Design and Simulation of Micro-Power Systems of Renewables

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- Note: This lecture note is a compilation of a 5-day lecture given at the Korean University of Technology Education in January 2013.

Course Introduction

- **Course Title:**

  "Hybrid Renewable System Design - Renewable Energy Sources for Smart Grid Application"

- **Course Objectives**
  - Competency in renewable energy sources and their characteristics
  - Competency in Micro-Power System Design of Renewable Energy Sources for Smart-Grid and Micro-Grid Application
  - Familiarization and Fluent Use of HOMER simulation software

- **Course Outcomes**
  - Learning in the basic concept of smart/micro grid
  - Learning in the sources and characteristics of renewable energy
  - Learning in Micro-power system
  - Running HOMER simulation under different Input data requirements
  - Design of Micro-power system of renewable energy sources
  - Design of Off-Grid and On-Grid Micro-Power System
  - Team Project
  - Team Presentation

Course Contents and Schedule

- 1. Smart Grid Overview
  - Overview of Smart Grid (SG) and SG technologies
  - Promises, Expectations, and Hypes,
  - Smart Meter, Lawsuits, and SG Bubbles (?)

- 2. Energy Sources
  - Renewable Energy Sources
  - Renewable Energy Source Characteristics
    - Wind Turbine
    - PV Module

- 3. Micro grid and Micro-power system
  - Micro grid definitions
  - More promises in island and military applications
  - Micro-Power System Design and Fundamental Concepts

Course Contents and Schedule

- **4. Micro-Power System Design Using HOMER – Part 1**
  - HOMER introduction
  - Design Examples
  - Resource Data Determination – Solar, Wind, and Diesel
  - Component Data Determination – Wind Turbine, PV, Converter, Battery, Diesel Generator, Grid, Fuel Cell, etc.

- **5. Micro-Power System Design Using HOMER – Part 2**
  - HOMER simulation
  - Off-grid system design --- Isolated System
  - Grid-Connected System Design

- **6. Practical System Design and Summary**
  - Team Project
    - Isolated or Grid-Connected Power System Design
  - Team Presentation
  - Summary and Conclusions

HOMER
(Hybid Optimization Model for Electric Renewablels)

1. Smart Grid Overview

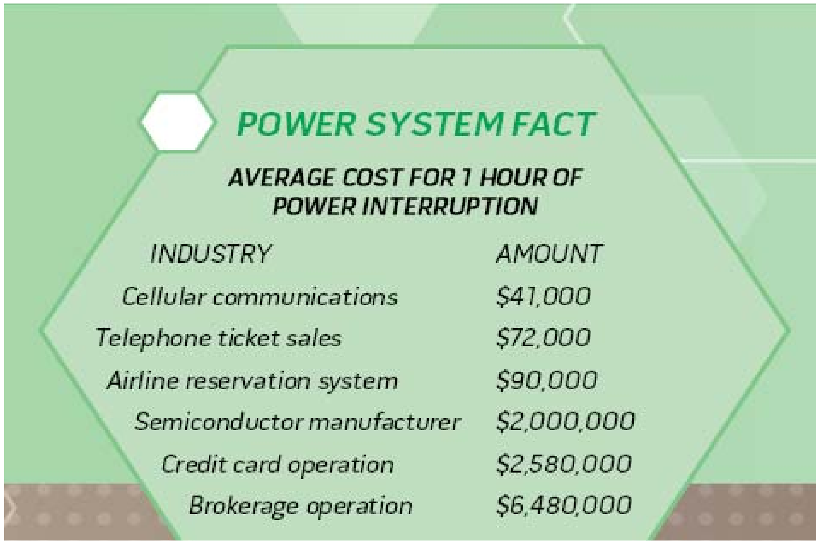
Charles Kim, Ph.D.

Howard University, Washington, DC USA

January 21, 2012

Background - Power System Fact

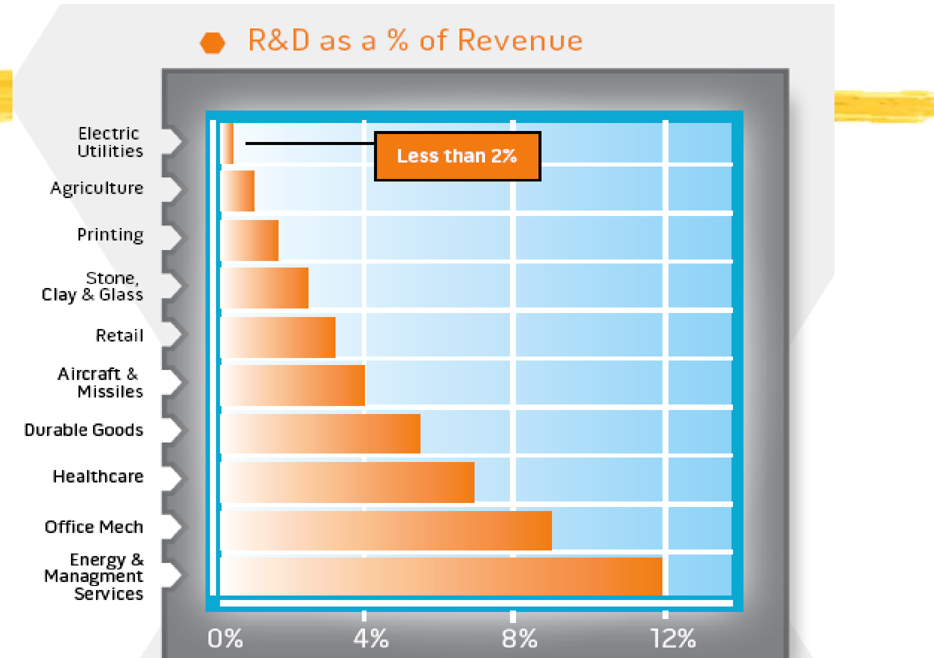
⌘ Bigger Impact, less investment, distinct load profile

