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Smart Grid Concepts

Hawaii Clean Energy Initiative

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Agenda

- **Understanding the Smart Grid**
- **How do we get there?**
- **What is the value proposition?**
- **Questions?**

What is the role of the MGS?

- **Define a vision for the Modern Grid**
- **Reach out to stakeholders for input**
- **Assist in the identification of benefits / barriers**
- **Facilitate resolution of issues**
- **Promote testing of integrated suites of technologies**
- **Communicate and educate stakeholders**

MGS is an "Independent Broker" for the Smart Grid

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Understanding the Smart Grid?

Smart Grid Vision includes:

- Key Success Factors
- Principal Characteristics
- Key Technology Areas
- Value Proposition
- Implementation Roadmap
- Metrics

Smart Grid Key Success Factors

The Smart Grid is MORE:

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

These values define the goals for grid modernization and suggest where benefits will be realized

Principal 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

It will "Enable active participation by consumers"

- **Consumers have access to new information, control, and options to engage in electricity markets**
  - See what they use, when they use it, and what it costs
  - Manage energy costs
  - Investment in new devices
  - Sell resources for revenue or environmental stewardship
- **Grid operators have new resource options**
  - Reduce peak load and prices
  - Improve grid reliability

Today	***Tomorrow***
Little price visibility, time-of-use pricing rare, 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
- **Number of smaller, distributed sources will increase – shift 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**
  - PHEV and vehicle to grid
  - Brokers, integrators, aggregators, etc.
  - New commercial goods and services
- **Provides for consistent market operation across regions**

Today	***Tomorrow***
Limited wholesale markets, not well integrated	**Mature, well-integrated wholesale markets, growth of new electricity markets**

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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 with asset management applications**

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**

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How do we get there?

Break it down

- Understand the vision
- Create the roadmap (milestones)
- Define the value proposition
- Identify and resolve barriers
- Apply resources
- Create metrics to monitor progress

Smart Grid Milestones

- **Consumer Enablement**
- **Advanced Distribution Operations**
- **Advanced Transmission Operations**
- **Advanced Asset Management**

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

Consumer Enablement Solutions

- Smart Meters & 2–way communications
- Consumer Portal / Home area network
- Meter Data Management
- Time of Use Rates
- Customer Information System
- IT upgrades and SOA
- Customer Education
- Demand Response and DER

CE empowers the customer and supports grid operations

Advanced Distribution Solutions

- **Smart sensors and control devices**
- **Distribution Management System**
- **Advanced Outage Management**
- **Distribution Automation**
- **Geographic Information System (GIS)**
- **Micro-grid operations**
- **Advanced protection and control**

Advanced Distribution enables "Self Healing"

Advanced Transmission Solutions

- **Substation Automation**
- **Advanced regional operating applications (RTO)**
- **Wide Area Measurement System (WAMS)**
- **Advanced materials and power electronics**
- **Hi-speed information processing (N-1-1 and N-2)**
- **Modeling, simulation, and visualization tools**
- **Advanced digital protection**
- **Advanced Energy Storage at T&D interfaces**

Deeply integrated with CE, AD and AAM – AT optimizes transmission operations

Advanced Asset Management Solutions

- **Advanced sensors**
  - System Parameters
  - Asset "health"
- **Integration of grid intelligence with other processes:**
  - Operations to optimize asset utilization
  - T&D planning
  - Condition based maintenance
  - Engineering, design, and construction
  - Work and resource management

