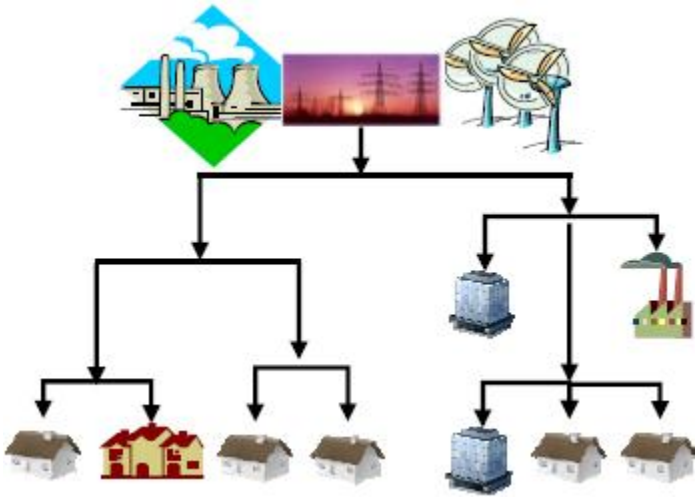
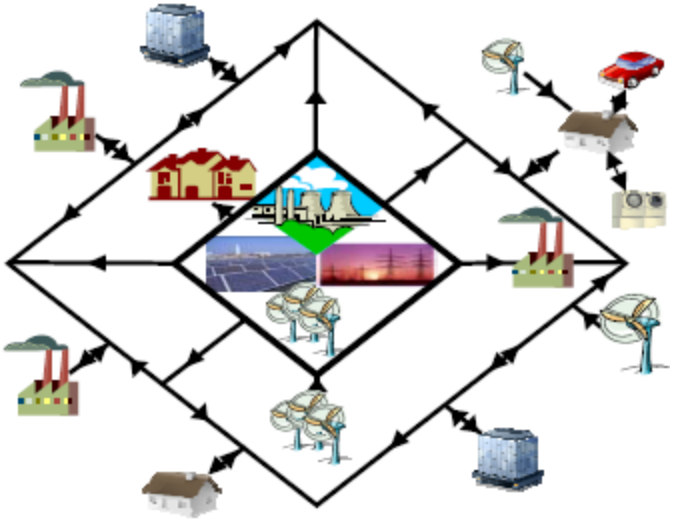
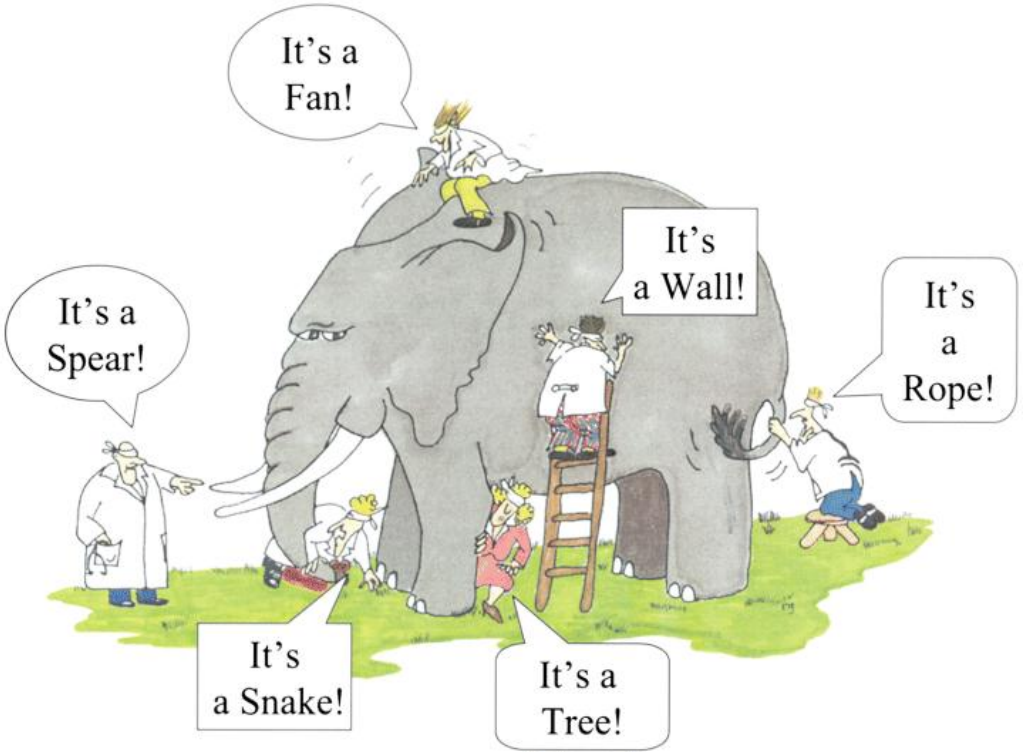
ELG4126: Smart Grid

