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SMART GRID FUNDAMENTALS

Electric Grid

- What do you understand by Electric Grid?

Electric Grid

- In the power industry, *electrical grid* is a term used for an electricity network which includes the following three distinct operations:
- Electricity generation - Generating plants are usually located near a source of water, and away from heavily populated areas. They are usually quite large in order to take advantage of the economies of scale.

Electric Grid

- Electric power transmission

  The transmission network will move the power long distances-often across state lines, and sometimes across international boundaries until it reaches its wholesale customer (usually the company that owns the local distribution network).

Electric Grid

- Electricity distribution - Upon arrival at the substation, the power will be stepped down in voltage—from a transmission level voltage to a distribution level voltage. As it exits the substation, it enters the distribution wiring. Finally, upon arrival at the service location, the power is stepped down again from the distribution voltage to the required service voltage(s).

Problems or Limitations of Current Grid

Despite the novel institutional arrangements and network designs of the electrical grid, its power delivery infrastructures suffer aging across the developed world. Four contributing factors to the current state of the electric grid and its consequences include:

Obsolete system layout

Obsolete system layout – older areas require serious additional substation sites and rights of-way that cannot be obtained in current area and are forced to use existing, insufficient facilities.

Aging Infrastructure of Current Grid

Aging power equipment – older equipment have higher failure rates, leading to customer interruption rates affecting the economy and society; also, older assets and facilities lead to higher inspection maintenance costs and further repair/restoration costs.

Outdated engineering of Current Grid

Outdated engineering – traditional tools for power delivery planning and engineering are ineffective in addressing current problems of aged equipment, obsolete system layouts, and modern deregulated loading levels

Old cultural value

Old cultural value – planning, engineering, operating of system using concepts and procedures that worked in vertically integrated industry exacerbate the problem under a deregulated industry

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
- The benefits of a modernized grid are substantial

We Are Losing Billions

We lose billions every year to blackouts, interruptions and congestion

- As much as $135B per year in consumer losses
  (Primen, 2004)
- In the NY ISO, 23% of the wholesale price is congestion costs, which are passed along to consumers
  (PNNL, 2006)
- August 2003 blackout: $4-6B, 50M people affected

Smart Grid Major Stakeholders

Government

- **Federal**
- **Provincial**
- **Local**

Policy & Regulation

- **NEPRA**
- **PNRA**
- **OGRA**
- **ETC.**

Smart Grid Major Stakeholders

Utilities

- **WAPDA**
- **NTDC**
- **KESC**
- **IPPs**

Consumers

- Industrial
- Commercial
- Residential

Smart Grid Major Stakeholders

Vendors

- **Technology**
- **Services**
- **Etc.**

Other

- Financial Firms
- Environmental Protection Agencies
- R & D Organizations

Smart Grid Goals-Success Factors

The Modern Grid is MORE:

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

Smart Grid Characteristics

Involving the consumer is win – win!

Motivate and include the consumer

- Well informed and active grid participants
- Provide new options for grid operators
- Customers see what they use, when they use it, and what it costs
- Different products and prices for different consumers
  - According to their preferences
  - According to their needs
  - According to their willingness to participate

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

It will Enable markets

- No constraints to shipping power among regions
- Consistent market operation from coast-to-coast
- Growth of selected, competitive retail markets
- Aggregated demand response involving the consumer
- Energy resources located closer to the consumer
- Growth of "electricity related" markets

Provide power quality for 21st century needs

- **Power quality standards will balance load sensitivity with delivered power quality at a reasonable price**
  - Suitable for computers and electronics
  - Addresses sags, spikes, harmonics and momentary interruptions
- **Varying grades of power quality at different pricing levels**
- **Solutions at both system and consumer level**

Provide power quality for 21st century needs

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

It will Optimize assets 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 and Condition Based Maintenance

