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NETL Modern Grid Strategy Overview

ABB 2008 Power World Conference

Bruce Renz

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Funded by the U.S. Department of Energy,
Office of Electricity Delivery and Energy Reliability

Conducted by the National Energy Technology Laboratory

The Modern Grid Strategy (MGS)

- President Bush has asked the U.S. Department of Energy to lead a national effort to modernize and expand the electric grid.
- The Office of Electricity Delivery and Energy Reliability has been given that assignment and is committed to leading a national effort to accomplish it.
- The National Energy Technology Lab is conducting the MGS.
- Getting the job done will involve time, investment, and unprecedented levels of cooperation among the electric power industry's many and diverse stakeholders.
- Neither government nor industry can get the job done alone.
- MGS is independent and neutral – previously known as the Modern Grid Initiative.

The Mission of the MGS is to accelerate our progress in modernizing the national grid

What is the role of the MGS?

- Define a vision for the Modern Grid
- Reach out to stakeholders to gain consensus
- Assist in the identification of barriers & issues
- Facilitate resolution of barriers & issues
- Act as “independent broker” consistent with the vision
- Promote testing of integrated suites of technologies
- Communicate success stories to stimulate deployment

Our role is Strategic rather than Tactical!

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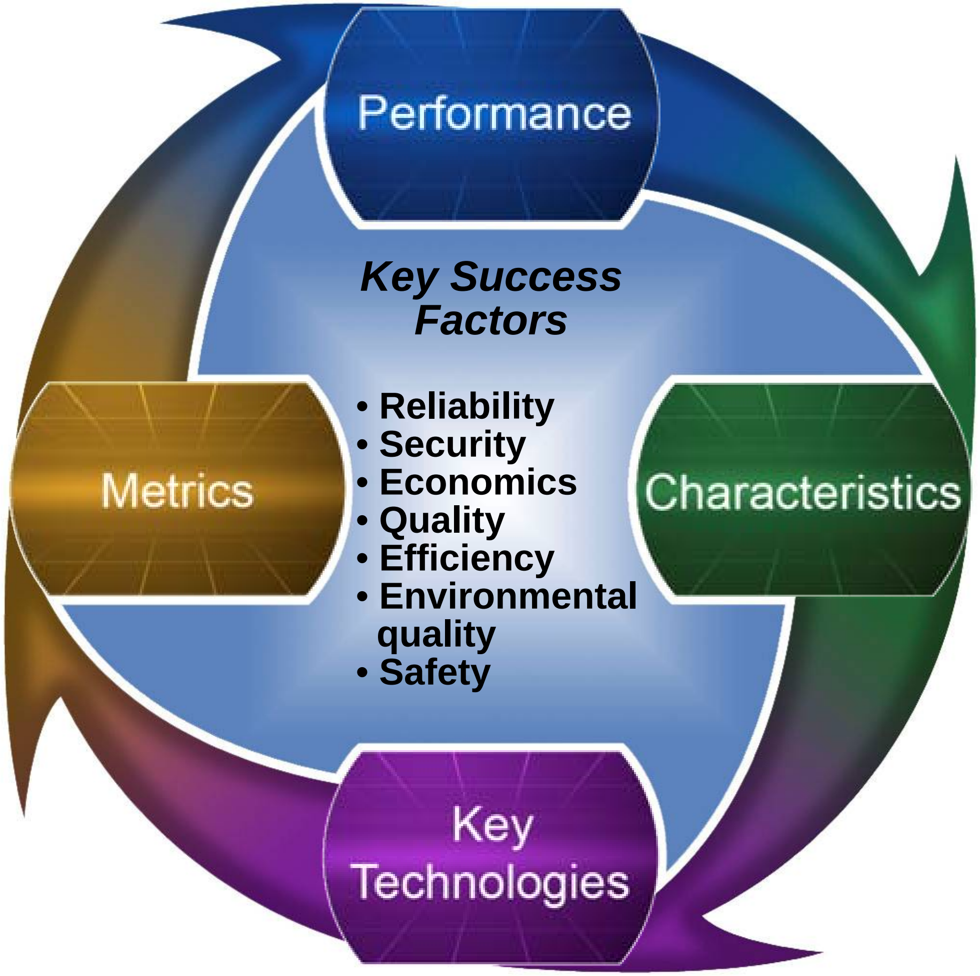
What is the Modern Grid?

The "Systems View" Approach



Modern Grid Goals – Key Success Factors

The Modern Grid is MORE:

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

Key success factors define the goals for grid modernization and define where metrics are needed to monitor progress.

It will "Motivate and include the consumer"

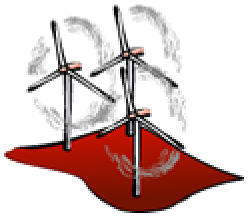
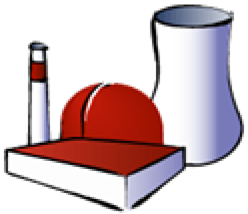
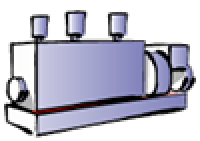
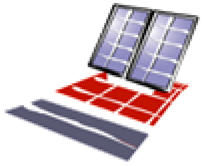
- **Well informed and active grid participants**
- **Provide new options for grid operators**
- **Customers see what they use, when they use it, and what it costs**
- **Consumer options…options….options**
- **Different products and prices for different consumers**
  - According to their preferences
  - According to their needs
  - According to their willingness to participate

Involving the consumer is win – win!

Characteristics of the Modern Grid

It will "Accommodate all generation and storage options"

- Seamlessly integrates all types and sizes of electrical generation and storage systems
- Simplified interconnection process analogous to "plug-and-play"
- Large central power plants including environmentally-friendly sources such as wind and solar farms and advanced nuclear plants will continue to play a major role
- Number of smaller, decentralized sources will increase

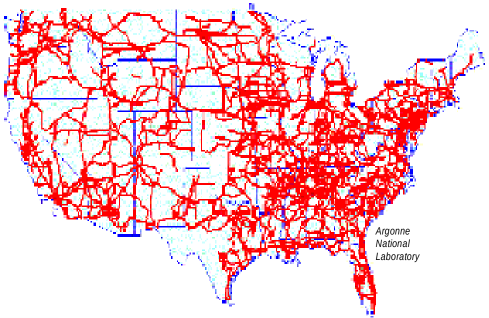






Characteristics of the Modern Grid

It will "Enable markets"

- **No constraints to shipping power among regions**
- **Consistent market operation from coast-to-coast**
- **Growth of selected, competitive retail markets**
- **Aggregated demand response involving the consumer**
- **Energy resources located closer to the consumer**
- **Growth of "electricity related" markets**

Markets motivate behavior and get results!