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

Steps to the Smart Grid

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

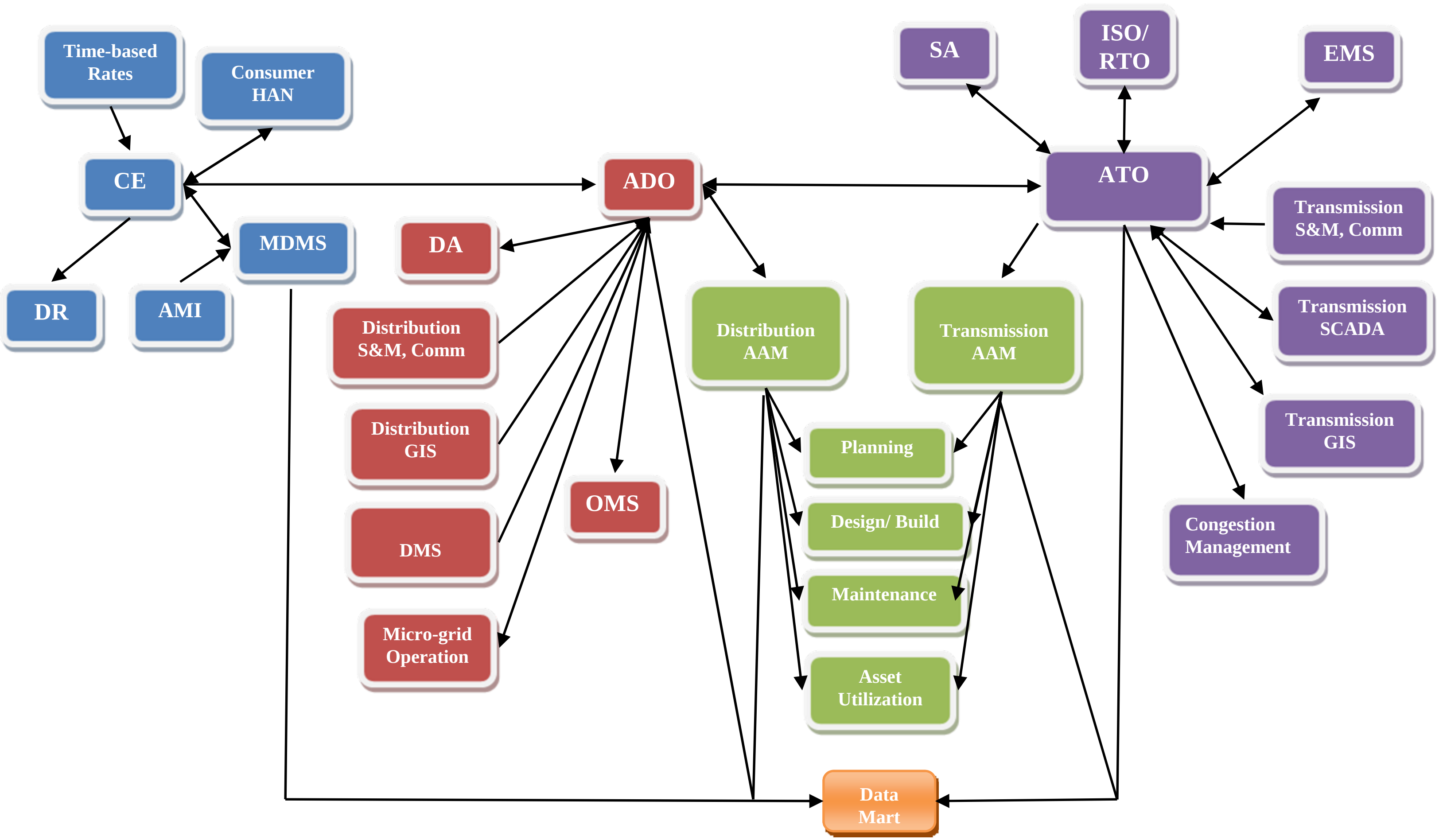
Advanced Asset Management

AAM helps utilities reduce costs and operate more efficiently

Characteristic – Milestone Map

Smart Grid Characteristic	CE	ADO	ATO	AAM
Enables Active Consumer Participation	✓	✓		
Accommodates All Generation & Storage Options	✓	✓	✓	
Enables New Products, Services and Markets	✓	✓	✓	
Provides PQ for Digital Economy	✓	✓	✓	✓
Optimizes Assets & Operates Efficiently	✓	✓	✓	✓
Anticipates and Responds to System Disturbances	✓	✓	✓	✓
Operates Resiliently Against Attack and Natural Disaster	✓	✓	✓	

The “Big Picture”



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What is the Value Proposition?

