Smart Grids:

Impacts for the Rural Electric System

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MREC Midwest Rural Energy Council

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TECHNOLOGICAL LEADERSHIP INSTITUTE
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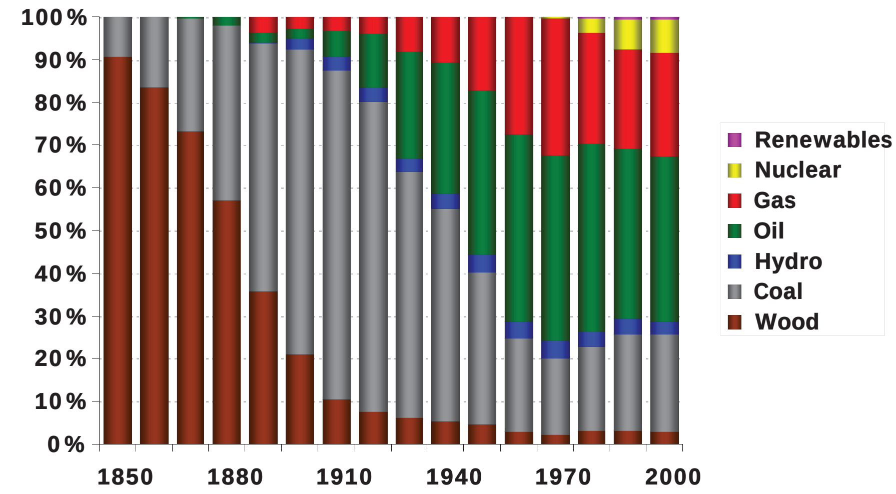
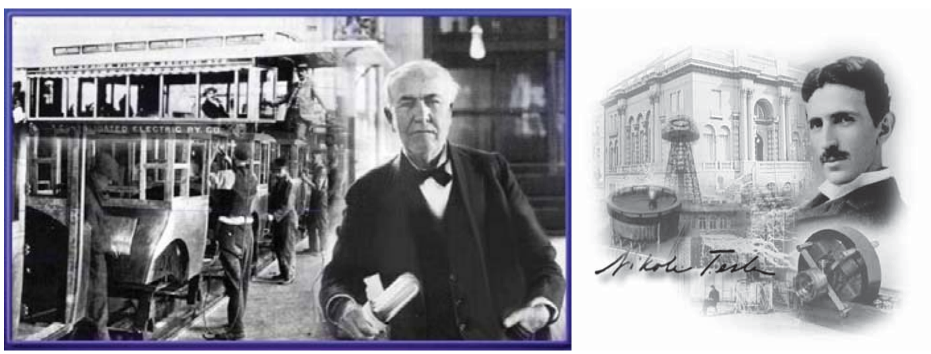
* Support from EPRI, NSF, ORNL, Honeywell and SNL is gratefully acknowledged.

Context: US Energy Supply Since 1850



Author: Koonin Source: EIA

Transforming Society



The vast networks of electrification are the greatest engineering achievement of the 20th century
– U.S. National Academy of Engineering

Power Grids Have Come Full Circle…

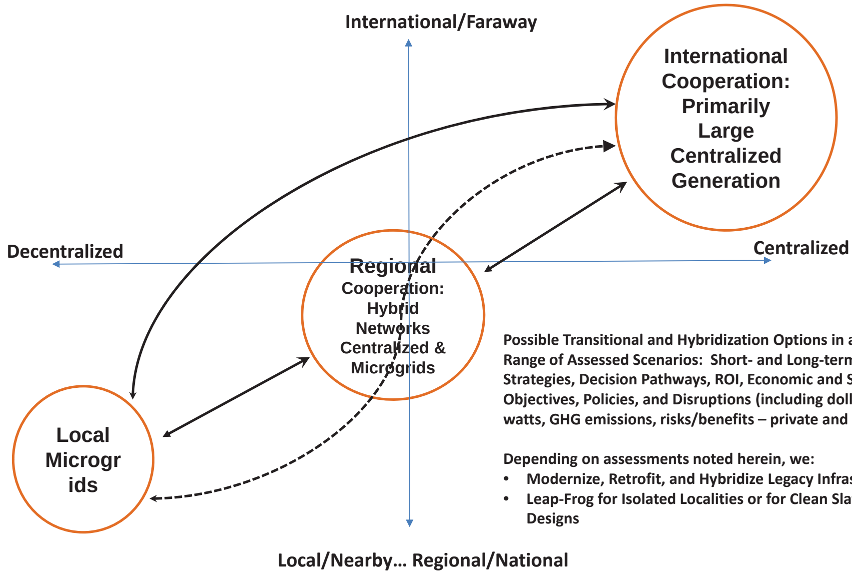
- DC systems
- Mini grids (AC)
- Single Transmission Grid (HVAC)
- HVDC
- Island-able smart grids (microgrids)

Historically, grids developed as isolated systems that were managed and controlled locally

These too could be viewed as microgrids

Present day changes are made possible –

- Changing economics
- Dynamic Geopolitics
- Improved Power electronics
- Better information & communication technology
- Mature renewable energy technologies…



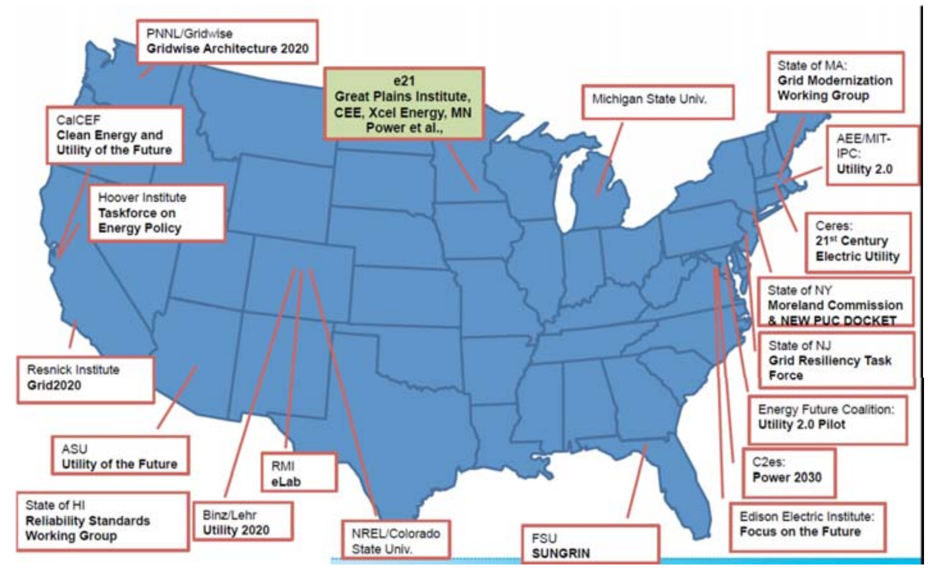
Possible Transitional and Hybridization Options in a Wide Range of Assessed Scenarios: Short- and Long-term Strategies, Decision Pathways, ROI, Economic and Societal Objectives, Policies, and Disruptions (including dollars, watts, GHG emissions, risks/benefits – private and public)

Depending on assessments noted herein, we:

- Modernize, Retrofit, and Hybridize Legacy Infrastructure
- Leap-Frog for Isolated Localities or for Clean Slate Designs

U.S. Regulatory Reform and Utility 2.0 Efforts

(source: The Energy Foundation)

