MODERN GRID
STRATEGY

The Modern Grid

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Office of Electricity Delivery and Energy Reliability

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Technology Laboratory

Today's Objectives

To share our views on several Modern Grid concepts:

- What is the Modern Grid Strategy?
- What is the Modern (Smart) Grid?
- Why do we need to modernize?
- What are some of the benefits?
- What are some of the barriers?
- How do we achieve a Modern Grid?

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What is the Modern Grid Strategy?

NETL

The Modern Grid Strategy (MGS)

- President Bush requested the U.S. Department of Energy lead a national effort to modernize and expand the electric grid
- The Office of Electricity Delivery and Energy Reliability was given that assignment and is committed to leading a national effort to accomplish it
- The National Energy Technology Lab (NETL) 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 and 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!

MGS results to date

NETL's Modern Grid Initiative

- Began concept development in early 2005
- Conducted regional summits (7) to gain input
- Numerous other presentations
- Incorporated feedback

Regulatory Technical Support

- PUC Ohio and PSC MO
- NARUC – FERC Smart Grid Collaborative

DOE Smart Grid Workshop

- Further unification of concepts with others
- Workshop planned for June 2008 with focus on metric development

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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)**

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

What is the Modern (Smart) Grid?

Modern Grid Values

The Modern Grid is MORE:

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

These values define the goals for grid modernization and suggest where metrics are needed to monitor progress.

Modern Grid Characteristics

The Modern 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

Modern Grid Characteristics

It will "Enable active participation by consumers"

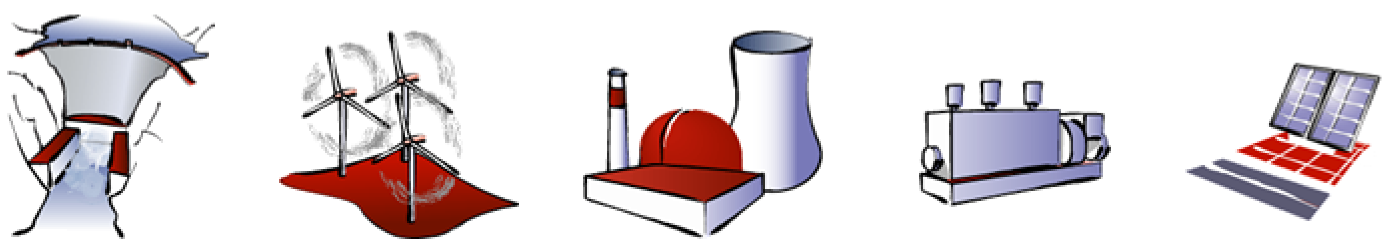
- **Customers see what they use, when they use it, and what it costs**
- **Consumers have access to new information, control and options**
  - Manage energy costs
  - Invest in new devices
  - Sell resources for revenue or environmental stewardship
- **Grid operators have new resource options**
  - Energy and capacity
  - Ancillary services

Involving the consumer is win – win!

Modern Grid Characteristics

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



Modern Grid Characteristics

It will "Enable new products, services and markets"

- Links buyers and sellers down to the consumer level
- Supports the creation of "secondary" electricity markets
  - Brokers, integrators, aggregators, etc.
  - New commercial goods and services
- Provides for consistent market operation across regions
- Supports growth of competitive retail markets
- Stimulates deployment of energy resources closer to the consumer

Markets motivate behavior and get results!

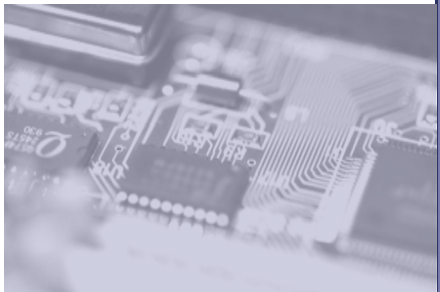
Modern Grid Characteristics

It will "Provide power quality for the digital economy"

- Monitors, diagnoses and responds to PQ issues
- Varying grades of power quality at different pricing levels
- Power quality standards will balance load sensitivity with delivered power quality at a reasonable price
- 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