It will 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

It will Self Heal

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

It will Resist attack

- Physical and cyber security built in
- Reduces threat, vulnerability
- Deters, detects, mitigates, responds, and restores
- Less vulnerable to natural disasters
- Energy security has become national security

The Grid - Today vs. Tomorrow

Characteristic	Today	Tomorrow
Motivates/Includes Consumer	No price visibility, time-of day pricing rare, few choices	Full price info, time-of-use pricing, choose from many plans and prices
Accommodates Generation/Storage	Dominated by central generation. Little DG, DR, storage or renewables.	Many “plug and play” distributed energy resources complement central generation
Enables Markets	Limited wholesale markets, not well integrated	Mature, robust, well integrated Wholesale markets
Meets PQ Needs	Focus on outages not Power quality	PQ a priority with a variety of quality/price options according to needs

The Grid - Today vs. Tomorrow

Characteristic	Today	Tomorrow
Optimizes	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
Resists Attack	Vulnerable to terrorists and natural disasters	Resilient with rapid restoration

Benefits of The Smart Grid

- Major Reduction in Outage Duration and Frequency
- Far Fewer Power Quality (PQ) Disturbances
- Virtual Elimination of Regional Blackouts
- Significantly Reduced Vulnerability to Terrorist
- Attack and Natural Disasters
- Improved Public and Worker Safety
- Reduction or Mitigation of Prices

Benefits of The Smart Grid

- New Options for Market Participants
- More Efficient Operation and Improved Asset
- Management at Substantially Lower Costs
- Electrical Losses Reduced
- Much Wider Deployment of Environmentally Friendly
- Resources

