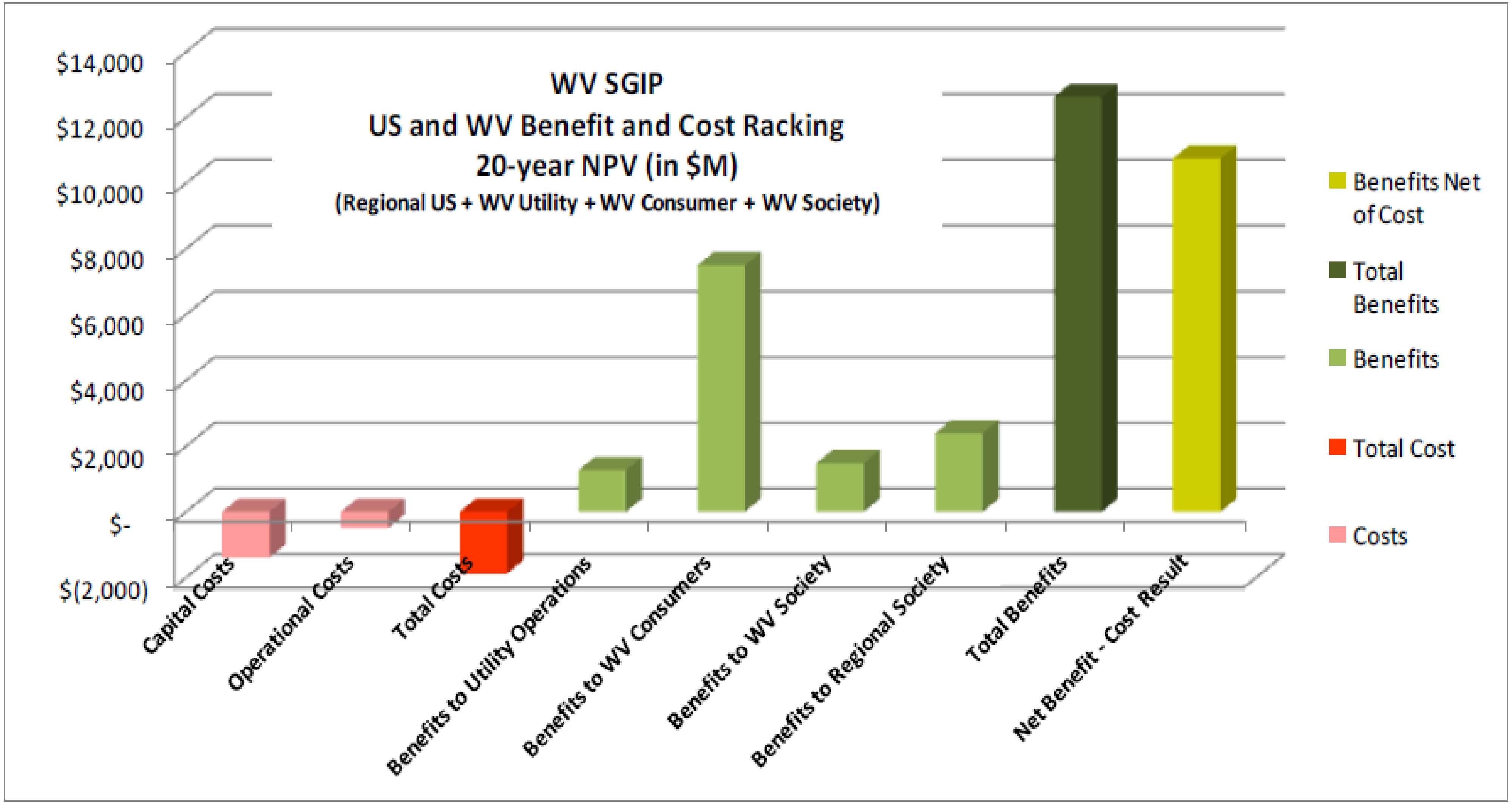
Key Findings from WGSIP 2009

NATIONAL ENERGY TECHNOLOGY LABORATORY

TABLE 1-4: WV SMART GRID BENEFITS (ANNUAL)