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**

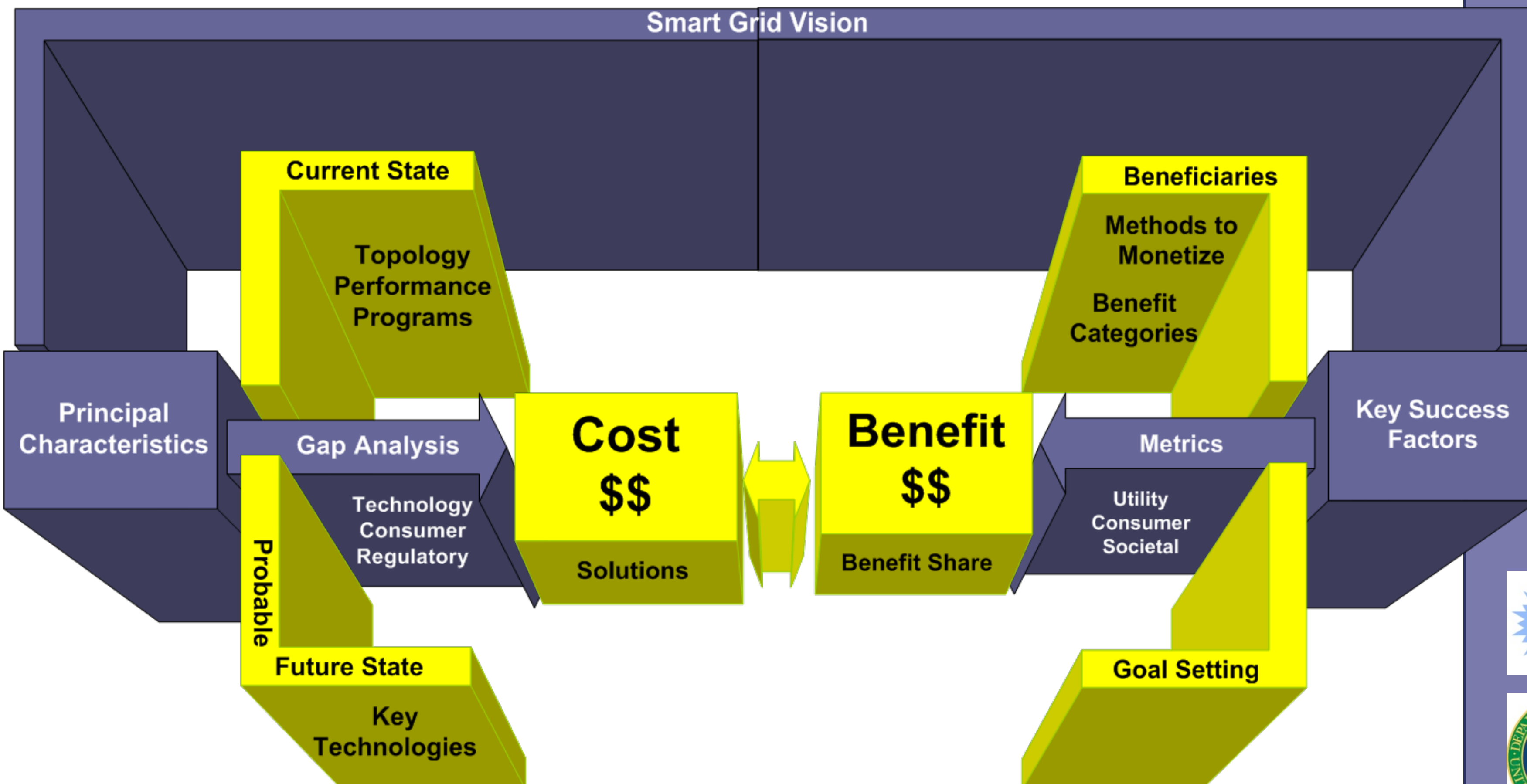
Benefit of Modernization

- **$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)

Business Case Framework



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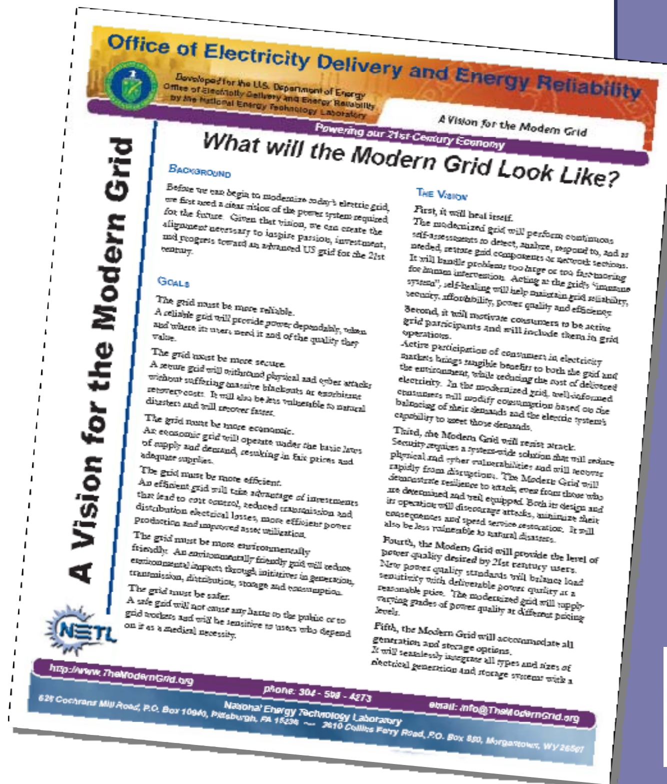

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A Vision for the Modern Grid

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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Questions?