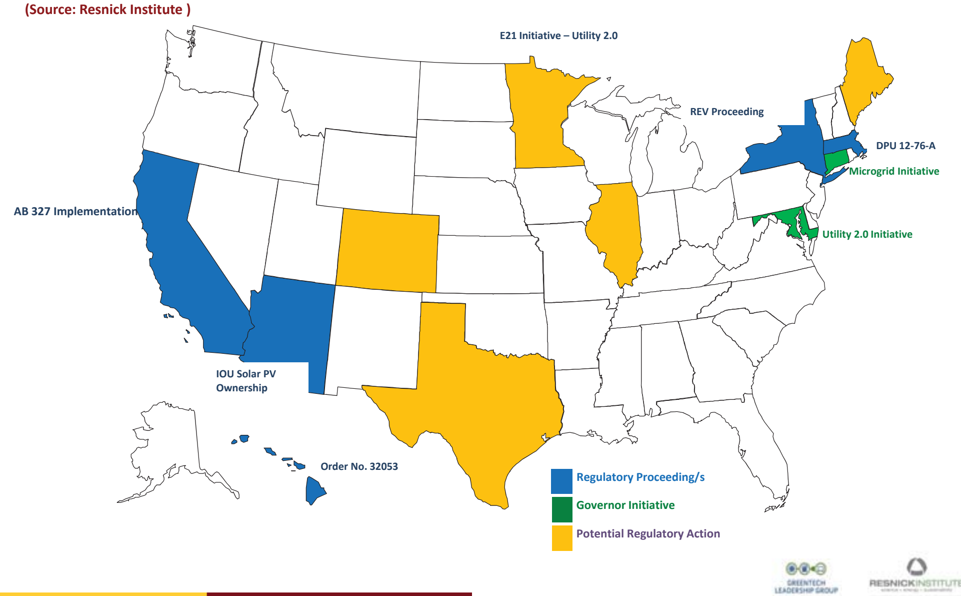


Utility of the Future: Initiative Status

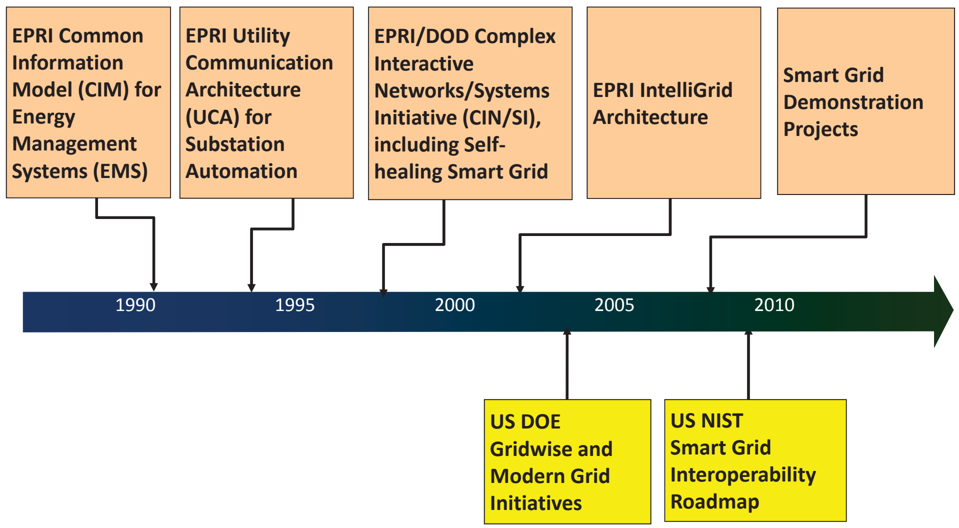
Utility	Scope of the Utility of the Future Initiative
Ameren	Initial exploration/learning
Duquesne	Assessment & planning
Duke	Assessment & technology testing
Xcel	Policy engagement
Portland General Electric	Differentiated customer services re: BUGs
Madison Gas & Electric	Various differentiated customer services
Puget Sound	Grid storage
Dominion	Advanced grid modernization
National Grid	NY REV scope
ConEdison	NY REV scope
Iberdrola-US	NY REV scope
Other NY utilities	NY REV scope
OG&E	Customer services and DR as a resource
NV Energy	Customer services and DR as a resource
PG&E	Range of CA activity related to grid modernization, DER integration and use as resource
SDG&E	Range of CA activity related to grid modernization, DER integration and use as resource
SCE	Range of CA activity related to grid modernization, DER integration and use as resource
APS	Utility investment in rooftop solar PV for customers
Tucson Electric	Utility investment in rooftop solar PV for customers
Centerpoint	Various customer market facilitation services - shopping portal
HECO	Range of HI activity related to grid modernization, DER integration and use as resource
Southern	Just started

Evolving smart grid policies in key states in the U.S., including NY and CA's DR Planning proceedings. TX and HI are also bellwether states in terms of evolving policies

(Source: Resnick Institute)



Evolution of Smart Grid Programs at DOE and EPRI



The Smart Grid: 17 Years in the Making

- Self-Healing Grid (May 1998- Dec. 2002)
  - 1998-2002: EPRI/DOD Complex Interactive Networks/Systems Initiative (CIN/SI):
  - 108 professors and over 240 graduate students in 28 U.S. universities funded, including Carnegie Mellon, Minnesota, Illinois, Arizona St., Iowa St., Purdue, Harvard, MIT, Cornell, UC-Berkeley, Wisconsin, RPI, UTAM, Cal Tech, UCLA, and Stanford.
  - 52 utilities and ISO (including TVA, ComEd/Exelon, CA-ISO, ISO-NE, etc..) provided feedback; 24 resultant technologies extracted.
- Intelligrid (2001-present): EPRI trademarked
- Smart Grid: Final name adopted at EPRI and DOE

Definition: Smart Self-Healing Grid

Source: Massoud Amin, "Toward a Secure and Smart Self-Healing Grid," presentation to the Strategic Science & Technology EPRI Research Advisory Committee (RAC), Tuesday, January 27, 1998 page 5 at http://massoud-amin.umn.edu/presentations/CINSI_01-27-1998_RAC.pdf

- What is a Smart Self-healing grid?

  The term "smart grid" refers to the use of computer, communication, sensing and control technology which operates in parallel with an electric power grid for the purpose of enhancing the reliability of electric power delivery, minimizing the cost of electric energy to consumers, and facilitating the interconnection of new generating sources to the grid.

- What are the power grid's emerging issues? They include
  1) integration and management of DER, renewable resources, and "microgrids";
  2) use and management of the integrated infrastructure with an overlaid sensor network, secure communications and intelligent software agents;
  3) active-control of high-voltage devices;
  4) developing new business strategies for a deregulated energy market; and
  5) ensuring system stability, reliability, robustness, security and efficiency in a competitive marketplace and carbon constrained world.

Definition: Smart Self-Healing Grid

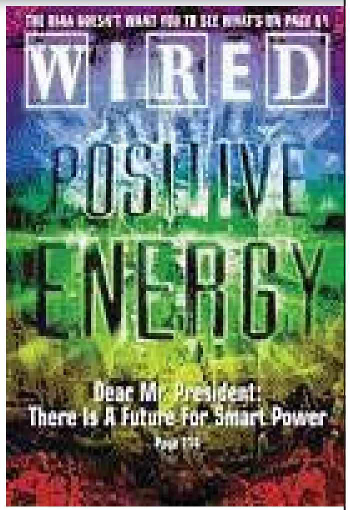
Source: Massoud Amin, "Toward a Secure and Smart Self-Healing Grid," presentation to the Strategic Science & Technology EPRI Research Advisory Committee (RAC), Tuesday, January 27, 1998 page 6 at http://massoud-amin.umn.edu/presentations/CINSI_01-27-1998_RAC.pdf

- What is "self healing"?
  - A system that uses information, sensing, control and communication technologies to allow it to deal with unforeseen events and minimize their adverse impact
- Why is self healing concept important to the Electric Power Grid and Energy Infrastructure?
  - A secure "architected" sensing, communications, automation (control), and energy overlaid infrastructure as an integrated, reconfigurable, and electronically controlled system that will offer unprecedented flexibility and functionality, and improve system availability, security, quality, resilience and robustness.

“… not to sell light bulbs, but to create a network of technologies and services that provide illumination…”

Smart Grid… “The best minds in electricity R&D have a plan: *Every node in the power network of the future will be awake, responsive, adaptive, price-smart, eco-sensitive, real-time, flexible, humming - and interconnected with everything else.”*

-- **The Energy Web,** Wired Magazine, July 2001
http://www.wired.com/wired/archive/9.07/juice.html



Energy Independence and Security Act

- Passed by U.S. Congress in 2007.
- “It is the policy of the United States to support the modernization of the Nation's electricity transmission and distribution system … that can meet future demand growth and to achieve each of the following, which together characterize a Smart Grid:
  1. Increased use of **digital information and controls technology to improve reliability, security, and efficiency of the electric grid**.
  2. **Dynamic optimization of grid operations and resources, with full cyber-security…”**

Smart Grid Definitions

FERC: “Grid advancements will apply digital technologies to the grid and enable real-time coordination of information from both generating plants and demand-side resources.”

DOE: “A smarter grid applies technologies, tools, and techniques available now to bring knowledge to power – knowledge capable of making the grid work far more efficiently…”

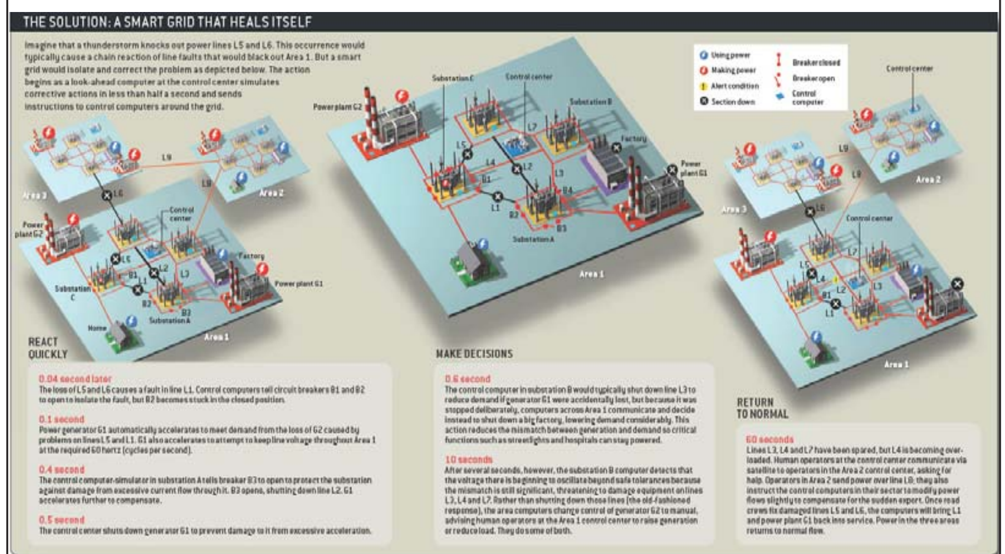
GE: “The Smart Grid is in essence the marriage of information technology and process-automation technology with our existing electrical networks.”

IEEE: “The term ‘Smart Grid’ represents a vision for a digital upgrade of distribution and transmission grids both to optimize current operations and to open up new markets for alternative energy production.”