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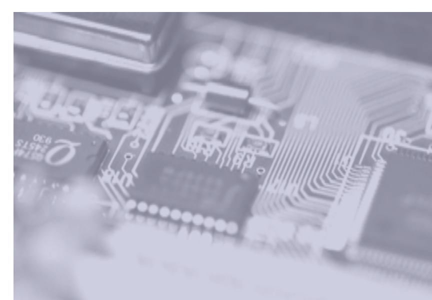
Characteristics of the Modern Grid

It will "Provide power quality for 21st century needs"

- **Power quality standards will balance load sensitivity with delivered power quality at a reasonable price**
  - Suitable for computers and electronics
  - Addresses sags, spikes, harmonics and momentary interruptions
- **Varying grades of power quality at different pricing levels**
- **Solutions at both system and consumer level**

Voltage dips that last less than 100 milliseconds can have the same effect on an industrial process as an outage that lasts several minutes or more

Primen, 2002



Characteristics of the Modern Grid

It will "Optimize assets and operate efficiently"

- **Improved load factors and lower system losses**
- **More power through existing systems**
- **The knowledge to build only what we need**
- **Tools for efficient, optimized designs**
- **Intelligent monitoring and diagnostics**
- **Computer-aided asset management, workflow management, outage management**
- **Condition Based Maintenance**

Convergence of operating information with asset management processes will dramatically improve grid efficiency

Characteristics of the Modern Grid

It will "Self Heal"

- **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**
- **Acts as the grid's "immune system"**
- **Supports grid reliability, security, and power quality**

The blackout of August 2003 took hours to build up. Once it breached the original service territory, it took 9 seconds to blackout 50M people.

PNNL, June 2006

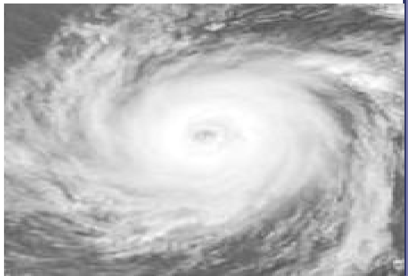
Characteristics of the Modern Grid

It will "Resist attack"

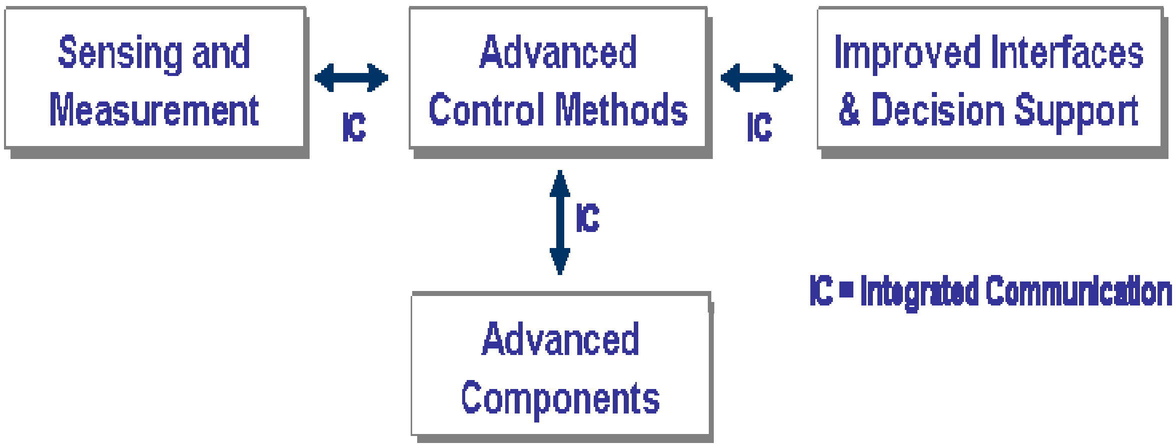
- **Physical and cyber security built in from the ground up**
- **Reduces threat, vulnerability, consequences**
- **Deters, detects, mitigates, responds, and restores**
- **Less vulnerable to natural disasters**
- **Energy security has become national security**

The lack of a concerted, deliberate technical approach risks serious consequences from security threats to the power delivery system infrastructure.

Erich Gunther, Power & Energy Continuity, 2002

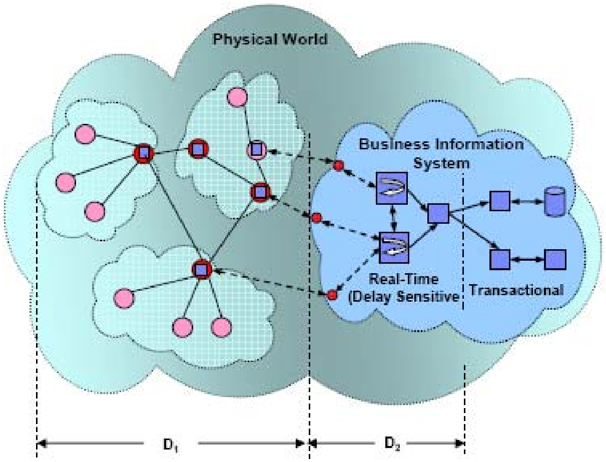


Modern Grid Key Technologies



An effective, fully-integrated communications infrastructure is an essential component of the modern grid:

- IC creates a dynamic, interactive "mega-infrastructure" for real-time information and power exchange
- IC allows the various intelligent electronic devices (smart meters, control centers, power electronic controllers, protection devices) and users to interact as an integrated system



Sensing and Measurement

Some examples:

- **Smart meters**
- **Dynamic rating of transmission lines**
- **Wide area monitoring systems (WAMS)**
- **Advanced system protection**
- **Asset condition monitors**
  - Transformer health sensors
  - Splice health sensor
  - Insulator leakage sensor
- **Detection of vegetation and equipment problems**
- **Electronic Instrument Transformers**

Advanced Components

Some Examples:

- Superconducting transmission cable
- Superconducting rotating machines
- Fault current limiters
- Advanced conductors
- Next generation FACTS/PQ devices
- Advanced distributed generation and energy storage

Decision Support

- **Data reduction**
  - Data reduced into the format, timeframe and technical categories most important to the operator
- **Visualization**
  - Presentation of information uses proven human factors techniques
- **Speed of comprehension**
  - Visualization methods provide information that can be rapidly converted to operator action
- **Decision support**
  - Artificial intelligence and agents identify existing, emerging, and predicted issues and provide for “what-if” analyses
- **System operator training**
  - Dynamic simulators and industry-wide certification programs significantly improve the skill sets and performance of today’s operators

Broad application of computer-based algorithms that:

- Collect data from and monitor all essential grid components
- Analyze the data to diagnose and provide solutions from both deterministic and predictive perspectives
- Determine and take appropriate actions autonomously or through operators (depending on timing and complexity)
- Provide information and solutions to human operators
- Integrate with enterprise-wide processes and technologies

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What are some of the metrics?