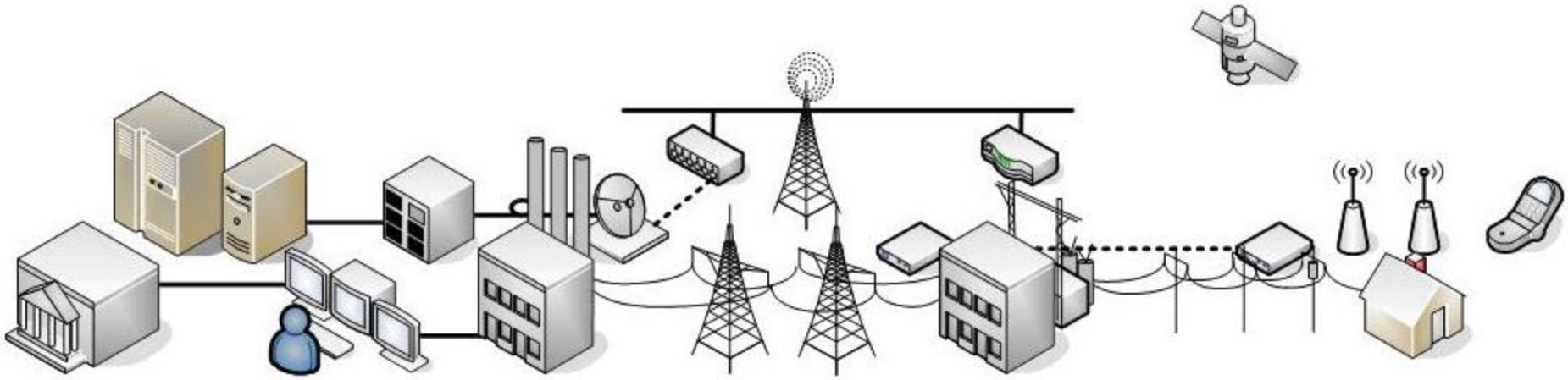




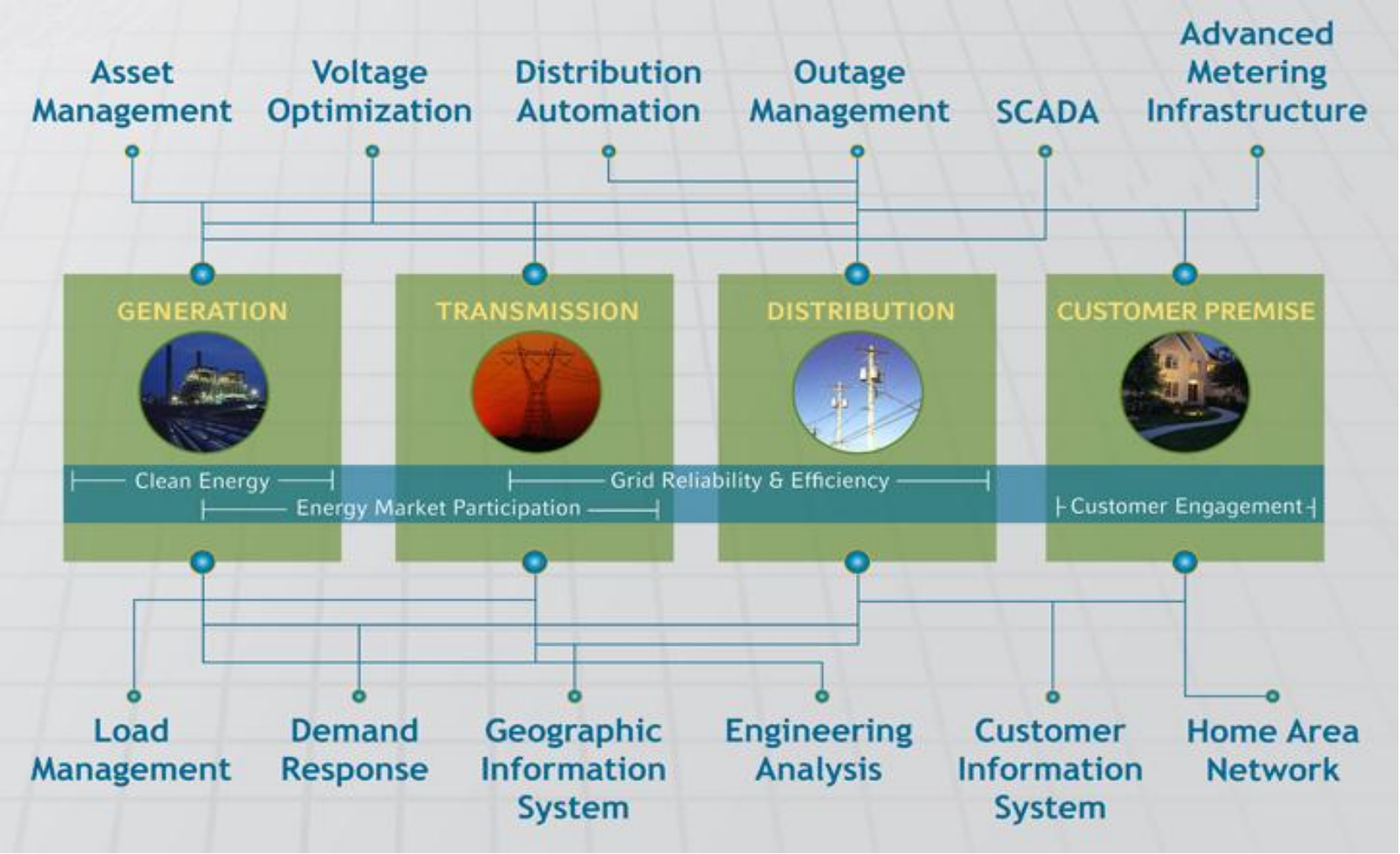


The Smart Grid

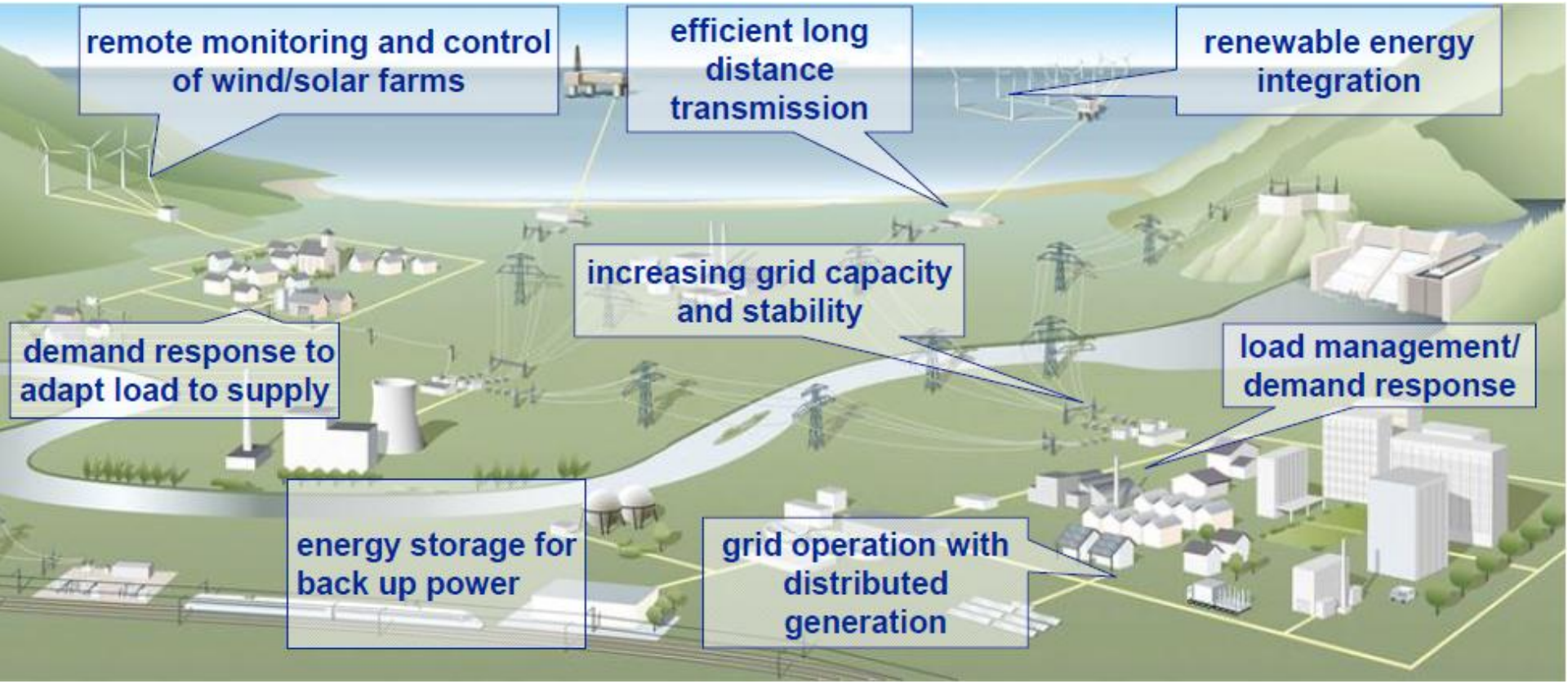
- Uses telecommunication and information technologies to improve how electricity travels from power plants to consumers.
- Allows consumers to interact with the grid.
- Integrates new and improved technologies into the operation of the electric grid.