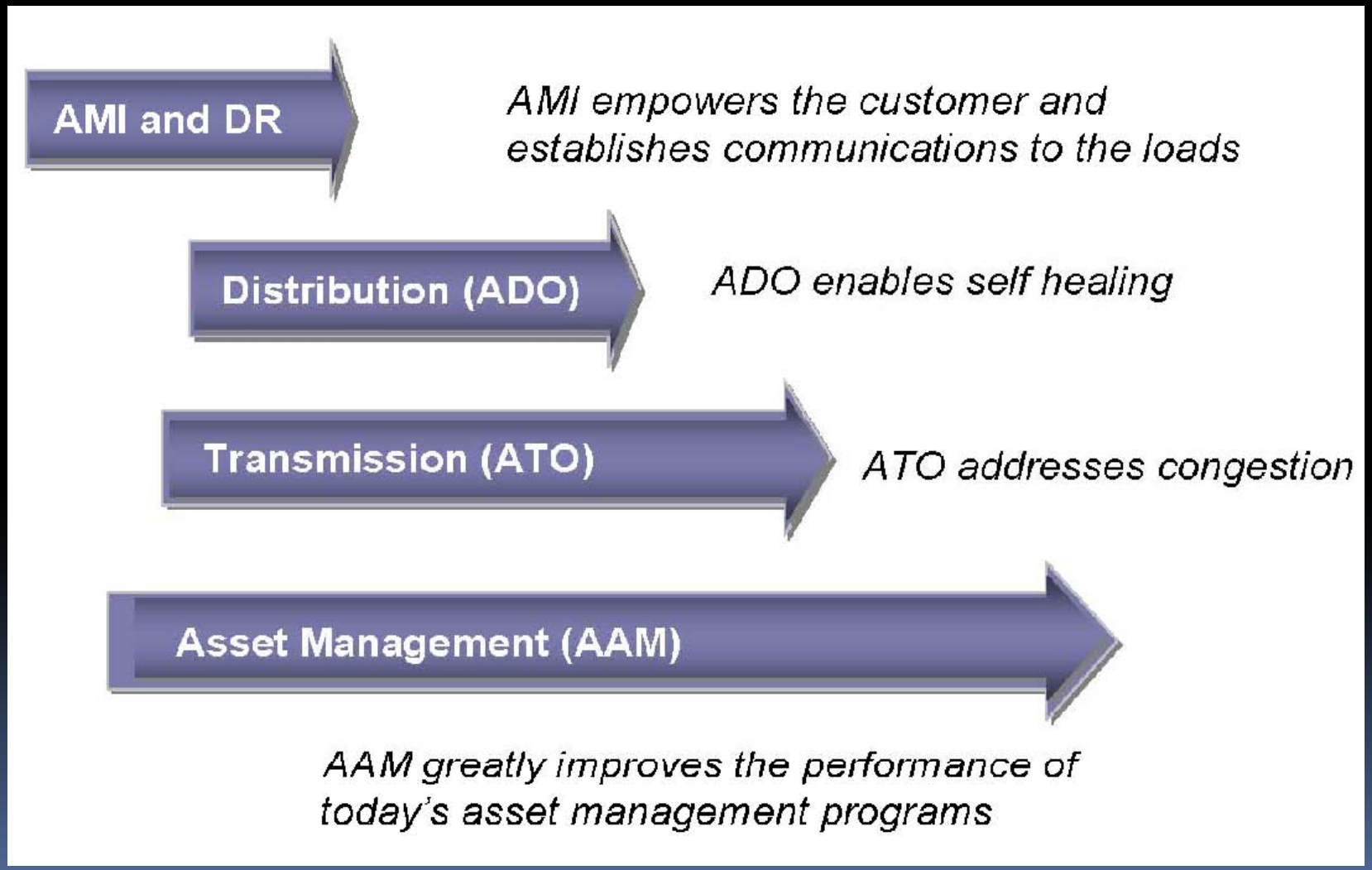
Value Proposition

- **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**

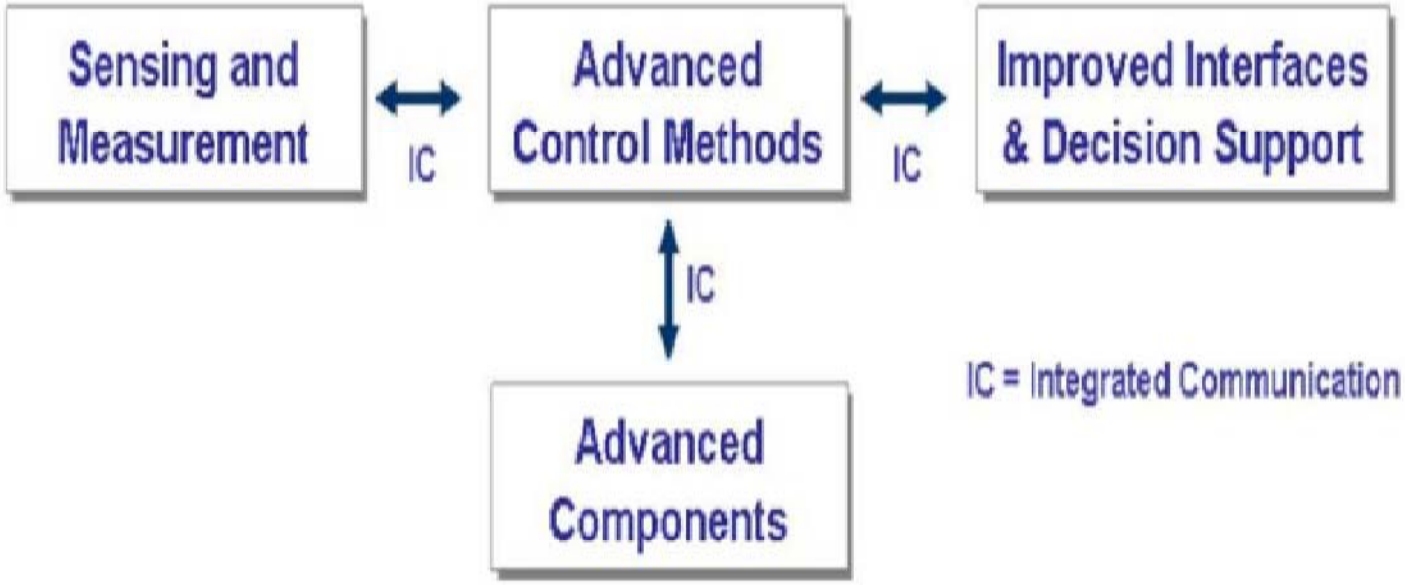
Value Proposition

- Benefit of Modernization
- 638B - $802B over 20 Years
- Overall benefit to cost ratio is 4:1 to 5:1