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Metrics aim at goal achievement

Reliability

- Outage duration and frequency
- Momentary outages
- Power Quality

Security

- Ratio of distributed generation to total generation
- Consumers participating in energy markets

Economics

- Peak and average energy prices by region
- Transmission congestion costs
- Cost of interruptions and power quality disturbances
- Total cost of delivered energy

Efficient

- System electrical losses
- Peak-to-average load ratio
- Duration congested transmission lines loaded >90%

Environmentally Friendly

- Ratio of renewable generation to total generation
- Emissions per kilowatt-hour delivered

Safety

- Injuries and deaths to workers and public

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Why do we need to modernize?

The Problem Is Urgent

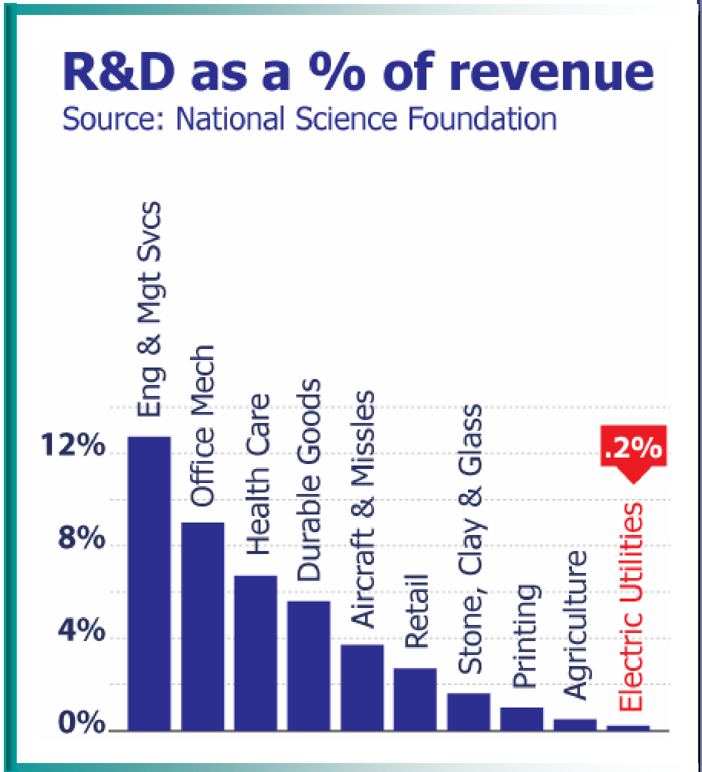
- **Losing billions per year**
  - From disturbances, interruptions and grid congestion
- **Falling behind other regions**
  - China, Europe, Middle East
- **Missing the chance to lead a new industry**
  - Distribution automation, smart meters, advanced monitoring and control

Some major power corridors are at maximum capacity more than 80% of the time... equivalent to rush hour from 5am to midnight.

National Transmission Grid Study, 2003

The Grid Is Under-Funded

- **Living off the investments of the 60s and 70s**
  - “Trust fund” is out of money
- **Less R&D than almost any other industry**
  - 0.2% of net revenues
  - 1/20th the average of all U.S. industries



Regulatory Barriers

Existing regulations in some states are barriers to modernization

- Current rate designs do not provide an incentive for consumers to become actively involved – ***time based rates are needed.***
- Many of the grid assets are not compatible with modern grid technologies and must be replaced even though they are not at the end of their functional lives – ***more favorable depreciation rules are needed.***
- Utility revenues are based on sales of KWh. Grid modernization may result in a reduction of KWh sales to utilities – ***policy changes are needed to give utilities an incentive to invest in grid modernization.***
- Uncertain cost recovery for investment in grid modernization is preventing a deeper deployment of new technologies – ***clear cost recovery policies are needed.***

Energy Independence and Security Act of 2007

- **Smart Grid Technology RD&D**
- **Smart Grid Regional Demonstration Initiative**
  - 50% Cost Share
  - $100M per year – 2008-2012
- **Federal Matching Funds**
  - 20% reimbursement for qualifying Smart Grid investments
- **States shall consider:**
  - Requiring utilities to consider Smart Grid solutions including societal benefits
  - Allowing utilities to recover capital, O&M and other costs
  - Allowing recovery of book value of technologically obsolete assets

Energy Independence and Security Act of 2007

- **US policy is to support grid modernization**
- **Smart Grid System Report**
  - Status and prospects of development
  - Regulatory or government barriers
  - Technology Penetration
  - Communications network capabilities, costs, obstacles
  - Recommendations for state and federal policies
- **Smart Grid Advisory Committee (thru 2020)**
- **Smart Grid Task Force (thru 2020)**
- **Smart Grid Interoperability Framework (NIST)**

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How do we achieve a Modern Grid?