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Modern Grid Characteristics

It will "Optimize asset utilization 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

Modern Grid Characteristics

It will "Anticipate & respond to system disturbances (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

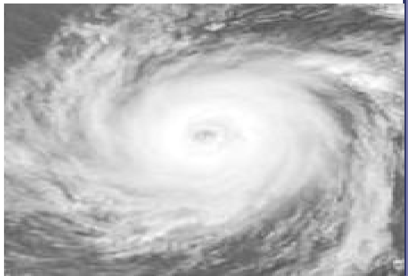
Modern Grid Characteristics

It will "Operate resiliently against attack and natural disaster"

- 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



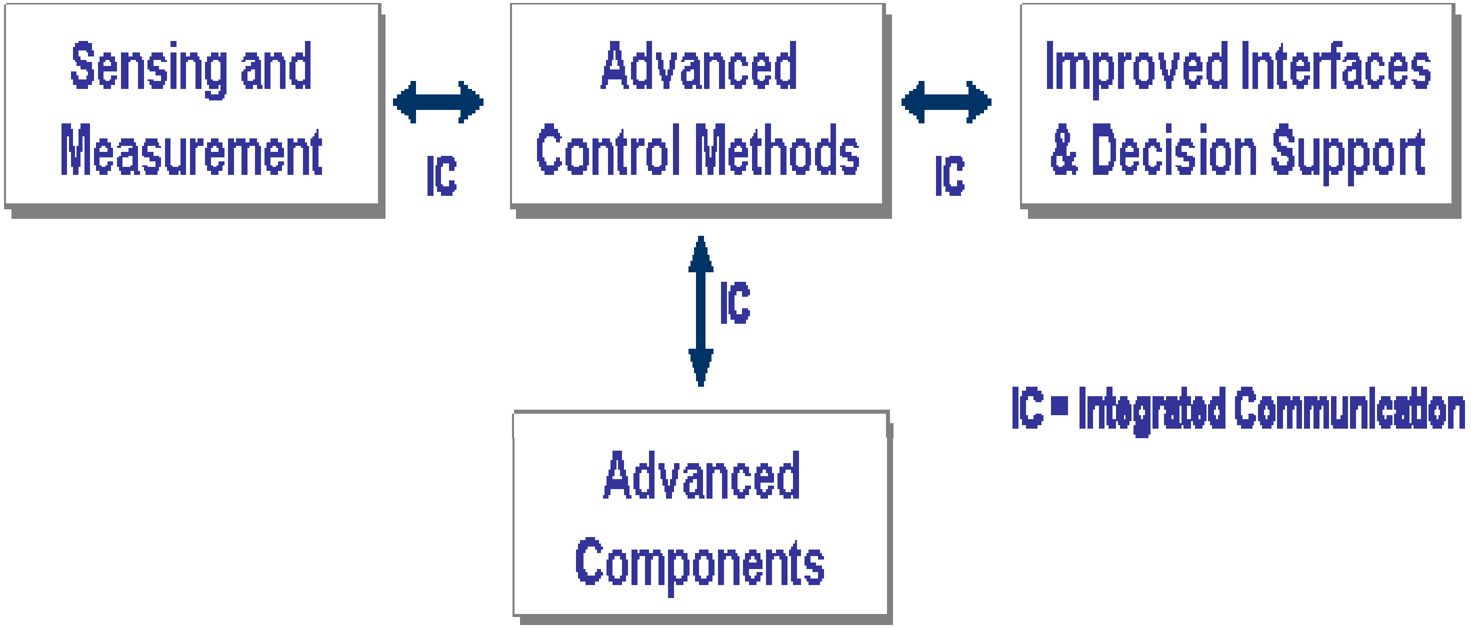
The Modern Grid Gap

Characteristic	*Today*	*Tomorrow*
Enables Consumer Participation	Little price visibility, time-of-use pricing rare, few choices	Full price info, choose from many plans, prices and options, buy and sell
Accommodates Generation/Storage	Dominated by central generation. Little DG, DR, storage or renewables.	Many “plug and play” distributed energy resources complement central generation
Enables New Markets	Limited wholesale markets, not well integrated	Mature, well-integrated wholesale markets, growth of new electricity markets
Meets PQ Needs	Focus on outages not power quality	PQ a priority with a variety of quality/price options according to needs

