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# Smart Grid Activities

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Office of Electricity
Delivery and Energy
Reliability

# Agenda



- Understanding the Smart Grid
- How do we get there?
- Is it a “good deal”?
- Some technical challenges?
- Some current activities
- Q&A

# Modern Grid Strategy Team's Role



*Mission – Accelerate the modernization of the Grid in the U.S.*

- Develop a vision for the Smart Grid
- Reach out to stakeholders to get input and consensus
- Assist in the identification and resolution issues
- Act as an "independent broker"
- Promote testing of integrated suites of technologies
- Communicate concepts to assist interested stakeholders

*MGS is an "Independent Broker" for the Smart Grid*

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# Understanding the Smart Grid

# The Big Picture



## Smart Grid Vision includes:

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

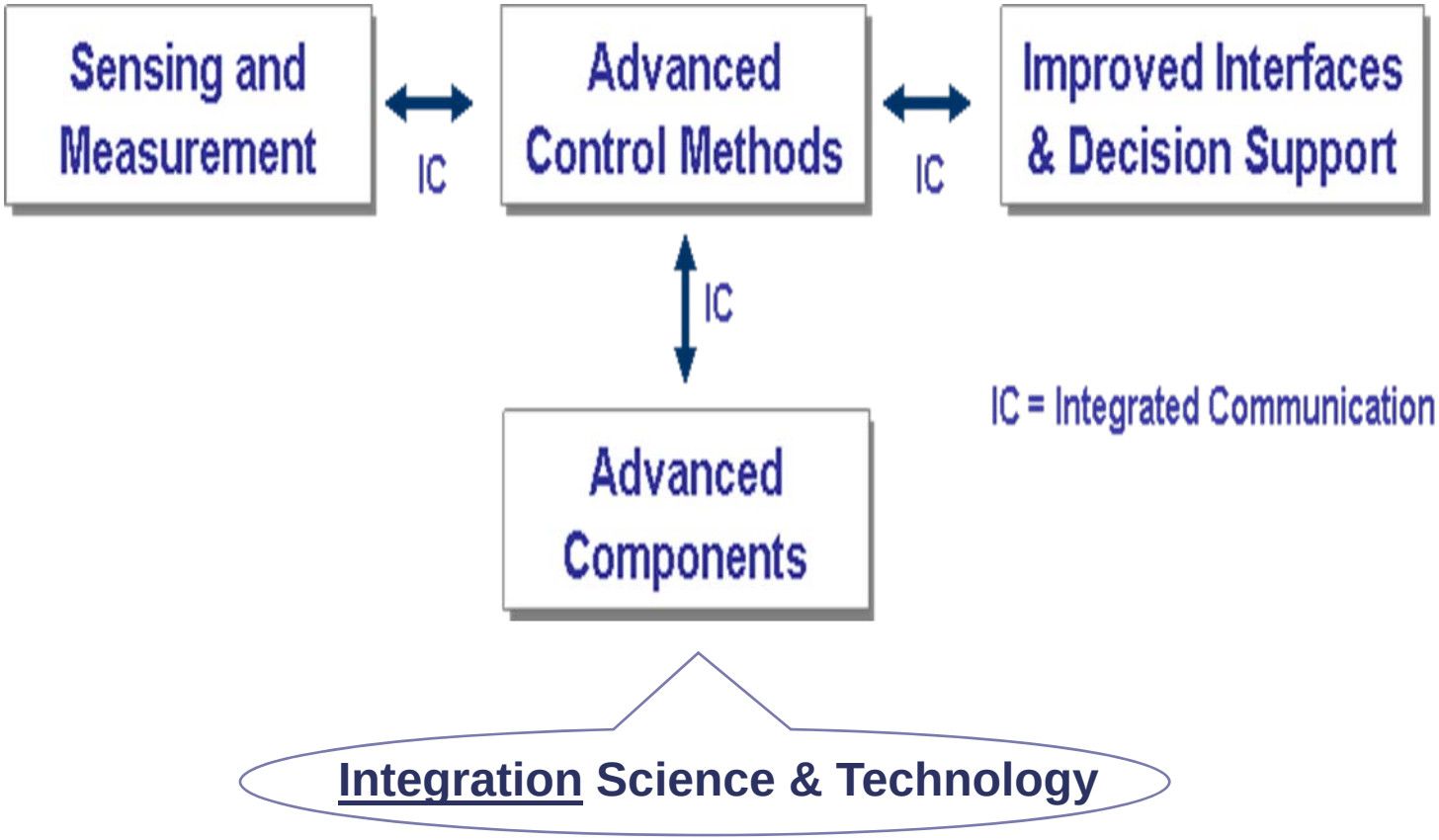


***The Smart Grid is "transactive" and will:***

- *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

# Smart Grid Key Technology Areas






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

# The Smart Grid – What's New?



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

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# How do we get there?