Milestone Sequence

AMI and DR

AMI empowers the customer and establishes communications to the loads

Distribution (ADO)

ADO enables self healing

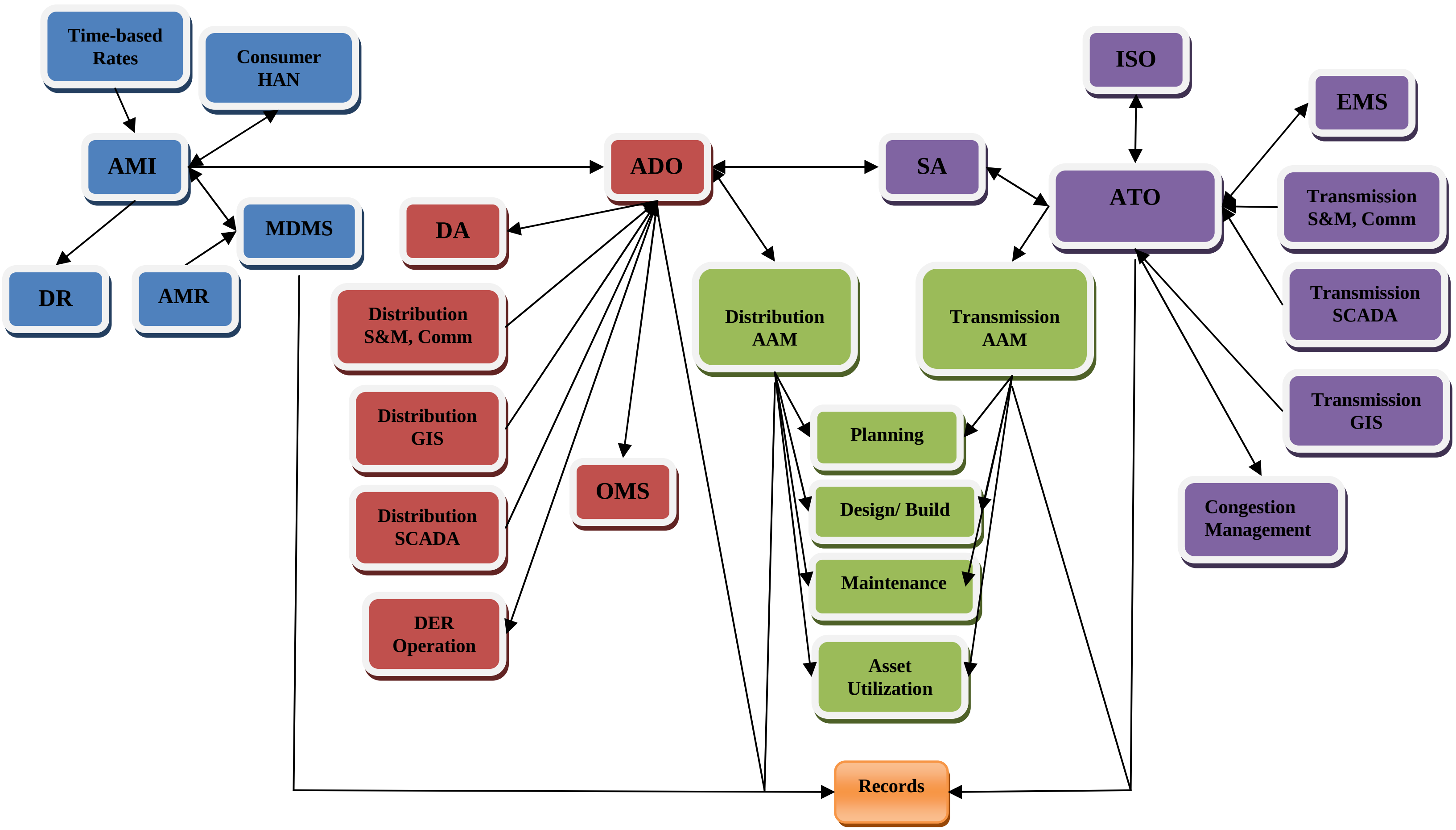
Transmission (ATO)

ATO addresses congestion

Asset Management (AAM)

AAM greatly improves the performance of today's asset management programs

The "Big Picture"



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What are some of the benefits?

Some Benefits

- Major Reduction in Outage Duration and Frequency
- Far Fewer Power Quality (PQ) Disturbances
- Virtual Elimination of Regional Blackouts
- Significantly Reduced Vulnerability to Terrorist Attack and Natural Disasters
- Improved Public and Worker Safety
- Reduction or Mitigation of Prices
- New Options for Market Participants
- More Efficient Operation and Improved Asset Management at Substantially Lower Costs
- Electrical Losses Reduced
- Much Wider Deployment of Environmentally Friendly Resources

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**

Benefit of Modernization

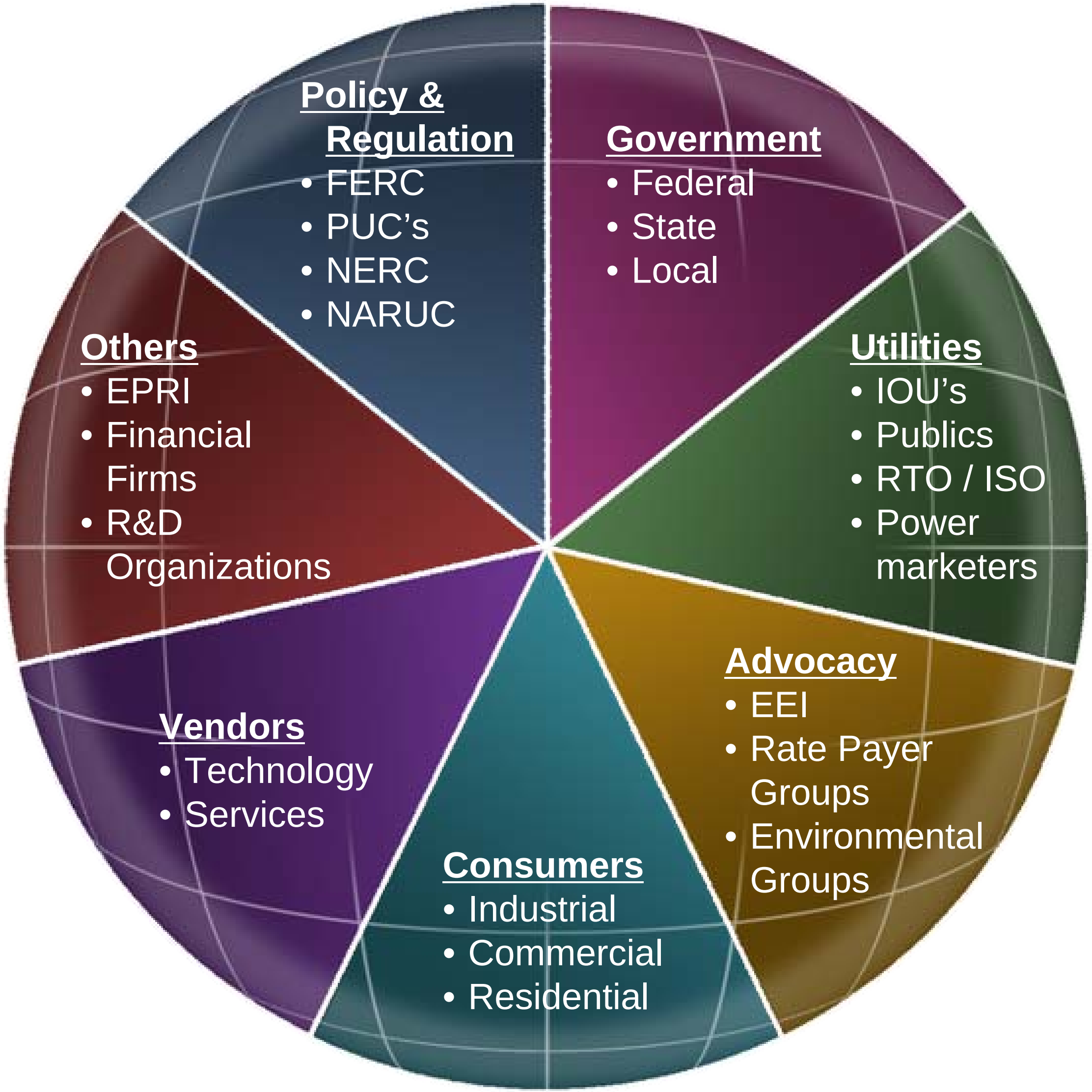
- **$638B - $802B over 20 years**
- **Overall benefit to cost ratio is 4:1 to 5:1**

