"Smart Grid" – An Overview

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Purpose of this Document

- The "Smart Grid" is at the center of current clean technology / alternative energy initiatives.
- This document is intended to provide readers with an overview of the concept, evolving business models, and why Smart Grid implementation will be a foundational enabler of a more Sustainable Energy approach*.
- The concepts presented are also intended to initiate stakeholder discussions on critical related issues including:
  - Technology coordination between utilities, communication service providers, energy software & hardware suppliers, and system integrators
  - Incentive design and support by policy makers to speed Smart Grid roll out
  - Standards development to ensure efficient implementation and "future proofing" of grid deployments
  - Development of content for K-12 education and community awareness programs that increase engagement of Smart Grid residential consumers
  - Program design by Higher Education institutions to prepare a workforce needed to support the Sustainable Energy industry evolution
  - Mechanisms to link investment and employment opportunities with professional talent seeking to participate in Smart Grid & Sustainable Energy initiatives.

**Visit the InvVEST website to learn more about a vision and approach to achieving a Sustainable Energy economy*

Document Contents

- Electric power supply, demand and CO_2 emissions outlook
- Rationale for a smarter grid
- The Smart Grid concept, taxonomy, and benefits
- Financing and Stimulus
- Initial investment areas for Smart Grid businesses
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The U.S. Electric Grid: Dawn of the 21st Century

- National Academy of Engineering #1 achievement of 20th century: "electrification as enabled by the grid"
  - Largest interconnected machine on earth
  - Consists of 9,200 electric generating units
  - 1,000,000 MW of generating capacity
  - 300,000 miles of transmission line
  - 99.97% reliable

But….

- Annual electric demand growth since 1982 has exceeded transmission growth by 25%
- R&D as a percentage of revenue is lower than almost any other industry
- System outages create economic costs of nearly $150B/yr
- Electricity generation is responsible for 40% of CO_2 emissions in the US
- The electric grid is tremendously inefficient capital investment, which is ultimately paid for by the rate base
  - 36% of total generation capacity (available for peak demand) provides only 4% of average system load
  - Overall grid utilization (average system output / total system capacity) is approximately 50%
- Current grid is unable to efficiently take on intermittent electric energy provided/consumed through Renewable Energy sources (eg, Wind, Solar, and Car batteries).

Source: Rebecca Johnson, University of Colorado, 2009
Department of Energy, 2008

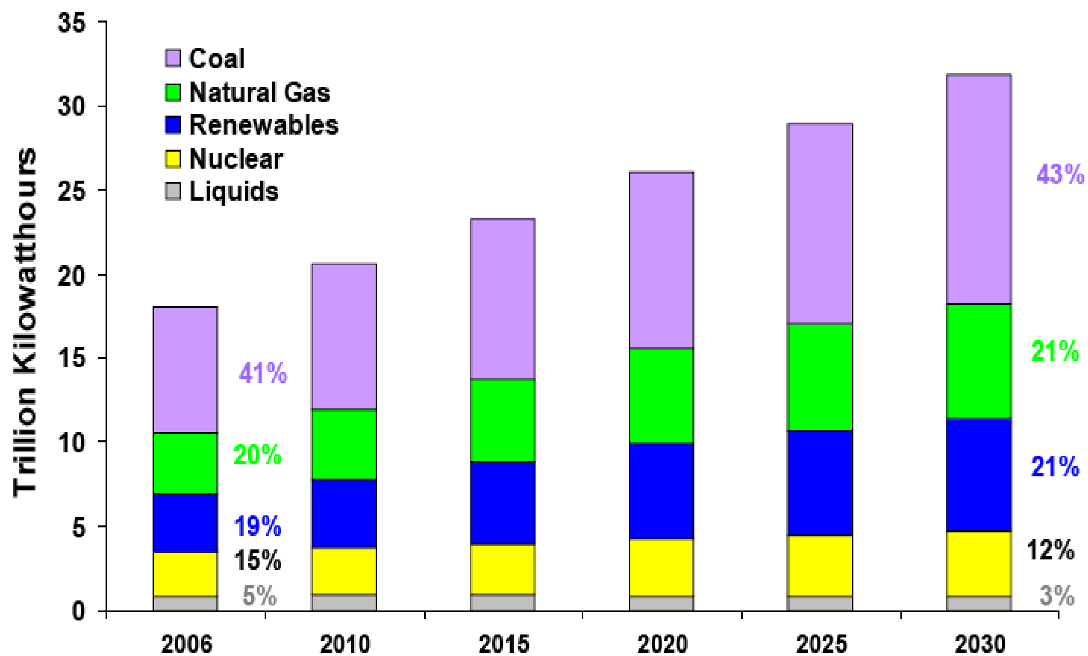
Electric Power Supply / Demand: BAU

US Fundamentals:

- International Energy Agency (IEA) projects US demand will increase by 18% over next ten years while supply increases only 6%
- Total transmission miles expected to increase only 10% during that same10 yr period
- The Brattle Group / DOE estimate a $1.5 Trillion price tag over the next two decades for electric power infrastructure upgrades
- EPRI estimates $165B in advanced (smart grid) infrastructure investment required over next 2 decades

Global Fundamentals:

- Energy Information Administration (EIA) projects renewable energy to be fastest growing energy source
- However, coal and natural gas are still projected to comprise nearly 2/3 of total energy supply