# 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**
- **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)**
- **Advance materials and power electronics**
- **Hi-speed information processing**
- **Modeling, simulation, and visualization tools**
- **Advanced digital protection**

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

# Advanced Asset Management Solutions

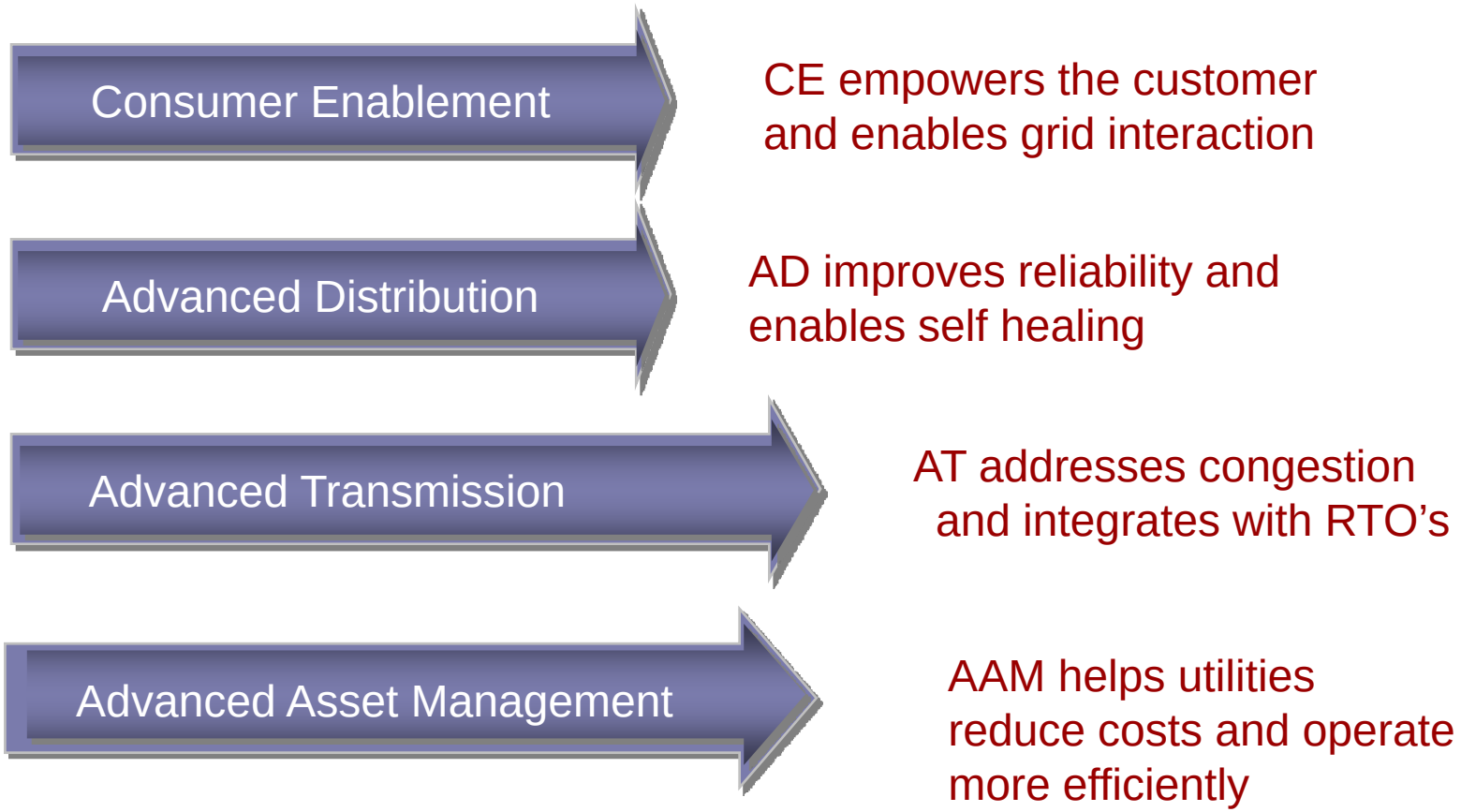


- **Advanced sensors**
  - System Parameters
  - Asset “health”
- **Integration of grid intelligence with other processes:**
  - Operations to optimize asset utilization
  - T&D planning
  - Condition based maintenance
  - Engineering, design, and construction
  - Work and resource management

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

# Steps to the Smart Grid





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Is it a good deal?