Wikipedia: “A Smart Grid delivers electricity from suppliers to consumers using digital technology to save energy, reduce cost, and increase reliability.”

Functionality Common themes:	*Technology*	*Reliability*	*Efficiency*
	Two-way communication	*Interconnectivity*	*Demand response*
	Advanced sensors	*Renewable integration*	*Consumer savings*
	Distributed computing	*Distributed generation*	*Reduced emissions*

Smart Self-Healing Grid

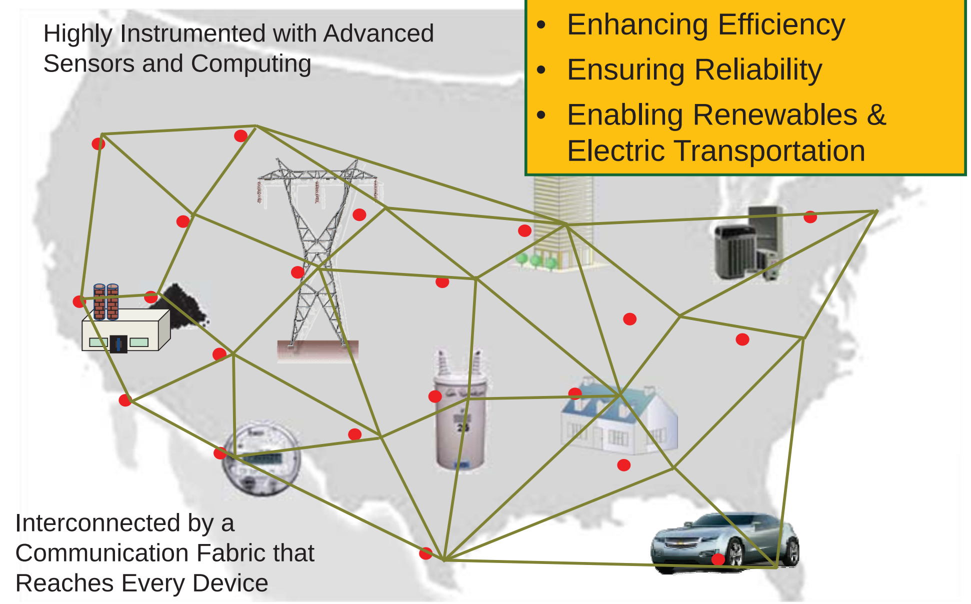


M. Amin and P. Schewe, “Preventing Blackouts,” Scientific American, May 2007

Smart Grid

- Engaging Consumers
- Enhancing Efficiency
- Ensuring Reliability
- Enabling Renewables & Electric Transportation

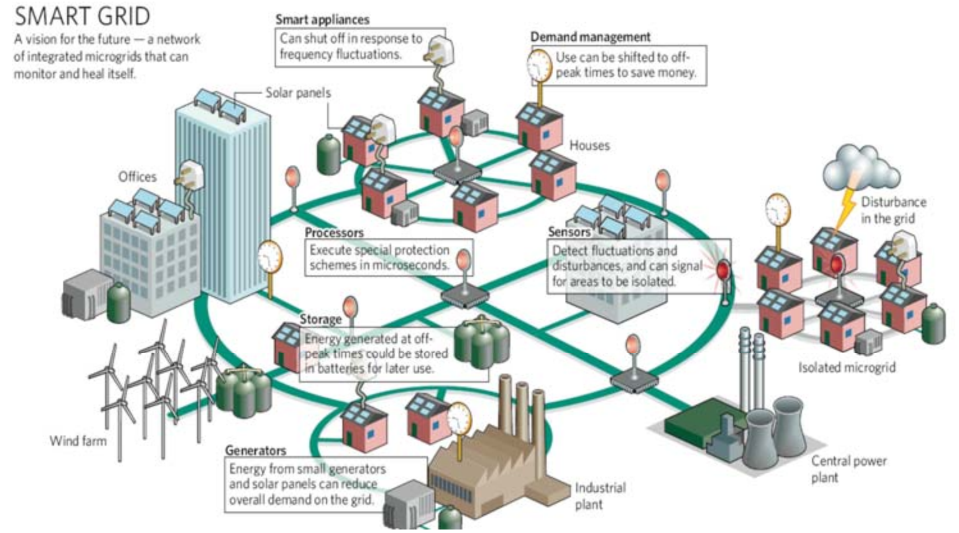
Highly Instrumented with Advanced Sensors and Computing



Interconnected by a Communication Fabric that Reaches Every Device

Enabling the Future

Infrastructure integration of microgrids, diverse generation and storage resources into a secure system of a smart self-healing grid

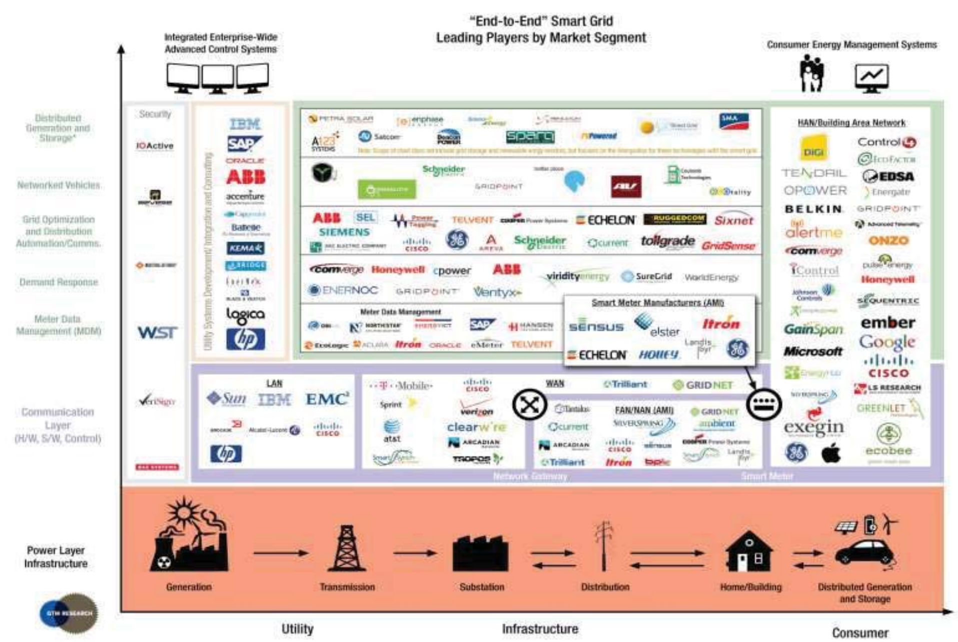


Source: Interview with Massoud Amin, "Upgrading the grid," *Nature*, vol. 454, pp. 570–573, 30 July 2008

Anatomy of the Smart Grid

Nerves	• AMI (meters and network) • Advanced grid sensing and visualization technology
Brains	• Demand Response (through dynamic pricing) • Building energy management systems • Meter Data Management Systems (MDMS) • End-use energy efficiency
Muscle	• Distributed generation from renewables, CHP, and other sources • Energy storage technologies (including PHEVs)
Bones	• New transmission lines (HVDC, superconducting) • New transformers and substation equipment

End-to-End Smart Grid Players/Opportunities



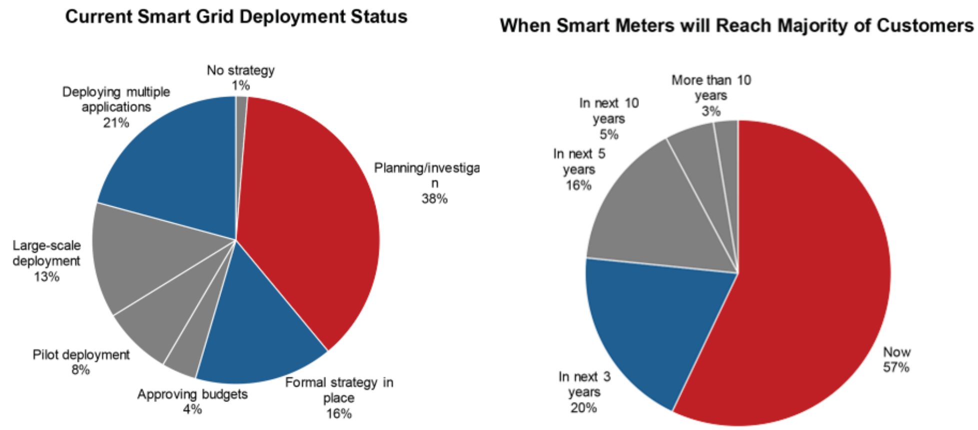
2014 Rural Smart Grid Survey Report*

- Challenges:
  - Many rural coops face a flat to declining customer base.
  - Customers have ever-increasing demands for improved communications and technologies.

- Improving available technologies not only satisfies current customers, but can even attract more customers to rural areas…
  - However, new technologies come at a cost; and
  - How feasible are smart grid technologies for rural electric coops with dispersed customers and limited resources?