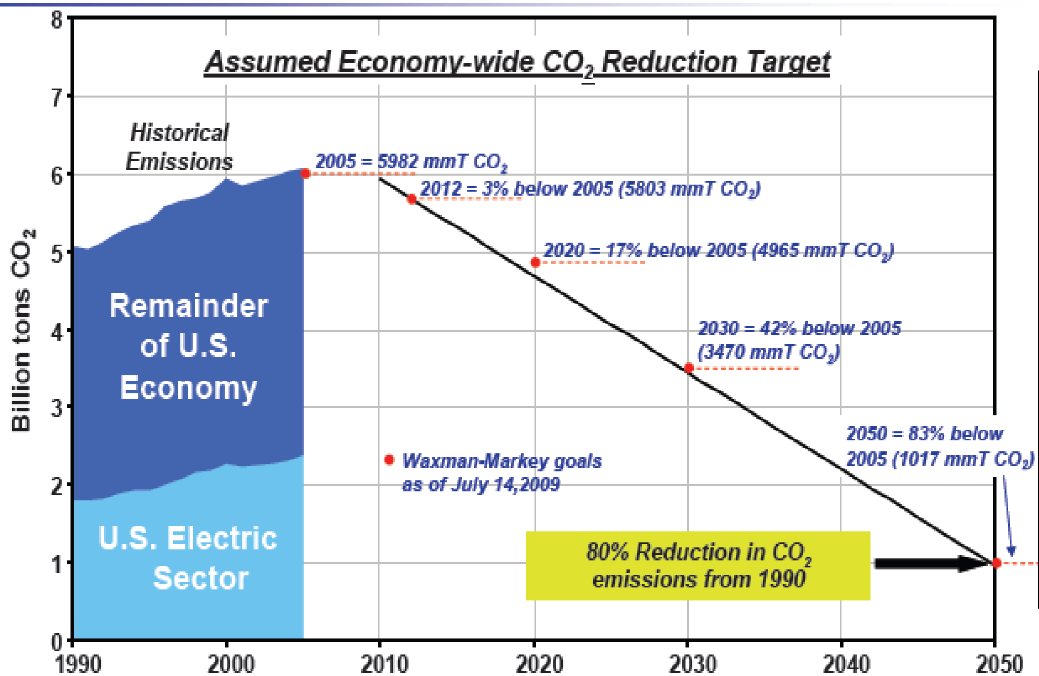
EIA Presentation, May 2009

Sources: IEA, 2009, EPRI, 2009, Energy Information Administration, 2009, DOE, 2008

The CO_2 Challenge

US Challenge to Act:

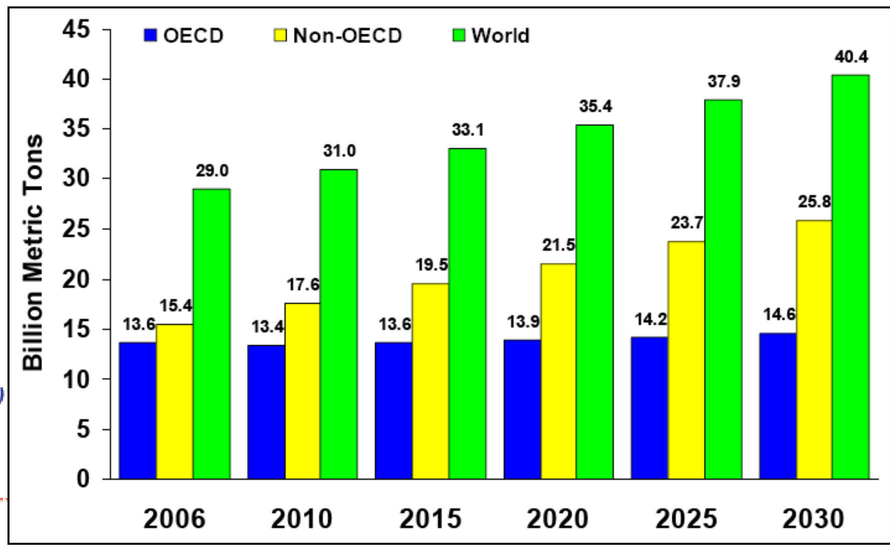
- Waxman-Markey energy and climate bill (HR 2454) proposes aggressive long term goal of 80% reduction from 2005 levels by 2050
- Renewable electricity standard of 20% targeted by 2020



Source: EPRI Presentation, August 2009

Global Reality if Non-OECD Countries don't get on board :

- Without policy changes, energy-related CO2 emissions will grow 39% worldwide between 2006-2030
- *US must take a leadership position*



Source: EIA Presentation, May 2009

Sources: EPRI and EIA, 2009; HR bill 2454

Why improve the current Grid?

- Electricity generation is the #1 source of green house gasses (GHG).
- Improved Grid management capabilities are essential to on-board an increasing supply of intermittent, renewable energy resources such as wind and solar, in line with Renewable Energy Standards designed to stabilize and ultimately reduce CO2 emissions.
- Enhanced communication and monitoring capabilities are necessary deliver real-time information about system conditions, enabling supply and demand balancing and demand response programs to avoid bringing "peaker" generation assets on-line during peak demand spikes.
- A 5% improvement in grid efficiency is equivalent to either 1) saving 41GW of power (~25 coal-fired power plants) or 2) permanently eliminating the fuel and GHG emissions from 53 million cars.
- Technologies to increase the reliability, efficiency and quality of power transmission and distribution will avoid economically disruptive system outages.
- Bi-directional communication capabilities are needed to enable utilities and consumers to more effectively and economically transact power consumption.