What is Smart Grid?



The Vision
One of Hottest Topic in Research Community!



Source: ABB

Current Electricity Grid

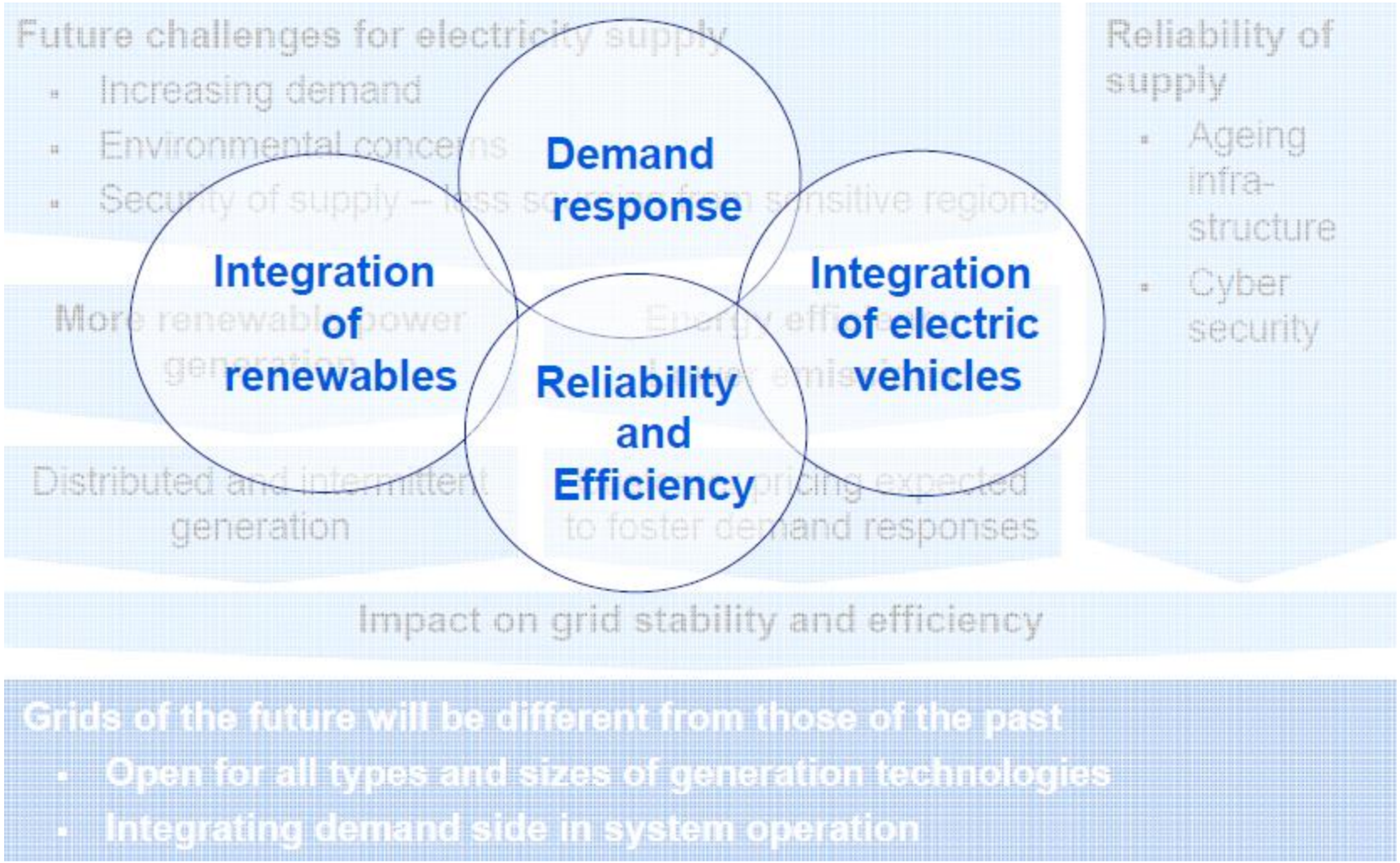
Aged; Centralized; Manual Operations; Fragile

Northeast Blackout – August 14, 2003

- Affected 50 million people
- Caused $6 billion lost
- Per year $135 billions lost for power interruption

Goal: Upgrade the grid in **Smart** way!

