MODERN GRID
STRATEGY

Taiwan Power Briefing on the Smart Grid

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Morgantown, WV
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Agenda

- Overview of the Modern Grid Strategy (MGS)
- Smart Grid Activities in the US
- Morgantown Developmental Field Test (DFT)
- Consumer Engagement and Other Key Concepts
- Smart Grid Costs, Benefits, and Business Case
- Barriers to the Smart Grid
- MGS Benefit from TPRI Involvement
- NETL Requirements to Participate in MGS (Optional)

MGS OVERVIEW

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 and 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

The MGS Team

- **25 Industry Professionals with more than 500 yrs of energy experience (National Energy Technology Laboratory, Illinois Power, Progress Energy, AEP, Wisconsin Electric, PJM, Istanbul Electric, TVA, Air Force, DTE Energy, GPU, Duquesne Light, etc) - senior management, engineering, operations, T&D, generation, fuels, R&D, asset management, regulatory, etc.**
- **Recognized internationally – previous and current work in Asia, North America, Europe, and Middle East**
- **Active relationships in >100 utilities, 6 RTO/ISO's, EEI, NARUC, 13 regulatory commissions, NETL, NREL, ORNL, >25 industry (public and private) organizations, 10 energy investment organizations, >100 vendors, 6 consumer groups, and 39 "Smart Grid" groups**

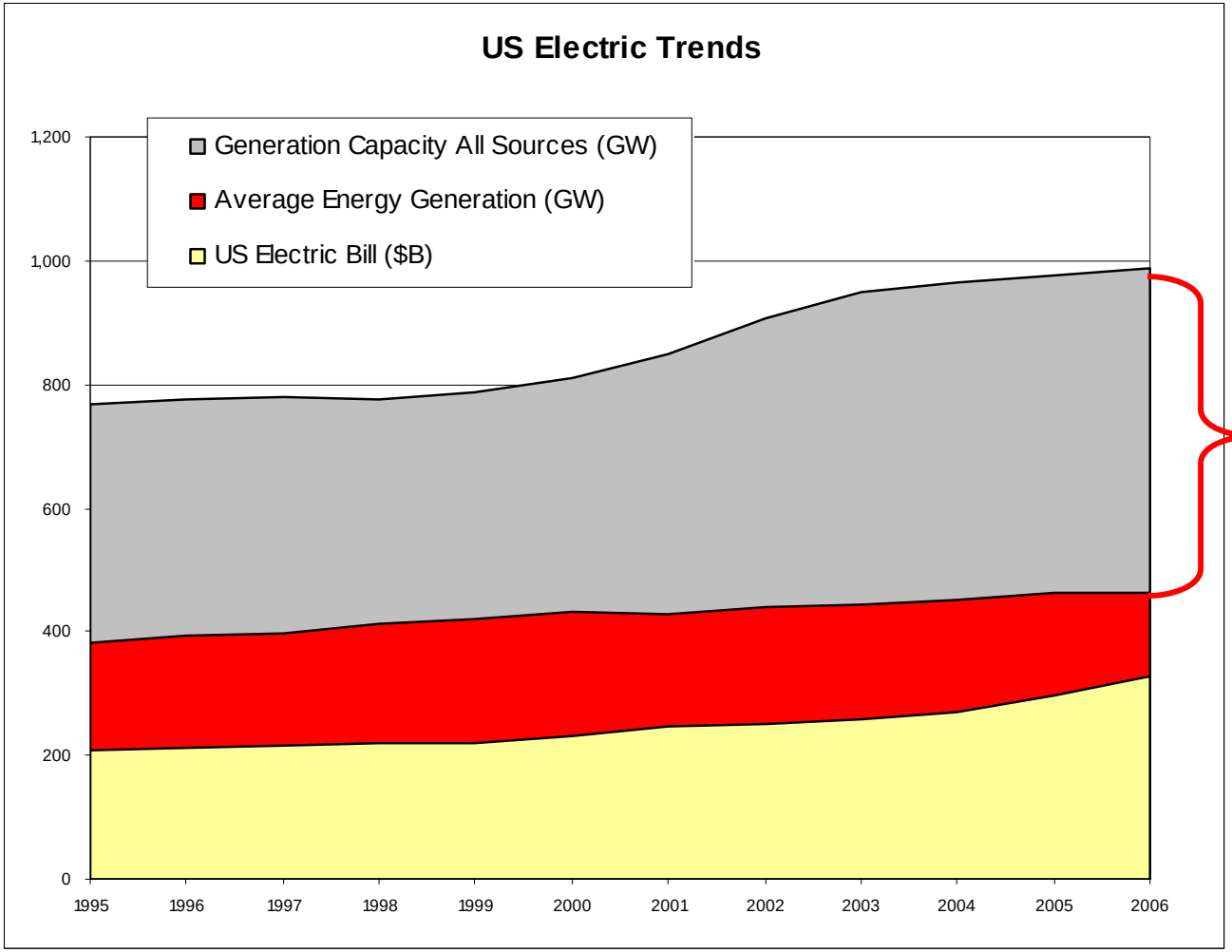
Why modernize the grid?

- Today's grid is aging and outmoded
- Unreliability is costing consumers billions of dollars
- 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
- Today's grid is significantly under utilizing the energy assets

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

Reid Detchon, Energy Future Coalition

Top Priority – Change the Peak



Ever-widening gap drives asset utilization down and cost up.

Average energy increased 16% over last decade, peak capacity increased 27%.

Source data: DOE EIA

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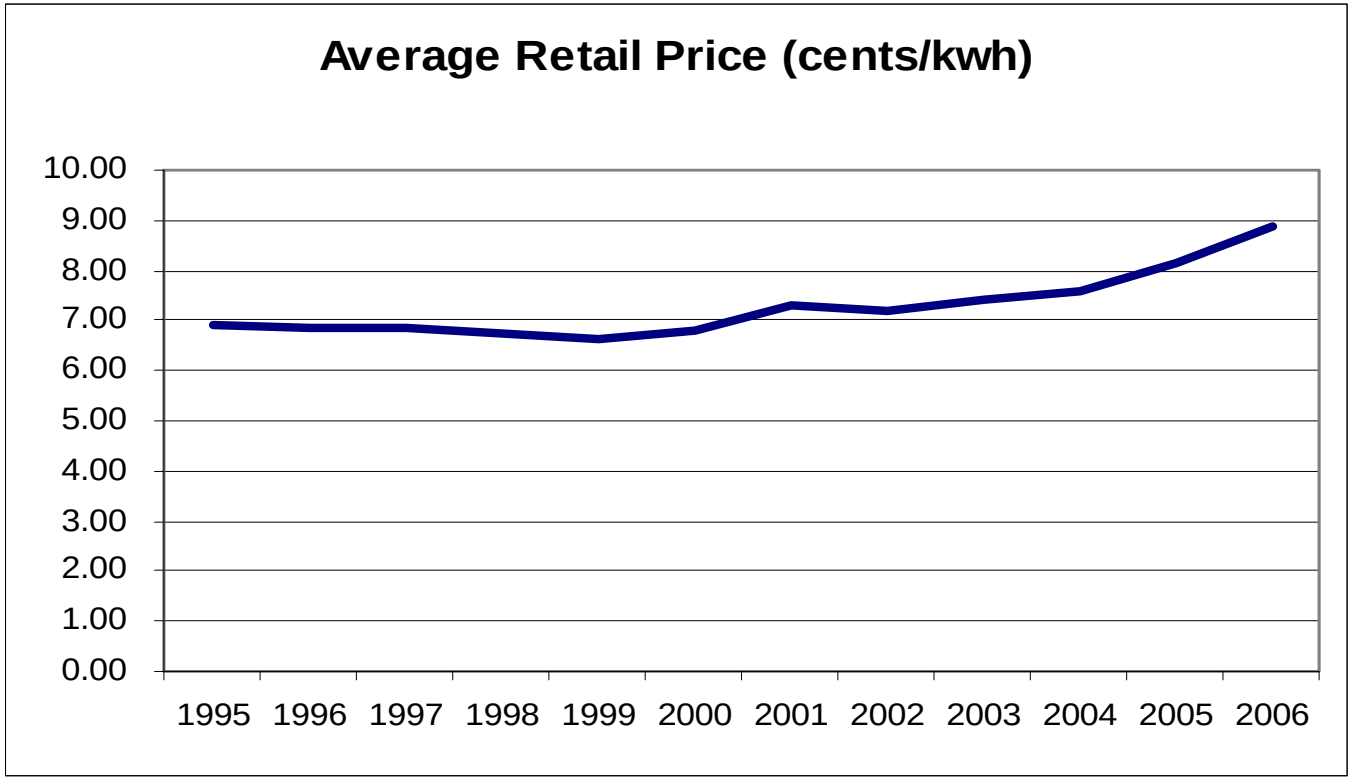
Retail prices are increasing