(Source: EPRI, 2004)

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)*

Appendix

Who are the Modern Grid stakeholders?



We Are Losing Billions

We lose billions every year to blackouts, interruptions and congestion

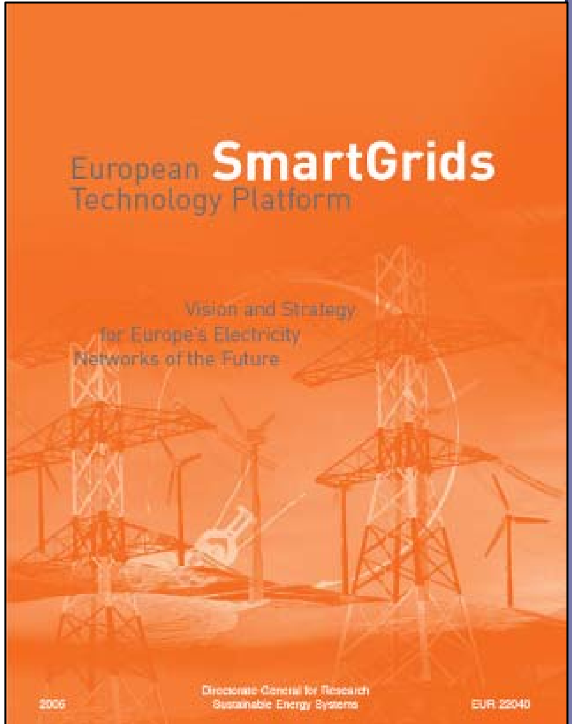
- **Unreliable power costs America more than $100B annually... the equivalent of a 30-cent surcharge on every dollar spent on electricity** ***(Galvin Electricity Initiative, 2005)***
- **$79B per year just from disturbances and interruptions [i.e. not counting blackouts]** ***(LBNL, 2004)***
- **As much as $135M per year in lost productivity** ***(Primen, 2004)***
- **In the NY ISO, 23% of the wholesale price is congestion costs, which are passed along to consumers.** ***(PNNL, 2006)***
- **August 2003 blackout: $4-6B, 50M people affected**

It is not the cost of electricity that drives our decisions. It is the cost of NOT having electricity.

Energy Director, Oracle Corporation, 2004

We Are Falling Behind

- **China**
  - $1B for a phasor-grade wide-area system
  - $8B to upgrade grid in one major province
- **India**
  - 10-year program, $50B on grid
  - Electrify 400M people
- **Middle East**
  - Gulf Grid
  - Mediterranean Ring
- **Europe**
  - ~$400M per year for grid R&D



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We Are Losing Jobs

- **Missing a once-a-century opportunity to lead a new industry**
  - At stake: jobs and export revenues
  - Smart Grid part of an $80B electricity infrastructure market worldwide (Center for Smart Energy, 2005)
  - Other regions -- France, Germany, China, Canada -- already taking a leadership role
- **We cannot be a world-class superpower without a world-class grid**

If I were running for president, I would say we need a new energy economy and we're going to create a million jobs with it. There is a trillion dollar untapped market for clean energy and energy conservation technologies already developed around the world.

Former President Bill Clinton, 2003

Where do we start?

- **Plan**
  - Create the vision
  - Identify the milestones
  - Determine the sequence
  - Define needed technology suites
- **Deploy**
  - Address the barriers
  - Apply resources
- **Measure**
  - Establish metrics
  - Monitor progress

The payoff to modernizing the electric infrastructure from the resulting economic progress could easily exceed $1T per year in additional GDP within a decade. *Galvin Electricity Initiative, 2005*

Modern Grid Milestones

- **Advanced Metering Infrastructure *(AMI)***
- **Advanced Distribution Operations *(ADO)***
- **Advanced Transmission Operations *(ATO)***
- **Advanced Asset Management *(AAM)***

Each Milestone requires the deployment and integration of various applications and suites of technologies

AMI Technology Suites

- **Smart Meters**
- **Two-way Communications**
- **Consumer Portal**
- **Home Area Network**
- **Meter Data Management**
- **Demand Response**
- **Customer Service Applications**
- **Operational Gateway Applications**

AMI empowers the customer and supports grid operations

ADO Technology Suites

- Distribution Management System with advanced sensors
- Advanced Outage Management ("real-time")
- DER Operations
- Distribution Automation
- Distribution Geographic Information System
- Micro-grid operations (AC and DC)
- Hi-speed information processing
- Advanced protection and control
- Advanced grid components for distribution

The functionality of ADO enables "Self Healing"

ATO Technology Suites

- **Substation Automation**
- **Geographical Information System for Transmission**
- **Wide Area Measurement System (WAMS)**
- **Hi-speed information processing**
- **Advanced protection and control**
- **Modeling, simulation and visualization tools**
- **Advanced grid components for transmission**
- **Advanced regional operational applications**