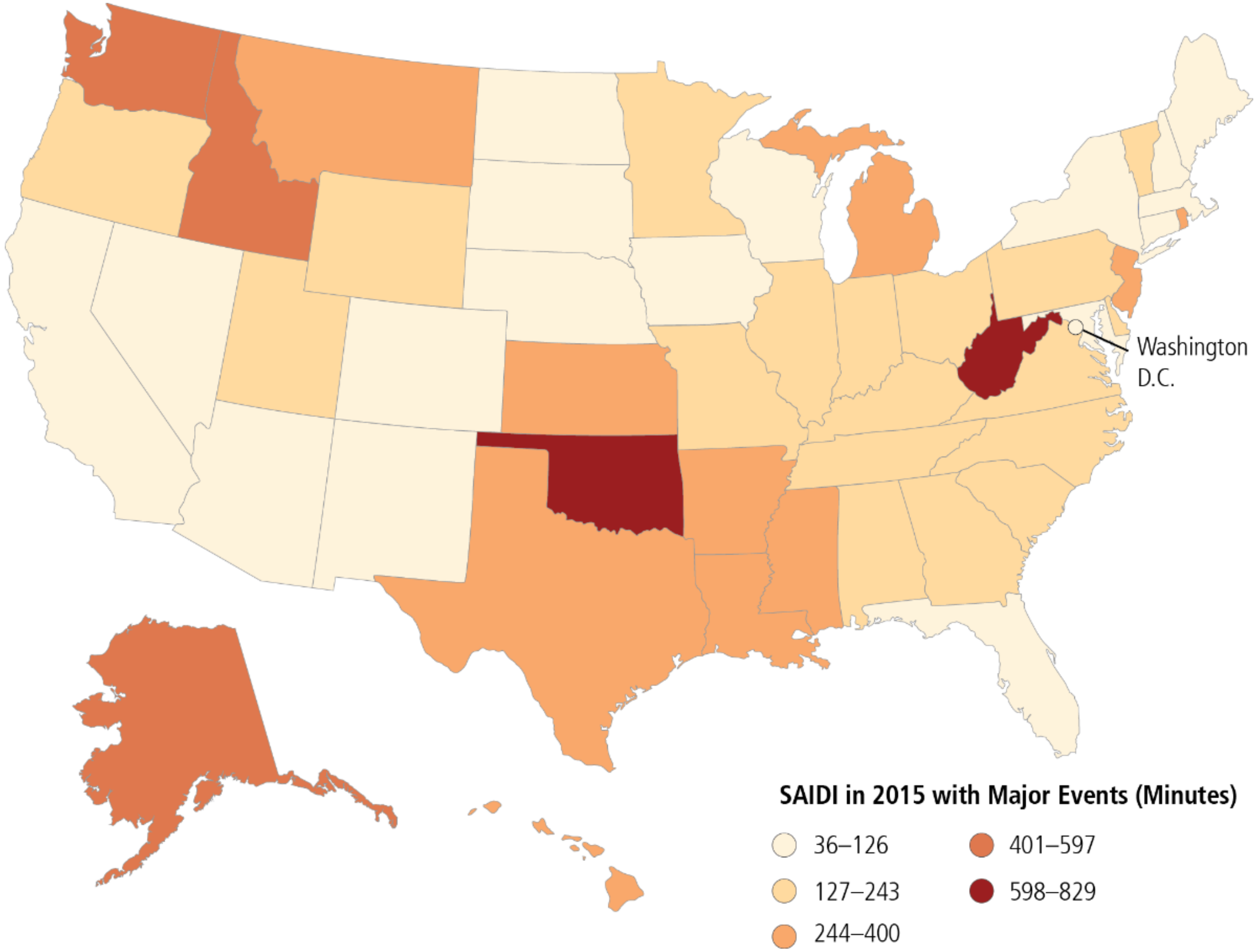
Key Success Factors	Benefits	Annual Benefits ($M) (All Beneficiaries)
Reliability	Reduced Consumer Losses	$898
	Reduce Power Quality Events	$131
Economic	Reduce Price of Electricity	$399
	Job Creation	$215
	Consumer Sales of DER Resources	$175
	Increased Energy Sales as Exports	$7
	Reduced Transmission 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