Areas of Emphasis



Source: ABB

An Array of Visions to an Array of Stakeholders!

"A smart grid is a modern electricity system. It uses sensors, monitoring, communications, automation and computers to improve the "flexibility, security, reliability, efficiency, and safety of the electricity system."

Paul Murphy et. al., Enabling Tomorrow's Electricity System: Report of the Ontario Smart Grid Forum, http://www.ieso.ca/imoweb/pubs/smart_grid/Smart_Grid_Forum-Report.pdf (September, 2010)

"The smart grid takes the existing electricity delivery system and makes it 'smart' by linking and applying seamless communications systems that can: gather and store data and convert the data to intelligence; communicate intelligence omnidirectionally among components in the 'smart' electricity system; and allow automated control that is responsive to that intelligence."

Miles Keogh, The Smart Grid: Frequently Asked Questions for State Commissions, The National Association of Regulatory Utility Commissioners, May 2009, p. 2, http://www.naruc.org/Publications/NARUC%20Smart%20Grid%20Factsheet%205_09.pdf, (June, 2010)

Capabilities of the Smart Grid
1. Demand Response

Gateways with bi-directional communication for
- Consumer
- Interaction
- Smart meters/AMI
- Internet/mobile telecom

Customer service systems including billing

Network Management
- Improved load management
- Real time pricing to support demand response
- Integration with smart house solutions
- Integration with industrial energy management solutions

2. Distributed Generation and Integration of Renewables

Network management

SCADA for control and monitoring of wind/solar farms.

SCADA/EMS enhanced security applications to account for intermittent renewable generation.

Support demand response based on real time pricing to compensate intermittent production.

SCADA/DMS dispatch applications for distributed generation.

Stationary and mobile energy storage to compensate intermittent production

Flexible AC Transmissions (FACTS) and **MV STATCOM** for voltage control (comply with grid code) and increased grid capacity.

High Voltage DC (HVDC) for efficient long distance transmission.

Cost effective and environmentally friendly underground cable connection of wind/solar farms.

Provide transmission capacity to even out variations in renewable production.

3. Integration of Plug-in Electric Vehicles

Charging infrastructure:

Various charging time options
Billing system for mobile customers
Internet/mobile telecom
Different payment systems/business models under
Evaluation with
Different impact on measuring and settlements

Network Management:

Load management
Charge at times of overcapacity
Use vehicles as consumer storage
Provide voltage control for distribution grids
Real time pricing to support demand response

4. Reliability and Efficiency

Network Management:

Improved outage management based on
Meter data instead of trouble calls for remote fault location,
Isolation, restoration and crew management
Increased stability and reduced losses by network control
Applications including volt/VAR optimization
Optimal mix between local and regional production
Cyber security applications

Substation and Feeder Automation, to increase reliability and

Provide faster switching

Asset management for improved maintenance and asset utilization

Underground power cables for increased reliability

Energy storage for peak, emergency and back up power

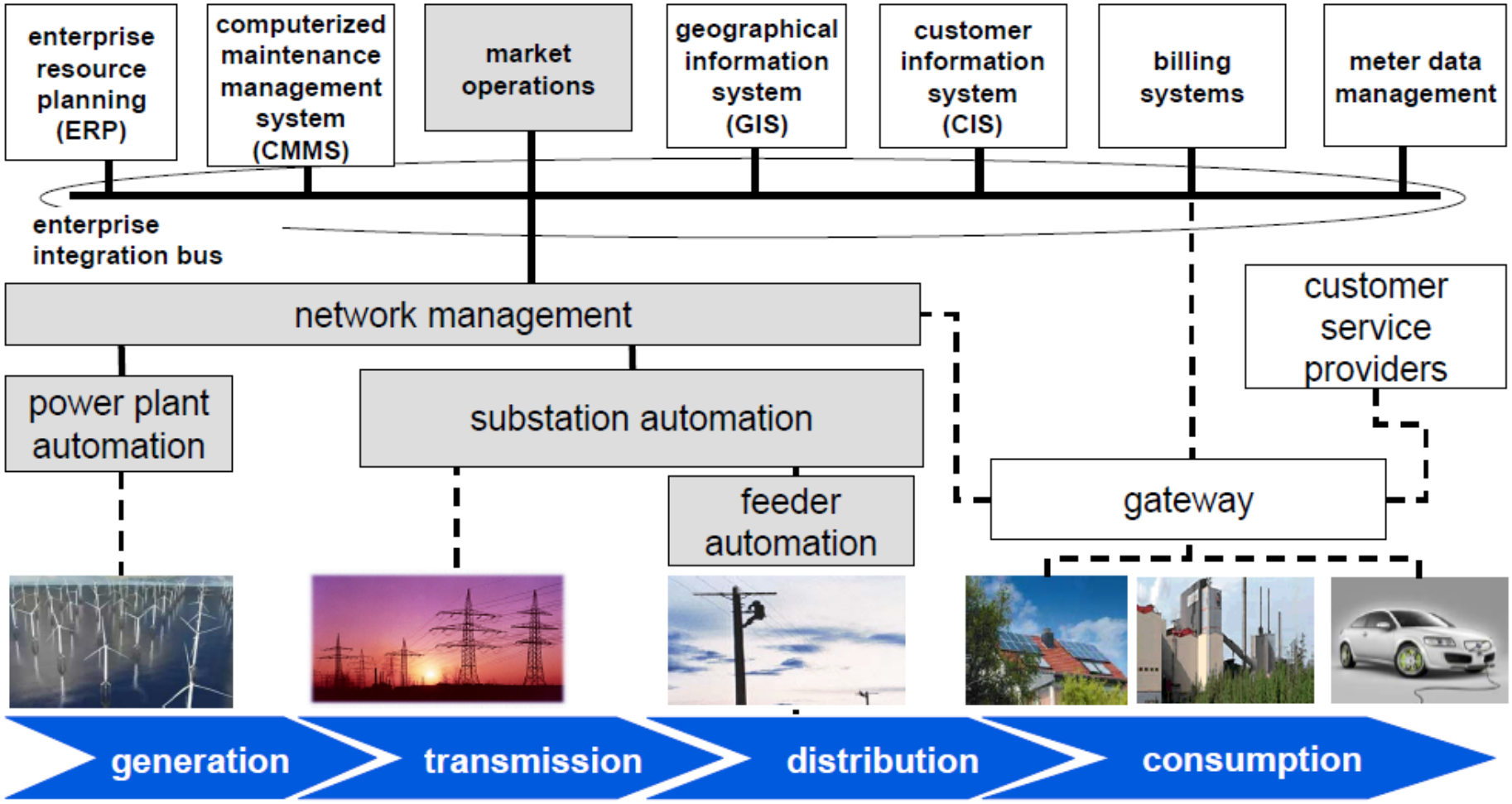
FACTS and HVDC for increased stability and reduced losses.