# 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

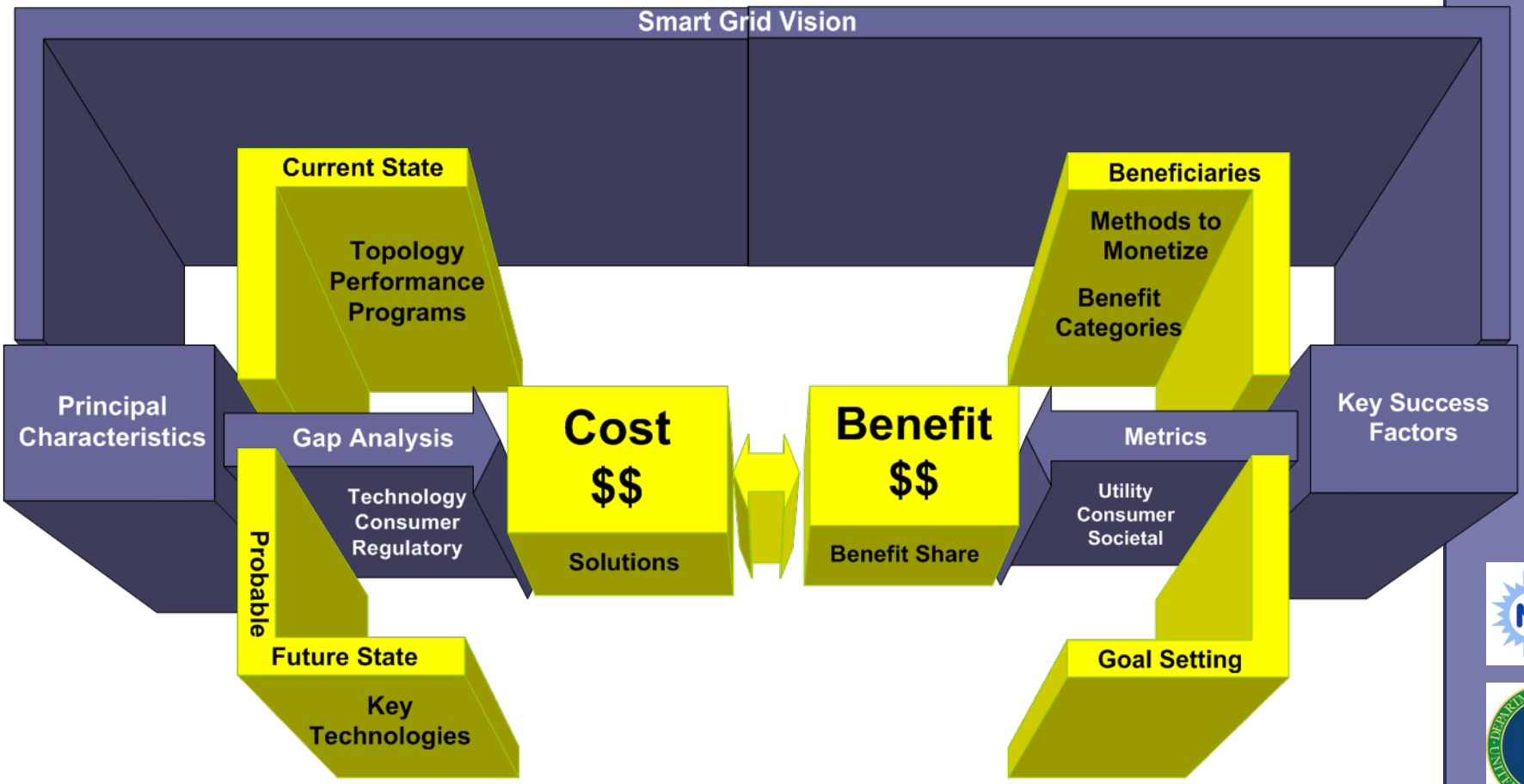
- **$638B - $802B over 20 years**
- **Overall benefit to cost ratio is 4:1 to 5:1**