Key Findings from WGSIP 2009



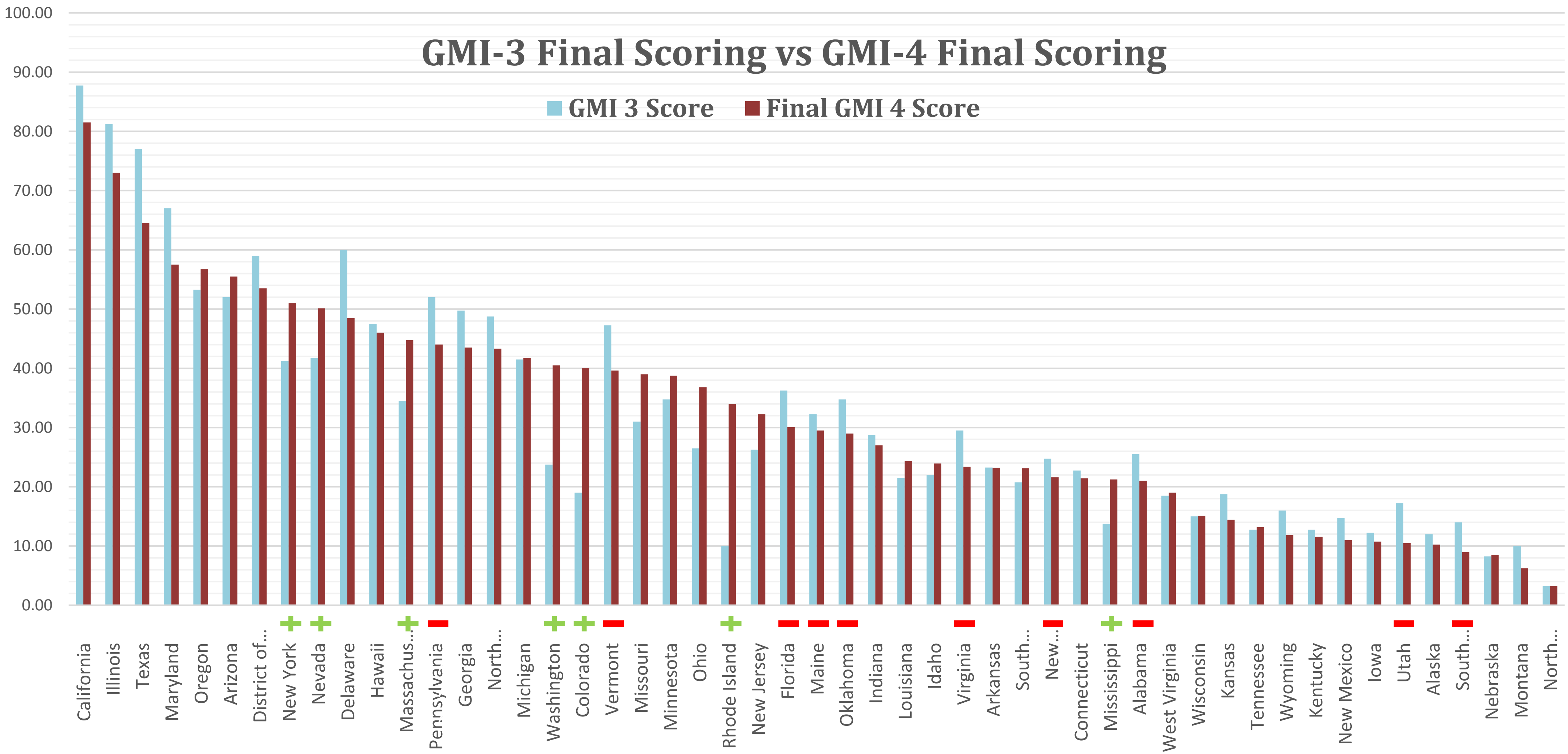
System Average Interruption Duration Index (SAIDI) in 2015 by State

States experienced varying levels of reliability in 2015. A reliable bulk power system does not necessarily mean reliable end-user electricity service because outages often originate on local distribution systems, as reflected in the SAIDI measurements in the map.