* Survey of 77 U.S. rural electric coops. Sponsored by Honeywell, Zpryme and the Rural Smart Grid Summit (RSGS).
Source: http://etsinsights.com/reports/2014-rural-smart-grid-survey-report/#sthash.NxhUudXq.dpuf, November 2014

Rural Smart Grid Initiatives: Trends



Source: http://etsinsights.com/reports/2014-rural-smart-grid-survey-report/#sthash.NxhUudXq.dpuf, November 2014

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Rural Smart Grid Initiatives: Trends, Challenges and Opportunities

Key findings include:

- Nearly all rural electric utilities have some sort of smart grid effort in place:
  - Most are at the planning and investigation phase (38%)
  - while others are deploying multiple applications (21%)
  - or at least have a formal strategy in place (16%)

- In the longer term, smart grid remains a priority for nearly all rural utilities. For 53% it will be a moderate priority.

- The top benefits for smart grid remained foundational benefits, including:
  - restoration time reduction (57%)
  - increased visibility and control (39%)
  - analytics-based decisions (42%)

- Seven out of10 utilities are experiencing a positive impact from smart grid
- About two-thirds of rural utilities are taking on AMR and AMI efforts
- As rural utilities take on AMI, many of them have already reached the majority of their customers (57%)

Source: http://etsinsights.com/reports/2014-rural-smart-grid-survey-report/#sthash.NxhUudXq.dpuf, November 2014

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Rural Smart Grid Initiatives: Trends, Challenges and Opportunities (cont.)

- Current AMI network functions in use include the basics, such as interval reads (60%) and voltage reads (47%)

- Other functions are expected to grow in the coming years as utilities become more comfortable with meter data programs.
  - Many utilities are making smart grid programs part of their core operations (42%)

- About two-thirds of rural utilities are taking on AMR and AMI efforts.

- Respondents' top three areas of expertise were technology and engineering (60%), grid technology (47%), and strategy and planning (46%).

- Although rural consumers typically lag behind their urban counterparts in technology awareness, interest in home energy management has increased significantly for rural consumers from 4% in Oct. 2013 to 16% in Oct. 2014

Source: http://etsinsights.com/reports/2014-rural-smart-grid-survey-report/#sthash.NxhUudXq.dpuf, November 2014

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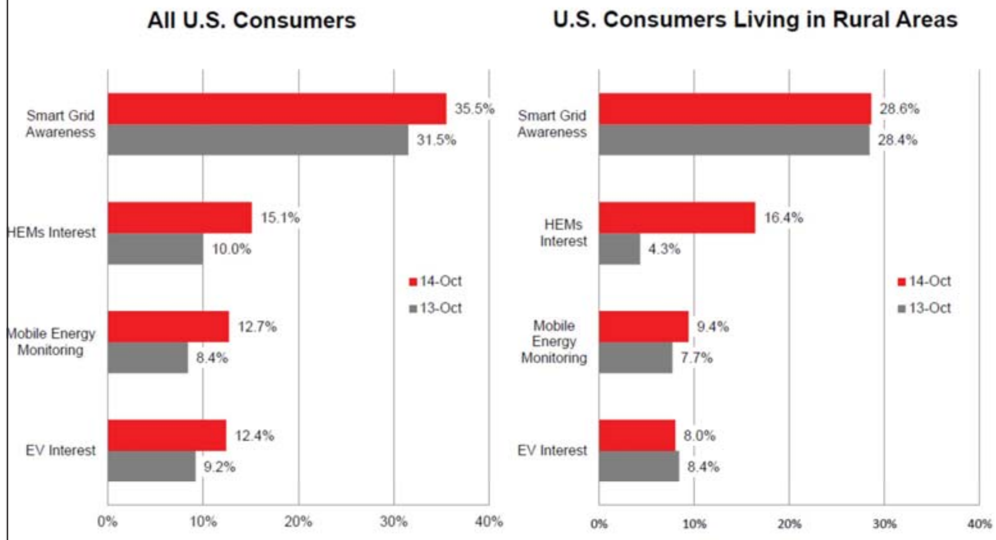
Rural Smart Grid Initiatives: Challenges

- Nearly half of rural utilities do not have a plan for renewables. Those who do have plans, are considering both centralized and decentralized generation. Electric vehicles have not significantly impacted rural electric utilities
- Opportunities for cloud-based and SaaS solutions are growing. Although more than half of rural utilities have yet to use these solutions, many others are beginning to dabble in them for AMI and data analytics
- Even with opportunities of a smarter grid… The most significant challenge is cost, followed by concerns around technology maturity.
- For technology, the biggest challenges facing rural electric utilities are handling distribution automation (36%) and systems integration (34%)
- Companies are facing difficulties finding individuals with the skills needed to effectively take on data analytics (42%) and systems integration (40%)
- Despite challenges, there is smart grid spending at rural electric utilities. In 2014 many companies spent up to $1M on smart grid technologies; the next 5 years will bring spending numbers closer to $5M or more.

Source: http://etsinsights.com/reports/2014-rural-smart-grid-survey-report/#sthash.NxhUudXq.dpuf, November 2014

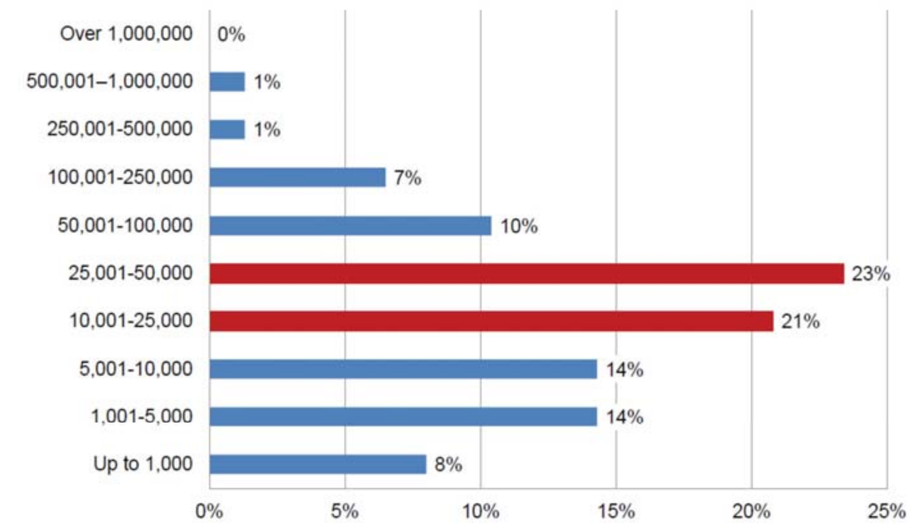
Consumer Trends by Technology



Although rural consumers typically lag behind their urban counterparts for technology awareness, interest in home energy management has increased significantly for rural consumers from 4% in October 2013 to 16% in October 2014.

Source: Source: Zpryme monthly consumer tracking surveys of smart grid sentiment, EV demand, HEMS demand, and Mobile Energy Monitoring. Data is based upon nationally representative survey of 1,000 U.S. adults (margin of error: +/- 3.5%)

How Many Electric Customers Do You Have?



Most respondents had 10,001 to 25,000 electric customers and 25,001 to 50,000 electric customers.

Source: http://etsinsights.com/reports/2014-rural-smart-grid-survey-report/#sthash.NxhUudXq.dpuf, November 2014

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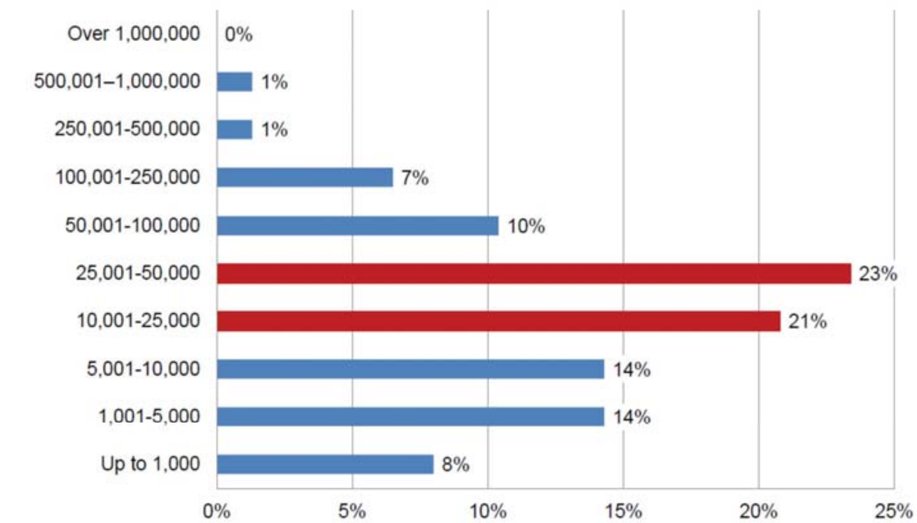

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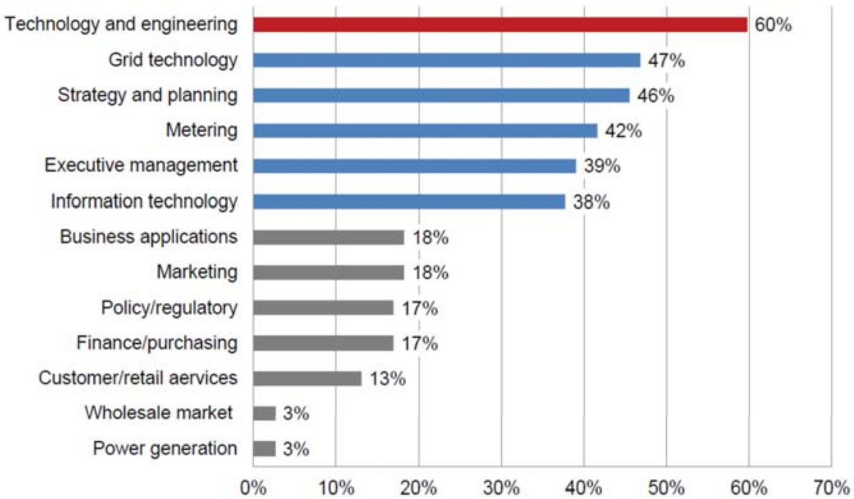
Areas of Expertise