Source: DOE, GTM Research 7/09

Current Grid – Anything but "Smart"

- Electricity supply must match electricity demand - almost simultaneously
- Electricity suppliers have minimal ability to influence demand at any point in time
- Electricity suppliers have less-than-optimal levels of information about what is happening on their system. Leads to lower precision in operation.
- Two-way information flow between suppliers and consumers is very limited. Consumers get a bill at the end of the month, call if there is a problem with their service.
- Consumers are insulated by fixed-rate pricing structures from the volatility of electricity prices at different levels of demand
- Consumers have very little information about the environmental attributes of the energy they are consuming (ex: coal versus wind)

Source: Rebecca Johnson, University of Colorado
Department of Energy, National Energy Technology Lab
http://www.netl.doe.gov/moderngrid/opportunity/vision_characteristics.html

Smart Grid – Overview and Vision

Smart Grid will incorporate telecommunications networking, IT applications, and physical and logical metering infrastructure to increase the intelligence and flexibility of the electric power transmission and distribution grid.

- "The grid will become "smart" when the technological capabilities of the infrastructure and the data it generates are leveraged to create new applications that increase energy productivity". – Tim Healy, CEO, Enernoc 2008 Annual Report

- "The infrastructure hardware of the smart grid is undoubtedly necessary and important, but it's the intelligent software – "The Soft Grid" – that has the ability to truly revolutionize this market and provide vendors an opportunity to create defendable intellectual property and differentiation." - GTM Research, 7/09