The Modern Grid Gap

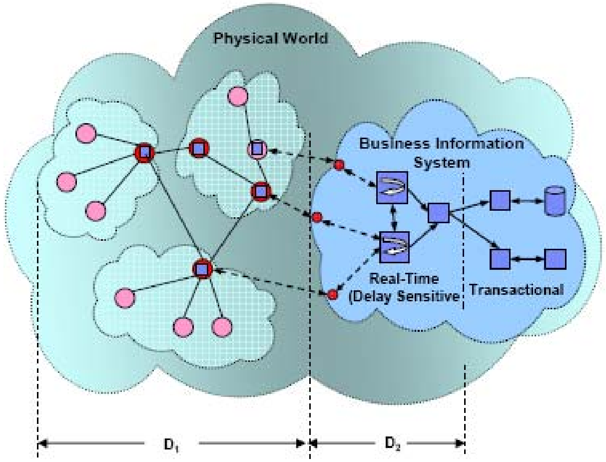
Characteristic	*Today*	*Tomorrow*
Optimizes Assets & Operates Efficiently	Little integration with asset management	Deep integration of grid intelligence with asset management software
Self Heals	Protects assets following disruption (e.g. trip relay)	Prevents disruptions, minimizes impact, restores rapidly
Resists Attack	Vulnerable to terrorists and natural disasters	Deters, detects, mitigates, and restores rapidly and efficiently

Smart Grid Key Technologies



An effective, fully-integrated communications infrastructure is an essential component of the Smart 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
- Ubiquitous system operating parameters
- Asset condition monitors
- Wide area monitoring systems (WAMS)
- Advanced system protection
- Dynamic rating of transmission lines

Advanced Control Methods

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

Some Examples:

- Next generation FACTS/PQ devices
- Advanced distributed generation and energy storage
- PHEV
- Fault current limiters
- Superconducting transmission cable & rotating machines
- Microgrids
- Advanced switches and conductors
- Solid state transformers

Decision Support

- **Data reduction**
- **Visualization**
- **Speed of comprehension**
- **Decision support**
- **System operator training**

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Why do we need to modernize?

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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
- **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

The Grid Is Under Stress

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Never designed for bulk power shipments

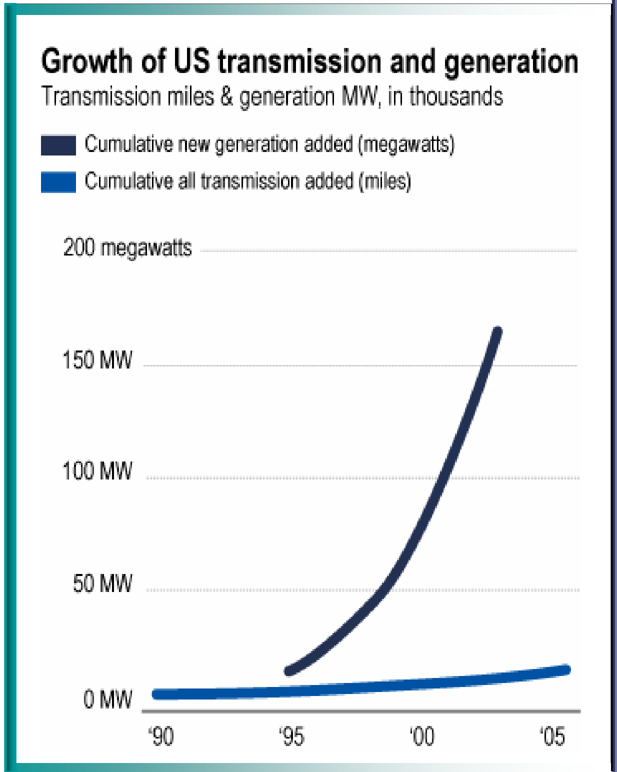
- Wholesale power transactions jumped 300% from 2000 to 2005. *Insight Magazine, Oct. 2005*

Blackouts, interruptions, near-misses increasing

- Transmission loading relief events near misses) up 1000% from 97 to 2002

Demand and supply grew dramatically but...