30% increase over last decade

DOE EIA Energy Outlook 2007

Today's grid is:

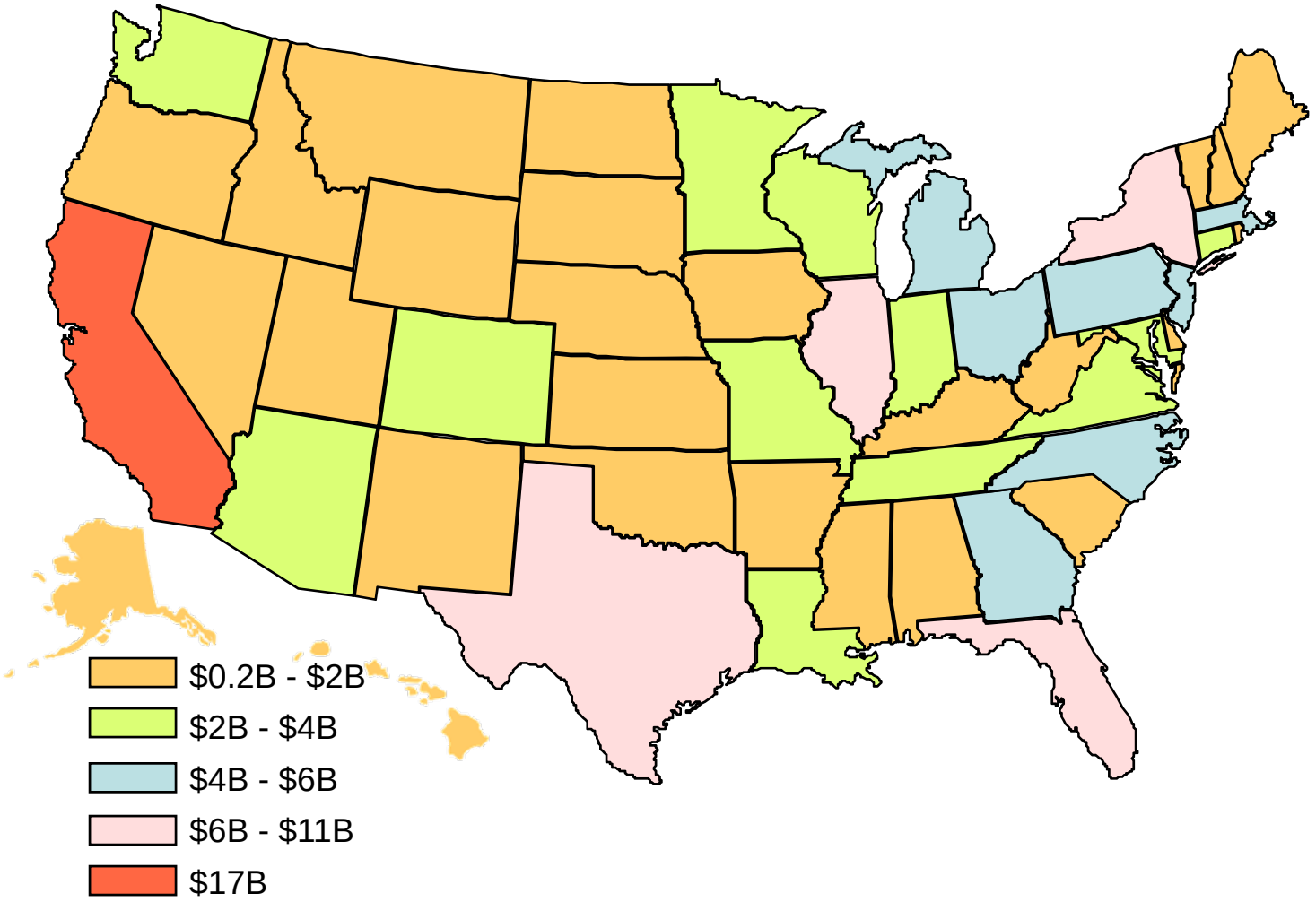
- **Aging**
  - 70% of transmission lines are 25 years or older
  - 70% of transformers are 25 years or older
  - 60% of circuit breakers are 30 years or older
- **Outmoded**
  - Designed in the 50s and installed in the 60s and 70s, before the era of the microprocessor.
- **Stressed**
  - Never designed for bulk power shipments
  - Wholesale power transactions jumped 300% from 2000 to 2005. *Insight Magazine, Oct. 2005*

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

EnergyBiz Magazine, Sept. 2005

Businesses losing billions

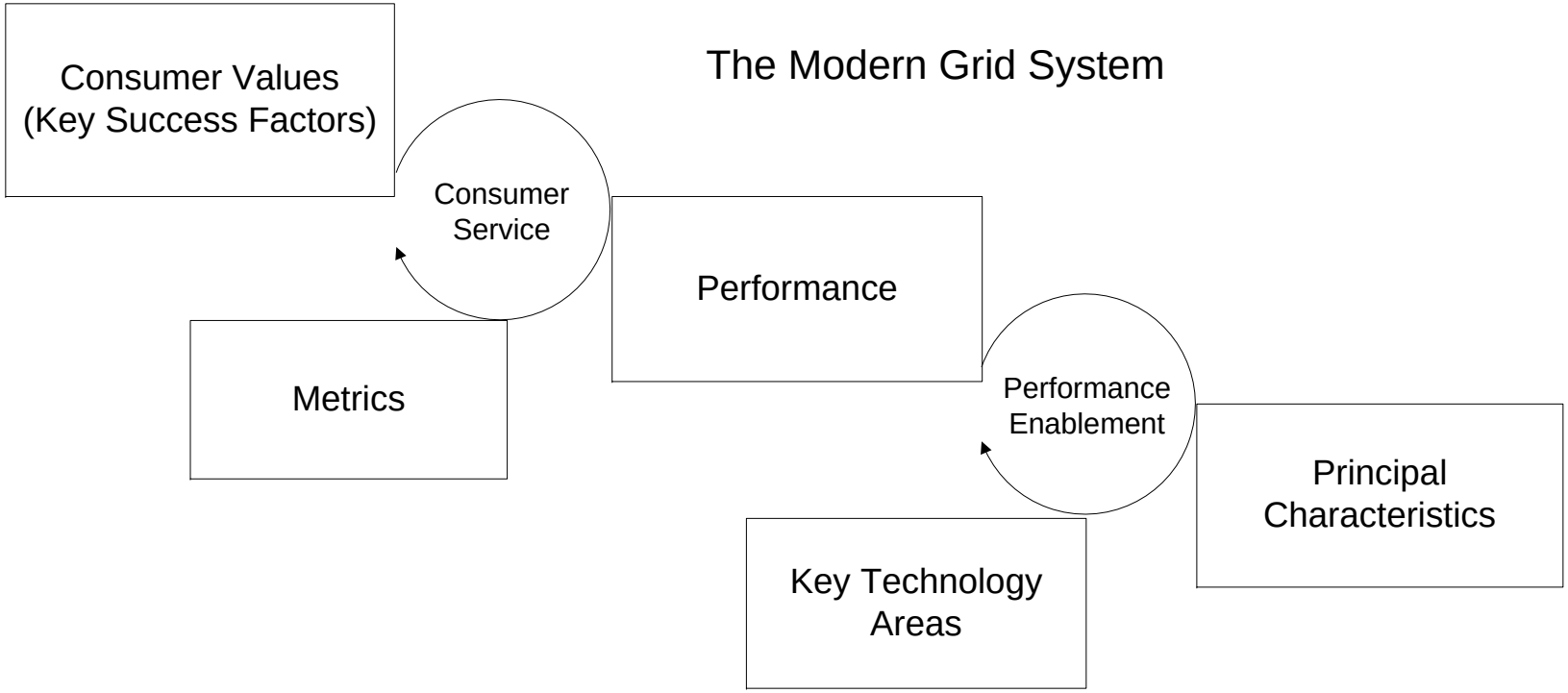
Primen Study: Up to $135B annually for power interruptions