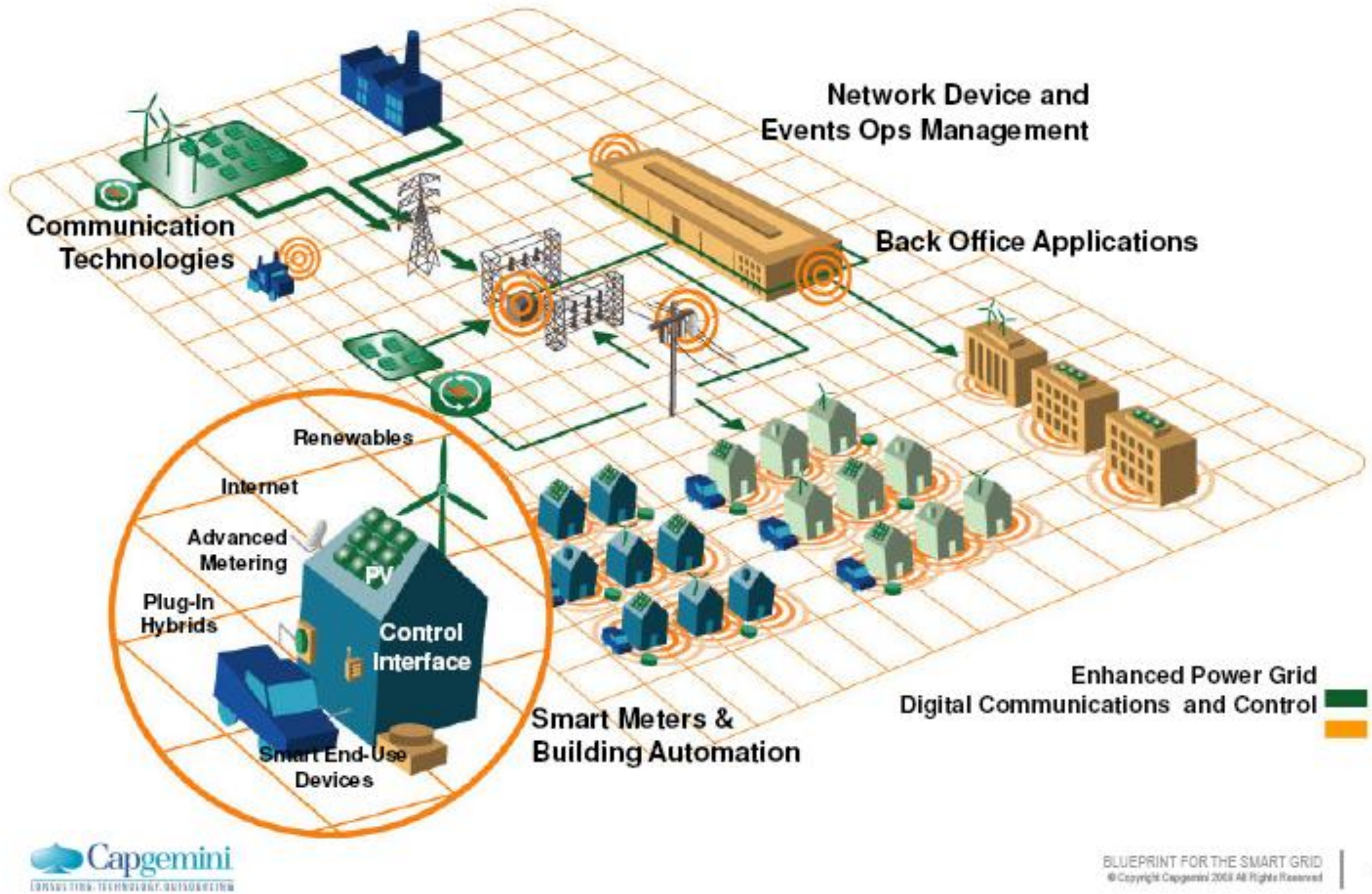
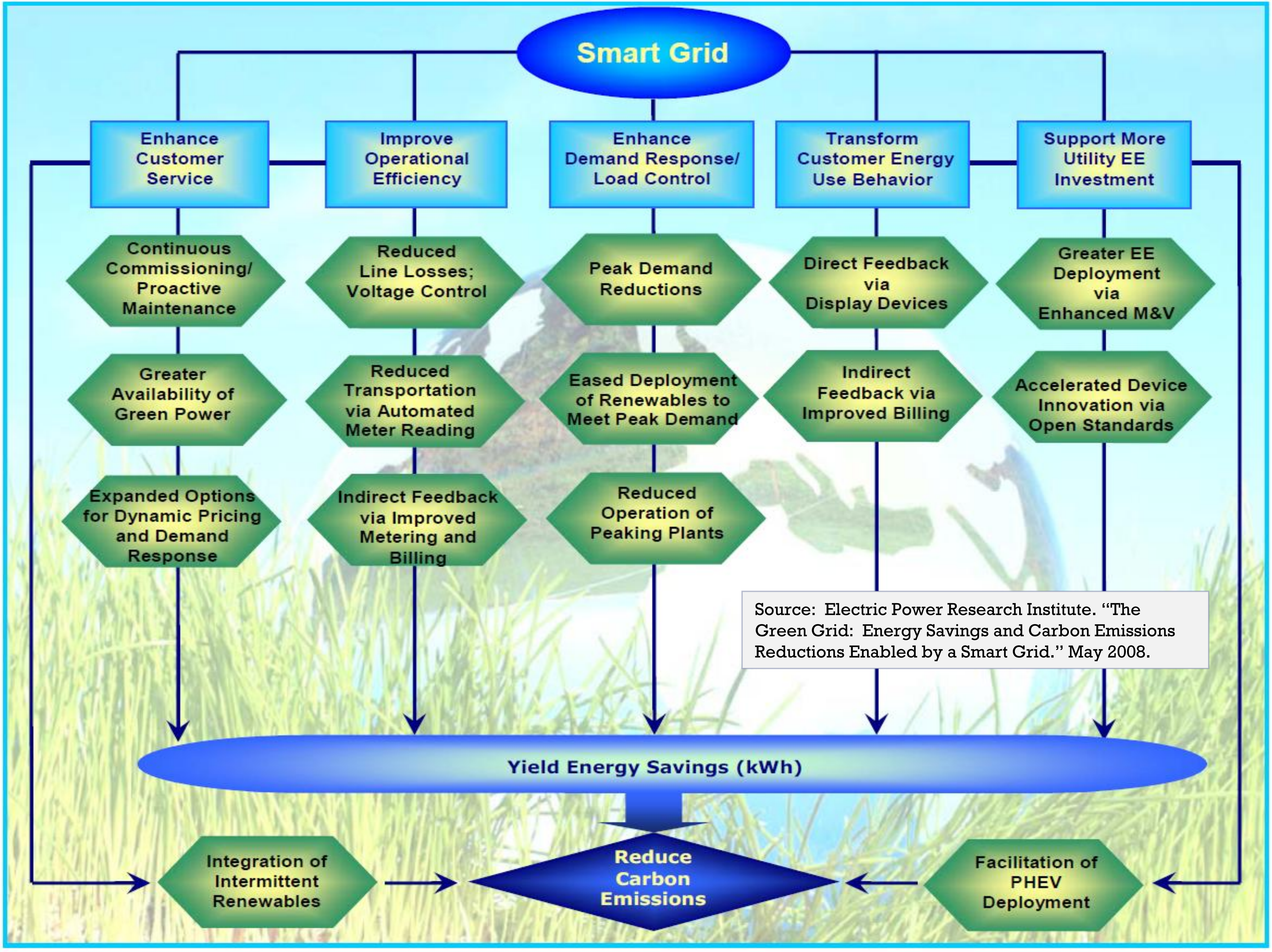


Illustration Source: CapGemini, Presentation, Aug 2009



Source: Electric Power Research Institute. "The Green Grid: Energy Savings and Carbon Emissions Reductions Enabled by a Smart Grid." May 2008.