- ... transmission saw virtually no increase



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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

Platform for Prosperity

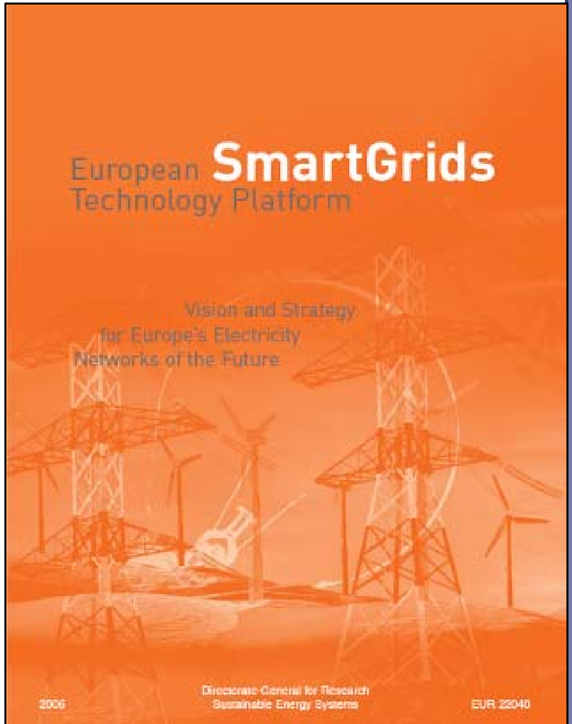
- **Economy now based on electricity**
  - Computers, networks, phone system, devices, robotic manufacturing, stock markets
- **Lifestyle now based on electricity**
  - Medical devices, appliances, air conditioners, computers
- **Must have infrastructure that facilitates growth**
  - The digital economy 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

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



Why Modernize the Grid?

- Today's grid is aging and outmoded
- Unreliability is costing consumers billions
- 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
- The benefits of a modernized grid are substantial

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

Reid Detchon, Energy Future Coalition

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What are some of the benefits?

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**

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)*

Improved Reliability

- **Major reduction in outage duration and frequency**
  - Reduces losses to consumers (>$100B/year)
  - Improves customer satisfaction
- **Far fewer Power Quality disturbances**
  - Reduces manufacturing losses
  - Improves safety
- **Virtual Elimination of Regional Blackouts**
  - Reduces huge societal costs by minimizing occurrences (>$10B per event)

Improved Security and Safety

- **Significantly reduced vulnerability to terrorist attack and natural disasters**
  - Intelligent networking and deployment of Distributed Energy Resources improves the resiliency of the grid
    - **Decentralization of DER**
    - **Diversity of fuels and size**
- **Improved Public and Worker Safety**
  - Improved monitoring and decision system support systems will quickly identify problems and hazards
  - Reduced number and duration of outages reduces public safety and crime issues proportionately

Improved Economics

- **Reduction or mitigation of electricity prices**
  - Consumer response to market prices will reduce peak demand leading to a reduction in peak prices
  - Deferral of capital investments will mitigate upward pressure on rates
  - Increased grid robustness and efficiency will also mitigate rate increases
- **New options for market participants**
  - Home energy management systems
  - Investment in resources
  - Sale of energy, capacity, ancillary services
- **Supports a growing national economy**

Improved Efficiency

- **Reduced O&M costs from more efficient operation and improved asset management**
  - Optimal loading of assets to prevent overloads and extending life
  - Improved planning process leading to “just in time” capacity additions
  - Improved understanding of asset health leading to more efficient maintenance practices
- **Reduction of electrical losses**
  - Reduces generation requirements
  - Extends life of assets

Reduced Environmental Impact

- **Much wider deployment of environmentally friendly resources**
  - “Plug and Play” simplifies interconnection of DER including renewables
  - Distributed renewable generation reduces the need for less environmentally friendly central generation
- **Electrical losses reduced leading to a corresponding reduction in system generation**
  - Less generation means less emissions

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What are some of the barriers?