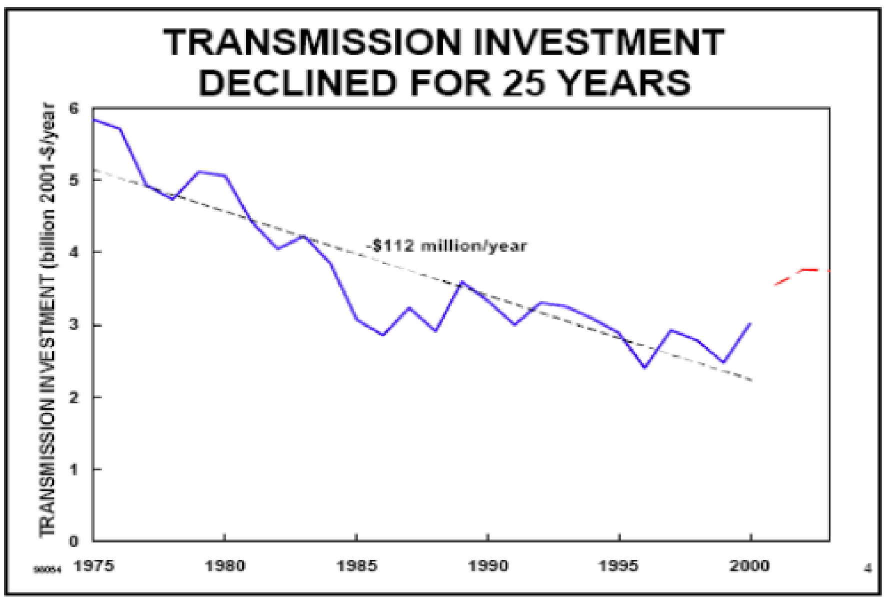


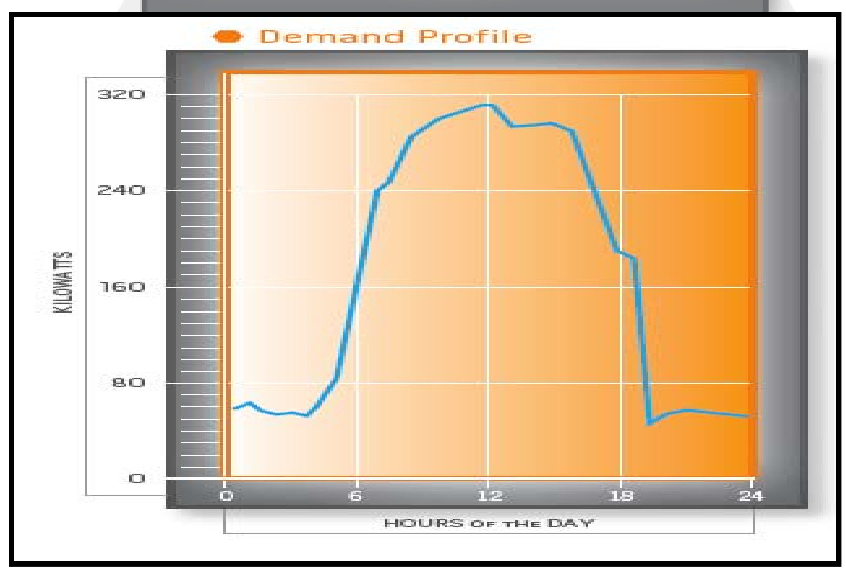
POWER SYSTEM FACT

AVERAGE COST FOR 1 HOUR OF POWER INTERRUPTION

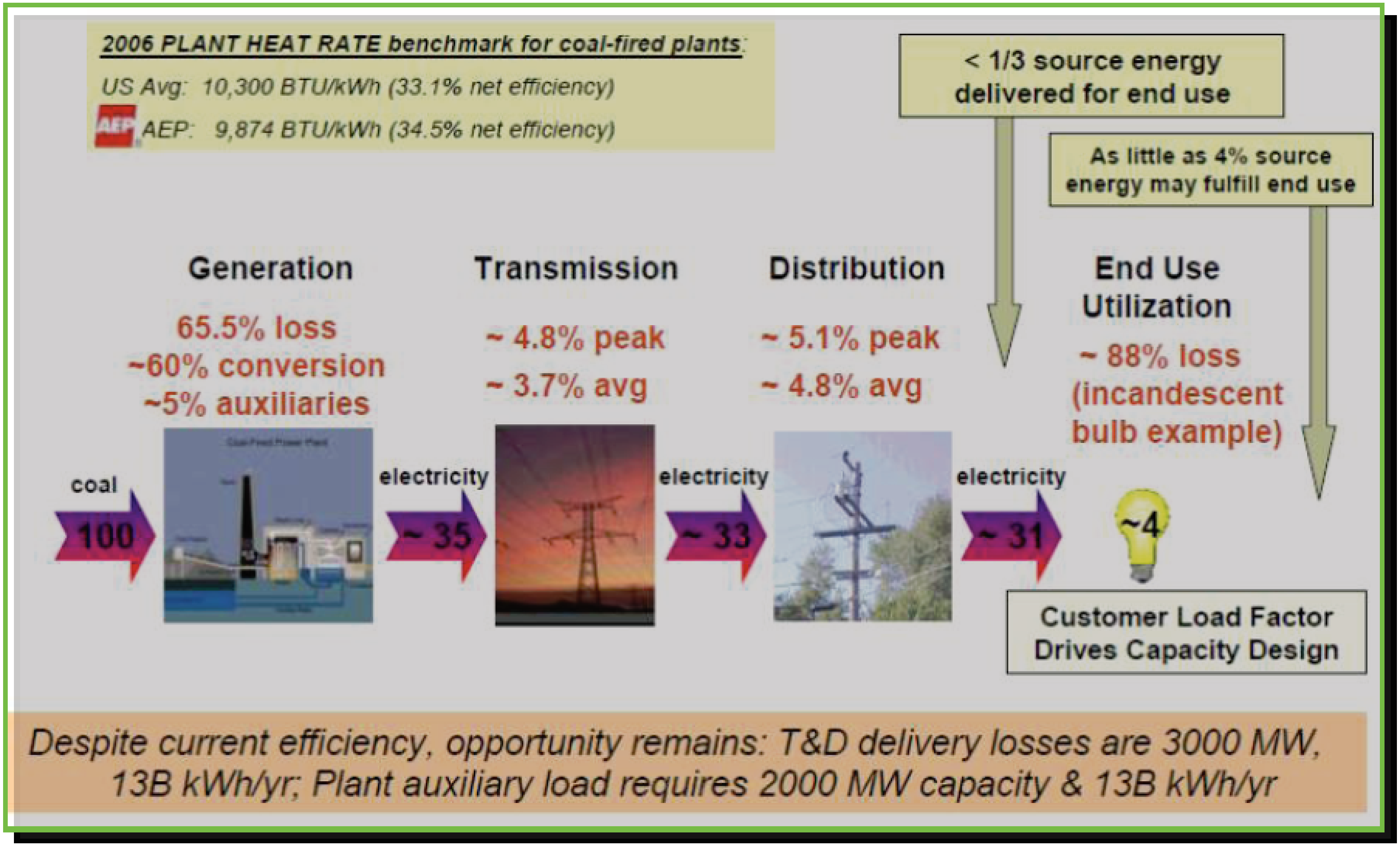
INDUSTRY	AMOUNT
Cellular communications	$41,000
Telephone ticket sales	$72,000
Airline reservation system	$90,000
Semiconductor manufacturer	$2,000,000
Credit card operation	$2,580,000
Brokerage operation	$6,480,000







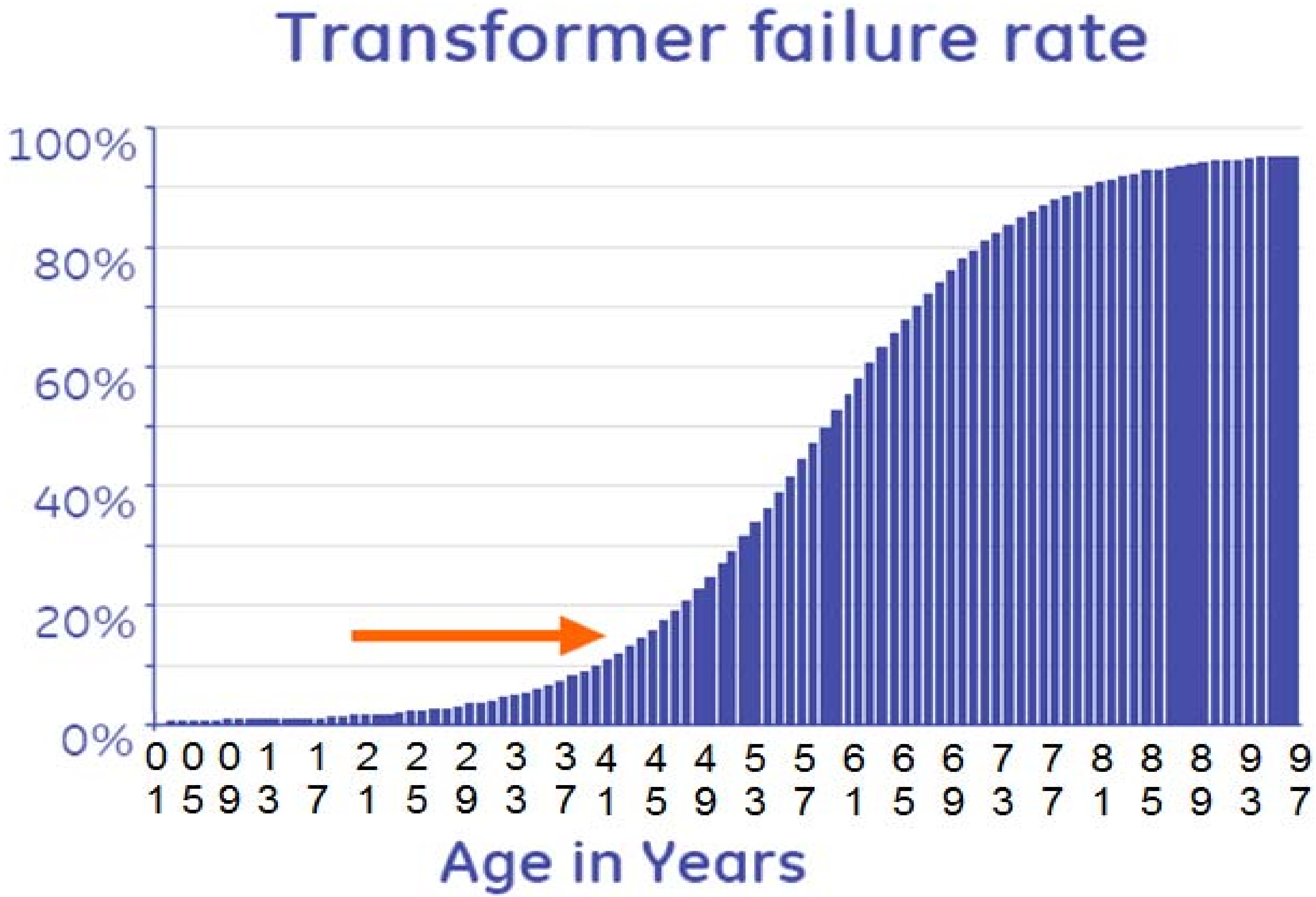
Background - Grid Inefficiency



Source: AEP PUC Hearing

Background - Aging Assets

- The average US transformer age is nearly 40 years old, at which the failure rate is almost 20%.