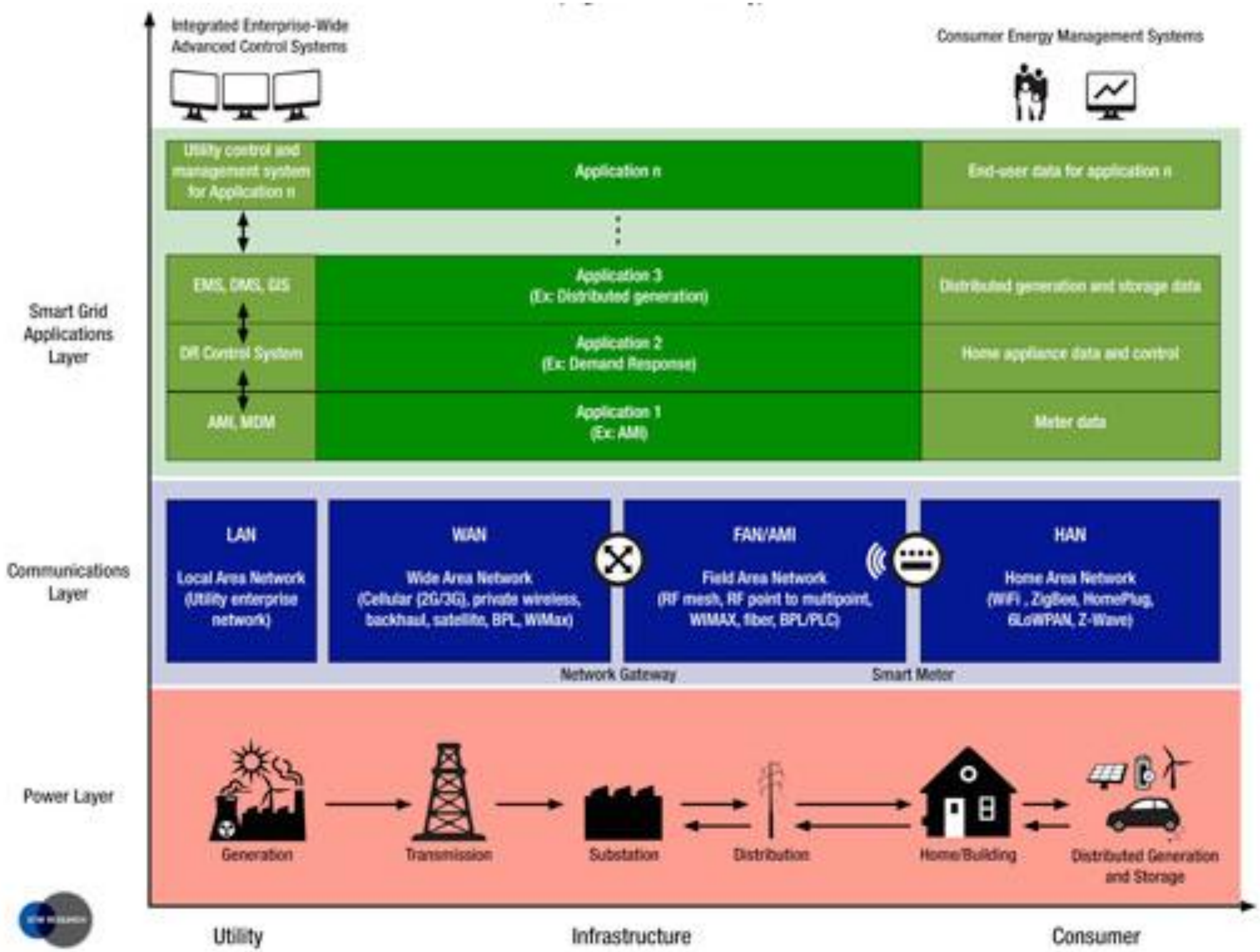
Smart Grid Benefits Matrix

Potential and Real Benefits to be Realized by Building and Implementing a Smart Grid						
Benefit	**Stakeholder**					
	Utility	**Independent Generator**	**Residential**	**Commercial**	**Industrial**	**Future Generations**
System Reliability and Economics						
Smart Grid technologies allow faster diagnosis of distribution outages and automated restoration of undamaged portions of the grid, reducing overall outage times with major economic benefits.	X		X	X	X	
Smart Grid's automated diagnostic and self-healing capability prolongs the life of the electric infrastructure.	X					X
Distributed generation is supported because the grid has the ability to dynamically manage all sources of power on the grid.	X	X	X	X	X	X
Price-sensitive peak shaving defers the need for grid expansion and retrofit.	X					
Price-sensitive peak shaving reduces the need for peaking generation capacity investments.	X		X	X	X	
Smart Grid technologies may allow better utilization of transmission paths, improving long distance energy transfers.	X	X				
Positive Environmental Impact						
Smart Grid can reduce distribution losses, thus reducing power generation demands.	X		X	X	X	X
Grid integration of high levels of renewable resources as called for in many state RPS standards will require Smart Grid to manage extensive distributed generation and storage resources.	X	X	X	X	X	X
A high penetration of PHEV will require Smart Grid to manage grid support of vehicle charging. Potential use of PHEV as Vehicle to Grid will absolutely require Smart Grid technologies.	X		X			X
A Smart Grid enables intelligent appliances to provide feedback through the system, sense grid stress, and reduce their power use during peak demand periods.	X		X			
Advanced metering technology can be used to help measure electricity use and calculate the resulting carbon footprint.			X	X	X	X
Increased efficiency of power delivery						
Direct operating costs are reduced through the use of advanced metering technology (AMR/AMI) such as connects/disconnects, vehicle fleet operations and maintenance, meter reads, employee insurance compensation insurance, etc.	X					
Smart Grid technologies, such as synchrophasors, offer the promise of reducing transmission congestion.	X	X	X	X	X	
Economic Development						
Standards and protocols supporting interoperability will promote product innovation and business opportunities that support the Smart Grid concept.	X	X	X	X	X	X
Consumer Choice						
Provide consumers with information on their electric usage so they can make smart energy choices.			X	X	X	X
Real-time pricing offers consumers a "choice" of cost and convenience trade-offs that are superior to hierarchical demand management programs.			X	X	X	
Integration of building automation systems offers efficiency gains, grid expansion deferral, and peak shaving.	X			X		