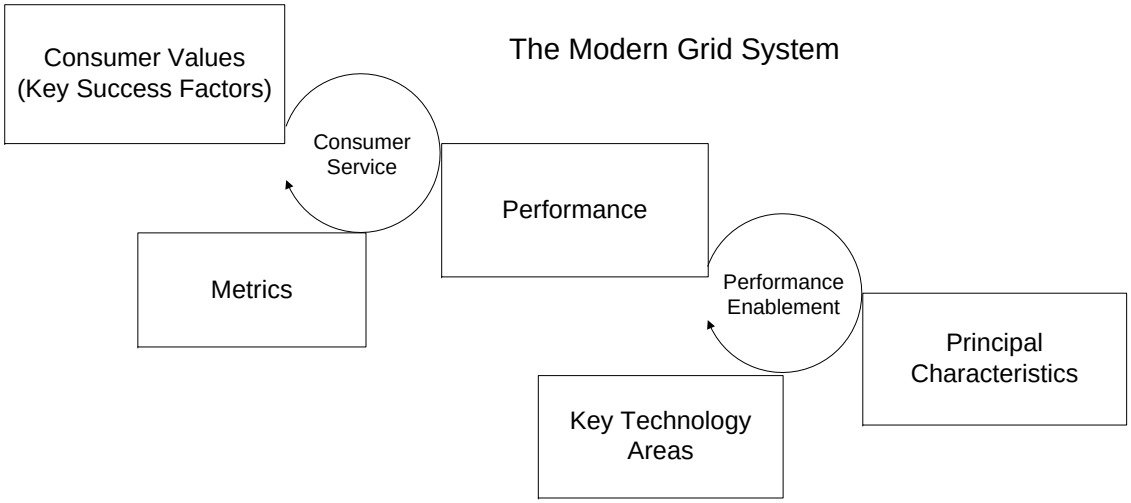
Other considerations

- **Jobs and the economic downturn**
- **US dependence on foreign energy sources**
- **Climate change**
- **National security**
- **50 coal plants canceled / delayed since January 2007**
- **Impact of electric vehicles**

The Systems View

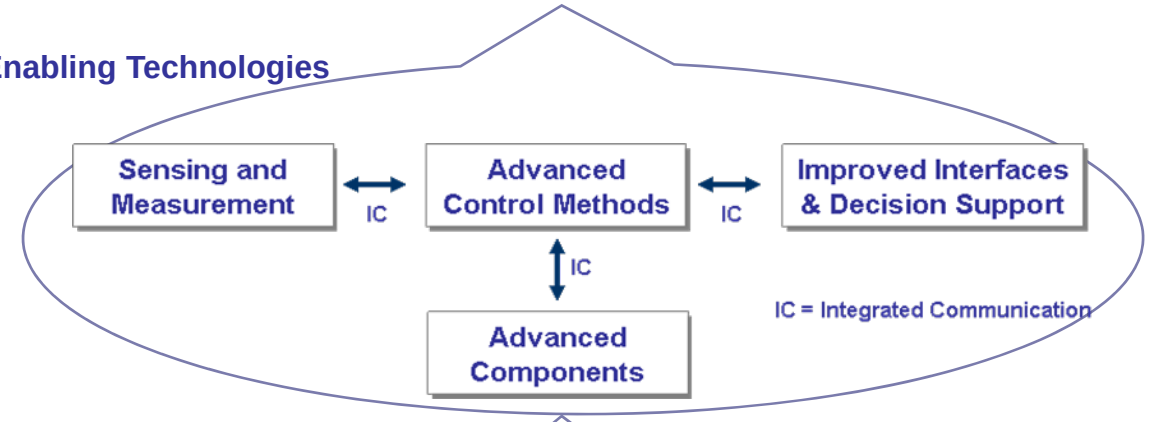


The Systems View



Needed leadership in the electricity delivery vision and operating model; industry too fractured to form a consensus in this area; Federal / States must take the lead – industry expects/needs this

Key Enabling Technologies



Tradition focus is in the technology development arena; this area is mature in assuring technologies streams

Integration Science & Technology

Integration – gap in today's science and technology development

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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"

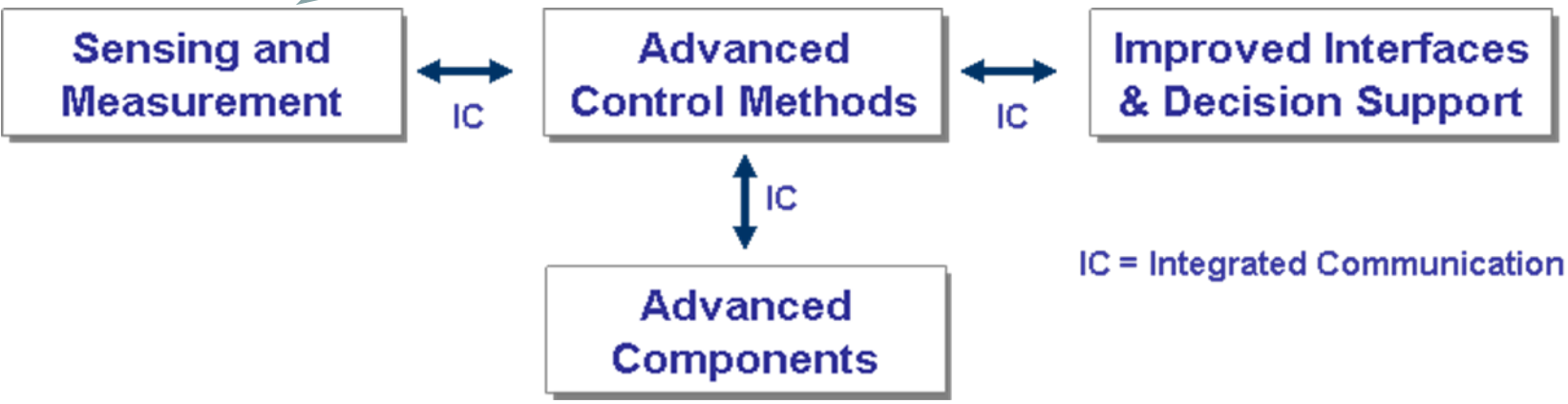
- **System-wide solution to physical and cyber security**
- **Reduces threat, vulnerability, consequences**
- **Deters, detects, mitigates, responds, and restores**
- **"Fort Knox" image**
- **Decentralization and self-healing enabled**

Today	*Tomorrow*
Vulnerable to terrorists and natural disasters	**Deters, detects, mitigates, and restores rapidly and efficiently**

Smart Grid Key Technology Areas

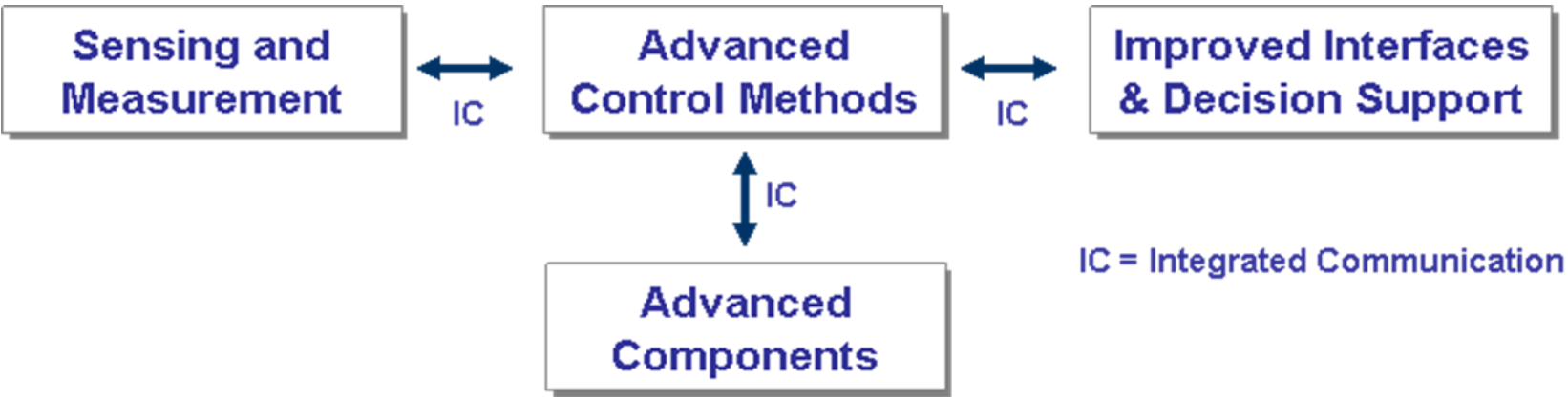
Smart meters
Smart sensors
- Operating parameters
- Asset Condition