Background – Acts and Associations

- Intelligent Grid Initiative
- American Public Power Association
- State-Level Exploration toward a smart grid

SMART GRID FACT

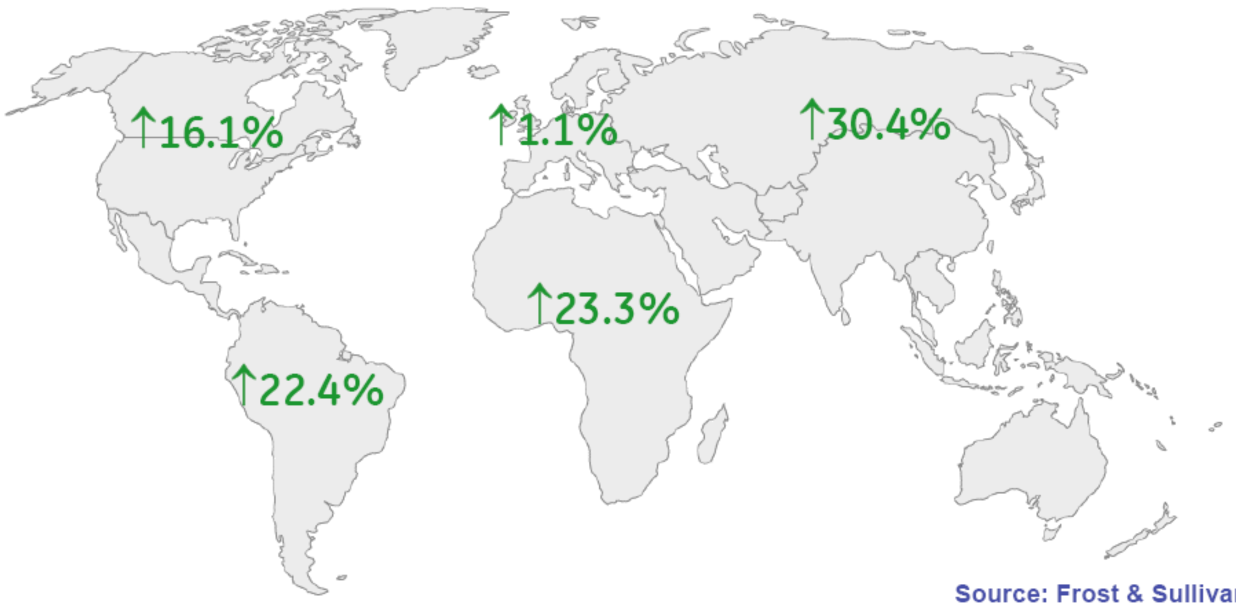
States such as Texas, California, Ohio, New Jersey, Illinois, New York and others are already actively exploring ways to increase the use of tools and technologies toward the realization of a smarter grid.

SMART GRID FACT

The American Public Power Association (APPA) has launched a task force to develop a framework for deploying Smart Grid technologies in a public-power environment.

Background- DG Growth and Challenges

- Explosive Growth of Distributed Generation (DG) or DER (Distributed Energy Resources)
- Challenges
  - Distribution system protection strategies for bi-directional power flows
  - Reactive power/ voltage control
  - "Islanding" issue



Source: Frost & Sullivan 2003

DG Growth Globally

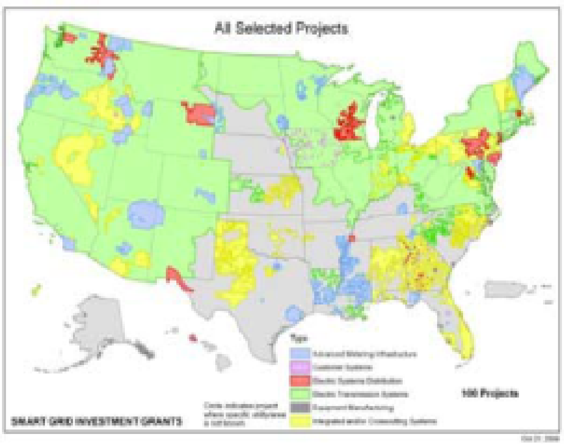
Smart Grid Advancements – Federal Activity

- 2007 EISA (Energy Independence and Security Act) Legislation
  - Energy Reduction; Energy Saving; Energy-Efficiency; Metering
  - NIST charged for standards development
  - States encouraged to investigate smart grid
- 2008 ARRA (American Recovery and Reinvestment Act) Stimulus
  - Education $53B; Energy $43B; Infrastructure $111B; Protection $81B
- 2009 NIST Roadmap & Smart Grid Interoperability Panel
- 2009 SGIG (Smart Grid Investment Grants) Awards – Federal Stimulus
  - Integrated Project
  - AMI
  - Distribution
  - Transmission
  - Total of $3.4 B

Category	$ Million
Integrated/Crosscutting	2,150
AMI	818
Distribution	254
Transmission	148
Customer Systems	32
Manufacturing	26
Total	3,429

18 million smart meters
1.2 million in-home display units
206,000 smart transformers
177,000 load control devices
170,000 smart thermostats
877 networked phasor measurement units
671 automated substations
100 PEV charging stations

Geographic Coverage of Selected Projects



Top 20 Recipients of ARRA (DOE)

Recipient (DUNS)	Award #	Order #	Awarding Agency	Award Type	Award Amount	Local Amount	Recipient Role
AMEREN ENERGY RESOURCES COMPANY, LLC (153005306)	DE-FE0005054		Department of Energy	Grants	$589,744,000.00	$589,744,000.00	Prime
SAVANNAH RIVER NUCLEAR SOLUTIONS LLC (798861048)	SR22470	2002153	Department of Energy	Contracts	$720,201,615.20	$508,570,695.82	Prime
FUTUREGEN INDUSTRIAL ALLIANCE, INC (603703799)	DE-FE0001882		Department of Energy	Grants	$404,985,000.00	$380,382,964.15	Prime
CH2M HILL PLATEAU REMEDIATION COMPANY (805603128)	DE-AC06-08RL14788	2002140	Department of Energy	Contracts	$600,418,168.34	$330,058,913.56	Prime
HYDROGEN ENERGY CALIFORNIA LLC (796738149)	DE-FE0000663		Department of Energy	Grants	$275,000,000.00	$275,000,000.00	Prime
JOHNSON CONTROLS, INC. (006092860)	DE-EE0002616		Department of Energy	Grants	$299,177,757.00	$272,400,047.22	Prime
AIR PRODUCTS AND CHEMICALS, INC. (003001070)	DE-FE0002381		Department of Energy	Grants	$284,012,496.00	$272,348,213.00	Prime
SAVANNAH RIVER NUCLEAR SOLUTIONS LLC (798861048)	SR22470	2002150	Department of Energy	Contracts	$416,711,472.35	$271,540,732.41	Prime
A123 SYSTEMS, INC. (130452506)	DE-EE0002022		Department of Energy	Grants	$249,090,000.00	$249,090,000.00	Prime
LEUCADIA ENERGY, LLC (831267492)	DE-FE0002314		Department of Energy	Grants	$261,382,310.00	$236,479,183.36	Prime
SUMMIT TEXAS CLEAN ENERGY, LLC (829030258)	DE-FE0002650		Department of Energy	Grants	$211,097,445.00	$211,097,445.00	Prime
DUKE ENERGY BUSINESS SERVICES LLC (830760216)	OE0000212		Department of Energy	Grants	$200,000,000.00	$200,000,000.00	Prime
BALTIMORE GAS AND ELECTRIC COMPANY (156171464)	DE-OE0000216		Department of Energy	Grants	$200,000,000.00	$200,000,000.00	Prime
PROGRESS ENERGY SERVICE COMPANY, LLC (102104846)	OE0000213		Department of Energy	Grants	$200,000,000.00	$200,000,000.00	Prime
FLORIDA POWER & LIGHT COMPANY (073216108)	DE-OE0000211		Department of Energy	Grants	$200,000,000.00	$200,000,000.00	Prime
CENTERPOINT ENERGY HOUSTON ELECTRIC, LLC (007931728)	DE-OE0000210		Department of Energy	Grants	$200,000,000.00	$200,000,000.00	Prime
PECO ENERGY COMPANY (007914468)	DE-OE0000207		Department of Energy	Grants	$200,000,000.00	$195,812,639.10	Prime
WASHINGTON RIVER PROTECTION SOLUTIONS LLC (806500521)	DEAC2708RV14800		Department of Energy	Contracts	$323,855,000.00	$185,373,028.27	Prime
CH2M WG IDAHO LLC (166527569)	DE-AC07-05ID14516	2002040	Department of Energy	Contracts	$199,947,354.00	$182,812,997.49	Prime
CH2M HILL PLATEAU REMEDIATION COMPANY (805603128)	DE-AC06-08RL14788	2002142	Department of Energy	Contracts	$315,663,000.00	$175,749,195.81	Prime

Top 20 Smart Grid Vendors by ARRA Award Amount

- Itron $304,828,804
- Trilliant Networks Inc. $99,494,396
- GE $98,668,171
- Honeywell $60,932,262
- Landis+Gyr $56,222,792
- Accenture $53,955,271
- Cooper Power Systems $48,680,230
- Sensus $43,319,354
- Elster $42,305,647
- IBM $42,261,054
- S&C Electric Company $39,431,504
- Alcatel Lucent $38,664,493
- BSC $32,078,744
- A123 Systems $29,923,083
- Oracle $28,673,666
- Silver Spring Networks Inc. $28,611,707
- Beacon Power Corporation $24,063,978
- Tantalus $21,059,544
- Undisclosed $18,399,024
- Ervin Cable Construction, LLC $16,959,700