What's taking so long to get there?

So many variables to align:

- **Lot of players**
- **Regulatory Policy**
- **Legislation**
- **Communication and Culture**
- **Technical**

Lot of players!

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- All Play a Part
- Need a clear vision
- Alignment critical
- Keep the “End in mind”
- Must be “win-win”

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Regulatory Policy

Regulatory policy should incentivize investment in the Smart Grid:

- ***Time based rates.*** **Incentives for consumers to become actively involved**
- ***More favorable depreciation rules.*** **Recovery of book value for assets that are retired early for "smart grid" reasons**
- ***Policy changes that provide incentives and remove disincentives to utilities.*** **Investment in a Smart Grid must make business sense**
- ***Clear cost recovery policies are needed.*** **Uncertain cost recovery increases investment risk and is preventing a deeper deployment of new technologies**
- ***Societal benefits.*** **Business cases should include societal benefits to ensure informed decisions are made by the regulator**

Legislation

What is the federal government's role:

- **Leadership**
- **Incentives**
- **Research, development, and demonstration**
- **Energy Independence and Security Act – 2007**
  - RD&D Program for SmartGrid technologies
  - Regional Demonstration Initiative with cost sharing
  - 20% Cost Reimbursement
  - Regulators "shall consider"
  - Good first step

Communication and Culture

A significant change management effort is needed:

- Strengthen consumer education and research
- Active leadership by regulators to stimulate progress
- Alignment around a common vision
- Metrics to monitor progress
- “De-siloed” utility culture

Technical

Some technical issues:

- Standards (interconnection and interoperability)
- Integration vs. “widgets”
- Distributed system behavior not well understood
- Decades behind in “computing and communications”
- Loss of skilled human resources
- Minimal funding of R&D

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How do we achieve a Modern Grid?

Where do we start?

- **Plan**
  - Create the vision
  - Identify the milestones
  - Determine the sequence
  - Define needed technologies and applications
- **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*

What are the steps?

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 technologies and applications

AMI Technologies

- **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 Technologies and Applications

- 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)
- Advanced protection and control
- Advanced grid components for distribution

The functionality of ADO enables "Self Healing"

ATO Technologies and Applications

- 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 Technologies and Applications