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

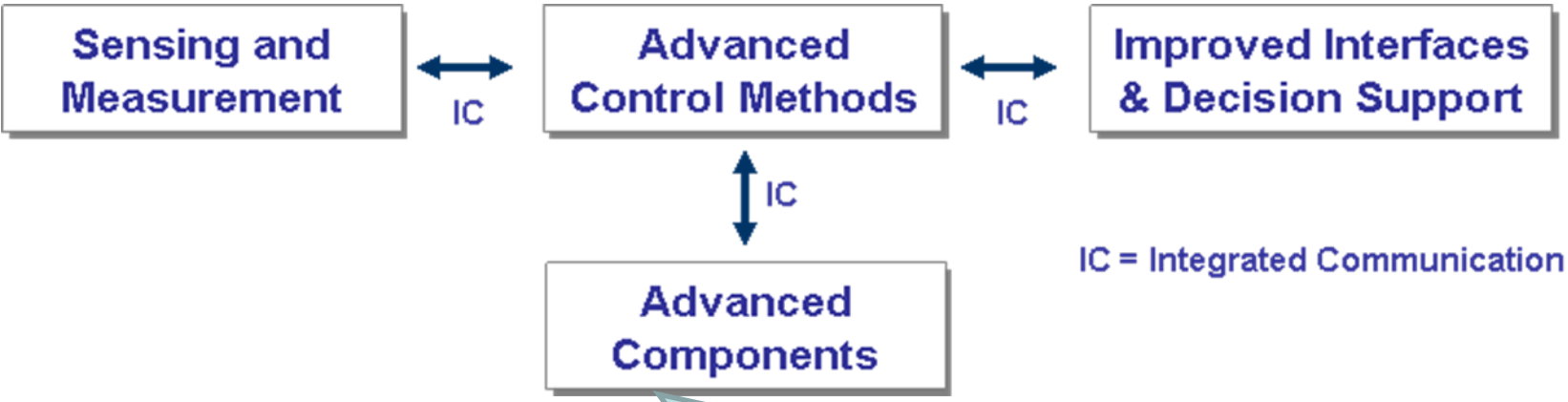


Smart Grid Key Technology Areas

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

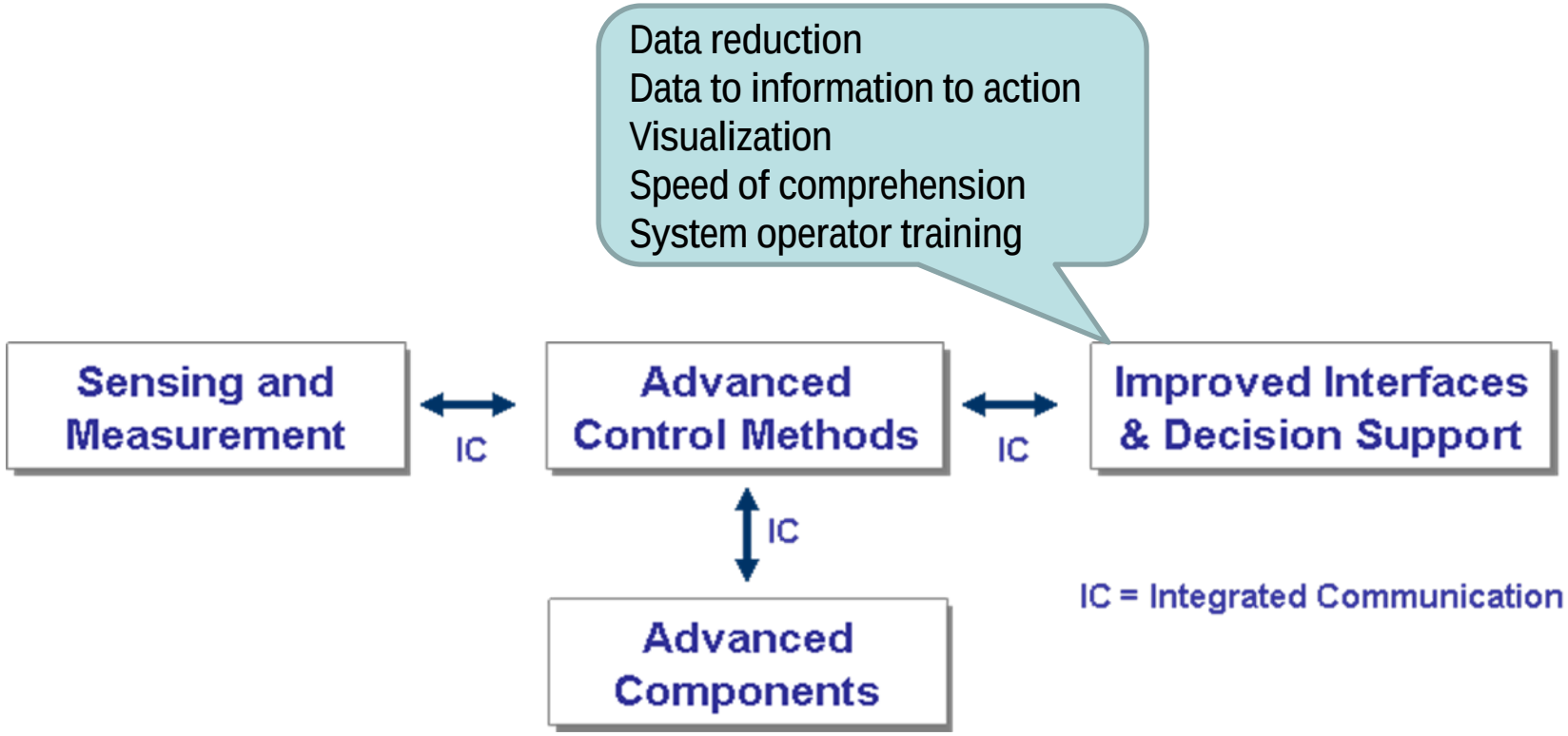


Smart Grid Key Technology Areas



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

Smart Grid Key Technology Areas



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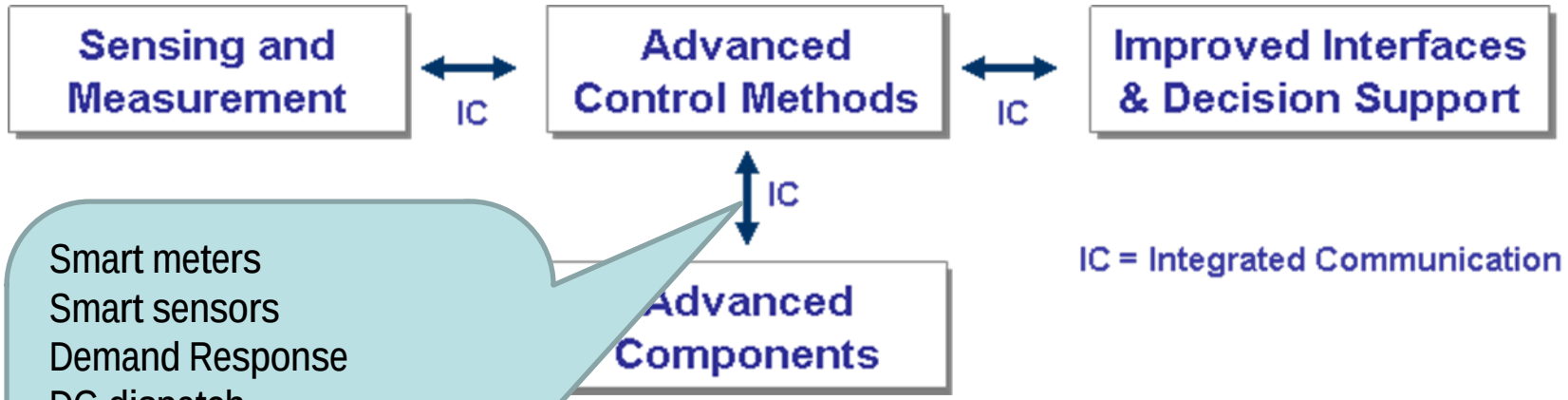
Smart Grid Key Technology Areas



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

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Value 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