States Receiving the Most Funds

State	Amount (02/17/09 - 09/30/2012)
CALIFORNIA	$6,520,613,417
ARIZONA	$3,140,031,343
WASHINGTON	$2,272,328,908
ILLINOIS	$2,105,554,461
SOUTH CAROLINA	$1,785,869,361

Cities Receiving the Most Funds

City	Amount (02/17/09 - 09/30/2012)
RICHLAND, WA	$1,660,460,810
AIKEN, SC	$1,548,709,290
GILA BEND, AZ	$1,359,333,196
SANTA MARGARITA, CA	$1,188,939,300
HINKLEY, CA	$1,124,110,000

Recipients Receiving the Most Funds

Recipient	Award Amount
ARIZONA SOLAR ONE LLC	$1,359,082,586
HIGH PLAINS RANCH II, LLC	$1,188,939,300
MOJAVE SOLAR LLC	$1,124,110,000
AGUA CALIENTE SOLAR, LLC	$967,000,000
FIRST SOLAR, INC.	$834,539,476

Renewable Portfolio by States

- **20% by 2020**

- CA: 20% by 2020
- IL: 25% by 2025
- CT: 23% by 2020
- MN: 25% by 2025
- NJ: 22.5 % by 2021
- NY: 24% by 2013
- AZ: 15% by 2025
- OR: 25% by 2025

STATES TAKING ACTION:

30 states have developed and adopted renewable portfolio standards, which require a pre-determined amount of a state's energy portfolio (up to 20%) to come exclusively from renewable sources by as early as 2010.

STATE	AMOUNT	YEAR	RPS ADMINISTRATOR
Arizona	15%	2025	Arizona Corporation Commission
California	20%	2010	California Energy Commission
Colorado	20%	2020	Colorado Public Utilities Commission
Connecticut	23%	2020	Department of Public Utility Control
District of Columbia	11%	2022	DC Public Service Commission
Delaware	20%	2019	Delaware Energy Office
Hawaii	20%	2020	Hawaii Strategic Industries Division
Iowa	105 MW		Iowa Utilities Board
Illinois	25%	2025	Illinois Department of Commerce
Massachusetts	4%	2009	Massachusetts Division of Energy Resources
Maryland	9.5%	2022	Maryland Public Service Commission
Maine	10%	2017	Maine Public Utilities Commission
Minnesota	25%	2025	Minnesota Department of Commerce
Missouri*	11%	2020	Missouri Public Service Commission
Montana	15%	2015	Montana Public Service Commission
New Hampshire	16%	2025	New Hampshire Office of Energy and Planning
New Jersey	22.5%	2021	New Jersey Board of Public Utilities
New Mexico	20%	2020	New Mexico Public Regulation Commission
Nevada	20%	2015	Public Utilities Commission of Nevada
New York	24%	2013	New York Public Service Commission
North Carolina	12.5%	2021	North Carolina Utilities Commission
Oregon	25%	2025	Oregon Energy Office
Pennsylvania	18%	2020	Pennsylvania Public Utility Commission
Rhode Island	15%	2020	Rhode Island Public Utilities Commission
Texas	5,880 MW	2015	Public Utility Commission of Texas
Utah*	20%	2025	Utah Department of Environmental Quality
Vermont*	10%	2013	Vermont Department of Public Service
Virginia*	12%	2022	Virginia Department of Mines, Minerals, and Energy
Washington	15%	2020	Washington Secretary of State
Wisconsin	10%	2015	Public Service Commission of Wisconsin

*Four states, Missouri, Utah, Vermont, & Virginia, have set voluntary goals for adopting renewable energy instead of portfolio standards with binding targets.

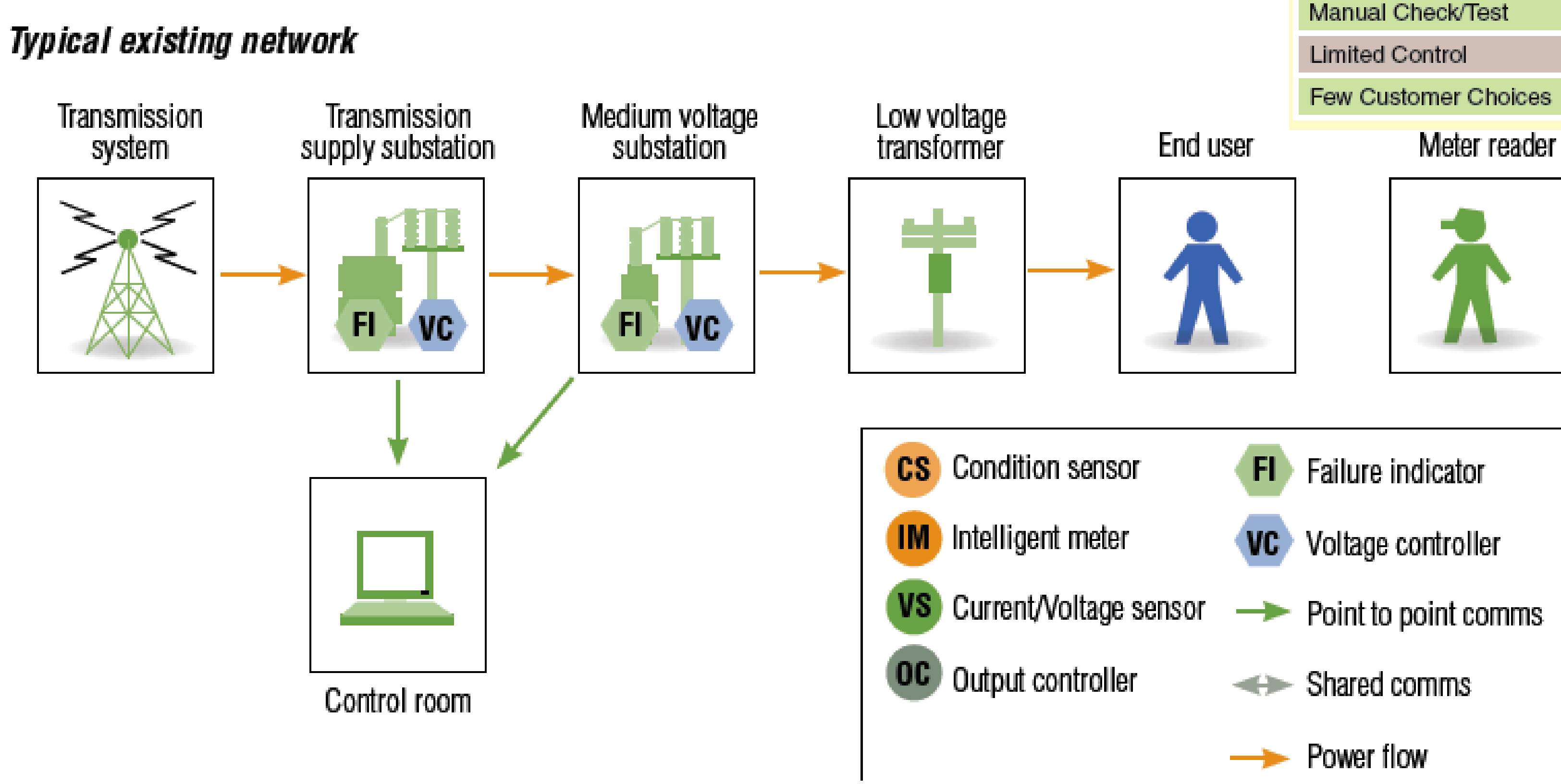
Smart Grid Overview

- Electric grid evolves to incorporate advances in information technology, communication systems and new technologies
- Ubiquitous communications backbone
  - Distributed sensors
  - New and/or automated control methodologies
  - Real-time ratings
- New technologies
  - Alternative system designs
  - Distributed Energy Resources
  - Predictive and condition based maintenance
- Information technology
  - Asset optimization
  - Operational excellence
  - Customer participation

Traditional Network

- Point-to-point communication systems
- Link the central control room to failure-indicators and switches on the grid, each with dedicated communication channel

Existing Grid
Electromechanical
One-Way Communication
Centralized Generation
Hierarchical
Few Sensors
Blind
Manual Restoration
Failures and Blackouts
Manual Check/Test
Limited Control
Few Customer Choices

