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STRATEGY

The Smart Grid - Some Technical Challenges

Symposium on Modeling & Control of Alternative Energy Systems

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Agenda

- **What is the Smart Grid?**
- **How do we get there?**
- **What are the challenges?**
- **What is the value proposition?**

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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What is the Smart Grid?

The Big Picture

Smart Grid Vision includes:

- Key Success Factors
- Principal Characteristics
- Key Technology Areas
- Value Proposition
- Implementation Plan
- 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**

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**

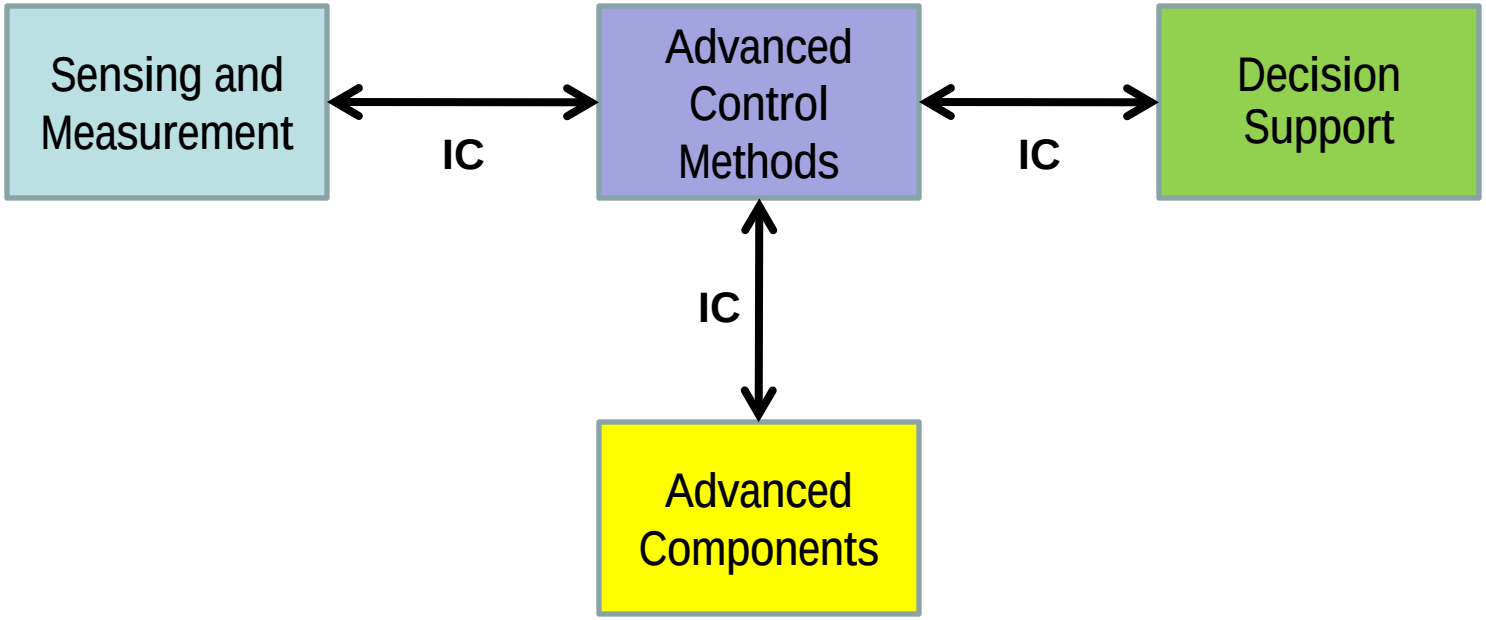
Today	*Tomorrow*
Protects assets following disruption (e.g. trip relay)	**Prevents disruptions, minimizes impact, restores rapidly**