Source: Table created for *Smart Grid: Enabler of the New Energy Economy* by EAC Smart Grid Subcommittee 2008

 Source: Electric Advisory Committee 12/08

Smart Grid Taxonomy



The Smart Grid can be compared to the physical and logical network layers that comprise the Internet:

- **Physical Layer** - consists of many enabling technologies including advanced distribution and transmission hardware, and advanced meter infrastructure (AMI)
- **Communications Layer** - built of wireless and wired communications systems and protocols.
- **Applications Layer -** Supported by the communications layer - - software applications will improve the generation, distribution, consumption, and monitoring of the Grid.

Source: GTM Research 7/09

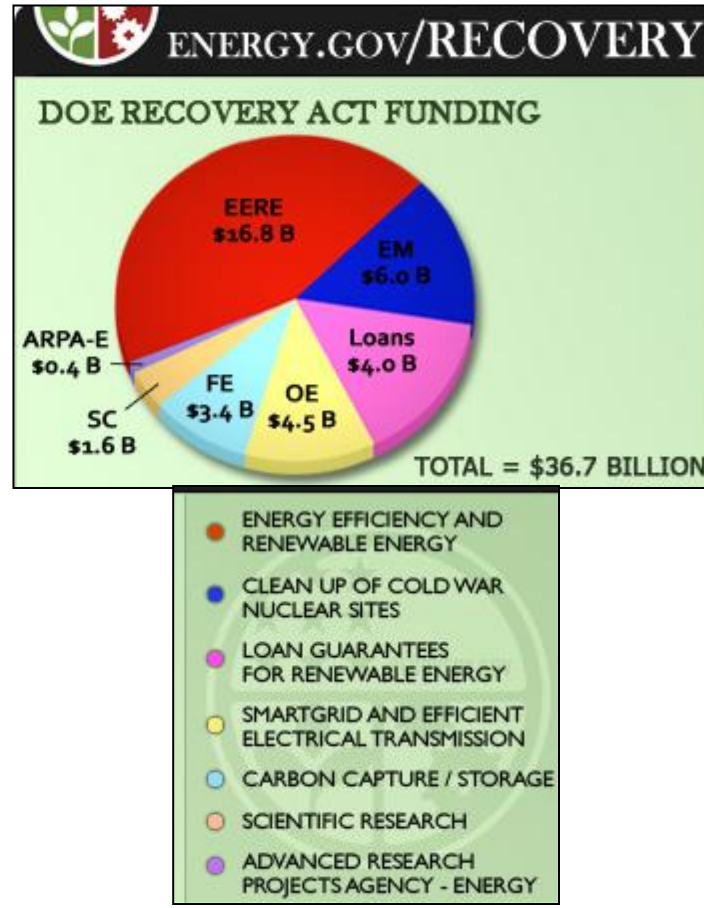
Sector Investment and Stimulus

The American Recovery and Reinvestment Act of 2009 has allocated $4.5B for Smart Grid and transmission efficiency projects.

- Eligible project categories include:
  - Transmission interconnection planning & analysis
  - Interoperability standards and framework
  - Smart Grid investment grant program
  - Energy storage demonstration project

- As many of the grants will be awarded in the form of 50/50 matching grants, the resulting direct investment in Smart Grid over the next three-year period will be approximately $7 to $8 billion, and may very well exceed $10 billion - a major boost for this industry during an economic downturn.

- Venture capital represents a material financing source as a number of funds have been established for clean tech. Roughly $1.3B in VC funding has already been deployed into Smart Grid technology during the period from 2005 thru 1H 2009.



Sources: GTM Research 7/09; DOE, 9/09

Initial Smart Grid Investment Areas:
Communication and Physical Layers

- **Advance Meter Infrastructure (AMI)** – Top 15 planned AMI projects will yield over 41 million meter installations by 2015, at an investment cost approaching $10 Billion.

- The **intelligent Field Area Network (FAN),** a smarter distribution network for a given utility, will require the deployment of communications technologies currently centering on several protocols (eg, 4G WiMax, 3G cellular, RF mesh) to transport AMI data.

- **Meter data management (MDM)** applications will to evolve to analyze the data from AMI-enabled networks.

- **Software and signaling technologies** will enable new pricing models by which utilities earn other sources of revenue, and consumers are incented to cede some control of their own consumption. Specifically, Time of Use (TOU) pricing schema will need to be deployed and begin to replace single, fixed-rate retail pricing.