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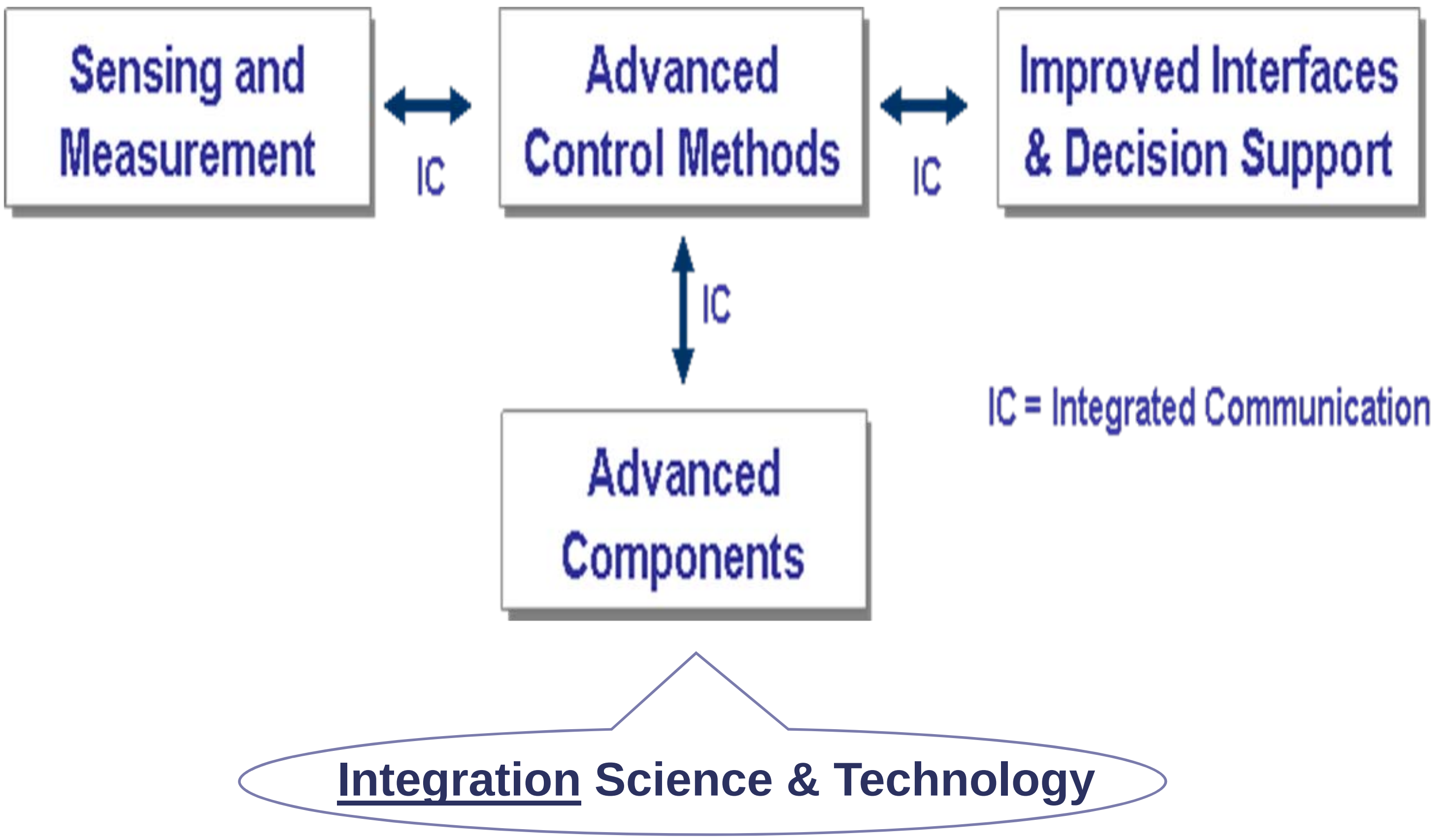
Back-up Slides

Smart Grid Technologies



Integration – biggest gap in today's science & technology development

Smart Grid Key Technology Areas

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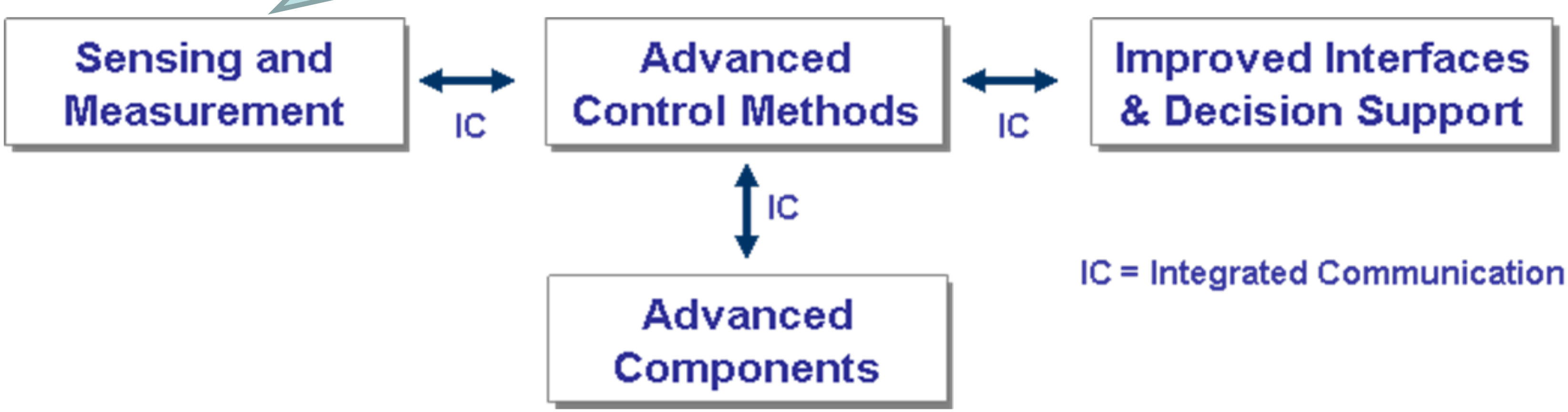
Smart meters
Smart sensors
- Operating parameters
- Asset Condition