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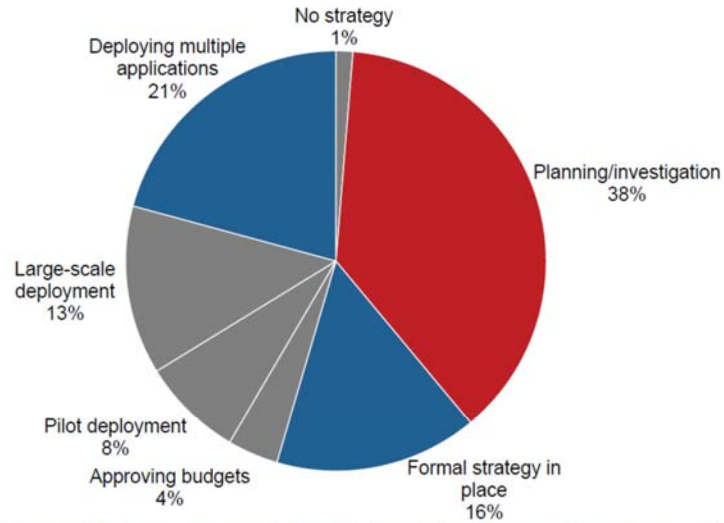
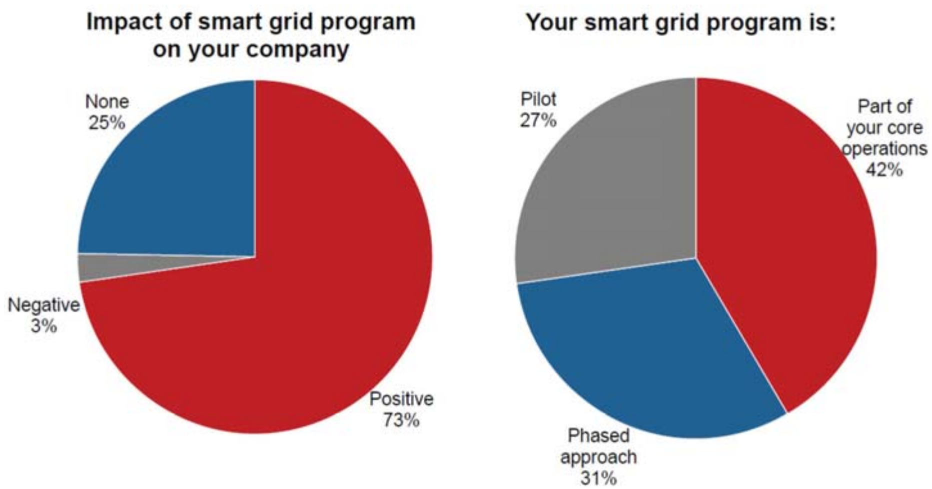
Current SG Deployment Status



Nearly all rural electric utilities have some sort of smart grid effort in place. Most are at the planning and investigation phase (38%), while others are deploying multiple applications (21%) or at least have a formal strategy in place (16%).

Source: http://etsinsights.com/reports/2014-rural-smart-grid-survey-report/#sthash.NxhUudXq.dpuf, November 2014

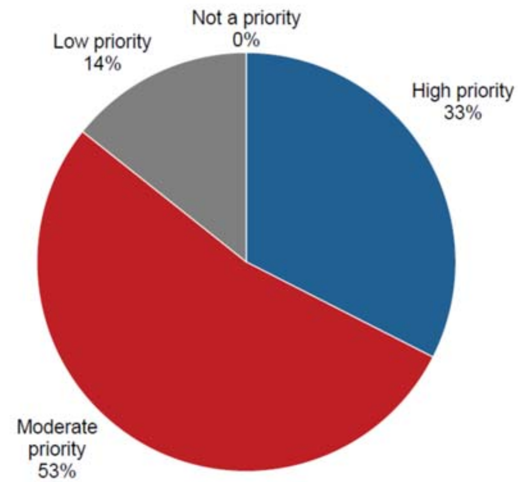
Smart Grid Impacts



For 7 out 10 utilities, they are experiencing a positive impact from smart grid programs. Many utilities are making their smart grid programs part of their core operations (42%).

Source: http://etsinsights.com/reports/2014-rural-smart-grid-survey-report/#sthash.NxhUudXq.dpuf, November 2014

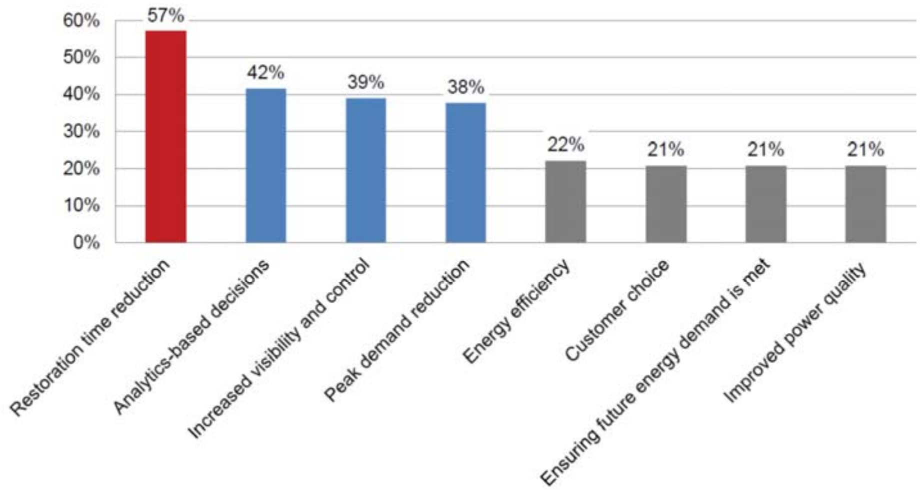
Importance of Smart Grid in the Next 5 Years



In the longer term, smart grid remains a priority for nearly all rural utilities. For most (53%), it will be a moderate priority and for one-third of respondents it will be a high priority.

Source: http://etsinsights.com/reports/2014-rural-smart-grid-survey-report/#sthash.NxhUudXq.dpuf, November 2014

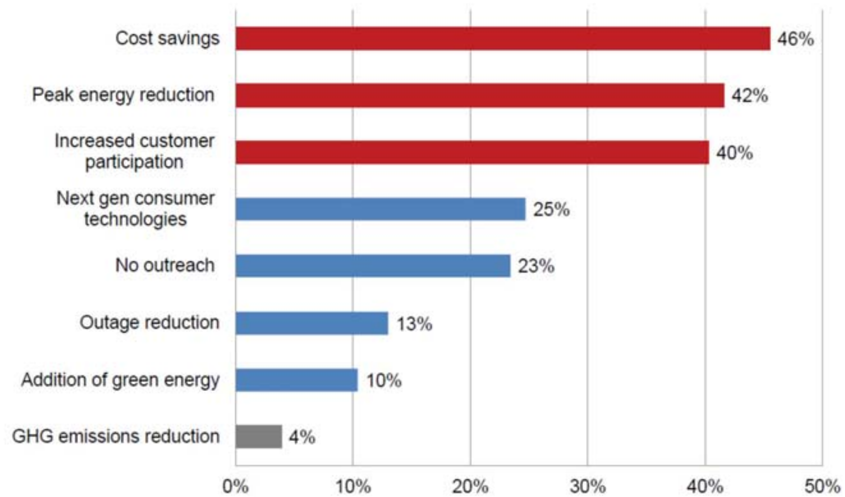
Top Smart Grid Benefits



The top benefits for smart grid remained foundational benefits, including restoration time reduction (57%) and increased visibility and control (39%). Another important benefit included analytics-based decisions (42%).

Source: http://etsinsights.com/reports/2014-rural-smart-grid-survey-report/#sthash.NxhUudXq.dpuf, November 2014

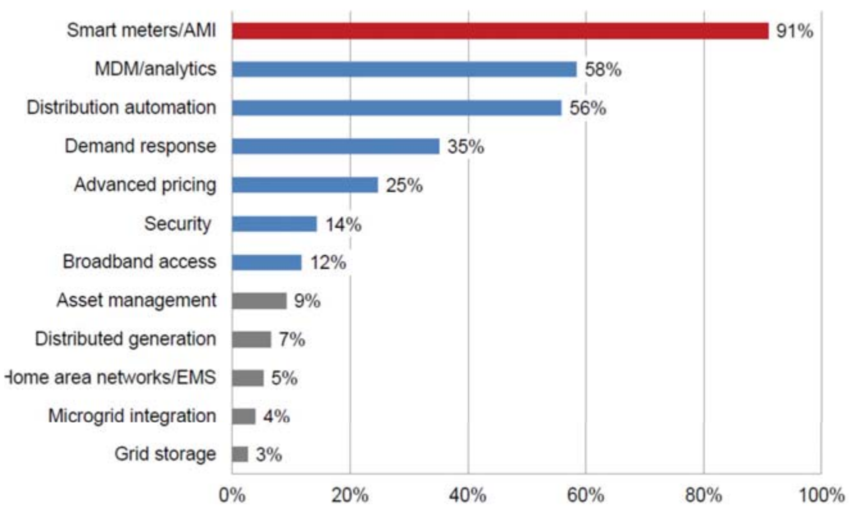
Areas of Importance for Consumer Communications



When communicating to customers about the value of a smart grid, most utilities communicated cost savings (46%) and opportunities to reduce peak demand (42%). GHG emissions reductions did not enter the conversation often (4%).