***(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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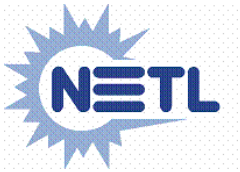
# Some Technical Challenges




# 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 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"

# 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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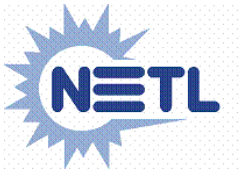
# Some Current Activities




# Developmental Field Tests (DFT)



- **Morgantown DFT**
  - Dynamic Feeder Reconfiguration (DFR) System
  - “Weak tie” concept
  - NETL / Allegheny Power
- **BPL DFT**
  - Broadband Over Power Lines at 69 kV
  - NETL / AEP

# West Virginia Smart Grid Implementation Plan



- **$540K project jointly funded by NETL, RDS, Allegheny Power, AEP, State of West Virginia, WVU, and DOE OE**
- **Results will describe approach and value proposition for implementing Smart Grid in WV**
- **Cost & benefit analysis comparing state of current electricity grid and future Smart Grid in WV**
- **Address role of coal in Smart Grid**
- **Support economic development in WV**
- **Only state-wide Smart Grid implementation plan**
- **Only second Smart Grid study to be published**

# DOE RDSI Program



- **NETL is managing nine RDSI projects**
  - $55M of DOE funds over 5 years; total is >$100M
  - Primary goal is to use DER to reduce peak load by 15%
  - DER (storage and DG), DR, Communications, Automation
- **Develop technologies, tools, and techniques to integrate load management and DER**
  - Develop and demonstrate Smart Grid technologies in an integrated and intelligent T&D network
  - Advance integration technologies to access renewable energy sources
  - Demonstrate DER to decrease peak load, increase asset utilization, and defer electric system upgrades

# Other NETL Smart Grid Activities



- **Smart Grid Maturity Model**
  - Roadmap of activities, investments, and best practices
  - Measures progress and level of achieving Smart Grid
- **Smart Grid Clearinghouse**
  - First-stop website for public information on Smart Grid
  - Technologies, tests and demonstrations, business cases, cost & benefits, best practices, legislation
- **Federal Smart Grid Task Force**
  - Multi-agency task force created by Title XIII of EISA 2007
  - DOE (OE&EE), NIST, DOD, USDA, DHS, EPA, FERC
- **Smart Grid and Clean Coal Relationship**

# Contact Information

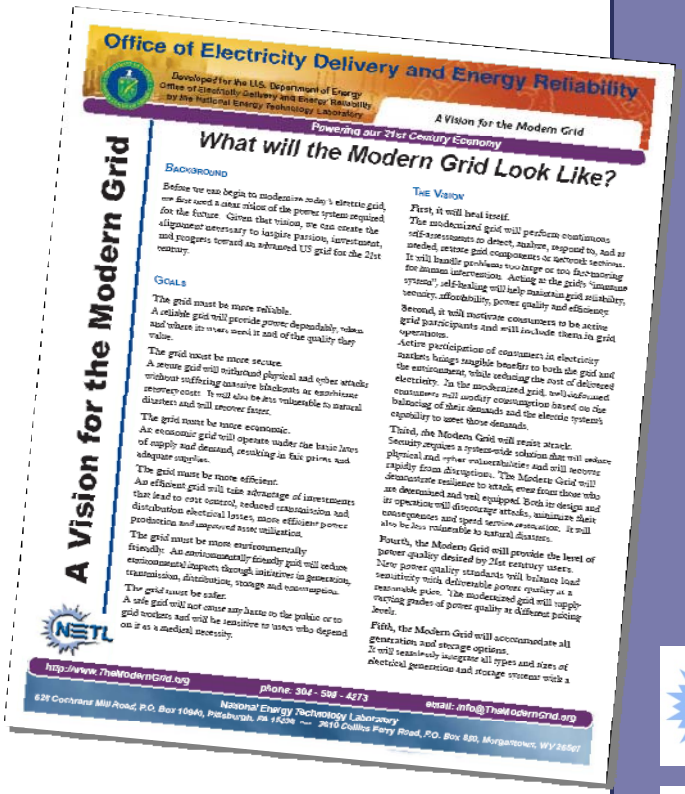


**For additional information, contact**

**Modern Grid Strategy Team**

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

**304-599-4273 x101**



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Questions?