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**

Smart Grid Technologies



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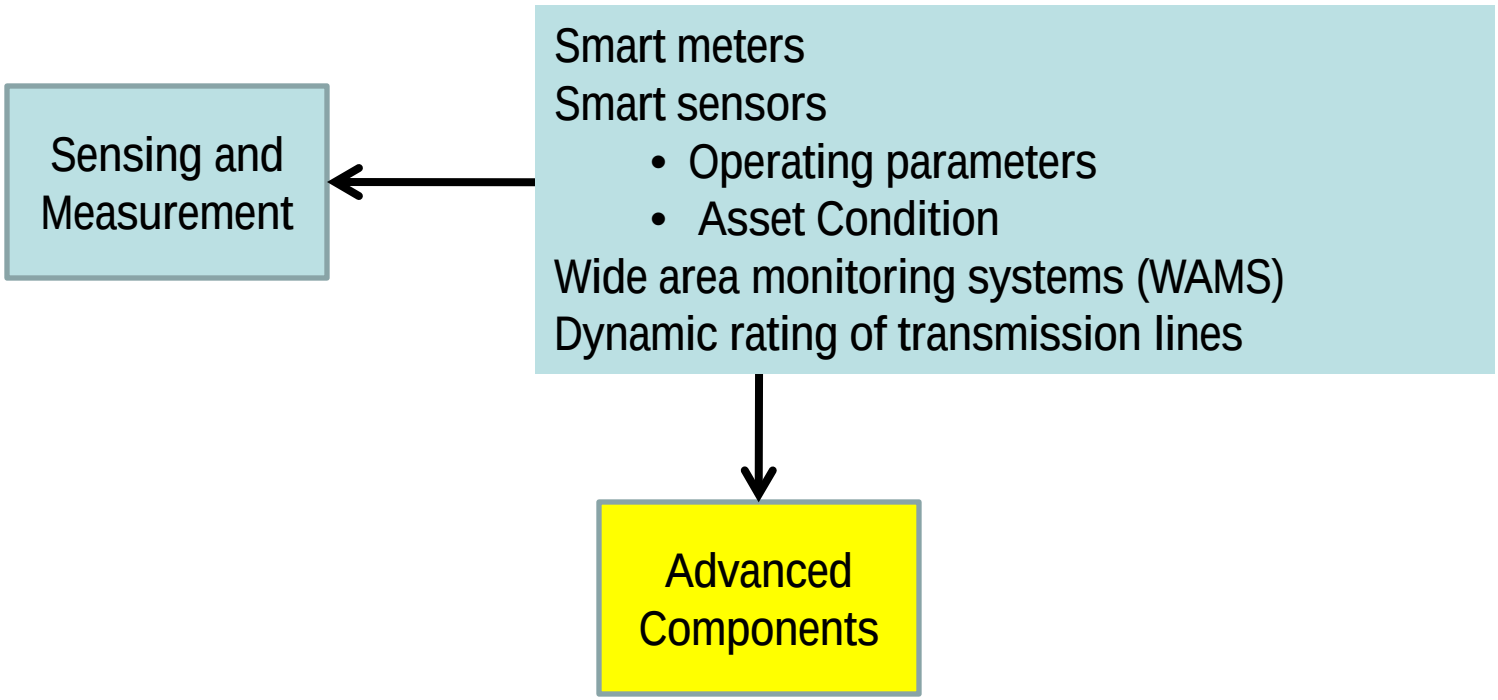
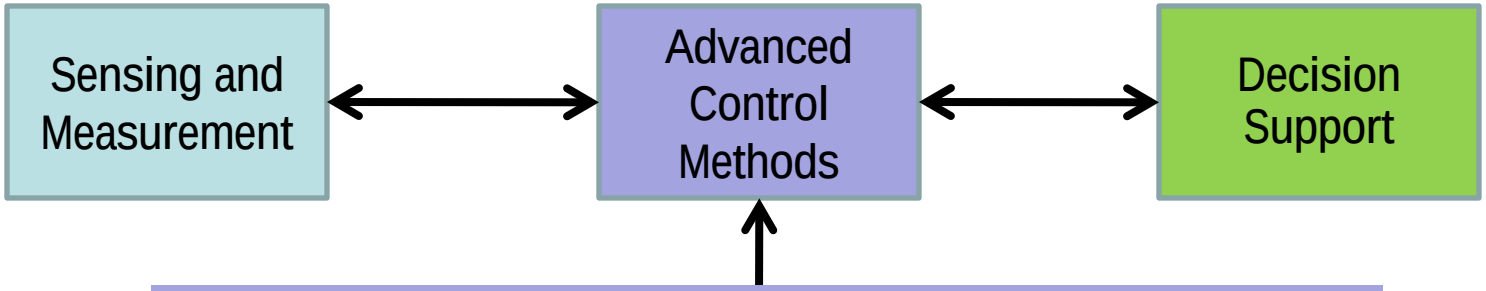
Smart Grid Technologies