Wide area monitoring systems (WAMS)
Dynamic rating of transmission lines



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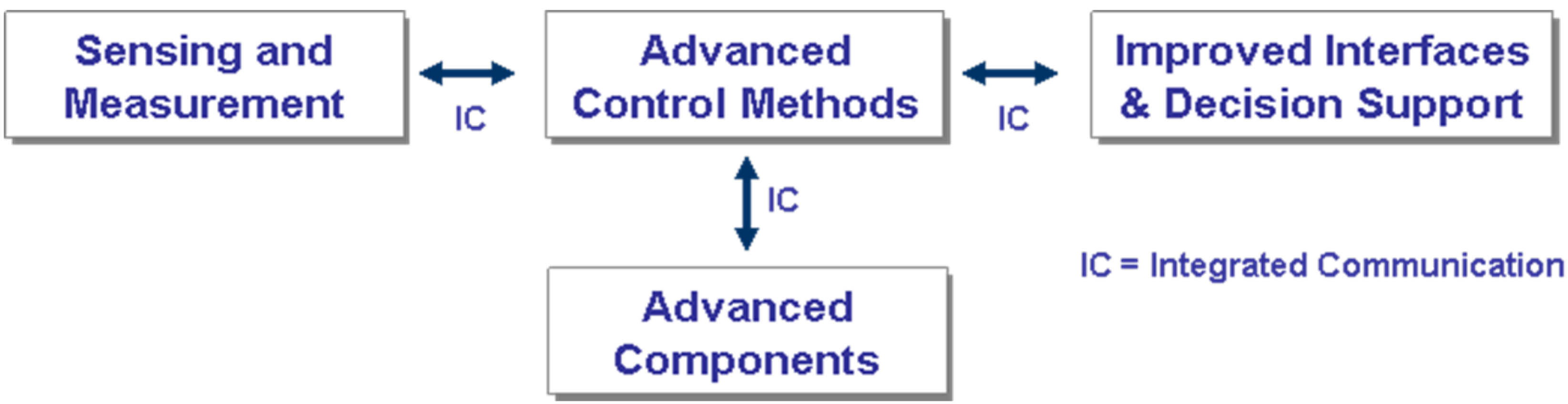
Smart Grid Key Technology Areas

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



Smart Grid Key Technology Areas

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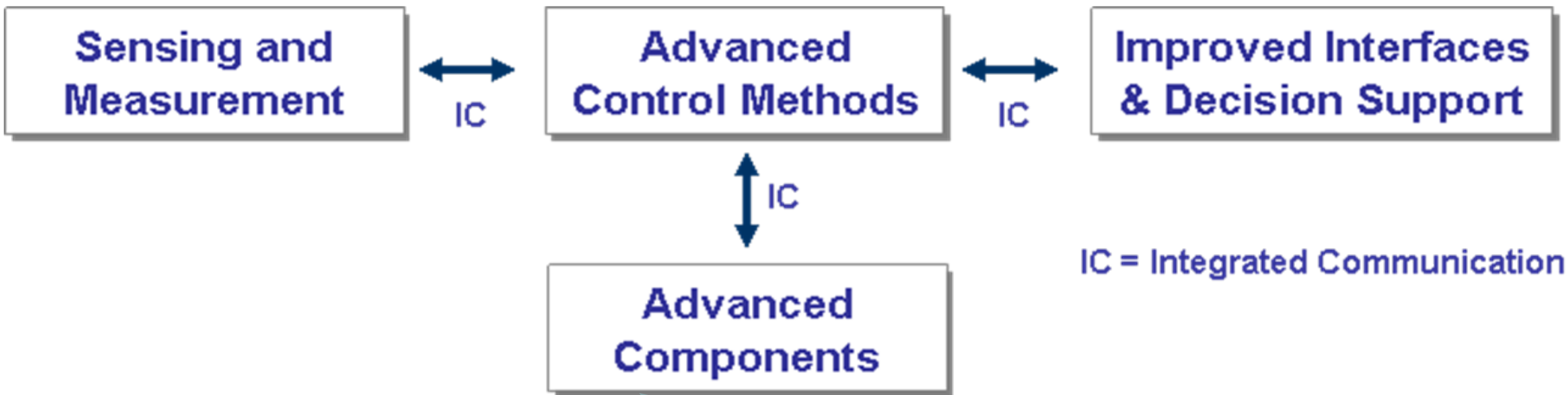