Initial Smart Grid Investment Areas:
Application Layers and Storage

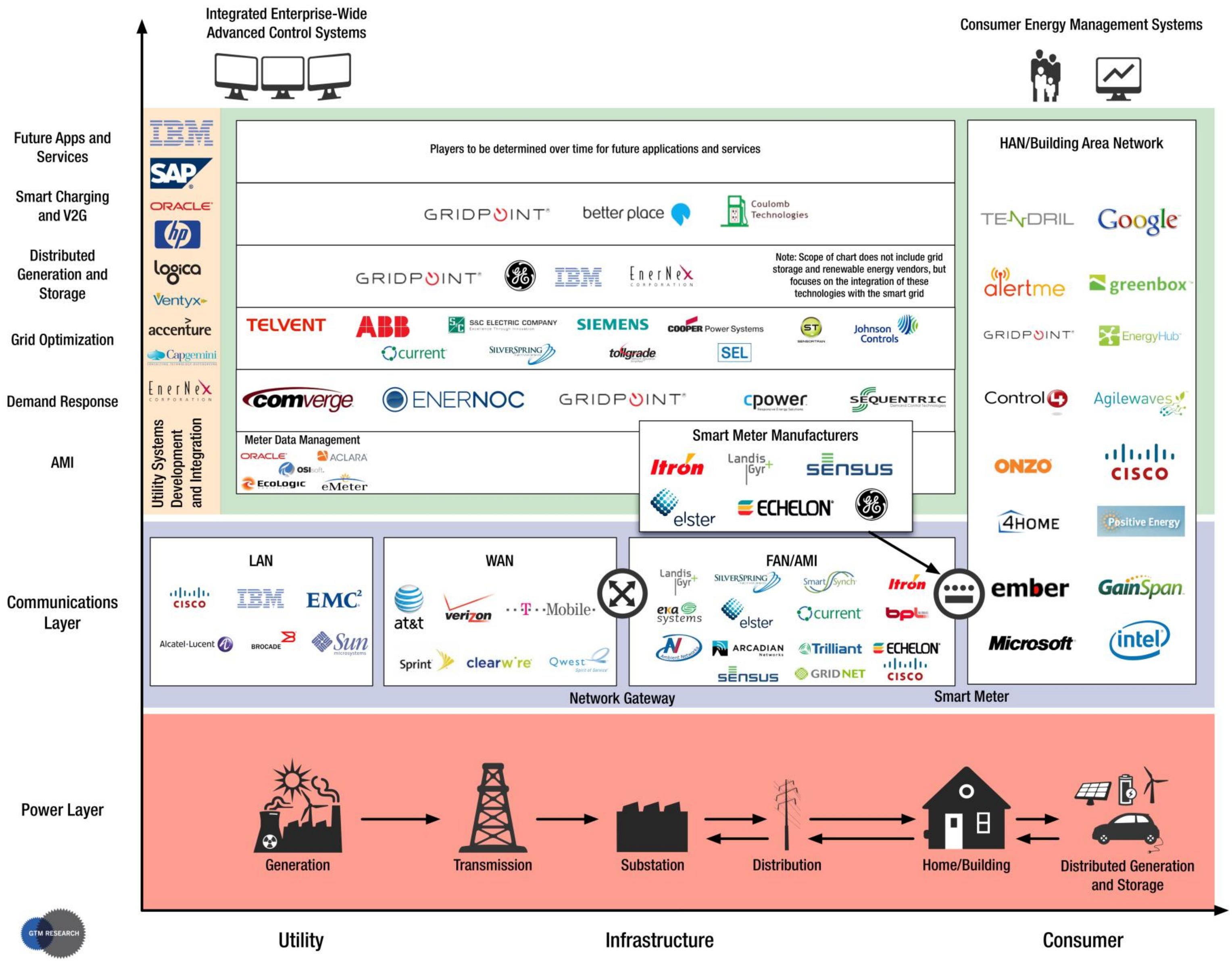
- **Demand Response (DR)** service providers are enabling power management and efficiency solutions for residential, commercial, and industrial consumers and the utilities that serve them. DR firms have successfully aggregated multiple GigaWatts of consumer commitments to reduce demand during peak events. This "virtual peak power" enables utilities to avoid activating gas-fired peaking plants during 1) demand spikes and 2) sudden declines in renewable energy generation output (eg, wind speeds slow down).

- **Home Area Networks (HAN)** will require new communication technologies and machine integration to interconnect home appliances and infrastructure to the Smart Grid.

- **PHEV** adoption will result in development of "smart charging" capabilities to manage potential demand spikes before more complex Vehicle To Grid (V2G) technologies are deployed.

- Initially, **energy storage** systems will be focused on making smaller-scale distributed power a feasible alternative to large, centralized power stations.

Smart Grid Companies / Players



InvVEST (www.InvVEST.org)

Source: GTM Research 7/09

Implementation Challenges:
Policies and Management of Infrastructure Deployment

The Smart Grid will be comprised of many "moving parts". Federal and state policies to govern, along with incentives to accelerate successful national-scale deployment, will be essential. Professional program management of individual projects comprised of multiple stakeholders will also be critical.

- New and upgraded transmission interconnects and corridors must be built to connect new, centralized, renewable generation facilities (eg, utility-scale wind and solar projects) to the grid. The Federal Energy Regulatory Commission (FERC) , along with Independent System Operators (ISO's) and individual utilities must play a role in ensuring a coordinated and prioritized outcome to on-ramp zero carbon generation that enables states to achieve Renewable Portfolio Standards.
- Distributed generation assets deployed at residences and industrial facilities (eg, PV arrays) will accelerate with continued clarity around investment tax credits, and will need to be effectively interconnected to the grid.
- While the ARRA provides for $3.9B in Grid-related Stimulus, ~$25B in grant requests have already be submitted over ~430 projects (6.4x oversubscribed). Additional Federal stimulus and incentive grants should to be made available to support continued innovation needed to fuel the estimated $150-200B investment to build the smart grid.
- Many, if not all, of the AMI deployment and smart grid demonstration projects underway involve the sponsoring utility working with multiple technology providers. Competent Program Management and System Integration professionals should be engaged to ensure efficient and effective project delivery.