5. Problem Detection and Mitigation

Many utility customers do not realize the limited information currently available to grid operators, especially at the distribution level. When a blackout occurs, for example, customer calls are mapped to define the geographic area affected. This, in turn, allows utility engineers to determine which lines, transformers and switches are likely involved, and what they must do to restore service.

It is not rare, in fact, for a utility customer care representative to ask a caller to step outside to visually survey the extent of the power loss in their neighbourhood. It is a testament to the high levels of reliability enjoyed by electric utility customers that most have never experienced this; however, it is also evidence of an antiquated system.

Information Technology Integration



Source: ABB

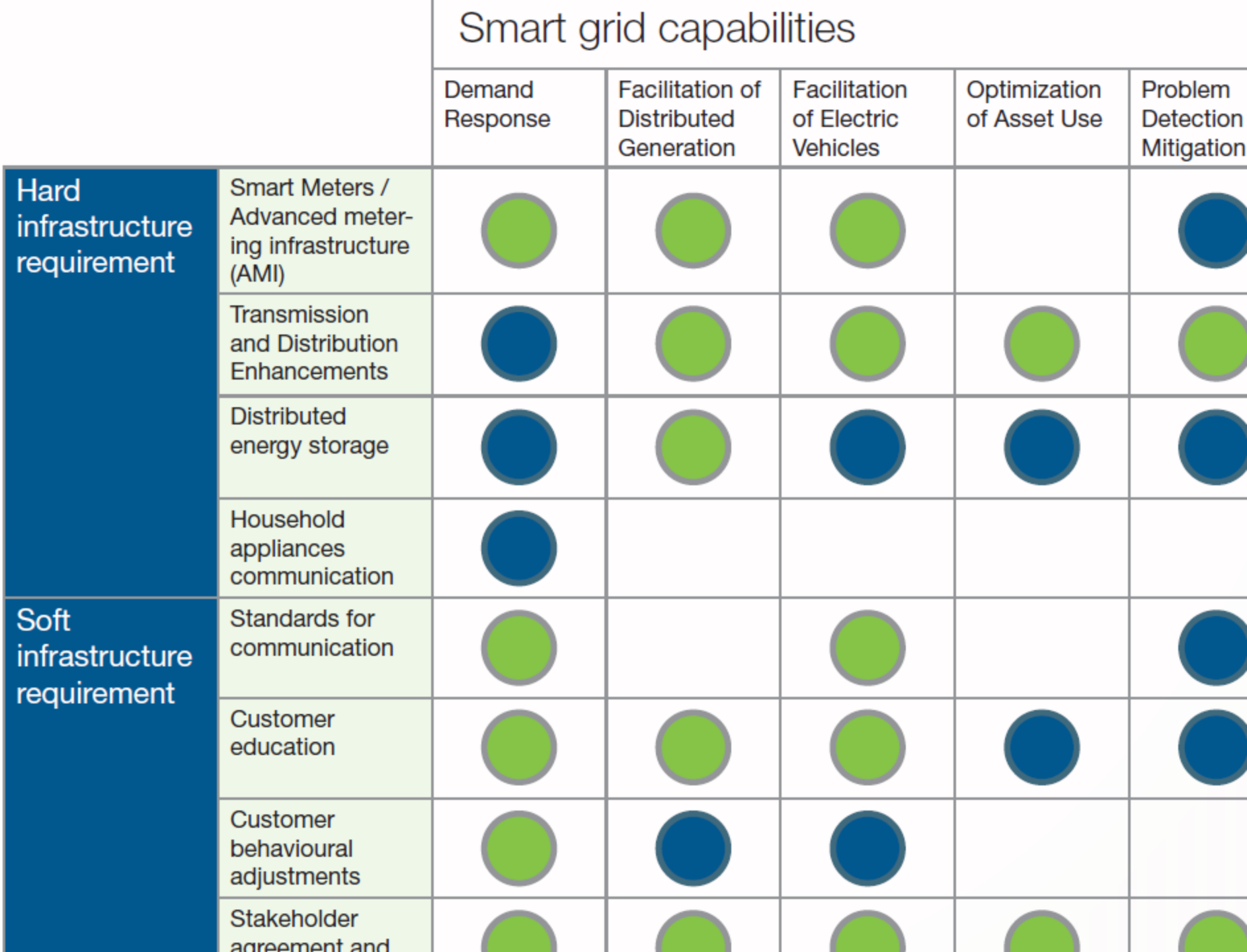
Smart Grid Building Block

Hardware Infrastructure

Smart Meters: Advanced Metering Infrastructure
Network Devices and Enhancement
Distributed Energy Storage
Home Appliances