Value Metrics – Work to date

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

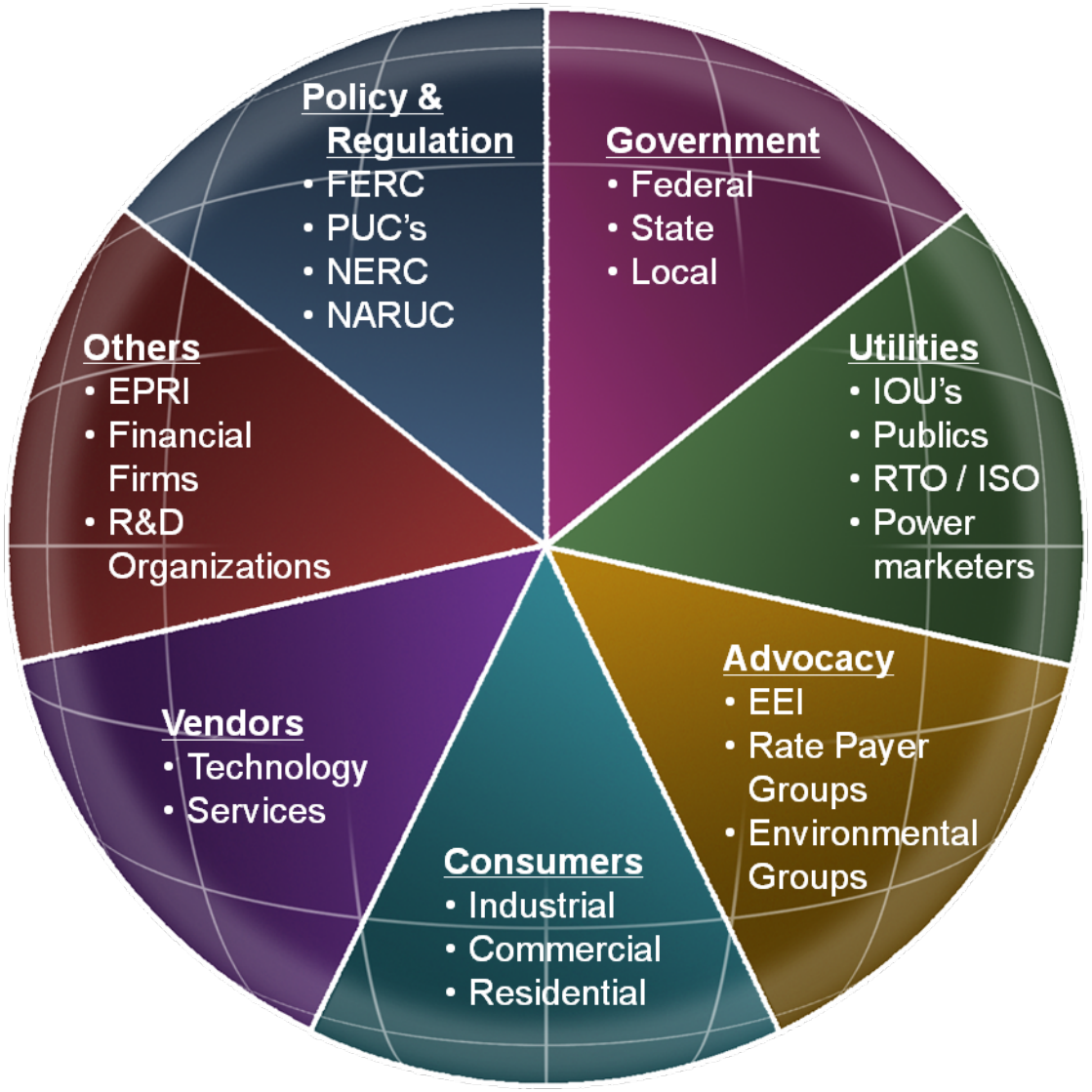
Safety

- Injuries and deaths to workers and public

Smart Grid Workshop in June – Developed “build metrics” for achieving the principal characteristics

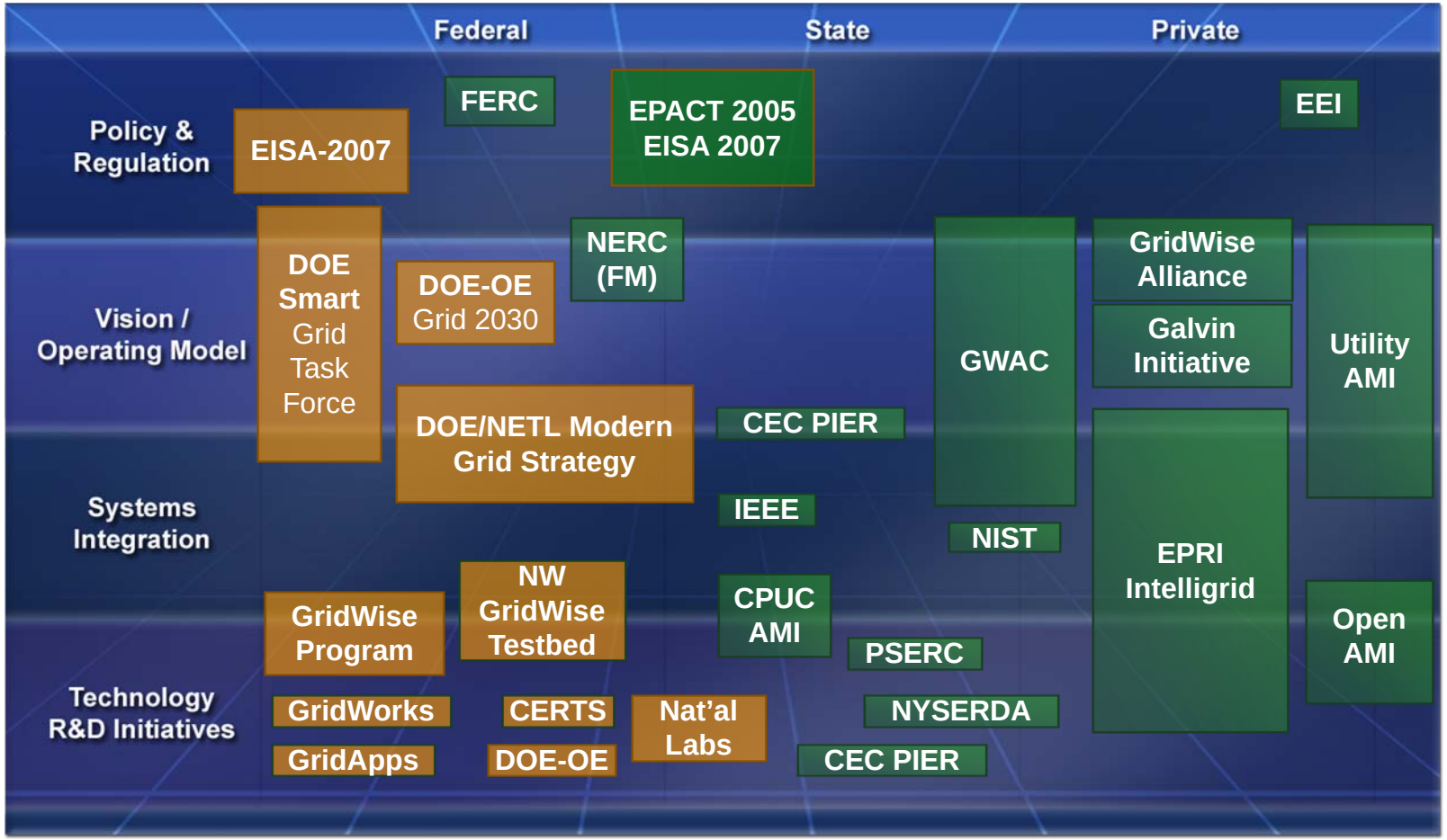
SMART GRID ACTIVITIES IN THE US

Many stakeholders



Smart Grid Groups

"To accelerate the modernization of the grid"



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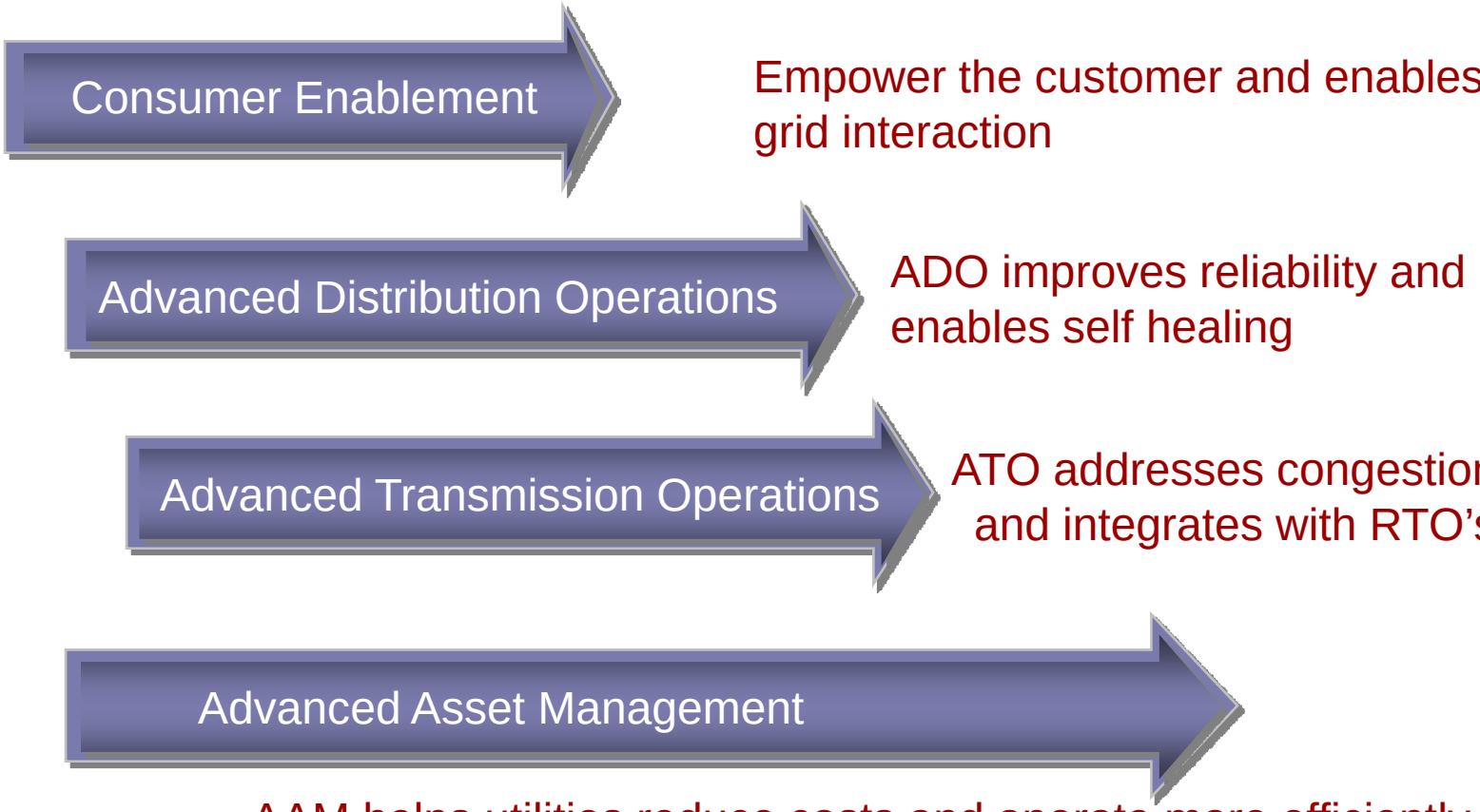
American Recovery & Reinvestment Act Key Energy Stimulus