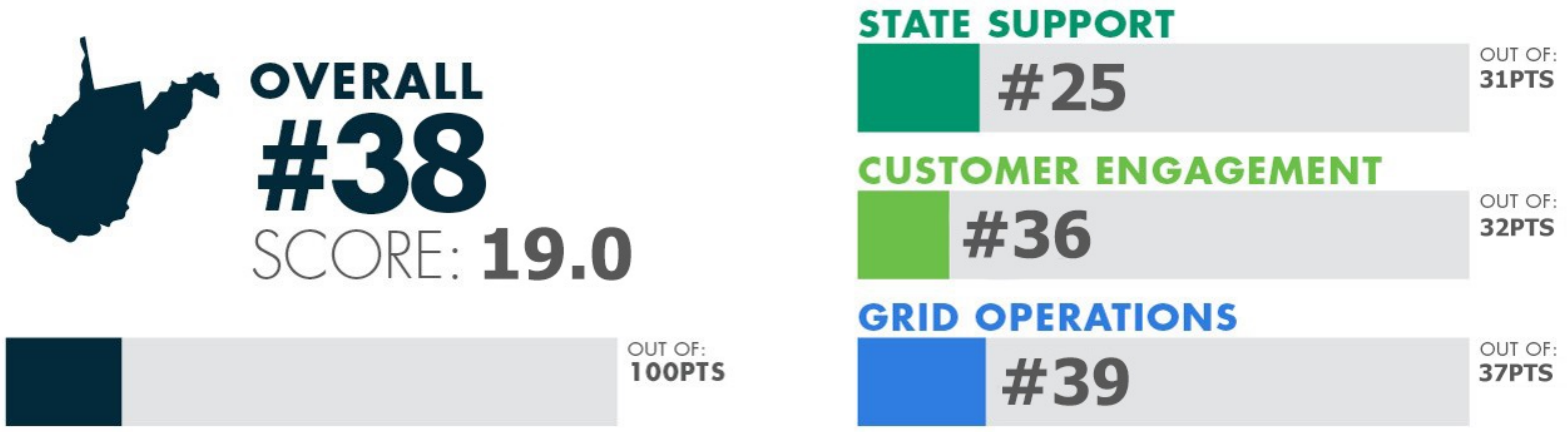
Source: "Transforming the Nation's Electricity Sector: The Second Installment of the QER" January 2017

GMI-4 Final Scoring Graph



U.S. DEPARTMENT OF ENERGY
GRIDWISE ALLIANCE
CLEAN EDGE

West Virginia GMI Recap



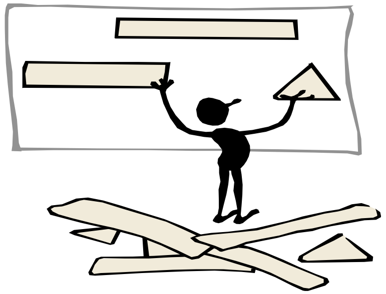
- West Virginia's overall GMI score rose to 19 in GMI-4.
- This score saw West Virginia ranked 38th overall, down from its ranking of 37th in GMI-3

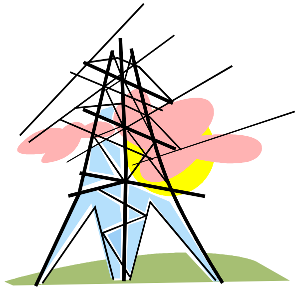
Some Challenges and Risks

Challenges for Smart Grid Deployment

Change Management:

- Common vision
- Consumer education and motivation
- Metrics needed for accountability





Regulatory:

- Dynamic rates
- Cost recovery
- Consumer privacy/safety concerns
- Societal benefits in business case

Technical:

- Interoperability and cyber security
- Communications
- Data management
- Central and distributed control
- Two-way protection

Questions?