Source: Subject matter expert interviews, 9/09

Implementation Challenges:
Standards and Interoperability

Given the spectrum of technology, utility, and regulatory stakeholders across the electric power delivery chain, clear and coordinated standards and policies must be rapidly developed to enable Smart Grid implementation and adoption.

- National Institute of Standards and Technology (NIST) charged with identifying and evaluating existing standards, measurements and technologies as well required standardization to support Smart Grid adoption.
- GridWise Architecture Council (supported by DOE) represents utility and tech stakeholders to develop an interoperability framework spanning the electricity delivery chain.
- American National Standards Institute (ANSI), Institute of Electrical and Electronics Engineers (IEEE) and the Zigbee Alliance driving standards to accept innovation across the physical, application, and communication layers of the grid.
- The Federal Energy Regulatory Commission (FERC) must adopt interoperability standards and protocols necessary to ensure smart-grid functionality and interoperability in the interstate transmission of electric power and in regional and wholesale electricity markets.

Source: DOE, FERC, 2009

Implementation Challenges:
Consumer Education / Adoption

To ensure broad-based support, consumers require education about the intent, strategy and benefits of the Smart Grid. As the primary customer-facing service provider, electric utilities have a significant marketing and educational challenge.

- Consumers asked to participate in pilot / demonstration projects often don't understand the benefits yet feel may feel as though Utility "Big Brother" is seeking to control their homes to increase revenues.
- More flexible, variable rate plans should emerge with the advent of the AMI- and HAN-enabled Smart Grid. These plans enable customers to better manage the economics of their consumption, and represent a critical incentive for participation. To date, utilities have been slow to file new tariff structures with the PUC's.
- Managing customer expectations about changing billing components is critical to understanding, support, and adoption.
- Within city-scale demonstration projects, usage portals with analytical models pertinent to consumers need to be trialed in parallel with the operational efficiency technologies that create cost savings for the utilities. Benefit measurement for the customer is essential to achieve their support for Smart Grid programs.

Source: Subject matter expert interview, 9/09

Selected Issues for Continued Discussion

Policies and Management of Infrastructure Deployment

- What are the best approaches by which utilities, IPP's, developers, and regulatory agencies can prioritize transmission interconnects necessary to scale renewable energy generation ? Advances in policy development , quantitative modeling and strategic analysis are all required.
- How should utilities plan for increasing amounts of distributed generation in terms of decreased demand on centralized generation, and the ability to supply power to the grid? Policy makers should consider incentive structures to accelerate consumer investment. Technologists need to create and segment value propositions for this emerging market.
- Given project complexity and cross-firm involvement, how can project management and system integration expertise best be deployed (eg, full-time vs. contract) and empowered to ensure project delivery?

Standards and Interoperability

- What are the pros and cons of various communications protocols link the HAN and the FAN (eg, RF, cellular, wi-max, broadband power line, over the top of existing internet connectivity)? Does it make sense for utilities to secure dedicated wireless spectrum?

Consumer Marketing and Education

- How can utilities do a better job of marketing and educating consumers to more rapidly roll-out Smart Grid and DR programs? Mechanisms (eg, web portals) to increase visibility and smart grid benefits are essential to building consumer goodwill and should be part of the Phase 1 of demonstration projects -- not Phase 3, 4, etc.
- How can utilities accelerate the development of variable rate plans that leverage the intelligence of the AMI and HAN infrastructure, while incenting consumers to more rapidly adopt Smart Grid?

**Visit the collaboration section of the InvVEST website to follow and contribute continued commentary…*

References / Resources for this Document

- Green Tech Media - Smart Grid Taxonomy: http://www.gtmresearch.com/report/smart-grid-in-2010
- DOE Smart Grid Vision / Economic Benefits: http://www.oe.energy.gov/SmartGridIntroduction.htm
- Electricity Advisory Committee report: http://www.oe.energy.gov/eac.htm
- Energy Information Administration: http://www.eia.doe.gov/
- Electric Power Research Institute: http://my.epri.com
- Federal Energy Regulatory Commission: http://www.ferc.gov/industries/electric/indus-act/smart-grid.asp
- American Clean Energy and Security Act, ACES, H.R. 2454: http://www.grist.org/article/2009-06-03-waxman-markey-bill-breakdown/

Learn More

- DOE Office of Electricity Delivery and Energy Reliability: http://www.oe.energy.gov/eac.htm
- NIST and the Smart Grid: http://www.nist.gov/smartgrid/
- Gridwise Alliance Resources: http://www.gridwise.org/resources_gwaresources.asp
- KEMA: http://www.kema.com/services/consulting/utility-future/Default.aspx
- News Journals covering Smart Grid Industry and Company developments
  - GreenTech Media: http://www.greentechmedia.com/articles/category/smart-grid/
  - Smart Grid News: http://www.smartgridnews.com/
- Colorado Smart Grid Demonstration Projects
  - SmartGrid City, Boulder, CO: http://smartgridcity.xcelenergy.com
  - FortZED, Fort Collins, CO: http://fortzed.com
- InvVEST: www.InvVEST.org