Deeply integrated with AMI, ADO and AAM – ATO optimizes transmission operations

AAM Technology Suites

- **Advanced sensors**
  - System Parameters
  - Asset "health"
- **Integration of real time information with other processes:**
  - Operations to optimize asset utilization
  - T&D planning
  - Condition based maintenance
  - Engineering design and construction
  - Customer service
  - Work and resource management
  - Modeling and simulation

Integration of AMI, ADO, and ATO with asset management processes will dramatically improve grid operations and efficiency

Address AMI Barriers

- **"Time based" rate design not yet implemented**
  - Consumers do not see market and/or time-based prices for energy.
- **Lack of a focused consumer education plan**
  - The AMI concept and its benefits have not been effectively communicated.
  - Clarity on the "end state" is lacking – the opportunities created by AMI that lead us to a Modern Grid are not well understood by stakeholders.
- **Lack of Incentives**
  - Financial and policy incentives might engage stakeholders to move forward.
- **Standards**
  - Agreement is needed on communication standards to facilitate exchange of information among applications and users.
- **Fear of stranded investments**
  - New technologies need to be "future proofed".

Address ADO Barriers

- **Cost recovery for technologically obsolete assets**
  - Regulations are needed to allow early retirement of assets that do not support the Modern Grid vision
- **Limited deployment of supporting technologies**
  - Integrated, hi-speed, two-way communications system
  - Hi-speed computing systems needed for analyzing large volumes of data
- **Distributed system behavior is not well understood**
  - Further study is needed to understand how various distribution systems interact when DER are broadly deployed (particularly their behavior during upset conditions).
- **Lack of Incentives**
  - Financial and policy incentives are needed that motivate utilities to invest in *ADO* technologies for the benefit of consumers and society
- **Universal interoperability**
  - Agreement is needed on communication standards to ensure interoperability among distribution assets

Address ATO Barriers

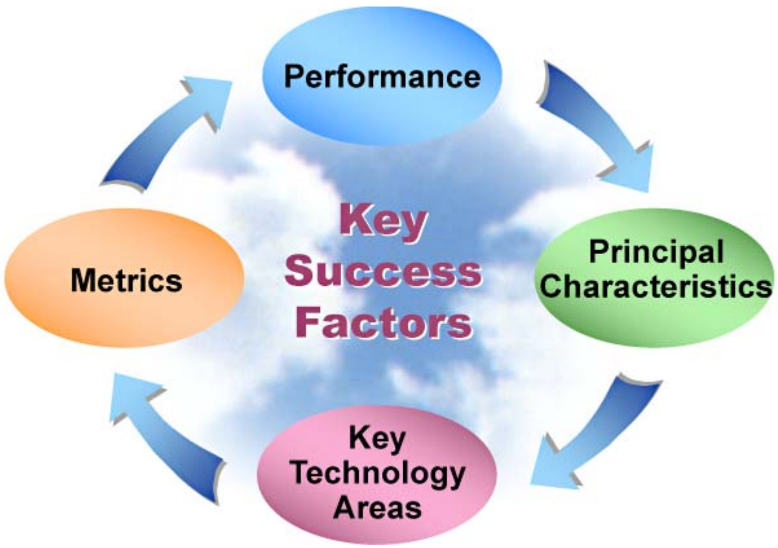
- **Inconsistent policies among states and federal regulators prevent effective collaboration across a national footprint**
- **Regulations that support integrated electricity markets are needed**
- **The not in my backyard (NIMBY) philosophy creates excessive delays in deploying needed upgrades to the grid**
  - Solutions are needed to reduce the concerns of citizens who object to the placement of new facilities near their homes and cities
- **Industry engineering staffs are reluctant to change traditions and standards**
  - Utility planning and design traditions and standards generally focus on the traditional model of the electric grid – centralized generation, legacy technologies, with little reliance on distribution assets and the consumer as active resources

Address AAM Barriers

- **The integration of multiple key technologies has not yet occurred**
  - The deployment and integration of advanced sensors, integrated communication systems, and advanced algorithms, including supercomputers, is needed to support the processing and analysis needed for advanced asset management.
- **Industry executives are reluctant to change processes and technologies**
  - Some utility cultures are resistant to change and operate in “silos” organizationally. As a result, changes to processes and technologies needed to improve asset management are difficult to initiate.
- **Human and financial resources at many utilities are limited and stressed**
  - The amount of resources available to look beyond day-to-day operations is limited

How do Metrics fit in?

- **KSF's are the "goals"**
- **PC's are the "specs"**
- **KTA's are the "technologies"**
- ***Metrics* measure "progress" towards meeting the goals**
- **Barriers are the obstacles we must overcome to make progress**
- ***Benefits* are positive outcomes from progress**



The Modern Grid Vision includes all these concepts!

Our experience at PUC Ohio

- **Commission order to conduct technical workshops on AMI and DR**
- **Staff set expectations for 6 workshops**
- **Modern grid team presented its perspectives on AMI/DR**
  - MGS suggested PUCO should expand their perspective to encompass overall grid modernization, with AMI as the foundation
- **Vendors presented their products and services**
- **Consumer groups expressed their thoughts**
- **Utilities presented AMI business case summaries**
- **MGS team providing continuing support**

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What are others doing to modernize?

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Who is thinking AMI in the United States?

- Oncor (TXU)
- ***CenterPoint Energy***
- ***Southern California Edison***
- Pacific Gas and Electric
- ***San Diego Gas & Electric***
- WE Energies
- ***Consolidated Edison***
- PEPCO / Delmarva
- ***Xcel Energy***
- Consumers Energy
- ***AEP***
- ***Duke***
- ***Puget Sound Energy***
- And many others

Advanced Distribution

- **CERTS Microgrid (University of Wisconsin, AEP)**
- **SCE's Circuit of the future**
  - DOE funding of $1M
  - Identify, analyze and isolate circuit problems
  - Fault current limiters
  - Plug and play distributed generation capability
- **CenterPoint Energy's Intelligent Grid**
- **Allegheny Power (Developmental Field Test)**
- **Southern Company**

Advanced Transmission

- **RTO's – Monitoring, Visualization, & Control**
- **Phasor Measurement and WAMS**
- **AEP**
  - 138 KV Unified Power Flow Controller
  - I-765 KV Network
- **SCE deployment of Static VAR Compensators**
  - Enhanced transmission capacity
  - Improved voltage stability
- **NYPA deployment of 345 KV Convertible Static Compensator**
  - Increased transmission capacity
  - Instantaneous voltage support