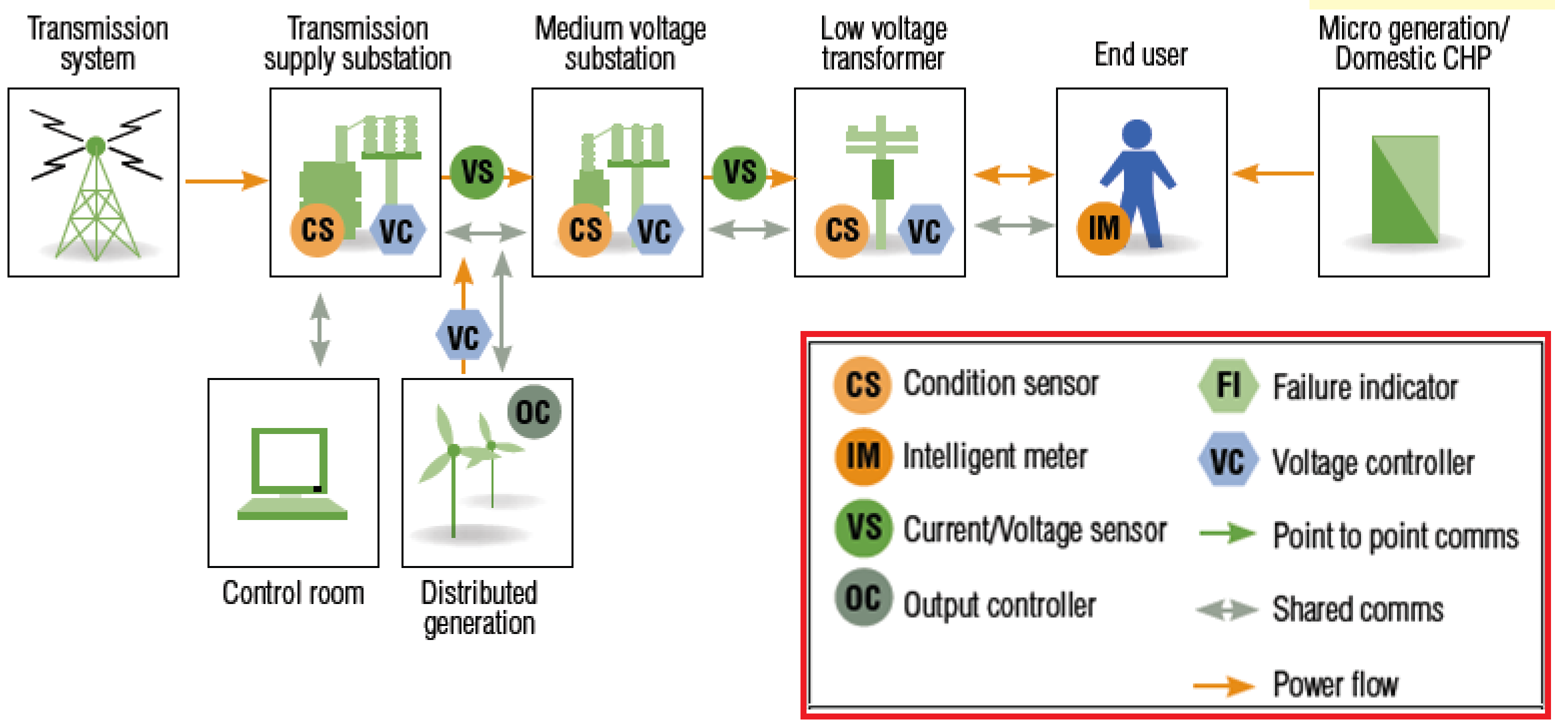


Intelligent Network

- Standardized packet based networking (like Internet).
- Simple failure-indicators are replaced by intelligent electronic devices (IEDs)
- Real-time situation-awareness provided to the system operators

Intelligent Grid
Digital
Two-Way Communication
Distributed Generation
Network
Sensors Throughout
Self-Monitoring
Self-Healing
Adaptive and Islanding
Remote Check/Test
Pervasive Control
Many Customer Choices

The intelligent network



2 layers: Electrical and Information

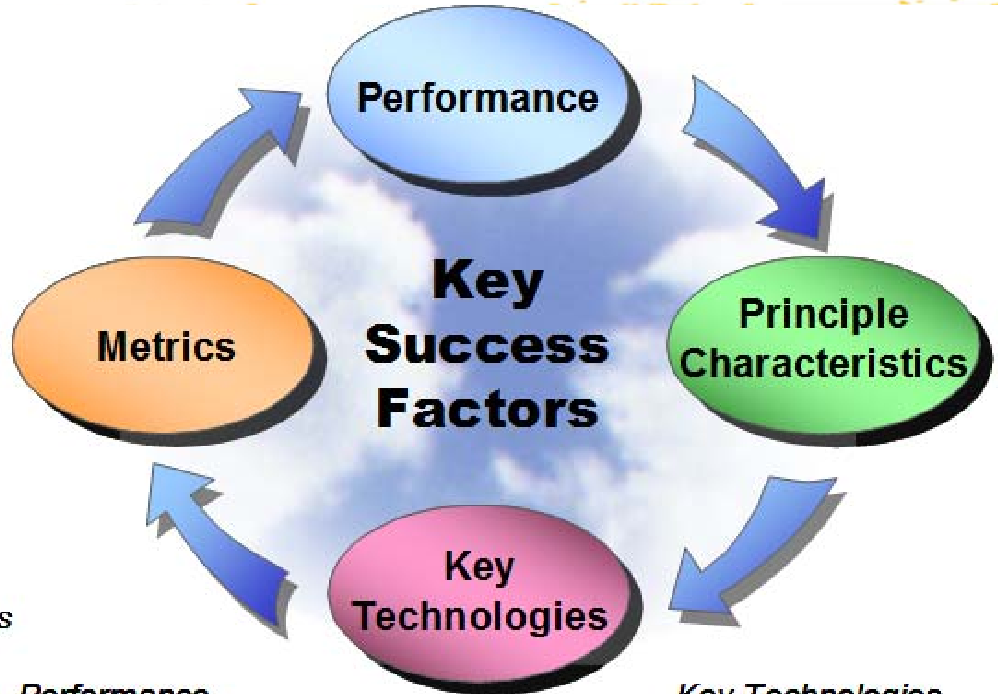
- Integration of two infrastructures securely: electrical and information
- The convergence of communication technology and information technology with power system engineering
- assisted by an array of new approaches, technologies and applications,
- allows the existing grid to traverse the complex yet staged trajectory of architecture, protocols, and standards towards the smart grid.

Emerging Capabilities

- Demand Optimization – Manage peak via consumption control
- Delivery Optimization – Reduce delivery losses
- Renewables Optimization – Use of forecast and smoothing
- Reliability Optimization – Wide Area protection and control

Smart Grid Overview

- Modern Grid Initiative



Key Success Factors

Reliability
Security
Economics
Power quality
Efficiency and environmental quality
Safety

Performance

Emergency Restoration
Routine Operations Optimization
Systems Planning

Principle Characteristics

Self-healing
Empowers and incorporates the consumer
Tolerates security attack
Provides 21st century power quality
Accommodates a wide variety of generation options
Fully enables electricity markets
Optimizes asset use; minimizes O&M expenses

Key Technologies

Integrated communications
Advanced control methodologies
Sensing, metering, and measurement
Advanced grid components
Decision support and human interfaces

Metrics

Congestion costs
Blackout probability
SAIFI
Restoration time
CAIDI
Peak-to-average load ratio
Capacity utilization

Functional Attributes

- **Functional Attributes** of Smart Grid
  - Self-healing
    - A grid able to rapidly detect, analyze, respond and restore from perturbations.
  - Empower and incorporate the consumer
    - The ability to incorporate consumer equipment and behavior in the design and operation of the grid.
  - Tolerant of attack
    - A grid that mitigates and stands resilient to physical and cyber security attacks.
  - Provides power quality needed by 21st century users
    - A grid that provides a quality of power consistent with consumer and industry needs.
  - Accommodates a wide variety of generation options
    - A grid that accommodates a wide variety of local and regional generation technologies (including green power).
  - Fully enables maturing electricity markets
    - Allows competitive markets for those who want them.
  - Optimizes assets
    - A grid that uses IT and monitoring to continually optimize its capital assets while minimizing operations and maintenance costs.

Technical Attributes

- **Technology Attributes** of Smart Grid
  - Grid-wide integrated communications
    - Internet for the power grid
  - Sensing, metering, measurement
    - Digital two-way communication devices
    - Enable generation connect and disconnect
    - Enhance operator information
  - Advanced control capabilities
    - Computer based grid monitoring
    - Enables dispatch of distributed resource
  - Advance grid components
    - Energy storage
    - Distributed generation
  - Decision Support
    - Analytics to guide grid operators
    - Semi-autonomous agent software

Smart Grid = Smart Meter ?

- Expectations of Smart Grid by only Smart meter?
- Does Smart Meter reduce electricity bill?
- Who pays for the smart meter?

FiLife™

'Smart' utility meters could roll over savings to homeowners

by: David Englander , MarketWatch | Sep 16, 2008

NEW YORK (MarketWatch) -- A new technology is coming to your electric meter. It's called a "smart meter" and it's part of a revolution in electricity delivery that has been coined the "smart grid," which has the potential to reduce your utility bills. But you'll have to pay for the new meter before your savings kick in.