Smart Grid Technologies

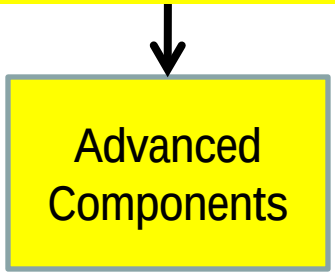


Applications that:

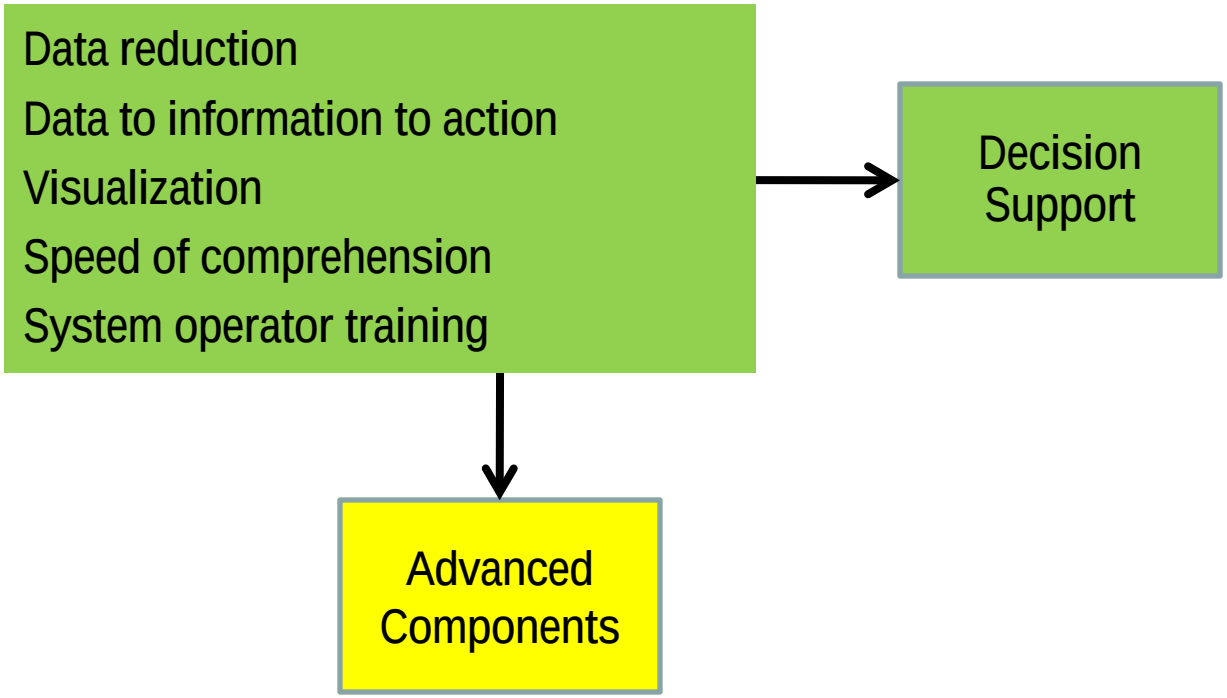
- Monitor and collect data from sensors
- Analyze data to diagnose and provide solutions
- Real time and predictive
- Determine and take action autonomously or via operators
- Provide information and solutions to operators
- Integrate with enterprise-wide processes and technologies