Extra Slides

What's Different with a Modern Grid

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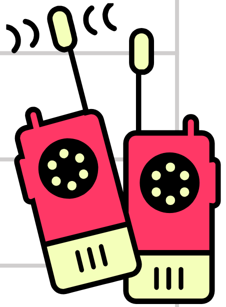
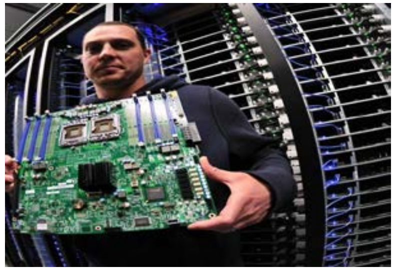
Current Grid	Modern Grid
Little consumer engagement	Consumer involvement
Radial system	Networked and integrated system
One-way power flow	Two-way power flow
One-way communications	Two-way communications
Central generation	Mix of central and distributed generation
Passive control	Active control
Fixed rates	Dynamic rates
Separate transmission & distribution	Interaction between T&D
Little ties with other infrastructures	Potential to transform transportation sector



The Modern Grid will …



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

Today's grid

status quo is not an option

- **Aging**
  - ➢70% of transmission lines are 25 years or older
  - ➢70% of transformers are 25 years or older
  - ➢60% of circuit breakers are 30 years or older
- **Outmoded**
  - ➢Designed in the 50s and installed in the 60s and 70s, before the era of the microprocessor.
- **Stressed**
  - ➢Never designed for bulk power shipments
  - ➢Increase in variable renewables (e.g., solar and wind farms)
  - ➢Increase in distributed generation (e.g., rooftop PV)
  - ➢Increase in consumer engagement (e.g, demand response)
  - ➢Many more assets to manage and control

Why Modernize the Grid?

- **Today's grid is aging and outmoded**
- **Unreliability is costing consumers billions of dollars**
  - Outages up 285% since 1984 – EIA estimates outage costs at $150 Billion/yr *

* SmartGridNews.com

- **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**
- **Adverse trends associated with the grid**
  - - Costs, reliability, peak loads, asset underutilization, TLRs, grid divorce
- **The benefits of a modernized grid are substantial**

Modernizing the Grid

Cost to Modernize:

- $338-$476B over 20 years
  - $ 82-90 B for transmission
  - $232-$339 B for distribution
  - $24-46 B for consumer
- $17-24 B per year

EPRI, 2011

Benefit of Modernization:

- $1294 – 2028 Billion
- **Overall benefit-to-cost ratio of 2.8 to 6.0**

Previous Studies:

- Benefit to Cost Ratio for West Virginia of 5:1
- Benefit to Cost Ratio for San Diego of 6:1
- Benefit to Cost Ratio for EPRI (2004) 4:1-5:1
  - $165 B Cost
  - $638 - $802 B Benefits

Attribute	Net Present Worth (2010) $B	
	Low	High
Productivity	1	1
Safety	13	13
Environment	102	390
Capacity	299	393
Cost	330	475
Quality	42	86
Quality of Life	74	74
Security	152	152
Reliability	281	444
Total	**1294**	**2028**