- **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

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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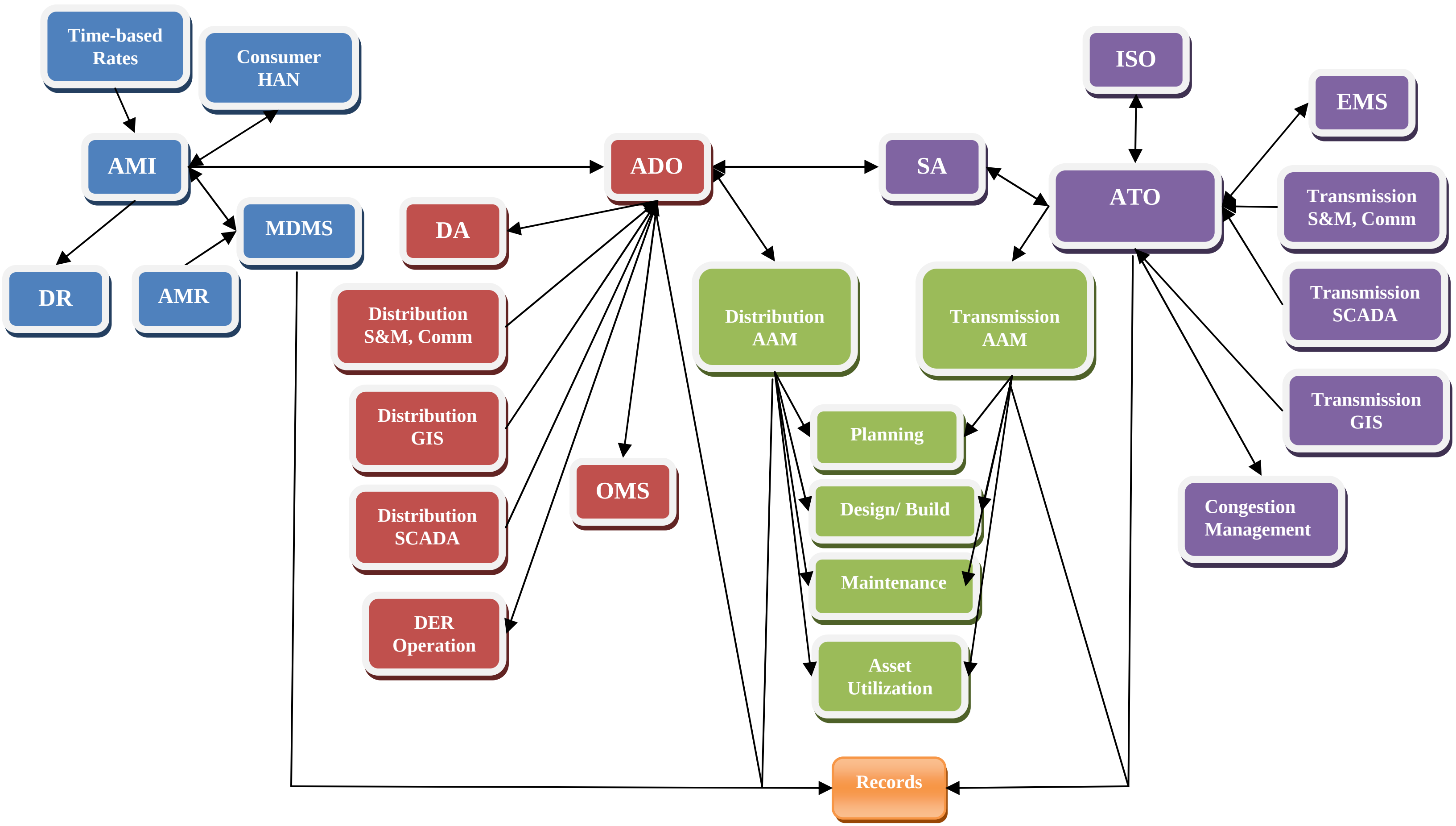

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Why do we need metrics?

- **Keep us on track**
  - Identify successes and opportunities for improvement
  - Initiate Corrective Action to address problems, reinforce good progress
  - Serve as an effective communication tool
  - Create alignment and motivation among stakeholders
- **Enable us to project future progress**
  - Establishes baseline for target setting
  - Provides insights for interdependent efforts
  - Keeps the “end in mind”

Smart Grid Workshop in June – Develop metrics for achieving the characteristics

Metrics – Work to date

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

Metrics – Work to date

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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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To Stay Involved

- **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

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Back-up Slides

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What are others doing to modernize?

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

International AMI

- Italy's Enel installed over 27 million communicating solid-state meters. (completed in 2006 – 4 year ROI)
- Sweden's Vattenfall is in the 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.
- Norway recently announced a smart meter roll-out to 2.6 million customers by 2013
- 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.
- Australia/United Kingdom and 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