Smart Grid Technologies

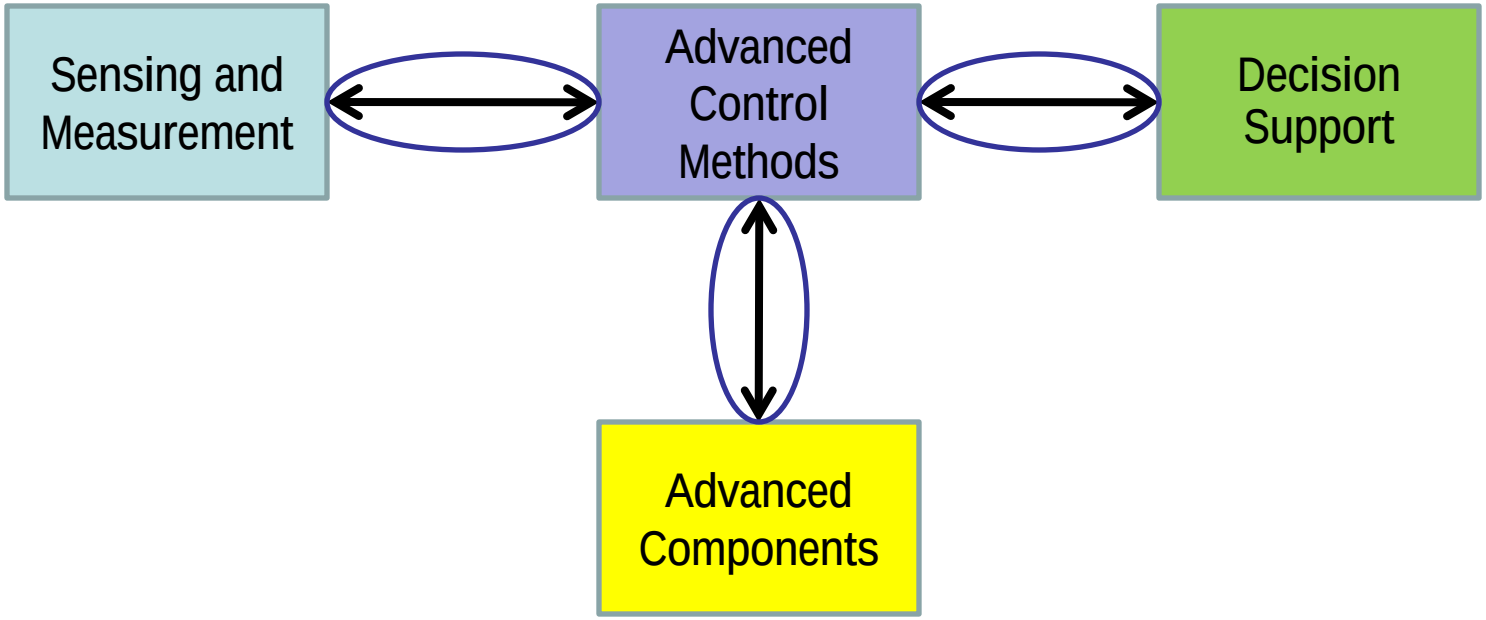
Next generation FACTS/PQ devices
Advanced distributed generation and energy storage
PHEV - V2G mode
Fault current limiters
Superconducting transmission cable & rotating machines
Micro-grids
Advanced switches and conductors



Smart Grid Technologies



Fully Integrated Communications Infrastructure



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How do we get there?