Soft Infrastructure

Communication Standards and Protocols
Security Standards
Frequency Spectrum
Customer Engagement
Stakeholder Agreement and Coordination


Smart grid capabilities
Demand Response
Facilitation of Distributed Generation
Facilitation of Electric Vehicles
Optimization of Asset Use
Problem Detection Mitigation
Hard infrastructure requirement
Smart Meters / Advanced metering infrastructure (AMI)
Transmission and Distribution Enhancements
Distributed energy storage
Household appliances communication
Soft infrastructure requirement
Standards for communication
Customer education
Customer behavioural adjustments
Stakeholder agreement and

Smart Grid Attributes

- Information-based
- Communicating
- Secure
- Self-healing
- Reliable
- Flexible
- Cost-effective
- Dynamically controllable

- Motivation
- Sensing and Measurement
- Communications and Security
- Components and Subsystems
- Interfaces and Decision Support
- Control Methods and Topologies
- Trading in Smart Grid

Advanced Sensing and Measurement

- Enhance power system measurements and enable the transformation of data into information.
- Evaluate the health of equipment, the integrity of the grid, and support advanced protective relaying.
- Enable consumer choice and demand response, and help relieve congestion.
- Advanced Metering Infrastructure (AMI): Provide interface between the utility and its customers: bi-direction control; Advanced functionality; Real-time electricity pricing; Accurate load characterization; Outage detection/restoration; California asked all the utilities to deploy the new smart meter

Distributed Weather Sensing

- Widely distributed solar irradiance, wind speed, temperature measurement systems to improve the predictability of renewable energy.
- The grid control systems can dynamically adjust the source of power supply.

Communications and Security

- High-speed, fully integrated, two-way communication technologies that make the smart grid a dynamic, interactive “mega-infrastructure” for real-time information and power exchange.
- Cyber Security: the new communication mechanism should consider security, reliability, QoS.

Wireless Sensor Network

- The challenges of wireless sensor network in smart grid
  - Harsh environmental conditions.
  - Reliability and latency requirements
  - Packet errors and variable link capacity
  - Resource constraints.
- The interference will severely affect the quality of wireless sensor network.

Experiments for Noise and Interference

(a) (b) (c)

Fig. 1. Experimental sites. (a) Outdoor 500-kV substation environment, (b) indoor main power room, and (c) underground network transformer vault environments.

- They measured the noise level in dbm (the larger the worse)
- The outdoor background noise level is -105dbm

Advanced Components and Subsystems

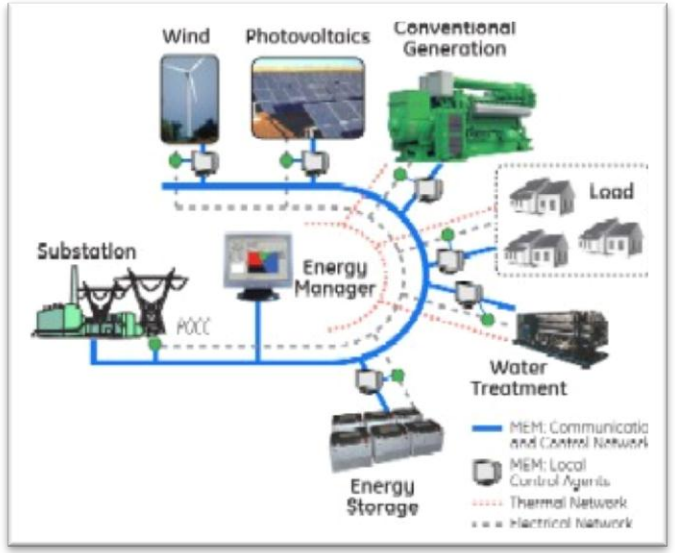
- These power system devices apply the latest research in materials, superconductivity, energy storage, power electronics, and microelectronics.
- Produce higher power densities, greater reliability and power quality, enhanced electrical.
- Advanced Energy Storage:
  - New Battery Technologies
    - Sodium Sulfur (NaS)
  - Plug-in Hybrid Electric Vehicle (PHEV)
    - Grid-to-Vehicle(G2V) and Vehicle-to-Grid(V2G)
    - Peak load leveling

Improved Interfaces and Decision Support

- The smart grid will require wide, seamless, often real-time use of applications and tools that enable grid operators and managers to make decisions quickly.
- Decision support and improved interfaces will enable more accurate and timely human decision making at all levels of the grid, including the consumer level, while also enabling more advanced operator training. Advanced Pattern Recognition
- Visualization Human Interface
  - Region of Stability Existence (ROSE)
    - Real-time calculate the stable region based on the voltage constraints, thermal limits, etc

APS: Autonomous Power System

- A localized group of electricity sources and loads
  - Locally utilizing natural gas or renewable energy
  - Reducing the waste during transmission
    - Using Combined Heat and Power (CHP)