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# Back-up Slides

# American Recovery & Reinvestment Act
# Key Energy Stimulus



- **Energy Efficiency and Renewable Energy ($16.8B)**
  - Energy Efficiency and Renewable Energy ($6.7B)
  - 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**

# *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"*

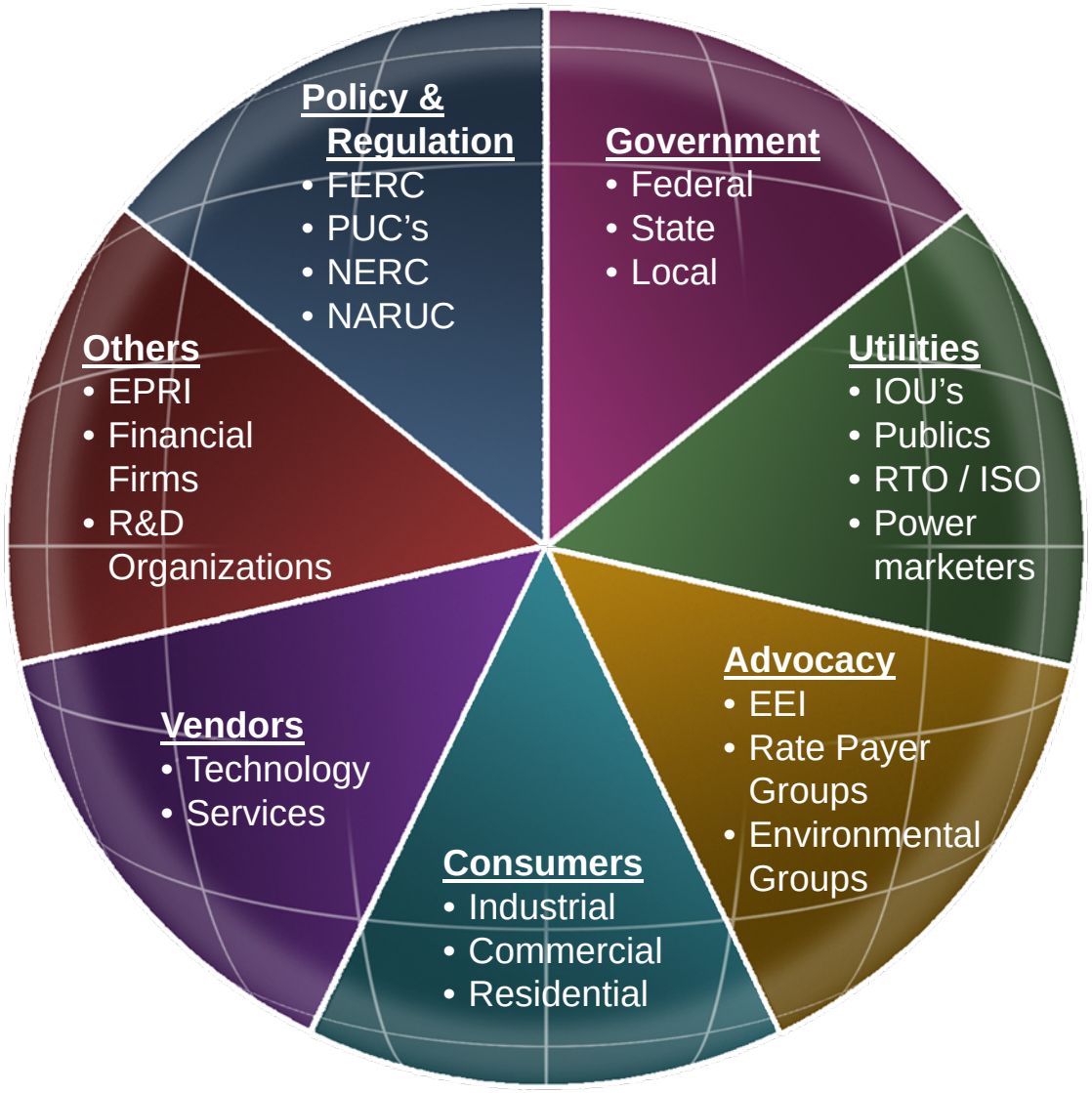


- **System-wide solution to physical and cyber security**
- **Reduces threat, vulnerability, consequences**
- **Deters, detects, mitigates, responds, and restores**
- **"Fort Knox" image**
- **Decentralization and self-healing enabled**