The smart grid is the modern electricity network, where sensors and computers will aid in providing constant information on electricity consumption. Some features include signaling to consumers real-time pricing of electricity and predicting places where demand surges.

Metering Trend and Smart Meter

- Energy Meters
  - key player in power system
  - Record the consumption

Functional	Electro mechanical	Electronic	Smart meter
Measurement	Coil, Rotating Discs and Counters	ADC's, DSP-Micro-Processor	Metering and Communication ASIC
Storage	Nil	EPROM,RAM, Flash	EPROM, RAM, Flash
Communication	Nil	Optical/RS232/ RS485	PLC/GPRS/CDMA/ RF Mesh/Wi-Max ..
Protocols	Nil	Proprietary/Open Protocol	Open Protocols DLMS(IEC-62056)/ ANSI C12 /M-Bus
Other functions	Nil	Multi tariff, billing schedules	Remote Connection/Disconnection, Demand Response/Real-time pricing/Sub-Meter/HAN

Smart Meter, Dumb Idea?

- Proponents of Smart Meters – Shows current energy usage and consume less as a result
- Opponents – Smart Meters are expensive charging customers an extra $3.24 a month for a meter with $444 for how long? Utility can easily terminate service. There are cheaper ways to reduce energy usage.

THE WALL STREET JOURNAL.
WSJ.com

APRIL 27, 2009, 6:50 P.M. ET

Smart Meter, Dumb Idea?

New devices promise to cut energy use by giving consumers more information. Critics say they aren't worth the cost.

By REBECCA SMITH

Not everyone thinks smart meters are such a smart use of money.

Utilities are spending billions of dollars outfitting homes and businesses with the devices, which wirelessly send information about electricity use to utility billing departments and could help consumers control energy use.

Proponents of smart meters say that when these meters are teamed up with an in-home display that shows current energy usage, as well as a communicating thermostat and software that harvest and analyze that information, consumers can see how much consumption drives cost -- and will consume less as a result.

Such knowledge, however, doesn't come cheap. Meters are expensive, often costing $250 to $500 each when all the bells and whistles are included, such as the expense of installing new utility billing systems. And utilities typically pass these costs directly on to consumers. CenterPoint Energy Inc. in Houston, for instance, recently began charging its customers an extra $3.24 a month for smart meters, sparking howls of protest since the charges will continue for a decade and eventually approach $1 billion.

Smart Meter Lawsuits

- Class action lawsuit in California against PG&E
- Class action suit in Texas against Oncor Electric Delivery

SUPERIOR COURT FOR THE STATE OF CALIFORNIA

FOR THE COUNTY OF KERN

PETE FLORES, on behalf of himself and all others similarly situated, Plaintiffs, v. PACIFIC GAS AND ELECTRIC COMPANY, a California company, PG&E CORPORATION, a California company, WELLINGTON ENERGY, INC., a Pennsylvania company, and DOE DEFENDANTS 1-100, Defendants.	Case No. **CLASS ACTION** **1. California Consumer Legal Remedies Act, California *Civil Code* § 1770 *et seq.*** **2. Unjust Enrichment** **3. Violation of Public Utilities Code § 451** **4. Negligence** **5. Breach of Contract** **6. Fraud and Deceit** **7. Violation of Public Utilities Code § 454** **8. California False Advertising Act, California *Business & Professions Code* § 17500 *et seq.*** **9. California Unfair Competition Law, California *Business & Professions Code* § 17200 *et seq.*** **10. Breach of Good Faith and Fair Dealing** **11. Negligent Misrepresentation** **DEMAND FOR JURY TRIAL**

Courthouse News

'Smart Meters' Soak Customers, Class Claims

By JAMIE ROSS

ShareThis

(CN) - Texas' biggest electric company installed defective "sı residential customers' bills to nearly $2,000 a month, accordin Dallas County Court. The class claims Oncor Electric Delivery (to the bank."

Named plaintiffs Robert and Jennifer Cordts say their mont $700 were driven above $1,800 after their smart meter was ins

Smart Meter and Privacy Concerns

Christina Nunez
For National Geographic News

Published December 12, 2012

Energy consultant Craig Miller, who spends much of his time working to make the smart grid a reality, got a jolt when he mentioned his work to a new acquaintance. The man, who happened to be a lineman at a Pennsylvania utility, responded earnestly: "Smart meters are a plot by Obama to spy on us."

Who's Watching? Privacy Concerns Persist as Smart Meters Roll Out

- Information collected by smart meters could reveal how many people live in a home, their daily routines, changes in those routines, what types of electronic equipment are in the home, and other details.
- "It's not hard to imagine a divorce lawyer subpoenaing this information, an insurance company interpreting the data in a way that allows it to penalize customers, or criminals intercepting the information to plan a burglary," the private nonprofit Electronic Frontier Foundation noted in a blog post about smart meters.
- **Marijuana Farm Discovery in CA**

Smart Grid Concerns

Forbes.com

Commentary

Smart Grid Shouldn't Be Too Smart

Kenneth G. Brill, 04.22.09, 6:00 AM ET

- Smart: upgrade national electricity grade
- But "Smart Grid" should not have to be too smart
- Transmission lines are needed to get the renewable energy produced in other parts of the country to another part.
- The true cost of renewable energy is really high.
- Renewable smoothing by energy storage, pumped hydro, or battery is not always good for all – environmentalists etc
- Dumb due to the significant loss of knowledge and judgment due to retirement and failure to replace the engineers who built what we have.
- Internet may be a curse to the smart grid – smart monitoring should be separated from dumb control functions which are intentionally separated

Smart Grid Security Vulnerability

Security and Privacy Challenges in the Smart Grid

- Smart meters are extremely attractive targets for malicious hackers, largely because vulnerabilities can easily be monetized. Hackers who compromise a meter can immediately manipulate their energy costs or fabricate generated energy meter readings. This kind of immediacy of return on the hacker investment has proven to be a great motivator in the past.
- Consider the early days of cable television, when signal hijacking kits were sold in huge volumes. Notably—even after 30 years of investment—cable theft continues to be a daunting problem for the entertainment industry.
- Imagine a day when we could purchase smart meter “hack” kits from Internet vendors for $100 or less. Possibly by exploiting bugs in the exposed infrared port or mesh network protocols, this fictional tool would let users manipulate internal energy tables or send forged control messages to supported systems within a home or enterprise.
- **Potential terrorist attacks on grid**
- **Stuxnet malware attack on an Iran nuclear site**

Smart Grid and Smart Meter Cyber Vulnerability

Four Ways to Hack the Smart Grid

By Preston Gralla
Published September 01, 2009
Tags: Data Centers, Servers, More...

- Attack Smart Meter RAM
- Hack the Meter's Digital radio
- Hack the Meter Wirelessly
- Spread Malware Throughout the Network