Break it down

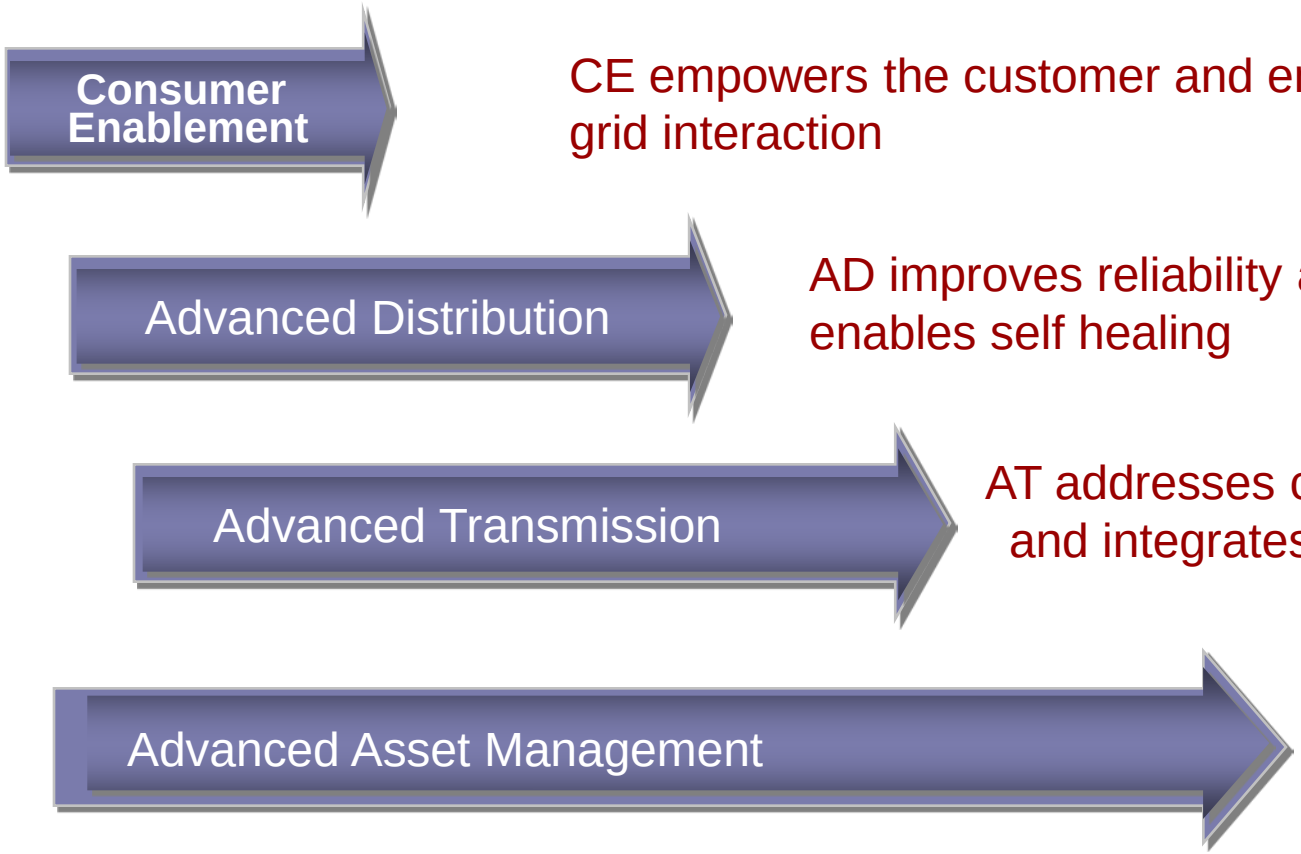
- **Understand the vision**
- **Create the roadmap (milestones)**
- **Define the value proposition**
- **Identify and resolve barriers**
- **Apply resources**
- **Create metrics to monitor progress**