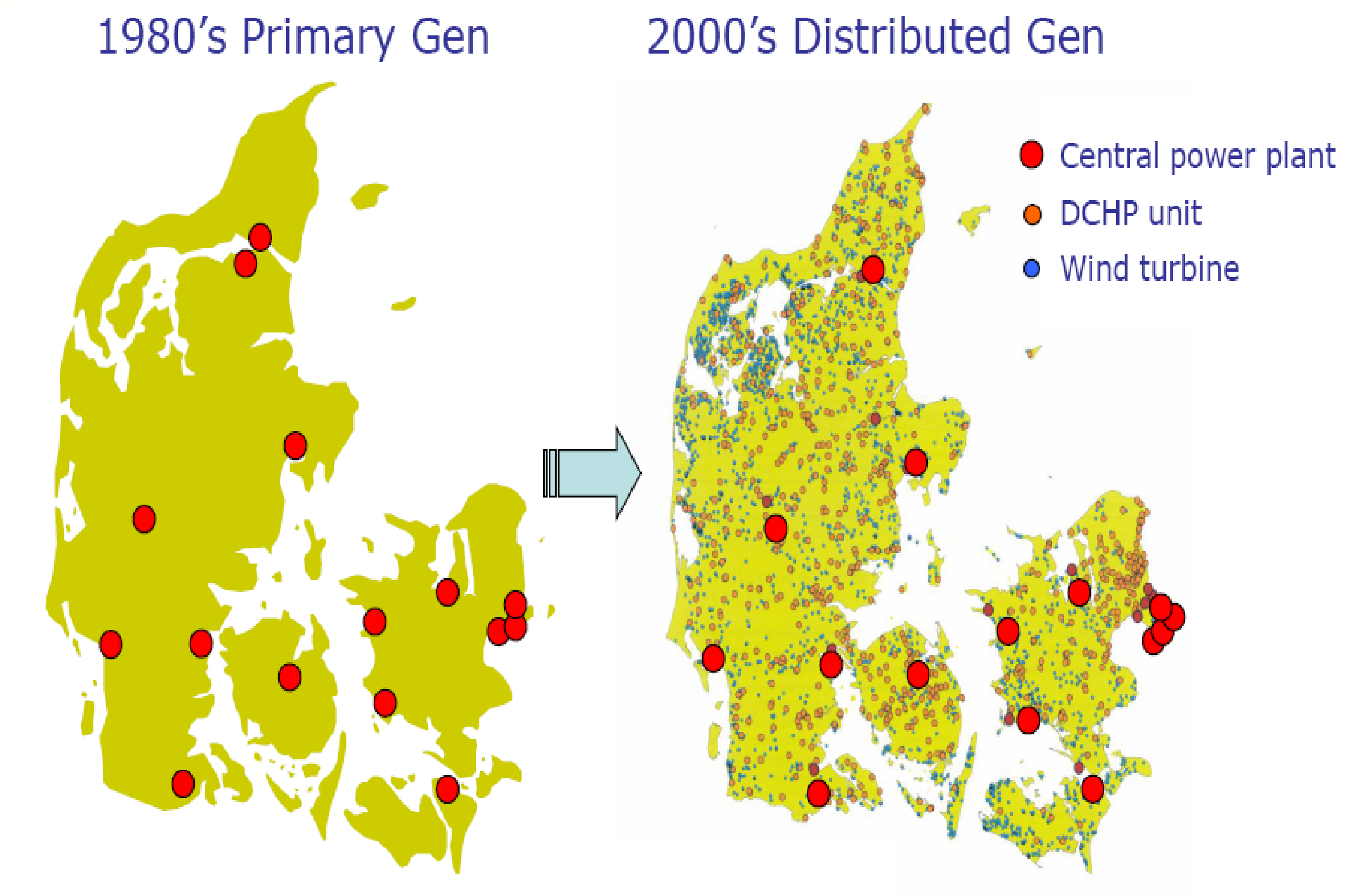
Asset Management

- **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 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