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

# Many stakeholders





# 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

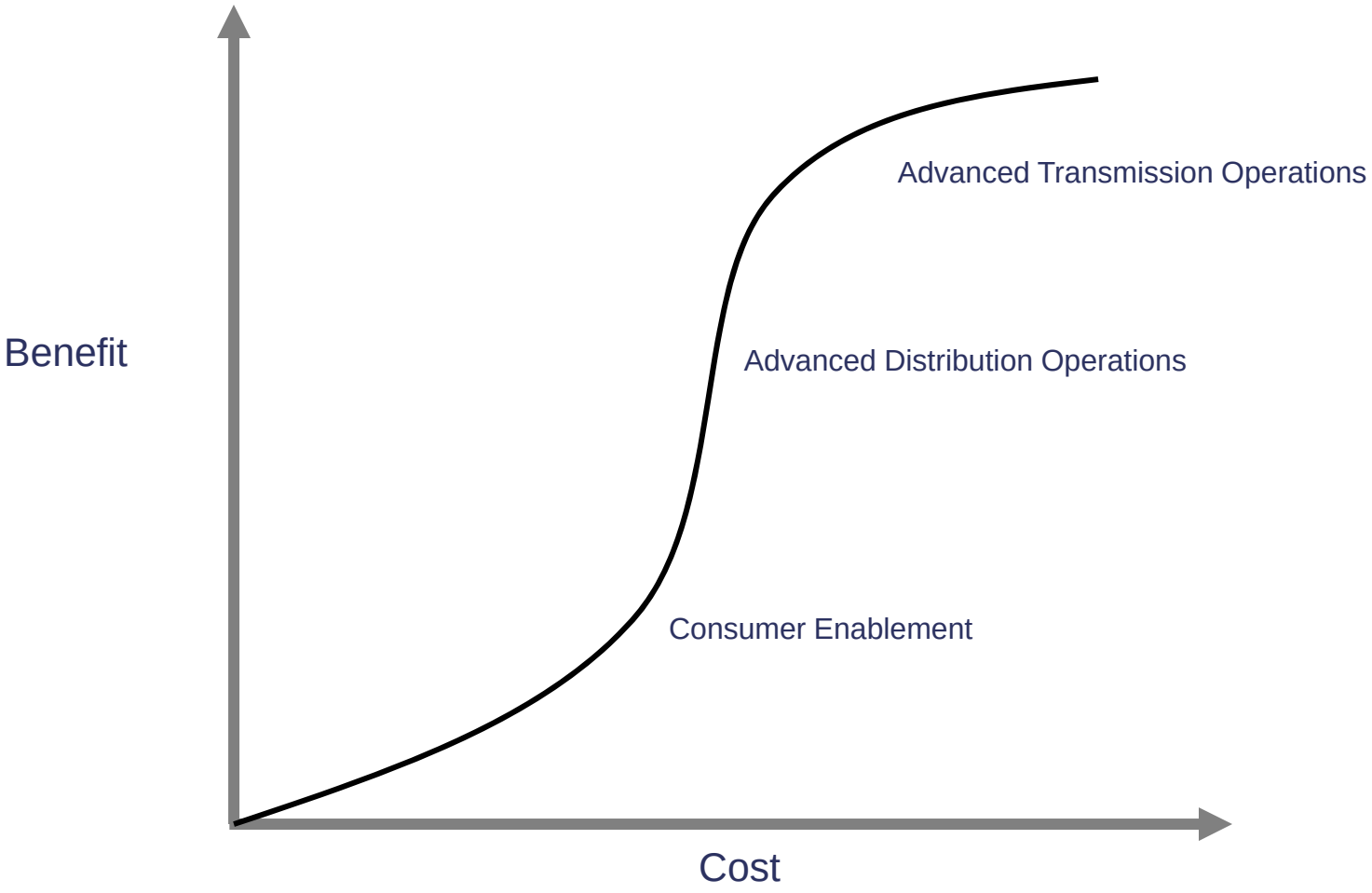
# Characteristic – Milestone Map



| *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 | ✓ | ✓ | ✓ | |

# Generally speaking...





# 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

# 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