Smart Grid Milestones

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

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

Steps to the Smart Grid



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**

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

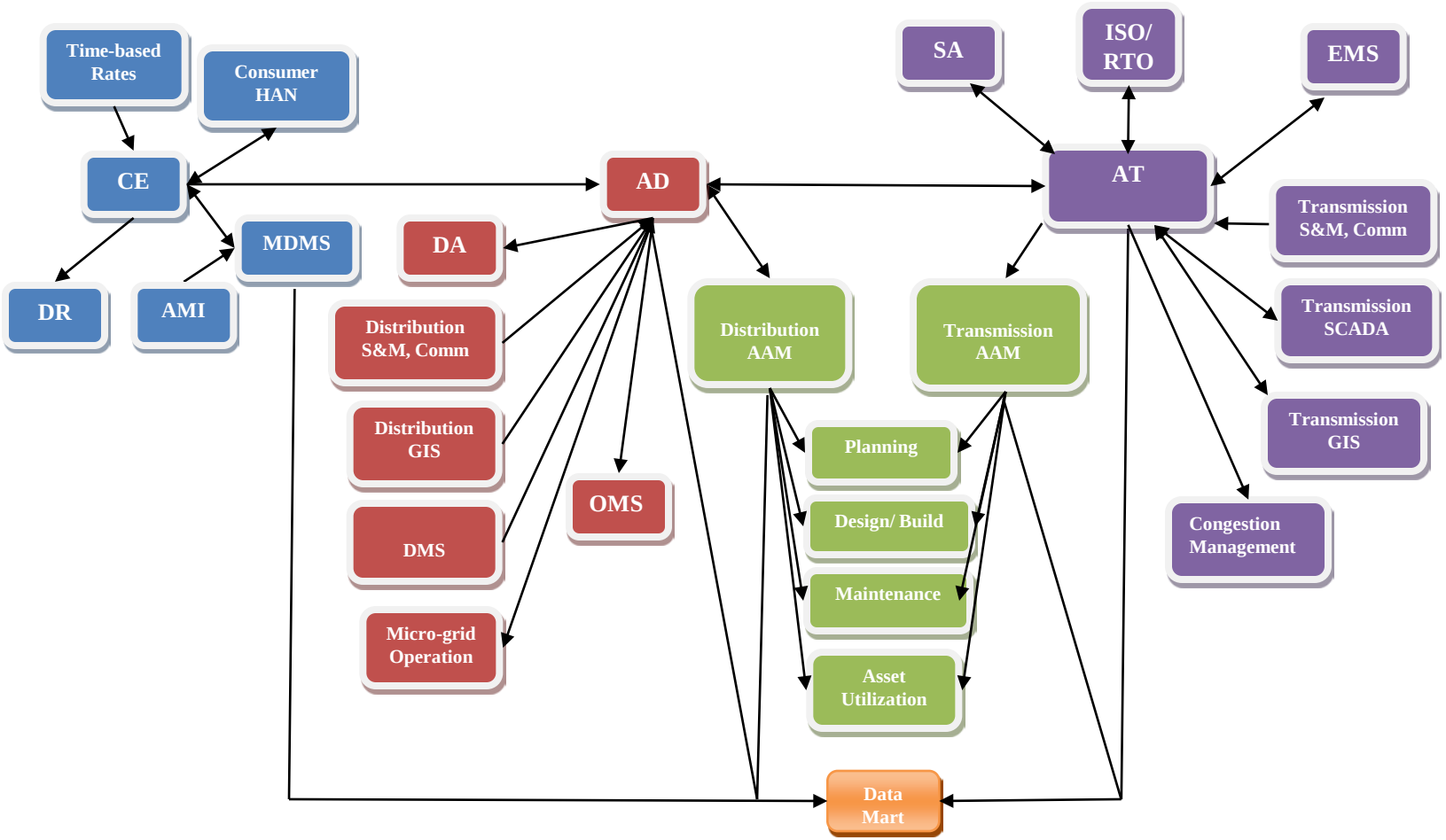
- **Advanced sensors**
  - System Parameters
  - Asset “health”
- **Integration of grid intelligence with other processes:**
  - Operations to optimize asset utilization
  - T&D planning
  - Condition based maintenance
  - Engineering, design, and construction
  - Work and resource management

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

Characteristic – Milestone Map

Characteristic	CE	AD	AT	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"



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

Smart Grid – What's New?

- Consumers actively involved
- Transactive (assets, financial, resources)
- 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**
- **Keeping the end in mind**

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!