- **Energy Efficiency and Renewable Energy ($16.8B)**
  - Energy Efficiency and Conservation Block Grants ($3.2B)
  - Weatherization Assistance ($5B)
  - State Energy Program ($3.1B)
  - Advanced Batteries ($2B)
- **Electricity Delivery and Energy Reliability ($4.5B)**
  - EISA 2007 Title XIII
  - Worker training
  - Development of regional transmission plans
- **Fossil Energy R&D ($3.4B)**
- **Advanced Research Projects Agency – Energy ($0.4B)**
- **Innovative Technology Loan Guarantee Program ($6B)**

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



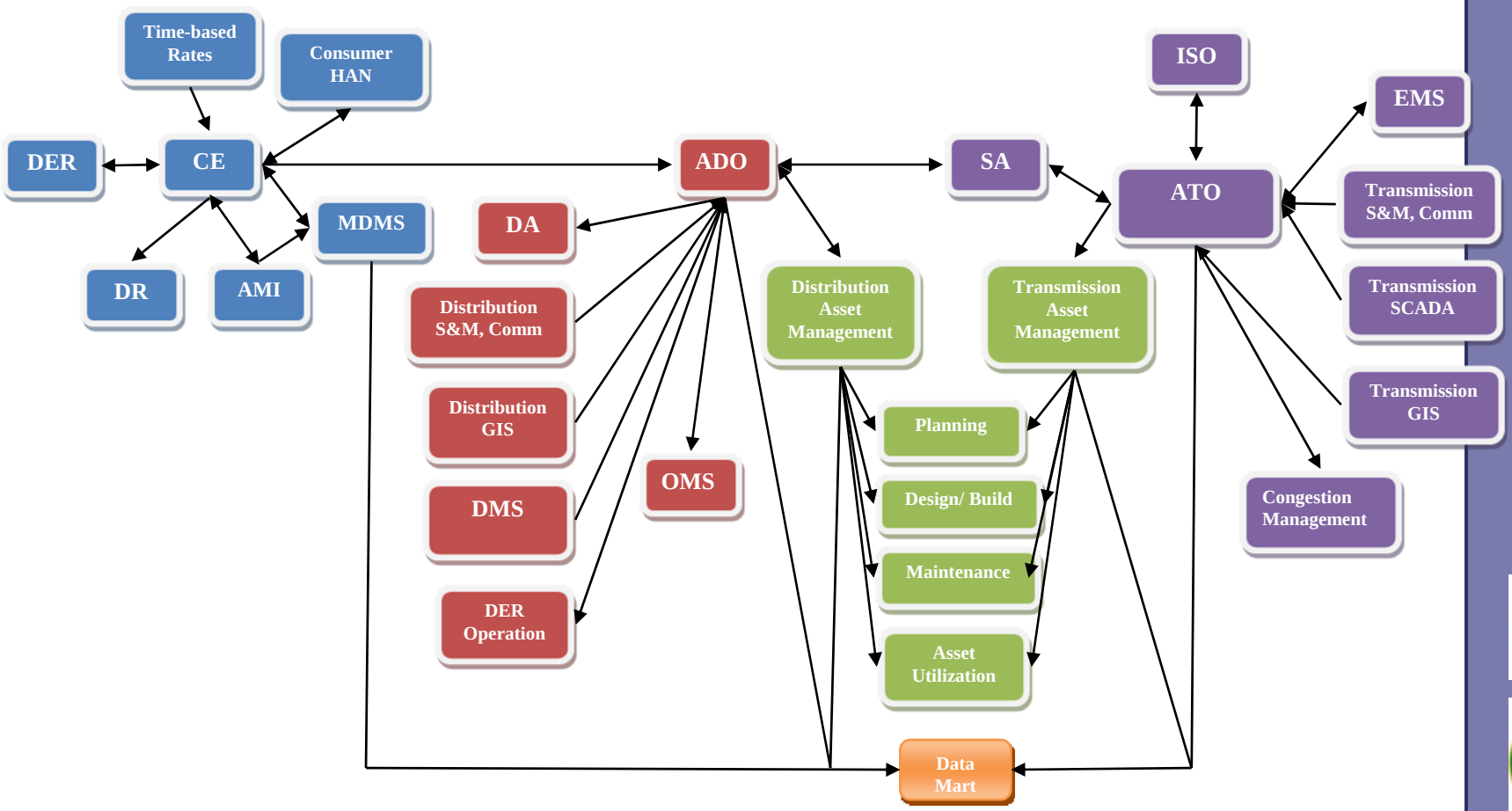
Each Milestone requires the deployment and integration of various technologies and applications

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**
- **Customer Education**
- **Demand Response**

CE empowers the customer and supports grid operations

The "Big Picture"



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)
- Advance materials and power electronics
- Hi-speed information processing
- Modeling, simulation and visualization tools

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 CE, ADO, and ATO with asset management processes will dramatically improve grid operations and efficiency

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	✓	✓	✓	

MORGANTOWN DEVELOPMENTAL FIELD TEST

CONSUMER ENGAGEMENT & OTHER KEY CONCEPTS

Key concepts

- **Prepare controls, interfaces, and transactions to engage consumers**
- **Prepare distribution for two-way power flow**
- **Prepare transmission to see distribution as a generation and storage resource**
- **Prepare utilities for a different business model in the future**
- **Prepare the regulatory environment to incentivize transformation**
- **Take serious and immediate action to reduce the peak to average capacity ratio**

Many aspects to address

- ***The financial elements*** **– how does the price of the transformation get paid?**
- ***Technical elements*** **– how will the many technologies be seamlessly integrated?**
- ***Operating elements*** **– how will autonomous and semi-autonomous control and transactional methods be established?**
- ***Regulatory elements*** **– how will incentives, metrics, and penalties work to drive the industry in the desired direction?**
- ***Stakeholder engagement elements*** **– how will the consumer be educated on this massive transformation of the electric service?**
- ***Culture and communications elements*** **– how will the industry coalesce in a new direction which both disruptive and necessary?**