Source: http://etsinsights.com/reports/2014-rural-smart-grid-survey-report/#sthash.NxhUudXq.dpuf, November 2014

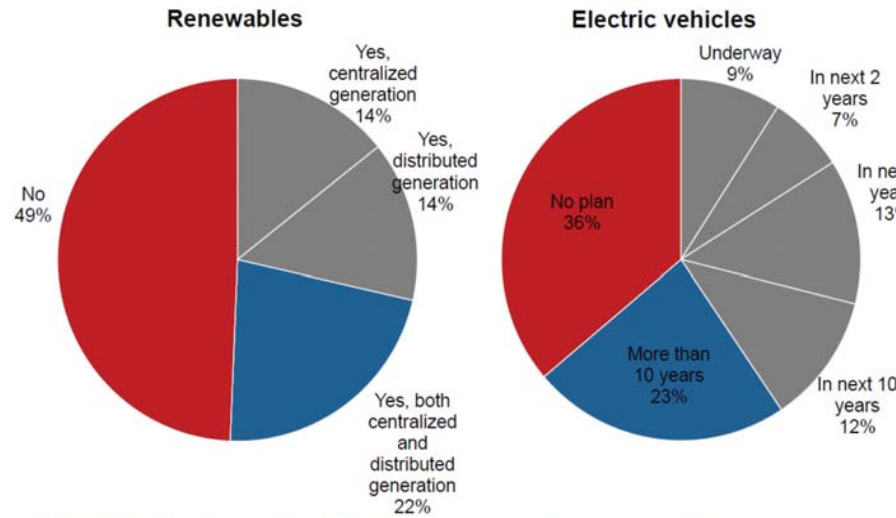
Most Important Smart Grid Applications



With the importance of AMI, rural utilities most frequently mentioned smart meters/AMI as a top smart grid technology (91%). Other important technologies included MDM/analytics (58%) and distribution automation (56%).

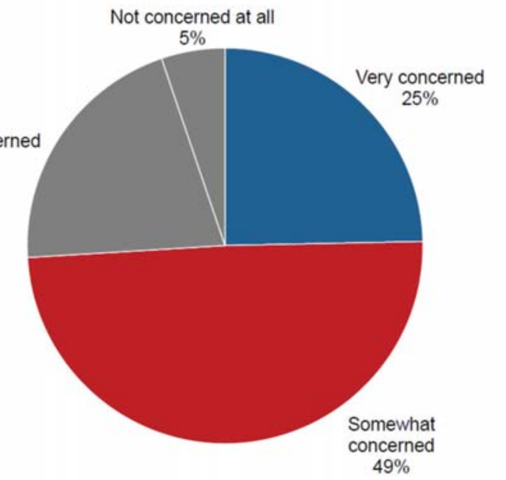
Source: http://etsinsights.com/reports/2014-rural-smart-grid-survey-report/#sthash.NxhUudXq.dpuf, November 2014

Renewables and EVs



Nearly half of rural utilities do not have a plan for renewables. Those who do have plans, are considering both centralized and decentralized generation. Electric vehicles have not significantly impacted rural electric utilities.

Concerns About Data and Analytics



Data and analytics is an important area for rural utilities, and there are concerns around security, privacy, network issues and the challenges of integrating disparate data sources.

Source: http://etsinsights.com/reports/2014-rural-smart-grid-survey-report/#sthash.NxhUudXq.dpuf, November 2014

Context: IT interdependencies and impact

Source: Massoud Amin, "Toward a Secure and Smart Self-Healing Grid," presentation to the Strategic Science & Technology EPRI Research Advisory Committee (RAC), Tuesday, January 27, 1998 page 7 at http://massoud-amin.umn.edu/presentations/CINSI_01-27-1998_RAC.pdf

Dependence on IT: Today's systems require a tightly knit information and communications capability. Because of the vulnerability of Internet communications, protecting the system will require new technology to enhance security of power system command, control, and communications.

Increasing Complexity: System integration, increased complexity: call for new approaches to simplify the operation of complex infrastructure and make them more robust to attacks and interruptions.

Centralization and Decentralization of Control: The vulnerabilities of centralized control seem to demand smaller, local system configurations. Resilience rely upon the ability to bridge top-down and bottom-up decision making in real time.

Assessing the Most Effective Security Investments: Probabilistic assessments can offer strategic guidance on where and how to deploy security resources to greatest advantage.

Adaptive Infrastructures

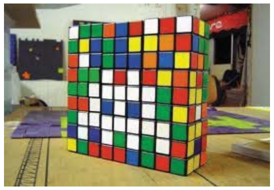
EPRI

Examples of SG Technologies & Systems

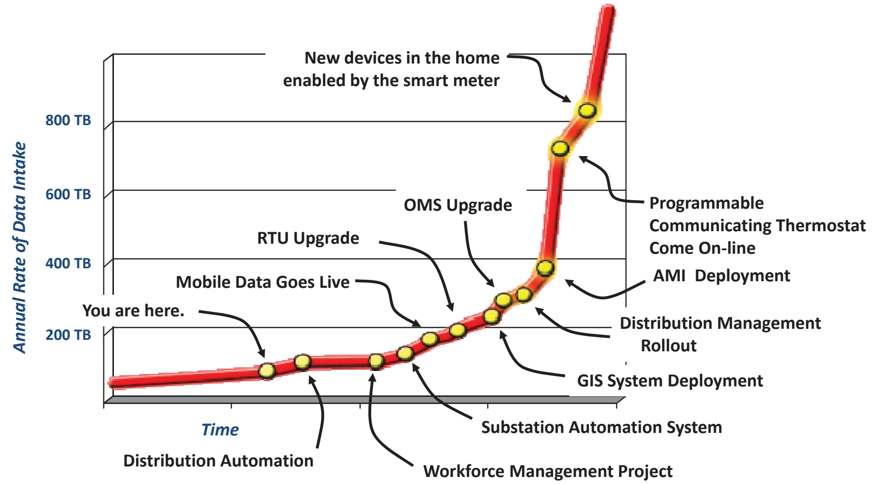
Electric Transmission Systems	Electric Distribution Systems	Advanced Metering Infrastructure	Customer Systems
			
• Synchrophaser technologies • Communications infrastructure • Wide area monitoring and visualization • Line monitors	• Automated switches • Equipment monitoring • Automated capacitors • Communications infrastructure • Distribution management systems	• Smart meters • Communications infrastructure • Data management systems • Back-office integration	• In-home displays • Programmable communicating thermostats • Home area networks • Web portals • Direct load controls • Smart appliances

Paradigm Shift – Data at MN Valley Coop

- Before smart meters
  - Monthly read
  - 480,000 data points per year
- After smart meters
  - 15-60 minute kWh
  - Peak demand
  - Voltage
  - Power interruptions
  - 480,000,000 data points per year



Smart Grid: Tsunami of Data Developing

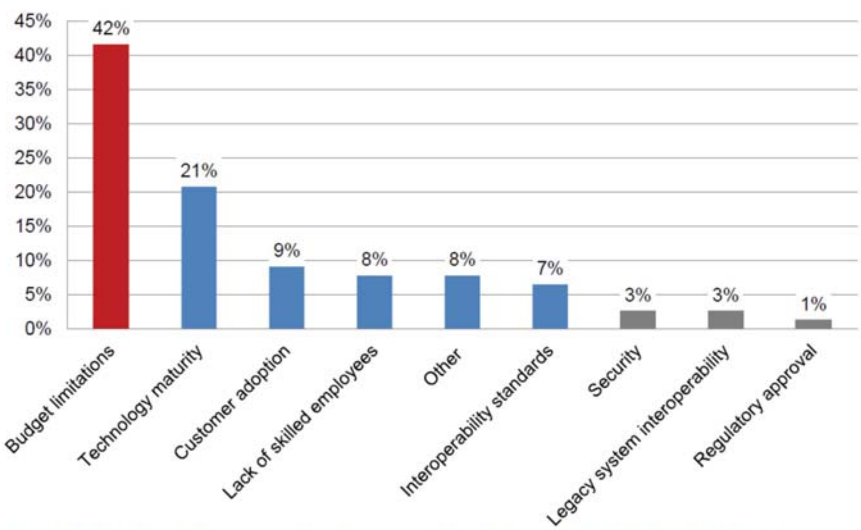


Tremendous amount of data coming from the field in the near future
- paradigm shift for how utilities operate and maintain the grid