Next generation FACTS/PQ devices
Advanced distributed generation and energy storage
PHEV - V2G mode
Fault current limiters
Superconducting transmission cable & rotating machines
Micro-grids
Advanced switches and conductors

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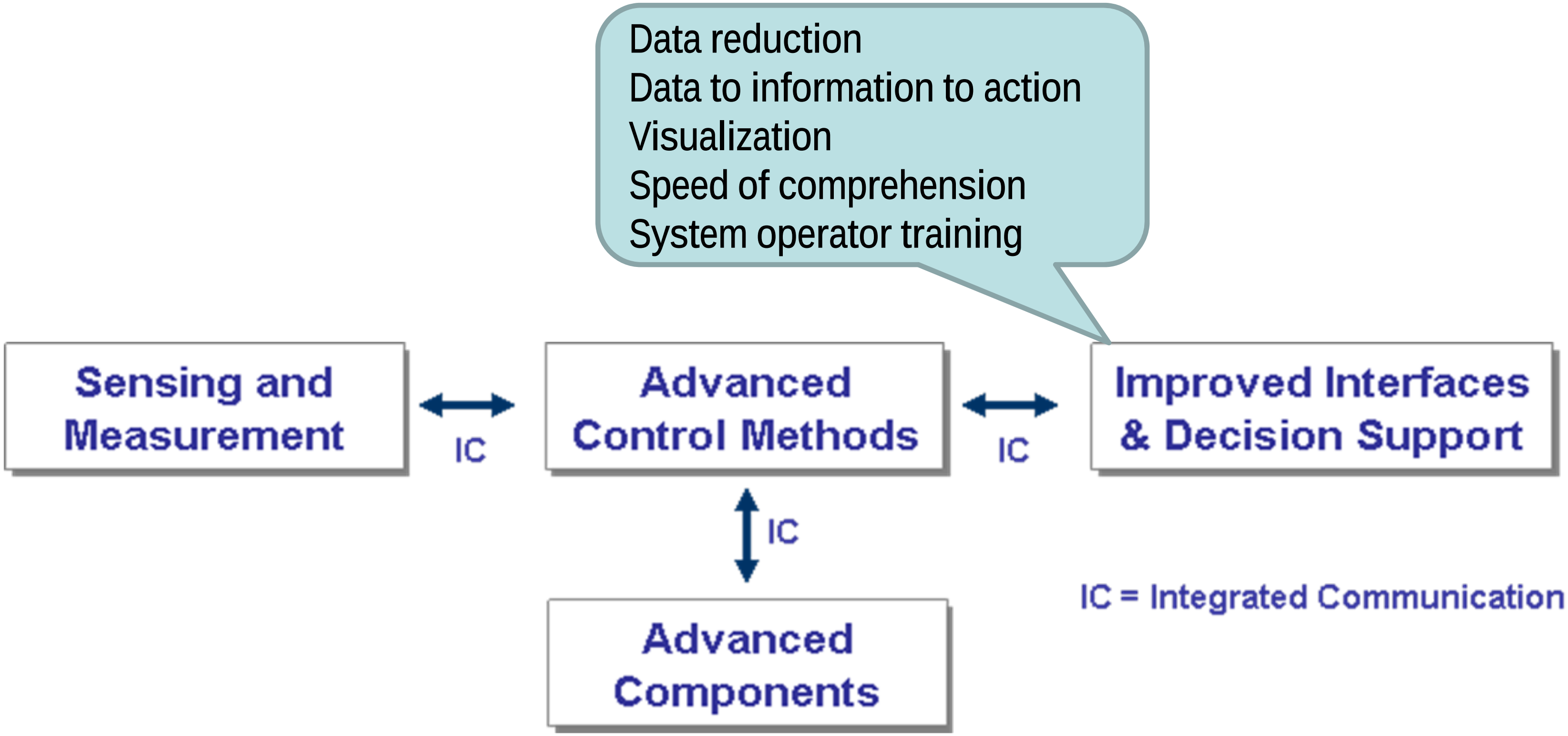
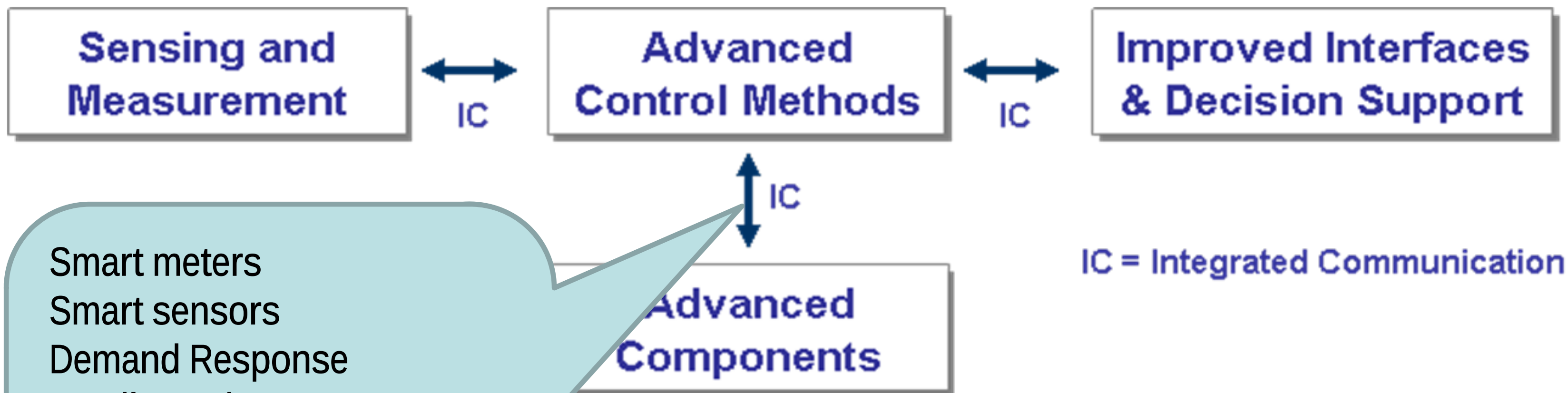
Smart Grid Key Technology Areas