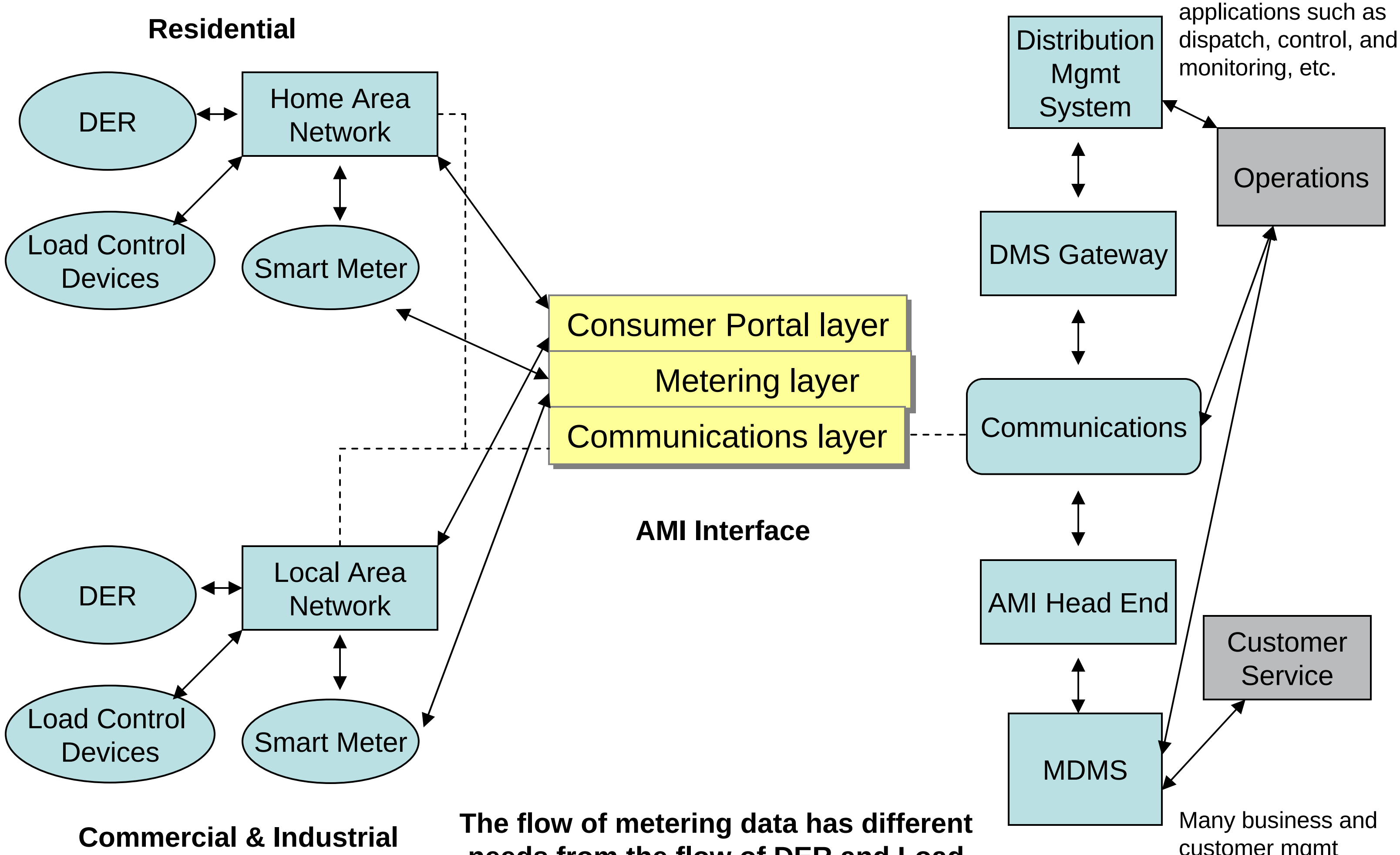
Danish Power System Transformation



AMI – What is it?

- AMI is the communications hardware and software and associated system and data management software that creates a network between advanced meters and utility business systems and which allows collection and distribution of information to customers and other parties such as competitive retail providers, in addition to providing it to the utility itself.
- An integration of technologies rather than a single technology
  - Smart meters
  - Home networks
  - Data collection and backhaul
  - Meter data management systems
  - Interface with existing software applications
- Open technology standards
- Enables other software applications to "snap in"
- Creates new opportunities for the consumer and the provider

AMI Technologies – How do they fit together?



Many system -side applications such as dispatch, control, and monitoring, etc.

The flow of metering data has different needs from the flow of DER and Load monitoring and control signals.

Many business and customer mgmt applications related to billing, accounts, etc.