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 hi 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"

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**

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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**

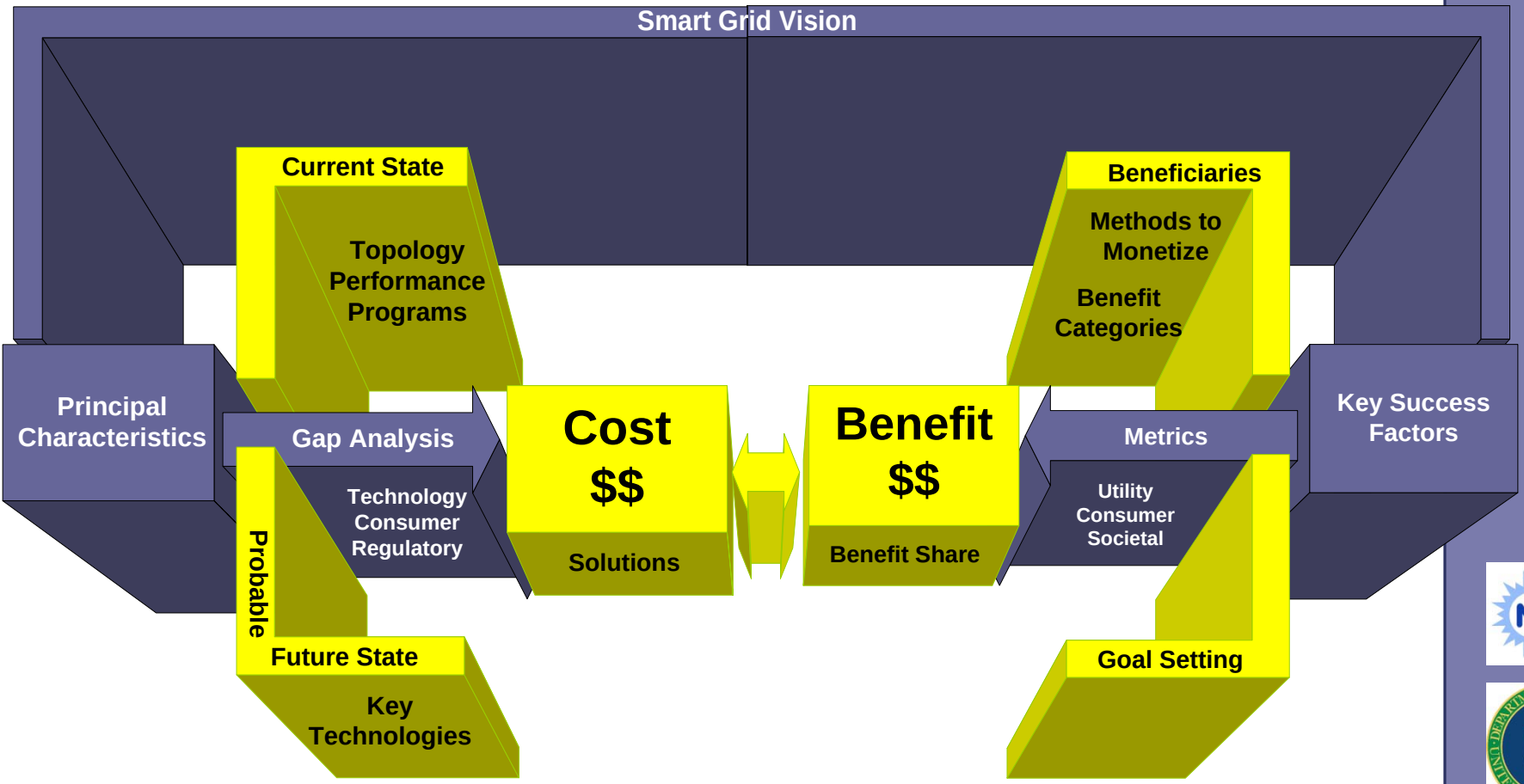
Benefit of Modernization

- **$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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Contact Information

For additional information, contact

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Questions?

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Back-up Slides

System Integrity Protection Systems

- **Protects a strategic part of the power system, not just a specific piece of equipment (as in protective relaying of a transformer or line)**
- **Requires multiple detection and actuation devices and high speed communications facilities connecting multiple locations**
- **Initiates multi-level corrective actions to satisfy real time power system needs**
- **Employs sets of logic to address a variety of evolving scenarios**

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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...