Milestone Sequence



Smart Grid Key Technologies



AMI Technologies

- Smart Meters
- Two-way Communications
- Consumer Portal
- Home Area Network
- Meter Data Management
- Demand Response
- Customer Service Applications
- Operational Gateway Applications

ADO Technologies and Applications

- **Distribution Management System with advanced sensors**
- **Advanced Outage Management ("real-time")**
- **Distribution Automation**
- **Distribution Geographic Information System**

ADO Technologies and Applications

- **Micro-grid operations (AC and DC)**
- **Hi-speed information processing**
- **Advanced protection and control**
- **Advanced grid components for distribution**

ATO Technologies and Applications

- Substation Automation
- Geographical Information System for Transmission
- Wide Area Measurement System (WAMS)
- Hi-speed information processing

ATO Technologies and Applications

- Advanced protection and control
- Modeling, simulation and visualization tools
- Advanced grid components for transmission
- Advanced regional operational applications

AAM Technologies and Applications

- **Advanced sensors**
- System Parameters
- Asset "health"
- **Integration of real time information with other**
- **processes:**
- Operations to optimize asset utilization

AAM Technologies and Applications

- T&D planning
- Condition based maintenance
- Engineering design and construction
- Customer service
- Work and resource management
- Modeling and simulation

Address Some Barriers

- The integration of multiple key technologies has not yet occurred
- The deployment and integration of advanced sensors, integrated communication systems, and advanced algorithms, including supercomputers, is needed to support the processing and analysis needed for advanced asset management.

Address Some Barriers

Industry executives are reluctant to change processes and technologies .
Some utility cultures are resistant to change and operate in "silos" organizationally. As a result, changes to processes and technologies needed to improve asset management are difficult to initiate.

Address Some Barriers

Human and financial resources at many utilities are limited and stressed

The amount of resources available to look beyond day-to-day operations is limited

Metrics

Reliability

- Outage duration and frequency
- Momentary outages
- Power Quality

Security

- Ratio of distributed generation to total
- Generation
- Consumers participating in energy
- Markets energy

Metrics

Economics

- Peak and average energy prices by Region
- Transmission congestion costs
- Cost of interruptions and power quality disturbances
- Total cost of delivered energy

Metrics

Efficient

- System electrical losses
- Peak-to-average load ratio
- Duration congested transmission
- lines loaded >90%