Smart Grid Key Technology Areas



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

Utility Benefits

Operational improvements

- *Metering and billing*
- *Outage management*
- *Process improvement*
- *Work force management*
- *Reduced losses (energy)*
- *Asset utilization*

Asset Management improvements

- *System planning*
- *Maintenance practices*
- *Engineering*

These benefits are expected to improve customer satisfaction and reduce O&M and capital costs.

Consumer Benefits

- Improved reliability
- Improved overall level of service
- Access to information
- Ability to manage energy consumption
- Option to participate in demand response
- Convenient interconnection of distributed generation
- Option to bid (sell) into electricity markets
- Potential to dramatically reduce transportation costs (PHEV)

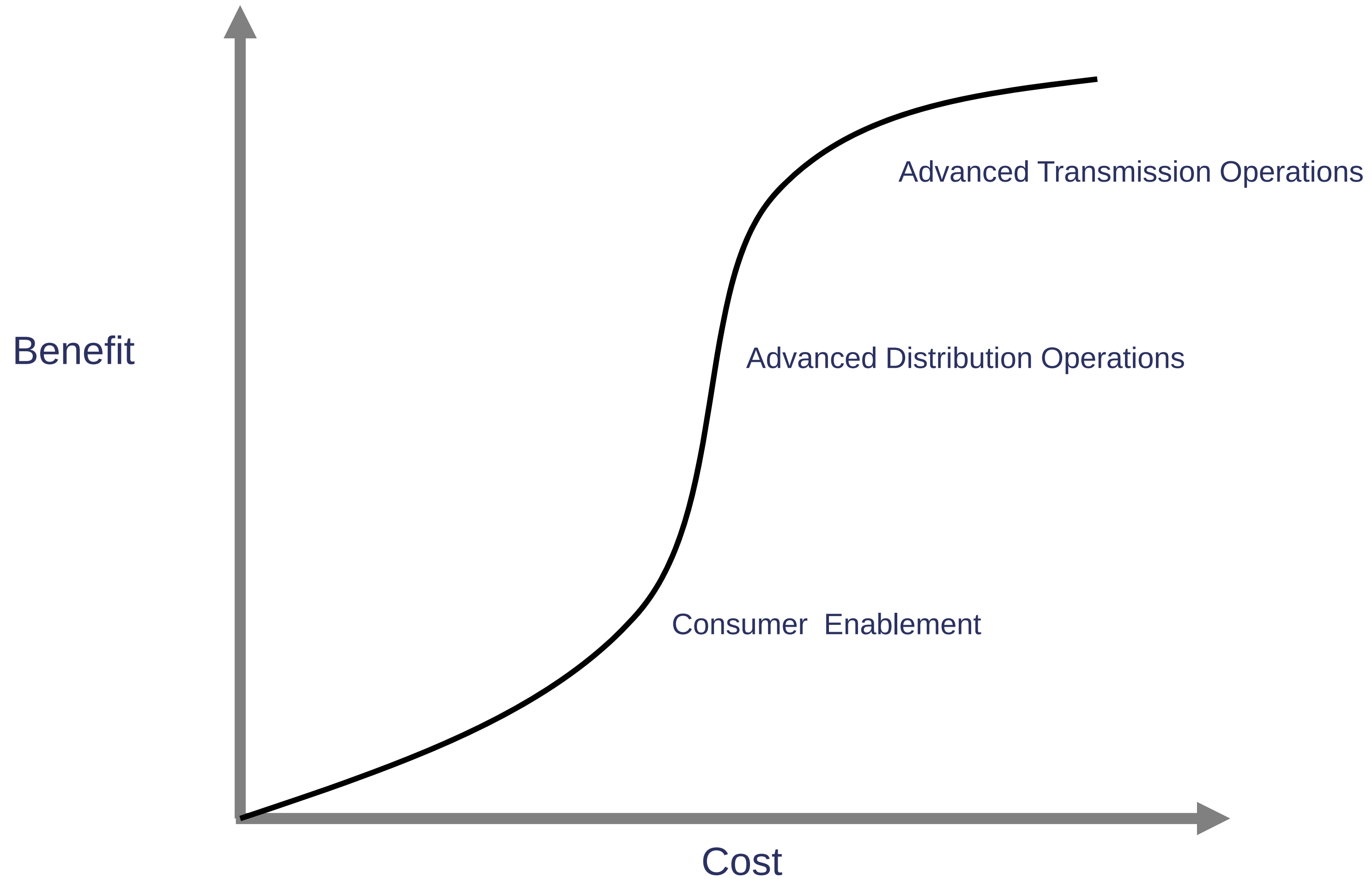
Consumers have access to information, control, and options