Diverse Energy Sources

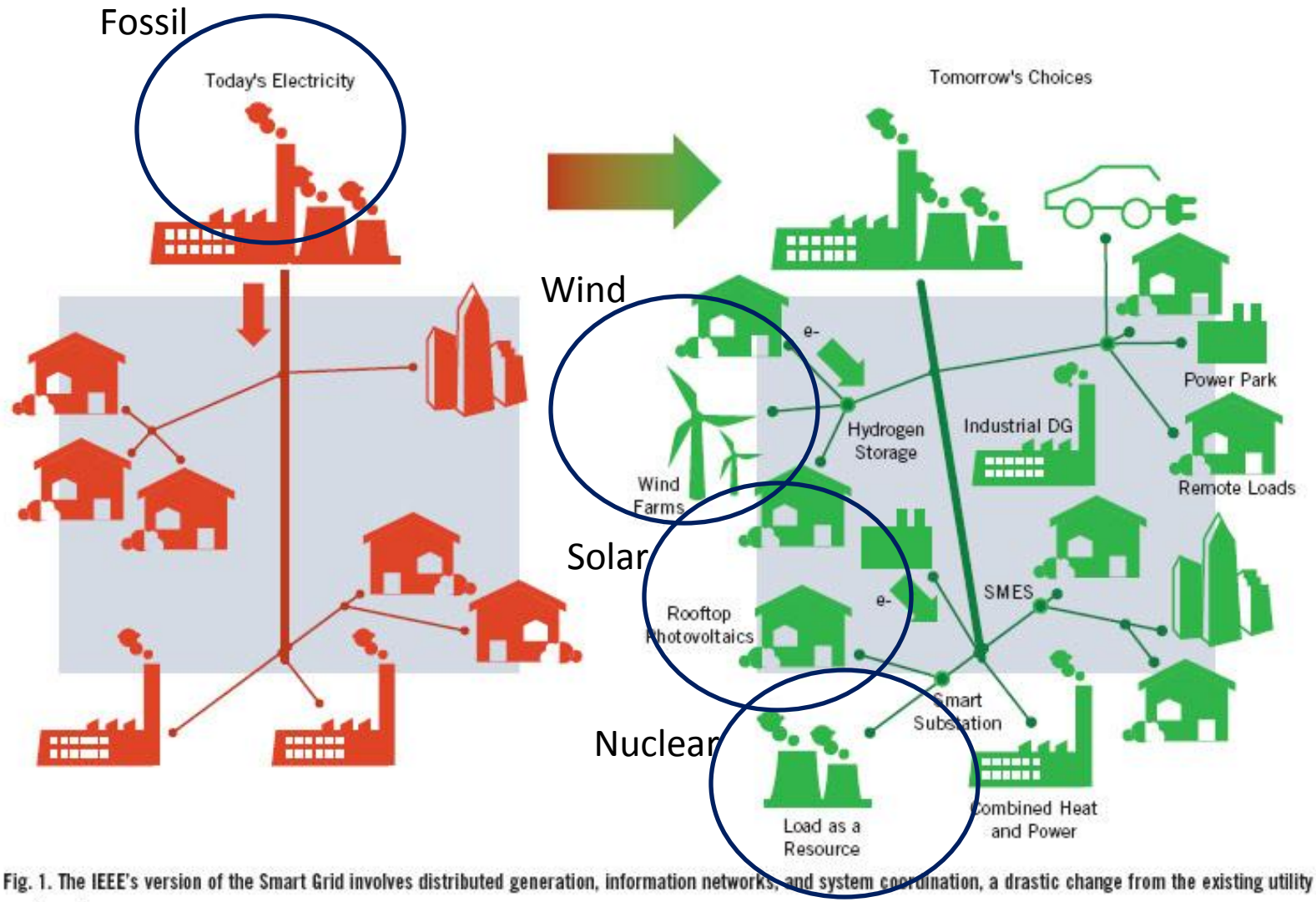
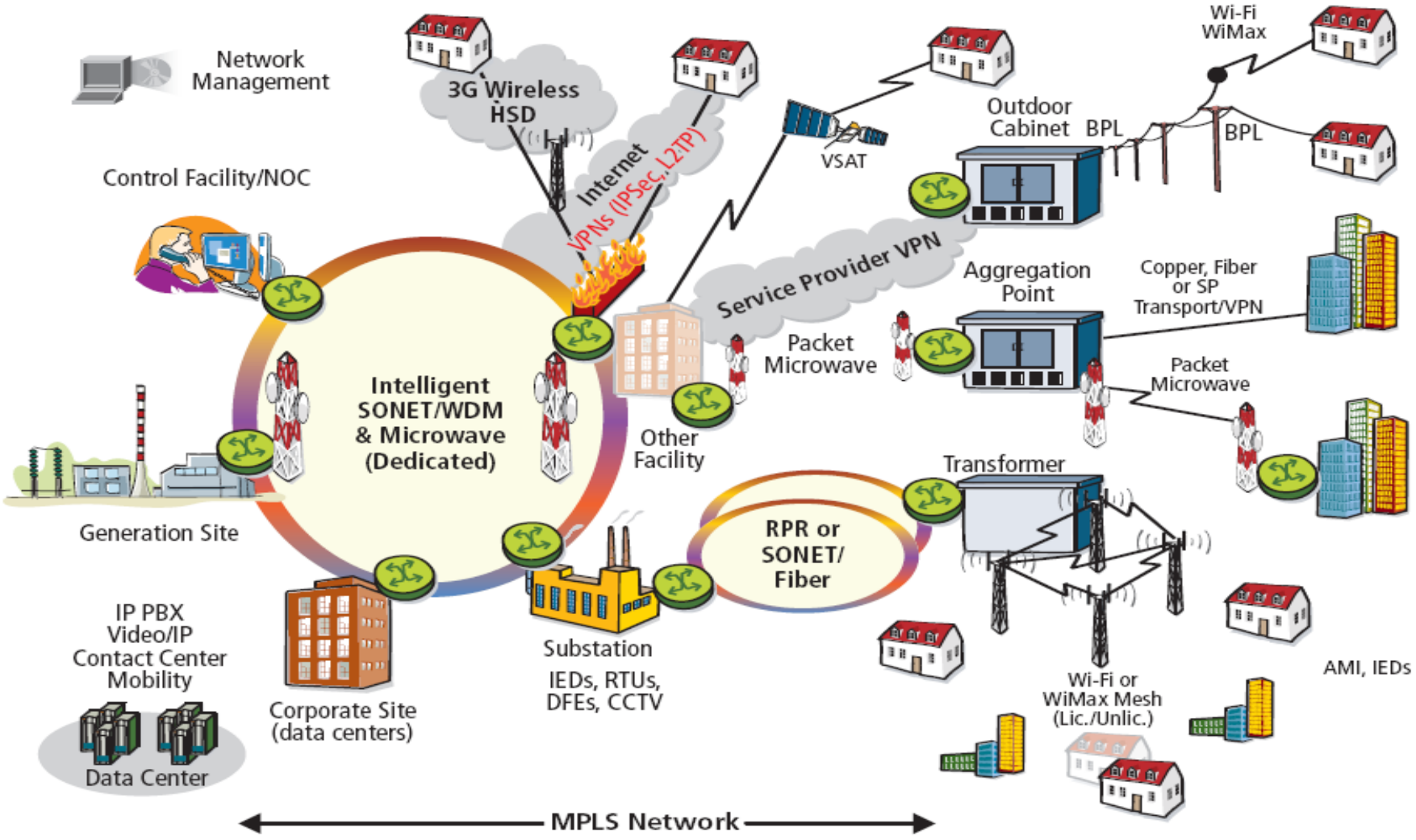