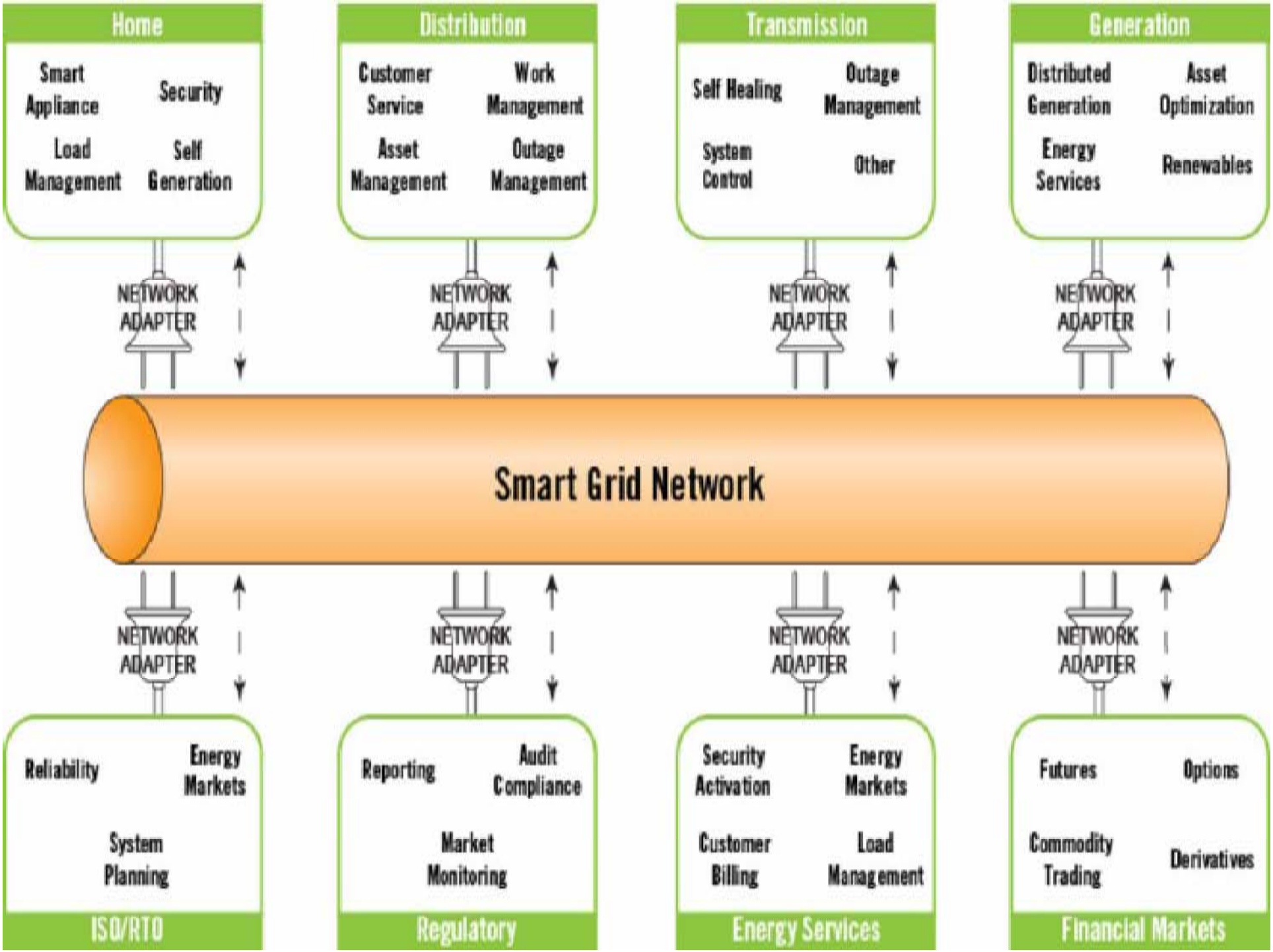
Environmentally Friendly

- Ratio of renewable generation to total
- Generation
- Emissions per kilowatt-hour delivered

Safety

- Injuries and deaths to workers and public

Smart Grid Network


Home
Smart Appliance
Security
Load Management
Self Generation
Distribution
Customer Service
Work Management
Asset Management
Outage Management
Transmission
Self Healing
Outage Management
System Control
Other
Generation
Distributed Generation
Asset Optimization
Energy Services
Renewables
NETWORK ADAPTER
NETWORK ADAPTER
NETWORK ADAPTER
NETWORK ADAPTER
Smart Grid Network
NETWORK ADAPTER
NETWORK ADAPTER
NETWORK ADAPTER
NETWORK ADAPTER
Reliability
Energy Markets
System Planning
ISO/RTO
Reporting
Audit Compliance
Market Monitoring
Regulatory
Security Activation
Energy Markets
Customer Billing
Load Management
Energy Services
Futures
Options
Commodity Trading
Derivatives
Financial Markets