Smart Grid Protection Schemes & Communication Requirements

Type of relay	Data Volume (kb/s)		Latency	
	Present	Future	Primary (ms)	Secondary (s)
Over current protection	160	2500	4-8	0.3-1
Differential protection	70	1100	4-8	0.3-1
Distance protection	140	2200	4-8	0.3-1
Load shedding	370	4400	0.06-0.1 (s)	
Adaptive multi terminal	200	3300	4-8	0.3-1
Adaptive out of step	1100	13000	Depends on the disturbance	

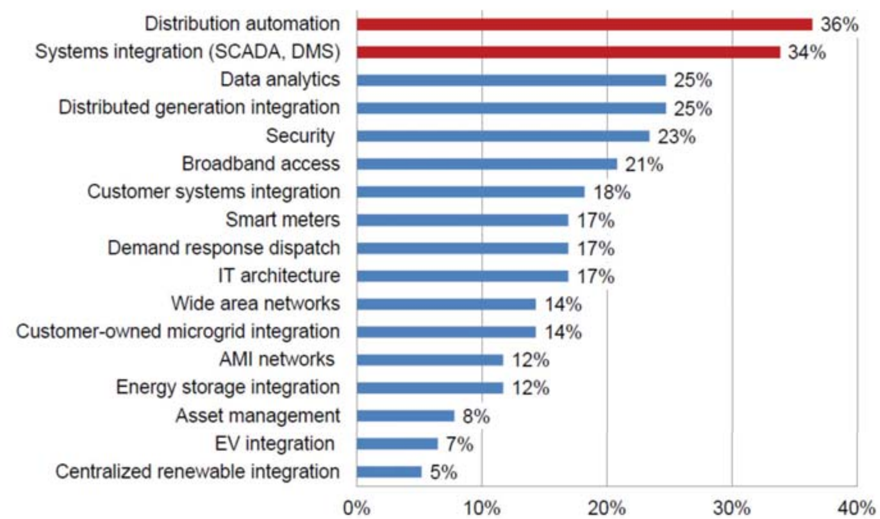
Main Challenges to Smart Grid Deployments



Even with the opportunities of a smarter grid, there are still challenges. The most significant challenge is cost, followed by concerns around technology maturity.

Source: http://etsinsights.com/reports/2014-rural-smart-grid-survey-report/#sthash.NxhUudXq.dpuf, November 2014

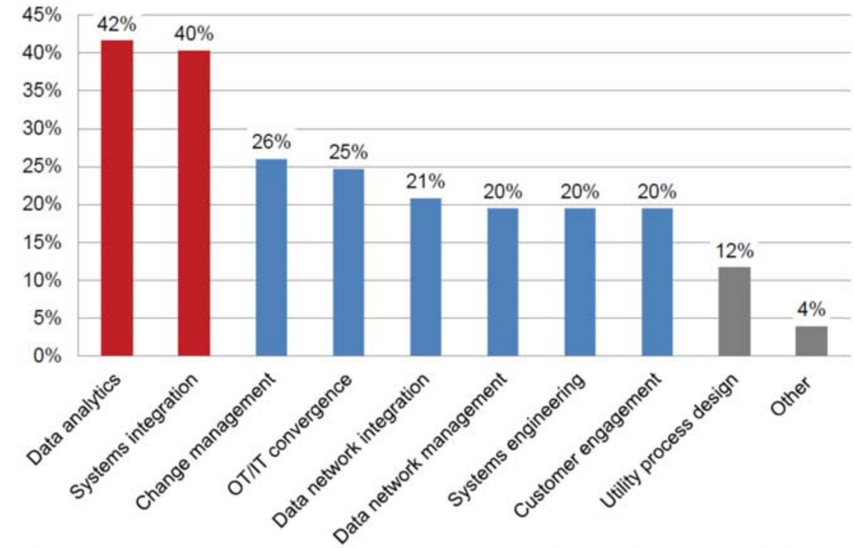
Technologies With the Biggest Challenges



For technology, the biggest challenges facing rural electric utilities are handling distribution automation (36%) and systems integration (34%).

Source: http://etsinsights.com/reports/2014-rural-smart-grid-survey-report/#sthash.NxhUudXq.dpuf, November 2014

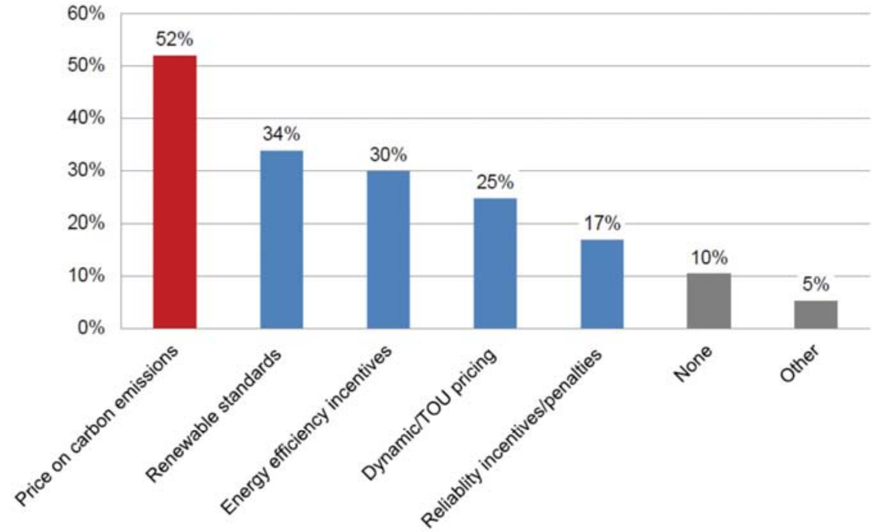
Smart Grid Skill Gaps in Existing Workforce



Those technology challenges are also reflected in workforce gaps. Companies are facing difficulties finding individuals with the skills needed to effectively take on data analytics (42%) and systems integration (40%).

Source: http://etsinsights.com/reports/2014-rural-smart-grid-survey-report/#sthash.NxhUudXq.dpuf, November 2014

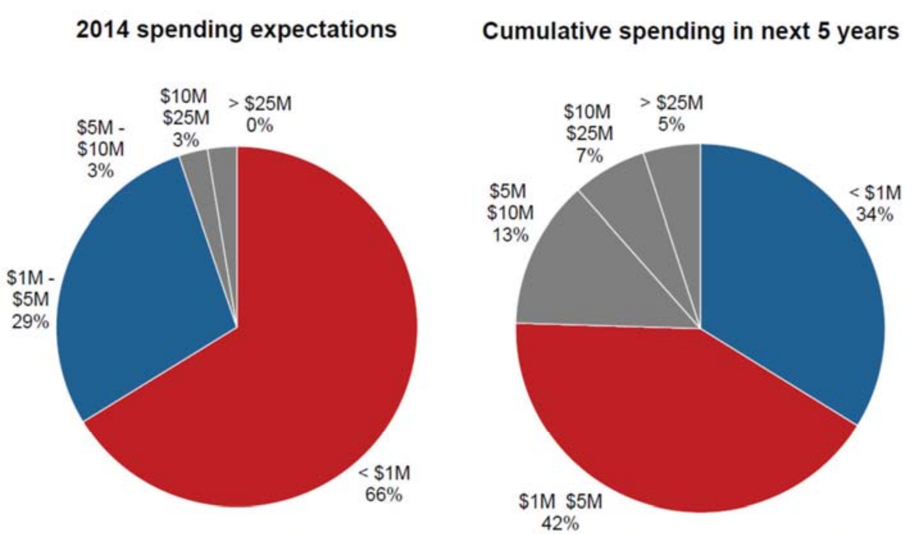
Legislation/Regulation Posing Challenges in Next 5 Years



Looming regulatory and legislative actions are causing rural utilities headaches, including placing a price on carbon emissions (52%), renewable standards (34%) and energy efficiency incentives (30%).

Source: http://etsinsights.com/reports/2014-rural-smart-grid-survey-report/#sthash.NxhUudXq.dpuf, November 2014

Smart Grid Spending Patterns



Despite these challenges, there is smart grid spending at rural electric utilities. In 2014 many companies are spending up to $1M on smart grid technologies; the next 5 years will bring spending numbers closer to $5M or more.

Source: http://etsinsights.com/reports/2014-rural-smart-grid-survey-report/#sthash.NxhUudXq.dpuf, November 2014

Overview of my team's projects at the UofM

- Microgrids
  - U of M - Morris campus project
  - UMore Park Project
  - Controller architecture
  - Resiliency
  - Dollars and watts -- Prices to devices
  - Storage and Renewables integration
  - Autonomous Microgrids
  - Big Data
- Smart Grid U™
- MN Smart Grid Coalition (2008-11) /Governor's Summit '14
- IEEE Smart Grid
- Discussion

Center for Smart Grid Technologies

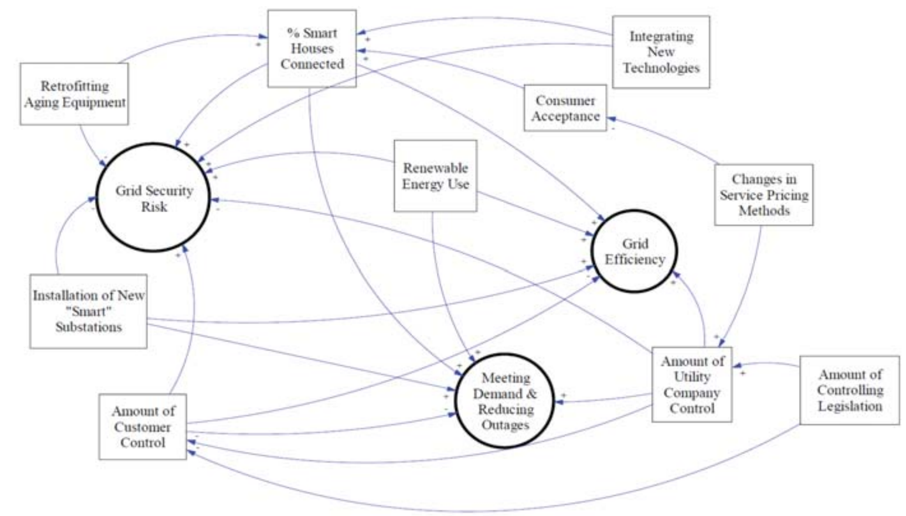
Smart Grids: What are we working on at the University of Minnesota?