Smart Grid Worldwide

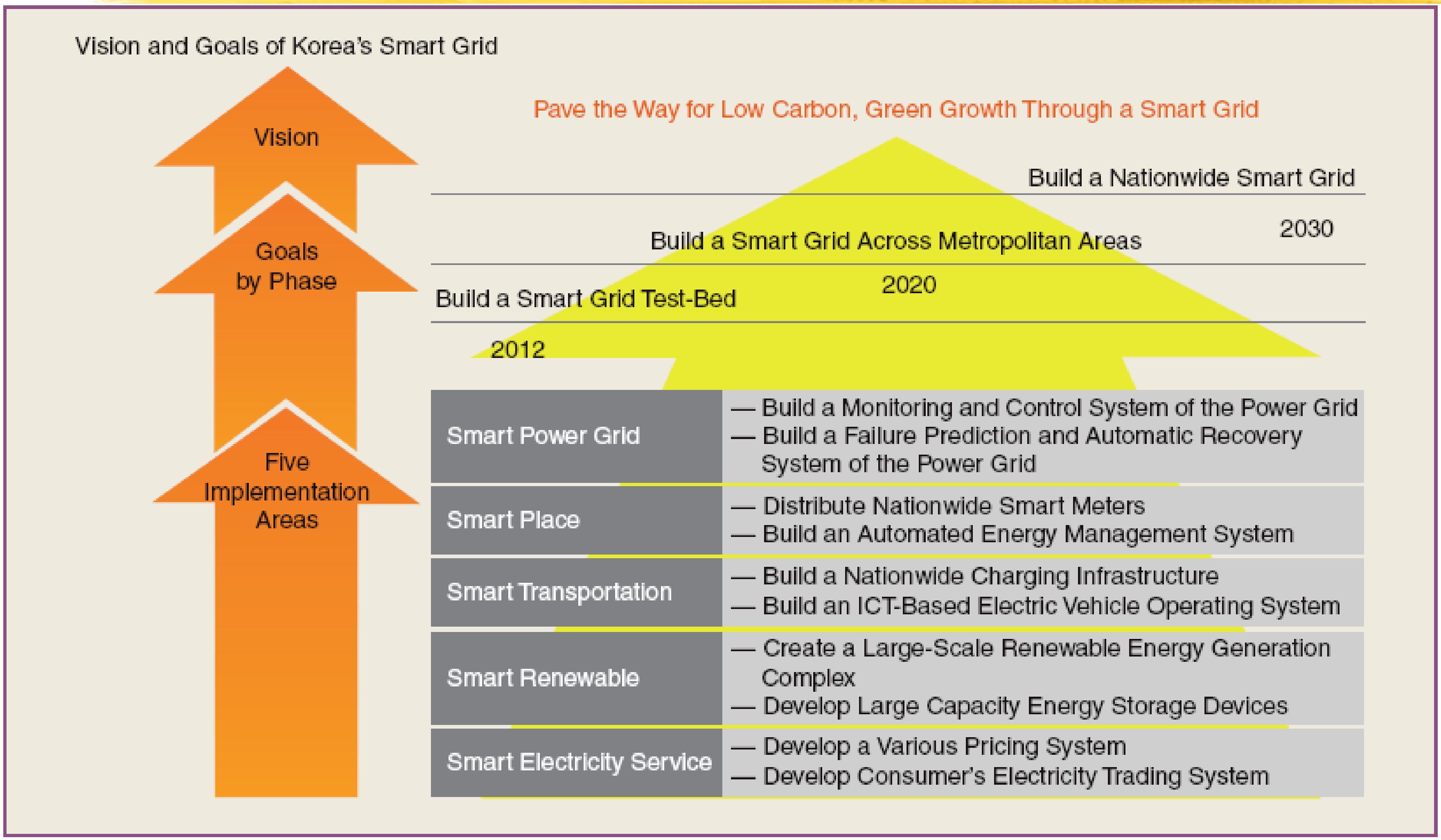
- **Worldwide Smart Grid Spending to Hit $46 Billion in 2015 – report by IDC Energy Insights**
- **SG Spending Growth: $46.4 billion in 2015, a spending increase of 17.4 percent over 2010.**
  - Asia the greatest growth by 2015, with spending increase by 33.7 %.
    - China set to spend $100 billion on smart grid infrastructure over the next five years, including the deployment of 300 million smart meters by 2015.
  - North America's next wave of spending will be on demand response technology that uses the information gathered from smart meters to automatically manage and respond to demand peaks and brings the power plants (renewable and otherwise) into the loop.
    - Hawaii Electric Co. is currently participating in a pilot program for automated demand response technology linked to a wind farm.
  - Europe is expected to increase smart grid investments as the EU's 2020 deadline approaches for a 20 % increase in renewable energy and a 20 % increase in energy efficiency.

Smart Grid in Korea

- National Vision for Low-Carbon, Green Growth – August 2008
- National Road Map for Smart Grid in Korea

Vision and Goals for Korea’s Smart Grid

- 2009 Smart Grid Road Map
  - Complete Nationwide Implementation of Smart Grid Technology by 2030

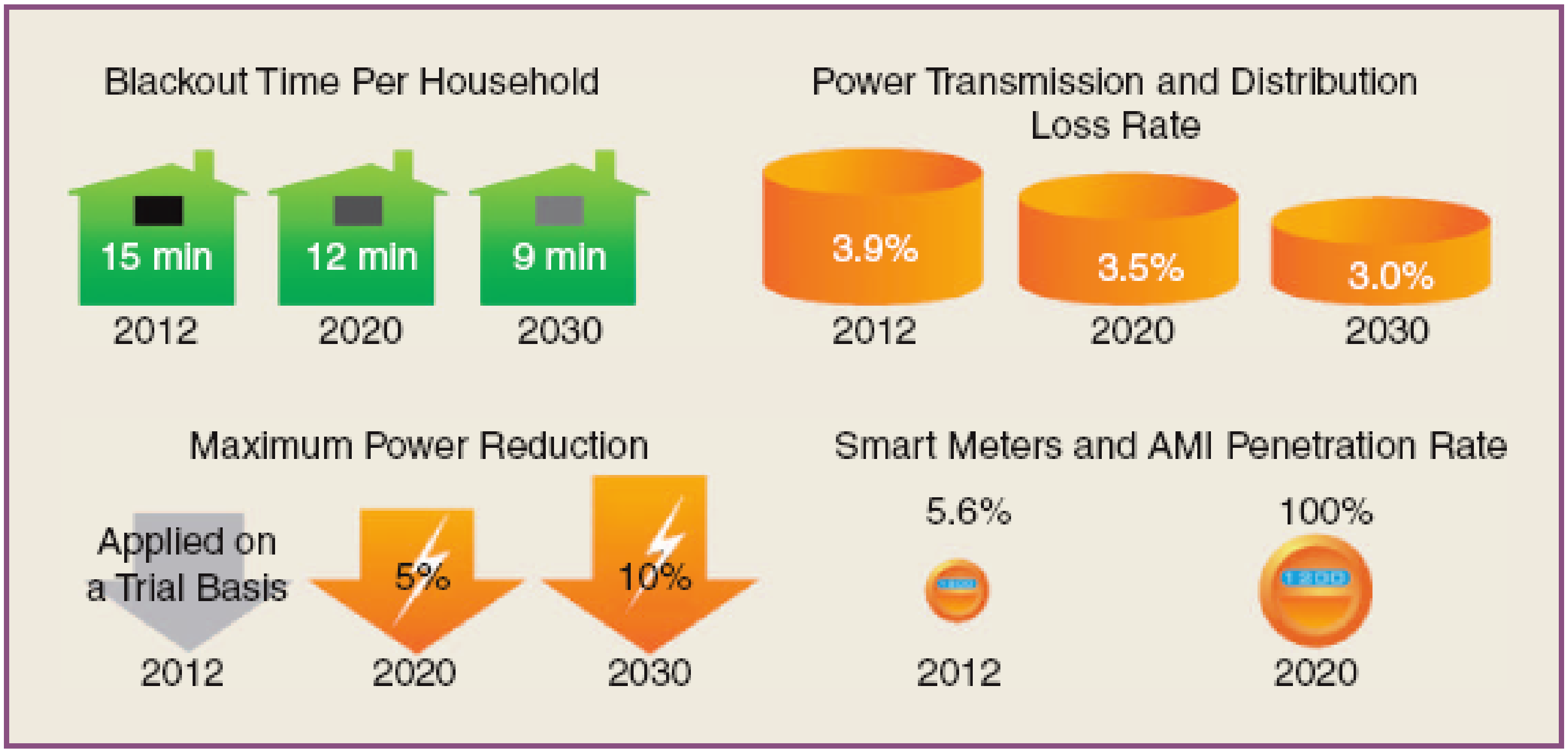


Smart Grid Implementation Plan

Implementation Directions by Phase	**First Stage (2010–2012)** Construction and operation of the smart grid test-bed (technical validation)	**Second Stage (2012–2020)** Expansion into metropolitan areas (intelligent consumers)	**Third Stage (2021–2030)** Completion of a nationwide power grid (intelligent power grid)
Smart Power Grid	—Real-time power grid monitoring —Digital power transmission —Operate optimal distribution system	—Predict possible failures in power grids —Connect the power system with that of other countries —Connect the power delivery system with distributed generation and power storage devices	—Self-recovery of power grids —Operate an integrated energy smart grid
Smart Consumer	—Power management of intelligent homes —Various choices for consumers including rates	—Smart power management of buildings/factories —Encourage consumers' power production	—Zero energy homes/ buildings
Smart Transportation	—Build and test electric vehicle charging facilities —Operate electric vehicles as a pilot project	—Expand electric vehicle charging facilities across the nation —Effective maintenance and management of electric vehicles	—Make the presence of charging facilities commonly available —Diversify charging methods —Utilize portable power storage devices
Smart Renewable	—Operate microgrids by connecting distributed generation, power storage devices and electric vehicles —Expanded utilization of power storage devices and distributed generation	—Optimal operation of the power system with microgrids —Expand the application of power storage devices	—Make renewable energy universally available
Smart Electricity Service	—Consumers' choice of electricity rates —Consumers' selling of renewable energy	—Promote transactions of electrical power derivatives —Implement real-time pricing system nationwide —Emergence of voluntary market participants	—Promote various types of electrical power transactions —Promote convergence for the market of electricity-based sectors —Lead the power market in Northeast Asia