EPRI Report: http://www.smartgridinformation.info/pdf/3272_doc_1.pdf

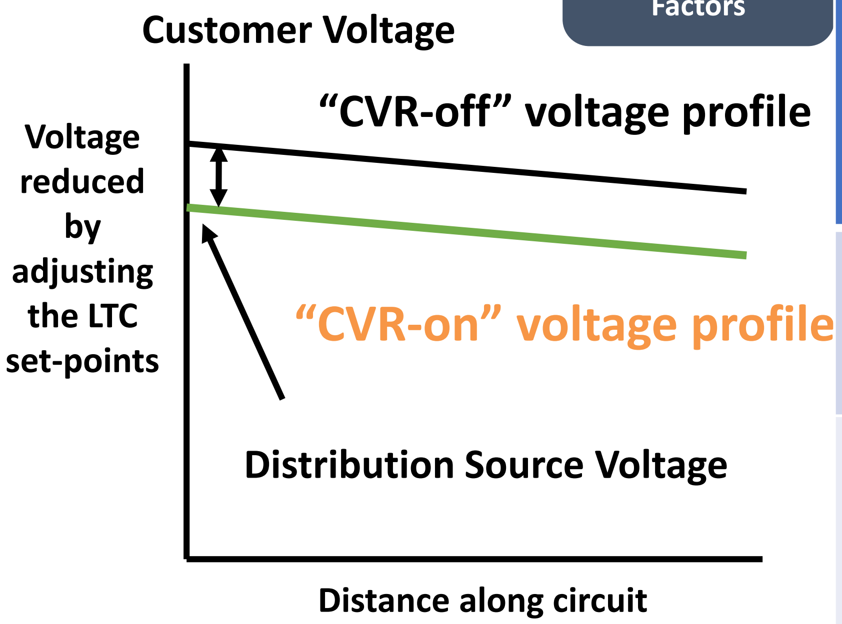
Peak Demand Reduction from AMI, Pricing, and Customer Systems

Project Elements	OG&E 770,000 customers	MMLD 11,000 customers	SVE 18,000 customers
Customers Tested	6,000 residential	500 residential	600 mostly residential
Time-Based Rate(s)	TOU and VPP, w/CPP	CPP	CPP
Customer Systems	IHDs, PCTs, and Web Portals	Web Portals	Web Portals
Peak Demand Reduction	Up to 30% 1.3 kW/customer (1.8 kW/customer w/CPP)	37% 0.74 kW/customer	Up to 25% 0.85 kW/customer
Outcome	Deferral of 210 MW of peak demand by 2014 with 20% participation	Lowers total purchase of peak electricity	Lowers total purchase of peak electricity
Customer Acceptance	Positive experience, many reduced electricity bills	Positive experience, but did not use the web portals often	Interested in continued participation, many reduced electricity bills

Applying Volt/VAR Optimization to Improve Energy Efficency

Conservation voltage reduction (CVR) reduces customer voltages along a distribution feeder for lowering peak demands and overall energy consumption

Energy and Capacity CVR Factors



Example Using SGIG Project Data

Results averaged across 11 circuits	% Reductions	Potential savings for a 7 MW peak circuit with 53% load factor	
Customer Energy Reduction	2.9%	943 MWh/year	$75,440 (at $.08/kWh)
Peak Demand Reduction	3%	210 kW	Defer construction of peaking plants

Top Ten Countries

Account for 80% of Global Smart Grid Investment by 2030*

- China
- United States
- India
- Brazil
- France
- Germany
- Spain
- United Kingdom
- Japan
- South Korea

Others

- Italy
- Norway
- Sweden
- Australia
- Russia

* Innovation Observatory

Smart Grid Key Success Factors

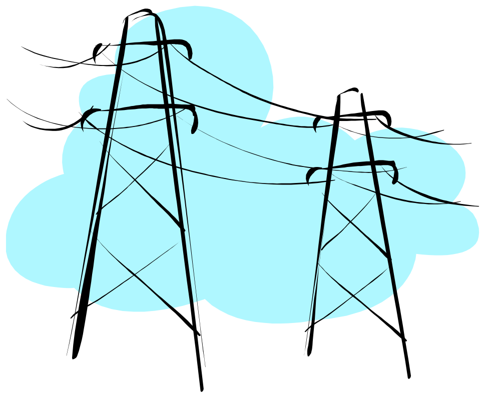
The Smart Grid is MORE:

- Reliable
- Secure
- Resilient
- Economic
- Efficient
- Environmentally friendly
- Safe

Smart Grid Principal Characteristics

The Smart Grid 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



Context of Smart Grid & Modern Grid

Smart Grid Technologies	Enhanced Technologies
Two-way communications Sensors Controls Decision support tools Components • Transformers • Power electronics • Conductors	Renewable energy resources Electric vehicles Energy storage Distributed generation Connected appliances/devices Load control/demand response
Attributes	**Enhanced Functionality**
Sensing, control, automation, power transformation, protection and communications	Generation, storage, and load

--------------------Modern Grid---------------------

The Smart Grid

should have quantifiable measurements of performance