Fig. 1. The IEEE's version of the Smart Grid involves distributed generation, information networks, and system coordination, a drastic change from the existing utility configurations.

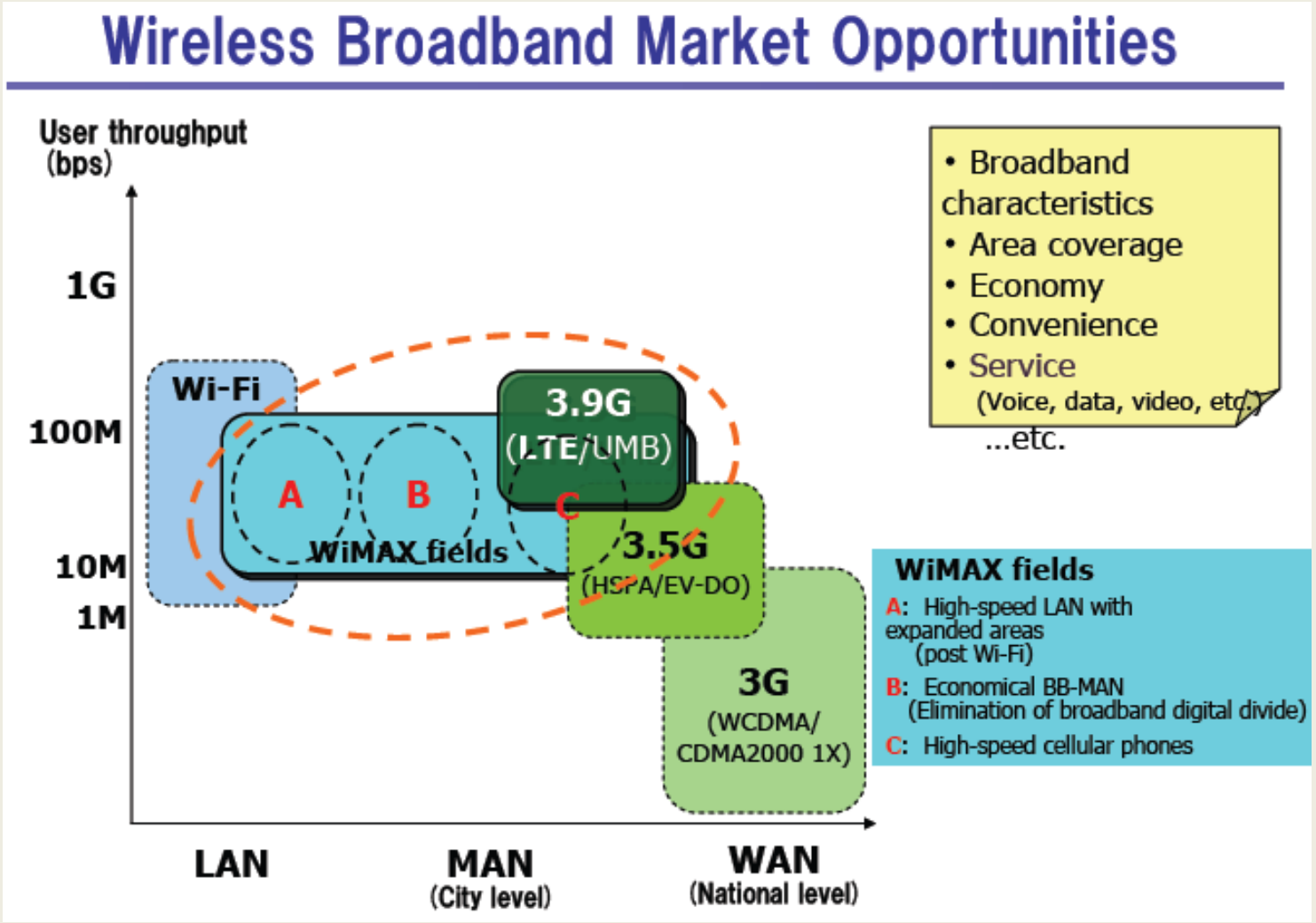
http://powerelectronics.com/power_systems/smart-grid-success-rely-system-solutions-20091001/

Telecommunication Options



Source: "Smart GridNet" Architecture for Utilities. Alcatel-Lucent Strategic White Paper.

Telecommunication Options
Wireless Technologies

- 

Electricity Market

"Trading Agents for the Smart Electricity Grid," AAMAS 2010.

- Current practice: Fixed market
  - Few producers, less competition
  - Regulated by government
- The future : **Free market**
  - Many producers (wind, solar, …)
  - Less regulation

Goal

- Setup a Electricity market
  - Self interested (producer, buyer, grid owner)
  - Free (no central regulation)
  - Efficient (no overload, no shortage)