Asset Management

- **SDG&E Operational Data Store**
  - Operational and maintenance information warehouse on intranet
- **FPL Advanced Technology Program**
  - Integrated system of GIS, CIS, OMS, Work and Asset Management
- **HV BPL Demonstration at AEP**
  - Station to station MB/s linkage for control and asset monitoring
  - Sponsored by DOE/NETL
- **Maintenance Management Workstation (MMW)**
  - Deployed at 25+ utilities (TXU, Pepco, Exelon, Duke, GPU, TVA, etc)

International AMI

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- Italy’s Enel has installed over 27 million communicating solid-state meters. (completed in 2006 – 4 year ROI)
- Sweden’s Vattenfall is in middle of rolling out 600,000 advanced meters and E.ON Sweden is in the early stages of rolling out 370,000 advanced meters.
- The Netherlands government has announced its intent to replace all 7.5 million electric meters in the country by the end of 2012.
- In Austria, Linz STROM recently announced plans to deploy advanced meters to 75,000 of its customers.
- In Canada, Hydro One has begun installation of smart meters in southern Ontario and expects to complete the installation of 1.3 million throughout its service territory by 2010.
- Norway recently announced a smart meter roll-out to 2.6 million customers by 2013
- Australia/United Kingdom and others.

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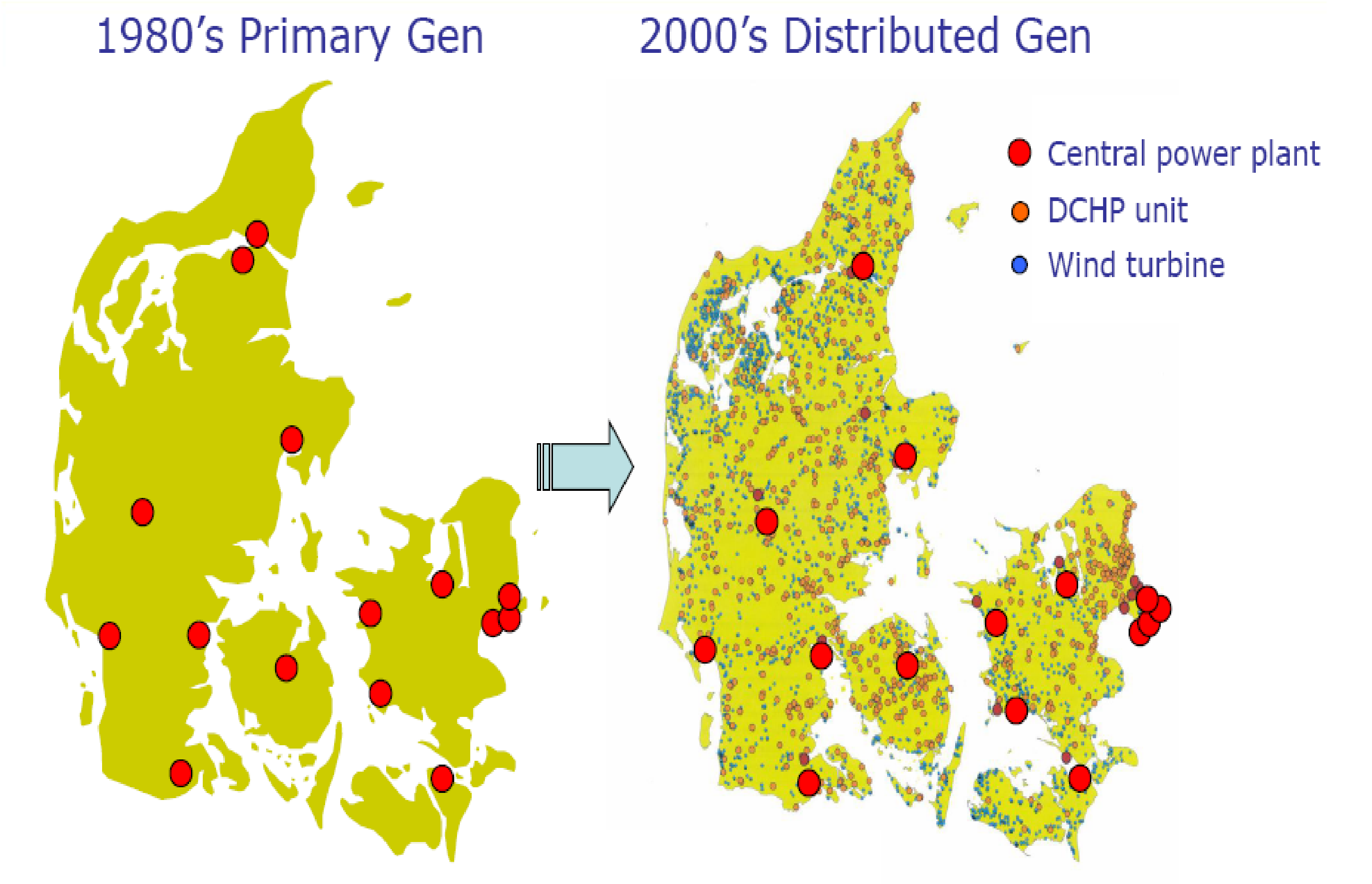
Danish Power System Transformation



International T&D

- Taipei, Taiwan – automated distribution network
- Japan - virtually 100% transmission visibility and automation with significant DA throughout country
- Singapore – automated distribution network
- Istanbul – complete distribution SCADA
- Thailand – Wide Area Monitoring System
- Oman - Advanced Substation Control System
- Northern Ireland – Advanced OMS/DMS
- Italy (ENEL) – Networked fault and event recorders