COSTS, BENEFITS, AND BUSINESS CASE

Costs and benefits per EPRI

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**

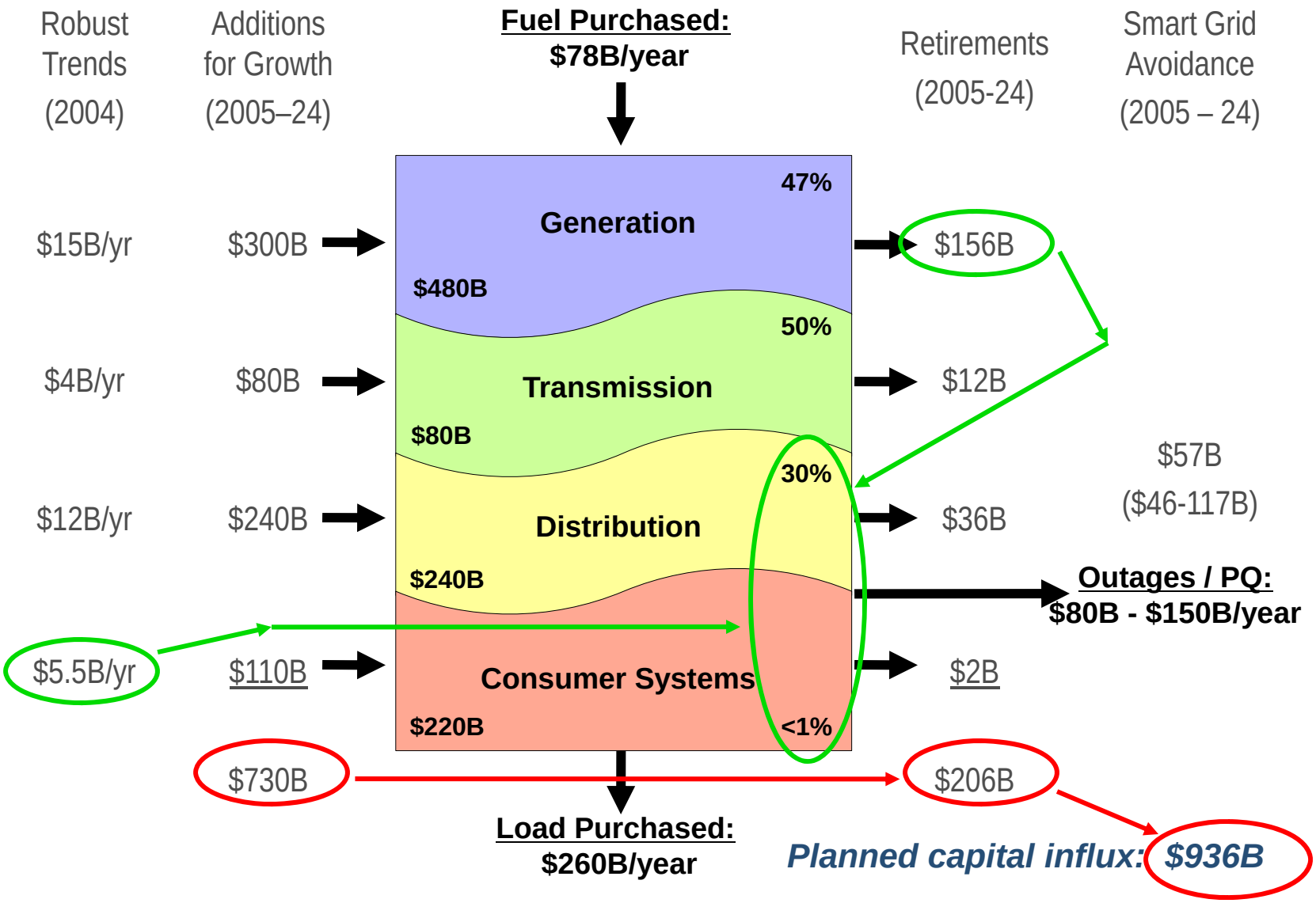
Benefit of Modernization

- **$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)

The Financial Electric System



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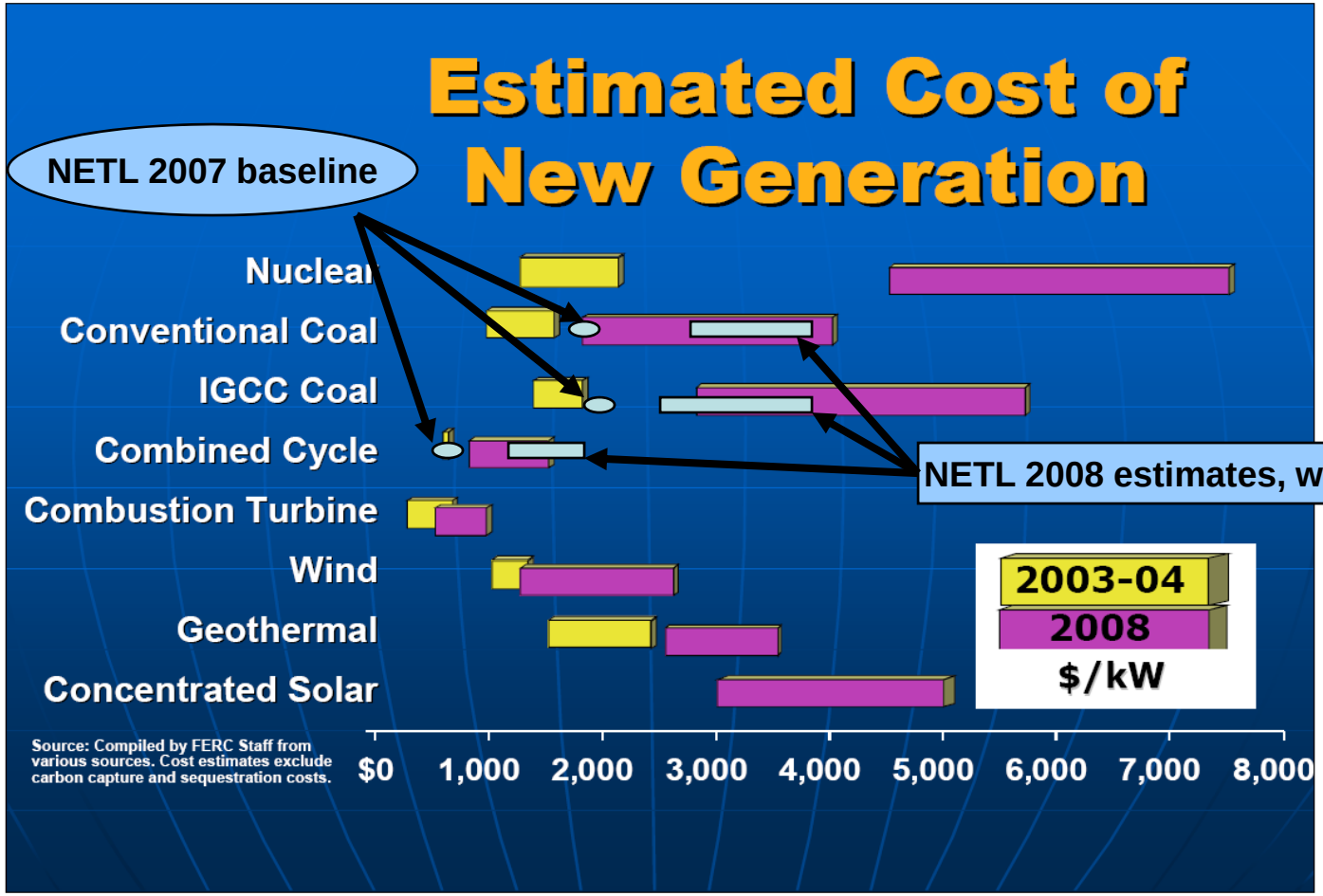
Capital Cost Uncertainty, FERC



FERC, "Increasing Costs in Electric Markets," June 19, 2008

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Over the next 20 years, if we just:

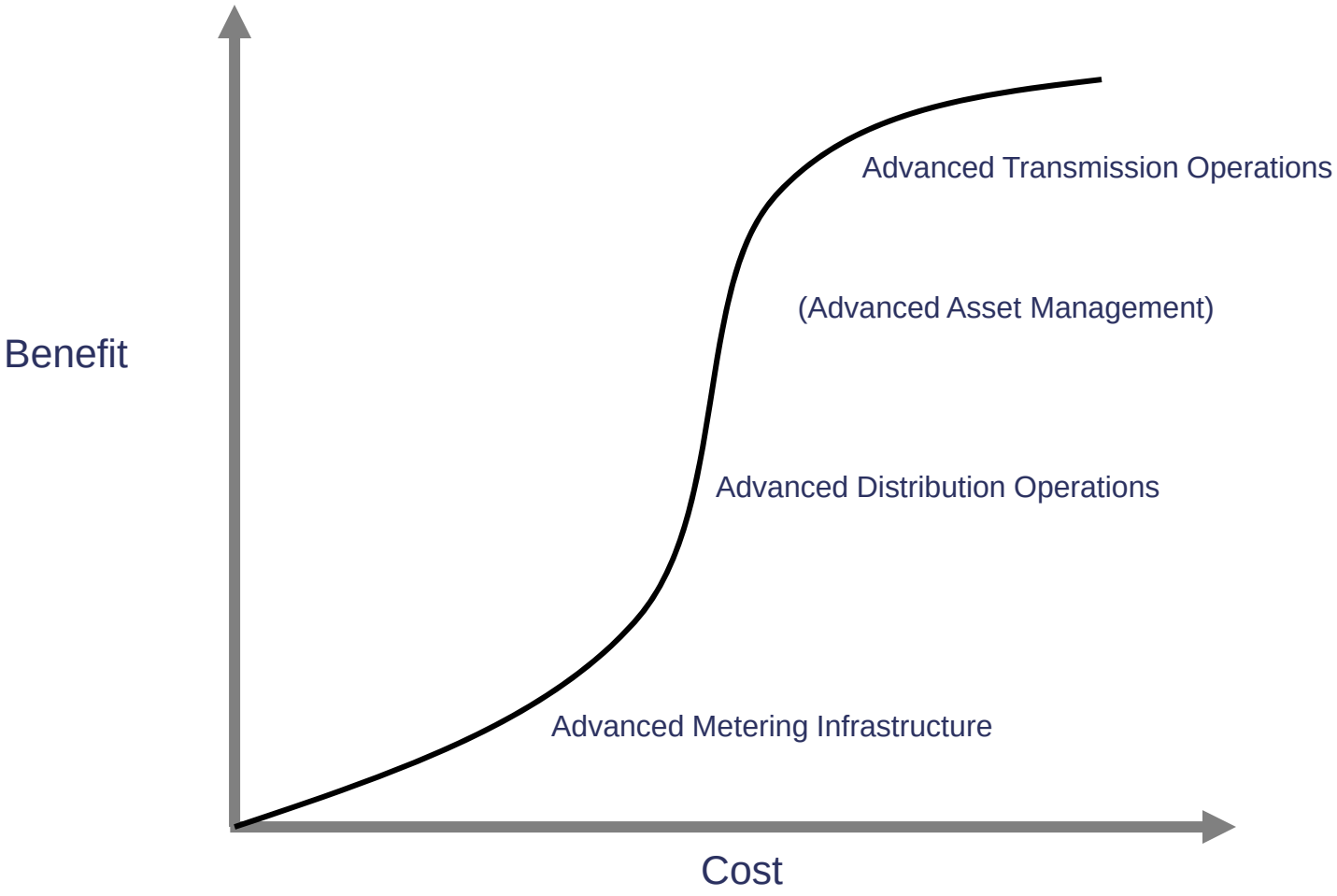
- **Use the $156B for planned retirements (because we have existing capacity) + the $5.5B/yr consumers will spend to invest in the Smart Grid, we can avoid the traditional ~$1 Trillion our industry already plans to spend**
- **Build the Smart Grid, we will raise distribution asset use above 40% and consumer system use above 10% offsetting the need to build new baseload generation and transmission for >20 yrs.**
- **Build the Smart Grid, we will enable renewables to reduce the US carbon footprint by 20%.**