Societal Benefits

- **Downward pressure on electricity prices** *through improved operating and market efficiencies, consumer involvement*
- **Improved reliability** *leading to reduction in consumer losses (~$135B)*
- **Increased grid robustness** *improving grid security*
- **Reduced losses and emissions** *through integration of renewables*
- **New jobs and growth in GDP**
- **Opportunity to revolutionize the transportation sector** *through integration of electric vehicles as generation and storage devices*

Societal benefits must be included in the value proposition

Generally speaking…



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What are the Challenges?

Change Management

A significant change management effort is needed:

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

Our challenge is to align under a common long term vision and make our short term investment decisions consistent with the “end in mind”.

Regulatory

- ***Time based rates -*** incentives for consumers to become actively involved
- ***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 should make business sense
- ***Clear cost recovery policies -*** uncertain cost recovery increases investment risk
- ***Societal benefits –*** quantified and included in business cases
- ***New regulatory models***

Technical Challenges – What's New?

- Consumers actively involved
- Transactive (financial, information, "electric")
- Decentralized with 2-way power flow
- Fully integrated
- Fully instrumented
- Huge amount of data
- High granularity of control
- Market driven

Design Challenges

- **Large numbers of small sources and storage**
- **Incorporating 2-way power flow into operations**
- **Micro-grids and dynamic islanding**
- **Adaptive protective "relaying"**
- **Getting the communications system right**
- **"Future proofing" the technologies**
- **Integration of new power electronics**
- **Cyber Security**
- **Autonomous decision making by agents vs. operator**

Moving to a more de-centralized model

Getting the Communications Right

- Home area network
- Smart meters
- Smart sensors
- Demand Response and DER dispatch
- Distribution automation
- Micro-grids
- Market transactions
- Work force management
- Security

Keep the end in mind – remember the 20 MB hard drive!

Human Resource Challenges

- **Meeting the challenge will require a special set of engineering talent, including expertise in:**
  - Power system engineering
  - Electronics, including power electronics
  - Engineering economics and finance
  - System architecture and integration
  - IT and software engineering
  - Communications
  - Project management
  - Environmental engineering
  - and more
- **The engineering opportunities will be huge**

Planning Challenges

- **Load forecasting**
  - Smart loads are now sources
  - Impact of renewables at the C&I and residential levels
- **Integration of transmission and distribution studies**
  - Reliability and markets
  - Level of detail (PHEV to nuke)
  - 2-way power flows on distribution system
  - Large numbers of small sources and storage
- **Asset management integration with grid intelligence**
- **Advanced contingency analyses**
  - Economics at the distribution level
  - Risk, carbon, etc.

More sophisticated planning tools and high power computing will be needed

Operating Challenges

- **Modeling, simulation, and visualization tools**
  - Faster than real time
  - Use of PMU's
  - Probabilistic Risk Assessment ("risk meter")
  - Data analytics
- **Optimization**
  - Loss reduction
  - Operating margins (component, circuit, system levels)
  - Reliability and risk
  - Markets (energy, capacity, ancillary services, carbon, retail, wholesale, etc.)
- **Autonomous decision making by agents vs. operator**

"Data" to "information" to "action"

West Virginia Smart Grid Implementation Plan

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- $525K project jointly funded by NETL, RDS, Allegheny Power, AEP, State of West Virginia, WVU, and DOE OE
- Federal involvement from NETL PMC and OSAP
- Results will describe approach and value proposition of implementing Smart Grid in West Virginia
- Cost & benefit analysis comparing state of current electricity grid and future Smart Grid in West Virginia
- Address role of coal in Smart Grid
- Support economic development in State of West Virginia
- Only state-wide Smart Grid implementation plan
- Establishes West Virginia and NETL as leader in Smart Grid
- Only second Smart Grid study to be published

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