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The Vision

Never designed for bulk power shipments

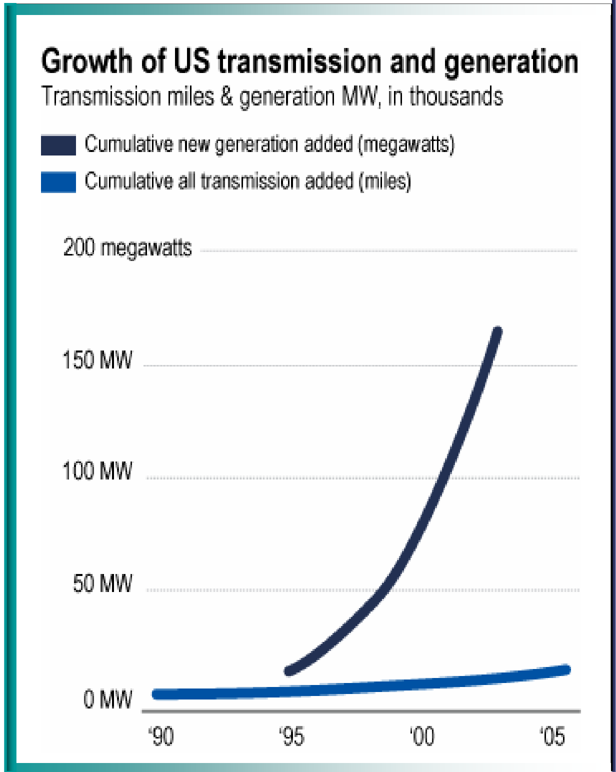
- Wholesale power transactions jumped 300% from 2000 to 2005. *Insight Magazine, Oct. 2005*

Blackouts, interruptions, near-misses increasing

- Transmission loading relief events (near misses) up 1000% from 1997 to 2002

Demand and supply grew dramatically but...

- ... transmission saw virtually no increase



The Grid Is Aging and Outmoded

- **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 (Eric Lightner, DOE, Jan. 2005)
- **Outmoded**
  - Designed in the 50s and installed in the 60s and 70s, before the era of the microprocessor.

Much of the equipment that makes up the North American grid is reaching the end of its design life.

EnergyBiz Magazine, Sept. 2005

Platform for Prosperity

- **Economy now based on electricity**
  - Computers, networks, phone system, devices, robotic manufacturing, stock markets
- **Lifestyle now based on electricity**
  - Medical devices, appliances, air conditioners, computers
- **Must have infrastructure that facilitates growth**
  - The digital economy is vulnerable
  - 20 years ago digitally controlled load negligible. 10 years ago 10%. Today, past 20% and climbing (EPRI, 2006)
- **Key to global competitiveness**
  - Other regions upgrading to create competitive advantage

Running today's digital society through yesterday's grid is like running the Internet through an old telephone switchboard.

Reid Detchon, Energy Future Coalition

The Grid - Today vs. Tomorrow

Characteristic	Today	Tomorrow
Motivates/Includes Consumer	No price visibility, time-of-day pricing rare, few choices	Full price info, time-of-use pricing, choose from many plans and prices
Accommodates Generation/Storage	Dominated by central generation. Little DG, DR, storage or renewables.	Many “plug and play” distributed energy resources complement central generation
Enables Markets	Limited wholesale markets, not well integrated	Mature, robust, well-integrated wholesale markets
Meets PQ Needs	Focus on outages not power quality	PQ a priority with a variety of quality/price options according to needs

The Grid - Today vs. Tomorrow

Characteristic	Today	Tomorrow
Optimizes	Little integration with asset management	Deep integration of grid intelligence with asset management software
Self Heals	Protects assets following disruption (e.g. trip relay)	Prevents disruptions, minimizes impact
Resists Attack	Vulnerable to terrorists and natural disasters	Resilient with rapid restoration

To Stay Involved

MODERN GRID
STRATEGY

- **The Modern Grid Strategy**
  - Collaborative, public/private effort open to all
  - Independent “broker”
- **www.netl.doe.gov/moderngrid/**
  - Downloadable documents
  - Forums
  - Meeting announcements
- **www.smartgridnews.com**
  - Grid modernization columns, articles and case studies
  - Modern Grid BLOG (future)
- **moderngrid@netl.doe.gov**
  - (304) 599-4273 x101

Office of Electricity Delivery and Energy Reliability

Developed for the U.S. Department of Energy Office of Electricity Delivery and Energy Reliability by the National Energy Technology Laboratory

A Vision for the Modern Grid

Powering our 21st-Century Economy

A Vision for the Modern Grid

What will the Modern Grid Look Like?

Background

Before we can begin to modernize today's electric grid, we first need a clear vision of the power system required for the future. Given that vision, we can create the alignment necessary to inspire passion, investment, and progress toward an advanced US grid for the 21st century.

Goals

The grid must be more reliable.
A reliable grid will provide power dependably, when and where its users need it and of the quality they value.

The grid must be more secure.
A secure grid will withstand physical and cyber attacks without suffering massive blackouts or exorbitant recovery costs. It will also be less vulnerable to natural disasters and will recover faster.

The grid must be more economic.
An economic grid will operate under the basic laws of supply and demand, resulting in fair prices and adequate supplies.

The grid must be more efficient.
An efficient grid will take advantage of investments that lead to cost control, reduced transmission and distribution electrical losses, more efficient power production and improved asset utilization.

The grid must be more environmentally friendly. An environmentally friendly grid will reduce environmental impacts through initiatives in generation, transmission, distribution, storage and consumption.

The grid must be safer.
A safe grid will not cause any harm to the public or to grid workers and will be sensitive to users who depend on it as a medical necessity.

The Vision

First, it will heal itself.
The modernized grid will perform continuous self-assessments to detect, analyze, respond to, and as needed, restore grid components or network sections. It will handle problems too large or too fast-moving for human intervention. Acting as the grid's "immune system", self-healing will help maintain grid reliability, security, affordability, power quality and efficiency.

Second, it will motivate consumers to be active grid participants and will include them in grid operations.
Active participation of consumers in electricity markets brings tangible benefits to both the grid and the environment, while reducing the cost of delivered electricity. In the modernized grid, well-informed consumers will modify consumption based on the balancing of their demands and the electric system's capability to meet those demands.

Third, the Modern Grid will resist attack.
Security requires a system-wide solution that will reduce physical and cyber vulnerabilities and will recover rapidly from disruptions. The Modern Grid will demonstrate resilience to attack, even from those who are determined and well equipped. Both its design and its operation will discourage attacks, minimize their consequences and speed service restoration. It will also be less vulnerable to natural disasters.

Fourth, the Modern Grid will provide the level of power quality desired by 21st century users.
New power quality standards will balance load sensitivity with deliverable power quality at a reasonable price. The modernized grid will supply varying grades of power quality at different pricing levels.

Fifth, the Modern Grid will accommodate all generation and storage options.
It will seamlessly integrate all types and sizes of electrical generation and storage systems with a

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