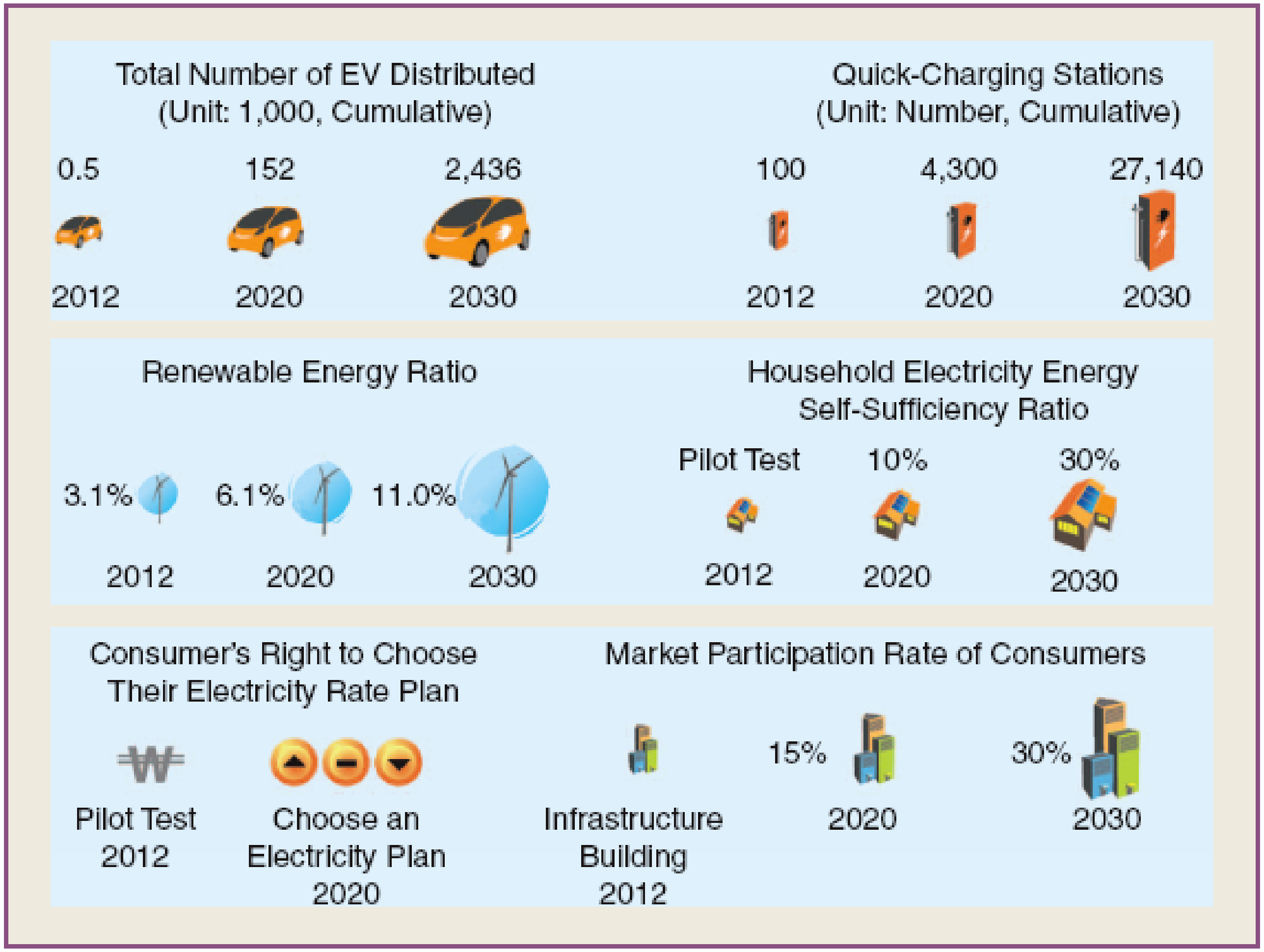
Key Targets

- Reduced outage time
- Reduced transmission and distribution losses
- Energy Saving in buildings and homes
- Smart Meter Deployment



Other Key Targets

- Smart Transportation
- Renewable Energy
- Electricity Service



Jeju Island Smart Grid Test-bed

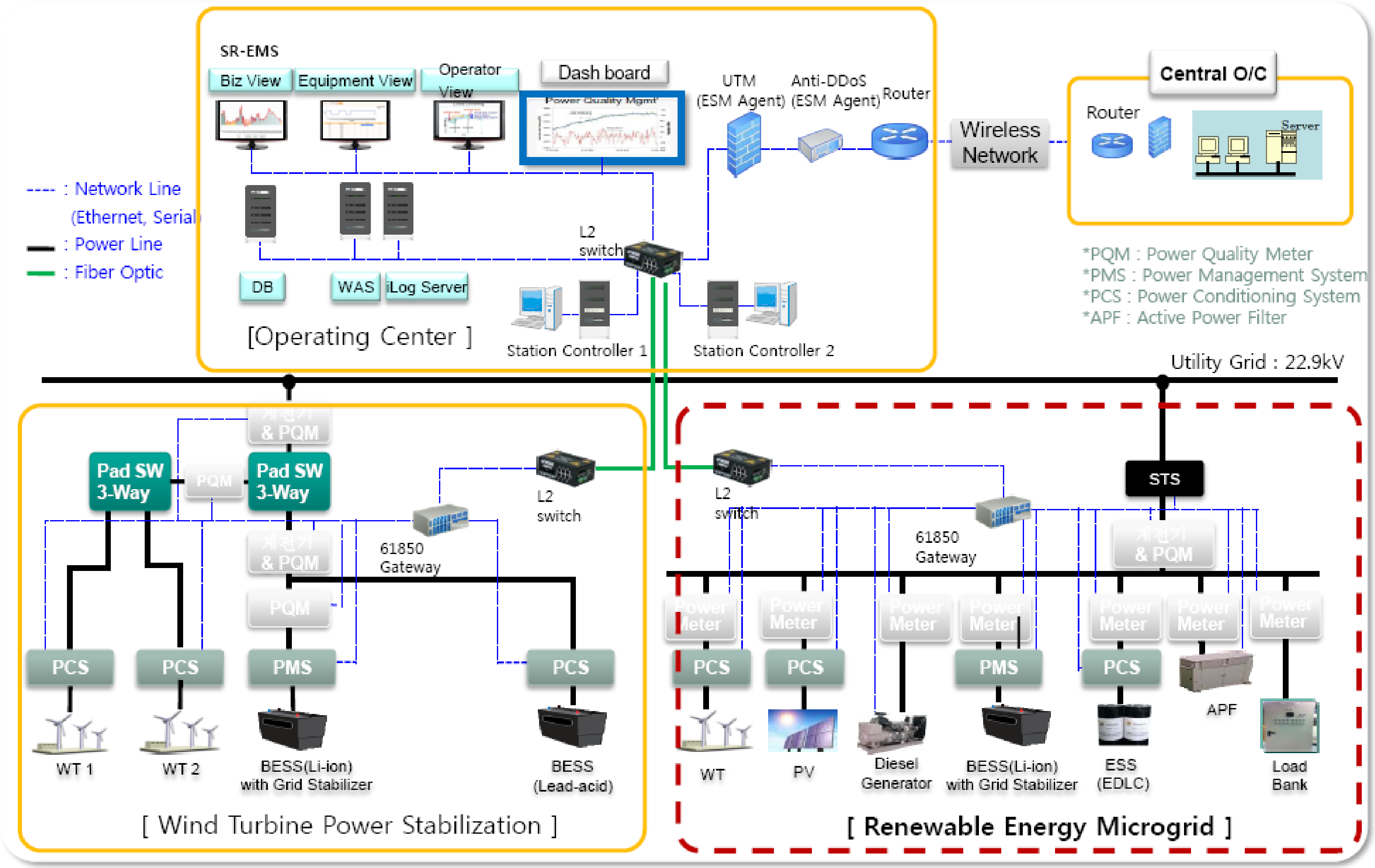
Features:

- — Integrated Test Bed
- — Close Collaboration Between Public and Private Sectors
- — Verification of Different Power Market Models
  - • Participants: Korea Electric Power Corporation(KEPCO) Plus Automakers, Telecommunications Companies and Home Appliance Manufacturers
    -Includes Major Companies Such as LG, SKT, KT, and Samsung
  - • Open to Foreign Companies

Test Bed Network Diagram

* Jeju island Smart Grid Test bed in Korea (RIST)

Global Green Growth Institute



Summary

Characteristics	Today's Grid	Smart Grid
Enables active participation by consumers	Consumers are uninformed and non-participative with power system	Informed, involved, and active consumers – demand response and distributed resources
Accommodates all generation and storage options	Dominated by central generation – many obstacles exist for distributed energy resources interconnection	Many distributed energy resources with plug-and-play convenience focus on renewables
Enables new products, services, and markets	Limited wholesale markets, not well integrated- limited opportunities for consumers	Mature, well-integrated wholesale markets, growth of new electricity markets for consumes
Provides power quality for the digital economy	Focus on outages – slow response to power quality issues	Power quality is a priority with a variety of quality/price options – rapid resolution of issues
Optimize assets and operates efficiently	Little integration of operational data with asset management – business process silos	Greatly expanded data acquisition of grid parameters – focus on prevention, minimizing impact to consumers
Anticipates and responds to system disturbances (self-heals)	Responds to prevent further damage – focus is on protecting assets following faults	Automatically detects and responds to problems – focus on prevention, minimizing impact to consumers
Operates resiliently against attack and natural disaster	Vulnerable to malicious acts of terror and natural disasters	Resilient to attack and natural disasters with rapid restoration capabilities