US Renewables Potential

- **Today's grid-connected electric capacity is 960 GW**
- **Today's average daily capacity used is 440 GW**
- **If we include reserve margin, the US needs a daily average of 530 GW**

- **NREL assessment of near-term practical potential by 2020 for electricity production:**
  - Biomass – 130 GW
  - Geothermal – 22 GW
  - Solar – 68 GW
  - Wind – 114 GW
- **Total = 334 GW**

Generally speaking...



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 emissions** *through integration of renewable generation and reduced losses*
- **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

Smart Grid and the Environment

- **Smart Grid is a key enabler to help reduce CO2 and other emissions through**
  - Reduced consumption from demand response
  - Reduce losses and increased grid efficiency
  - Integration of renewables and CHP DG
  - Enabling energy system diagnostics
  - Enabling PHEV adoption

- **Will provide a "window" for concerned consumers to assess and react to their personal environmental desires (Prius effect)**

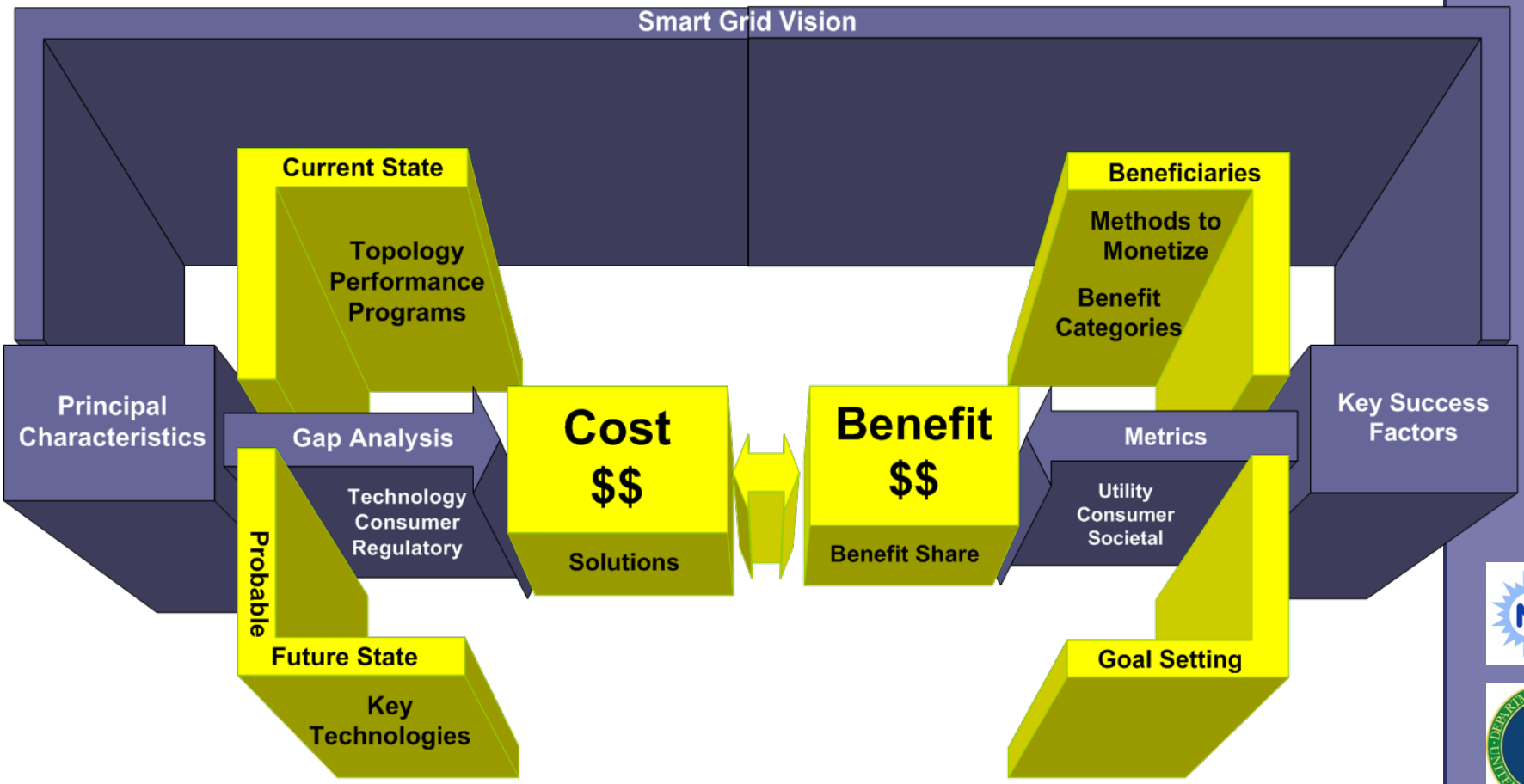
Smart Grid could reduce global power system emissions of CO2 14% by 2020

Climate Group, 2008

The Smart Grid and Reliability

- Rapid detection of degraded conditions
- Distributed generation and micro-grids
- Automatic isolation and reconfiguration
- Rapid damage assessment and diagnosis
- Rapid dispatch of repair crews
- Overall self-healing capability

Business Case Framework



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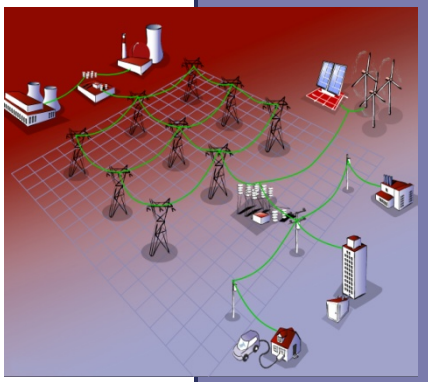
Smart Grid Study Results

- **Only 4 data points, but……**
- **If primary purpose is to improve reliability, then the cost delta will be +6% over the existing capital expense plan**
- **If primary purpose is to improve renewables penetration, then the cost delta will be -20% less than the existing capital expense plan**

West Virginia Smart Grid Implementation Plan

- **$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**



Insanity is defined as doing the same old thing expecting a different result.

BARRIERS TO THE SMART GRID

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

- Incorporating 2-way power flow into operations
- Simplifying interconnection standards while maintaining safety
- Getting the communications system right
- Integration of disruptive technologies
- Sharing successes and “lessons learned”
- Need a “real” electricity market
- Lack of resources to “change” and also “keep the lights on”
- Shortage of skilled human resources
- More focus on R&D – breakthrough technologies

TAIWAN POWER BRIEF

NETL REQUIREMENTS FOR TPRI TO PARTICIPATE IN MGS

Contact Information

For additional Information, contact

Modern Grid Strategy Team

http://www.netl.doe.gov/moderngrid/

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