- Integration and optimization of storage devices and PHEVs with the electric power grid
- Grid agents as distributed computer
- Fast power grid simulation and risk assessment
- Security of cyber-physical infrastructure: A Resilient Real-Time System for a Secure & Reconfigurable Grid
- Security Analyses of Autonomous Microgrids: Analysis, Modeling, and Simulation of Failure Scenarios, and Development of Attack-Resistant Architectures

University of Minnesota Center for Smart Grid Technologies (2003-present)
Faculty: Professors Massoud Amin and Bruce Wollenberg
PhD Candidates/RA and Postdocs: Anthony Giacomoni (PhD'11), Jesse Gantz (MS'12), Laurie Miller (PhD'13), Vamsi Parachuri (part-time PhD candidate, full-time at Siemens), Sara Mullen (Phd'09)
PI: Massoud Amin, Support from EPRI, NSF, ORNL, Honeywell and SNL

Center for Smart Grid Technologies

Smart Grid Interdependencies
Security, Efficiency, and Resilience



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IEEE SMARTGRID

Massoud Amin, Chairman
Wanda Reder, Founding Chair
Angelique Rajski Parashis, Project Manager

IEEE PES Governing Board Meeting
February 17, 2015

IEEE Advancing Technology for Humanity

Collaboration Across IEEE

2014 Updates:
- Met with 25+ IEEE Presidents and VPs in February 2014 (resulting in 9 partner societies), and 20+ IEEE Presidents and VPs during November 2014 IEEE Board Series
- Possible new partners in 2015: PELS, IES, SMCS
- Implemented six functional committees with work focused on: Marketing, Education, Standards, R&D, Publications, and Meetings & Conferences

IEEE Smart Grid Attracts the Best and Brightest in the Industry

Industry
Cisco, United Technologies, ComEd, Verizon Business, NREL, Chrysler, Siemens, Alstom, EPRI Electric Power Research Institute, Duke Energy, GE, Pacific Gas and Electric Company, IBM, Honeywell, KEMA, Toshiba Leading Innovation, Edison International, Whirlpool

Academia
Carnegie Mellon University, Clemson University, Duke University, Berkeley University of California, Georgia Institute of Technology, Stanford, Lehigh University, Brown, MIT Massachusetts Institute of Technology, Rensselaer, Princeton University

Associations
iea, APPA American Public Power Association, ASME, SAE International, GSM, Bipartisan Policy Center, WiMAX Forum

Government
U.S. House of Representatives, TVA, Argonne, NASA, Sandia National Laboratories, INL Idaho National Laboratory, NIST, U.S. Army, Ontario Power Authority, Pacific Northwest National Laboratory

IEEE Smart Grid Attracts the Most Influential Media and Analysts

Technology & Mainstream
EE Times, examiner.com, Government Technology, FierceTelecom, GCN, CIO Insight, electronic design, The Wall Street Journal, npr, ZDNet, theenergycollective, InformationWeek, Forbes, Network World, World News

Smart Grid
SmartGridToday, ClimateWire, greentechmedia, SmartGrid smart-grid.tmcnet.com, Renewable Energy World.com, FierceSmartGrid, renew GRID, Smart Grid News.com

Utilities
Public Utilities Fortnightly, Pipeline, Electric Energy Online.com, Electricity Today, intelligentutility, PowerGrid International

Industry Analysts
IDC, Forrester, ABIresearch, PikeResearch, Frost & Sullivan, yankee group, In-Stat, IEEE, Gartner

IEEE Smart Grid Growing Community: 56,500+

~25% increase over December 2013

Position as a meaningful NEW marketing channel for IEEE Societies to tap into to promote their products and services

LinkedIn Group: **26,000+ members** **Now, the largest Smart Grid related group!**

Twitter: **10,200+ followers**

Newsletter Subscribers: **14,200+** **Most popular page on the IEEE Smart Grid portal with more than 102k page views in 2014**

Technical Community Members: **6,100+** **2nd largest Technical Community in IEEE!**

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IEEE Smart Grid Portal

smartgrid.ieee.org

Gateway for IEEE Smart Grid content
- 15,000+ visits per month
- 1.4 million+ page views since 2010
- Visitors from more than 200 countries

Landing point for visitors looking for Smart Grid-related information
- Newsletter archives
- Webinar archives
- Standards information
- Publications, conferences, videos and more

Revamping website with a plan to move to Joomla 3.0 platform by June 2015!

IEEE SMARTGRID

IEEE Advancing Technology for Humanity

IEEE Smart Grid Newsletter

More than 14,200 subscribers

Most popular page on the IEEE Smart Grid portal with more than 102k page views in 2014

Insightful articles published by leading Smart Grid experts from around the world – platform for IEEE Society exposure

Special Issues

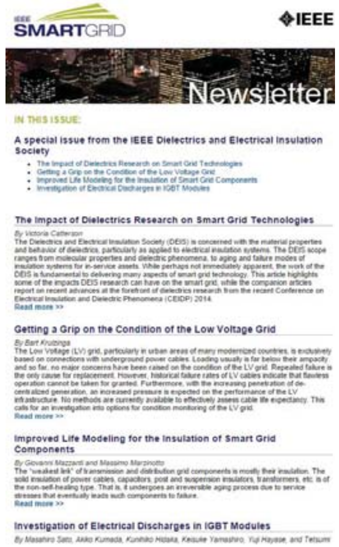
November 2014: IEEE Computer Society

January 2015: IEEE Dielectrics & Electrical Insulation Society

March 2015: IEEE Instrumentation & Measurement Society

April 2015: IEEE Systems, Man & Cybernetics Society

May 2015: IEEE Communications Society



SMARTGRID IEEE

Newsletter

IN THIS ISSUE:

A special issue from the IEEE Dielectrics and Electrical Insulation Society

- The Impact of Dielectrics Research on Smart Grid Technologies
- Getting a Grip on the Condition of the Low Voltage Grid
- Improved Life Modeling for the Insulation of Smart Grid Components
- Investigation of Electrical Discharges in IGBT Modules

The Impact of Dielectrics Research on Smart Grid Technologies

By Victoria Catterson

The Dielectrics and Electrical Insulation Society (DEIS) is concerned with the material properties and behavior of dielectrics, particularly as applied to electrical insulation systems. The DEIS scope ranges from molecular properties and dielectric phenomena, to aging and failure modes of insulation systems for in-service assets. While perhaps not immediately apparent, the work of the DEIS is fundamental to delivering many aspects of smart grid technology. This article highlights some of the impacts DEIS research can have on the smart grid, while the companion articles report on recent advances at the forefront of dielectrics research from the recent Conference on Electrical Insulation and Dielectric Phenomena (CEIDP) 2014.

Read more >>

Getting a Grip on the Condition of the Low Voltage Grid

By Bart Kruizinga

The Low Voltage (LV) grid, particularly in urban areas of many modernized countries, is exclusively based on connections with underground power cables. Loading usually is far below their ampacity and so far, no major concerns have been raised on the condition of the LV grid. Repeated failure is the only cause for replacement. However, historical failure rates of LV cables indicate that flawless operation cannot be taken for granted. Furthermore, with the increasing penetration of de-centralized generation, an increased pressure is expected on the performance of the LV infrastructure. No methods are currently available to effectively assess cable life expectancy. This calls for an investigation into options for condition monitoring of the LV grid.

Read more >>

Improved Life Modeling for the Insulation of Smart Grid Components

By Giovanni Mazzanti and Massimo Marzinotto

The "weakest link" of transmission and distribution grid components is mostly their insulation. The solid insulation of power cables, capacitors, post and suspension insulators, transformers, etc. is of the non-self-healing type. That is, it undergoes an irreversible aging process due to service stresses that eventually leads such components to failure.

Read more >>

Investigation of Electrical Discharges in IGBT Modules

By Masahiro Sato, Akiko Kumada, Kunihiko Hidaka, Keisuke Yamashiro, Yuji Hayase, and Tetsumi

IEEE SMARTGRID

IEEE Advancing Technology for Humanity

IEEE Smart Grid Webinars

Tentative 2015 Calendar:

(1) Smarter Citizens for Smarter Cities with Roberto Saracco (January 29, 2015) – Completed!
(2) Electric Vehicles and the Smart Grid – Part 2 with Lee Stogner (February 26, 2015)
(3) Storage (Title TBD) with Imre Gyuk (March 19, 2015)
(4) Title TBD with Ben Kroposki (May 21, 2015)
- Actively working to schedule one webinar per month until the end of 2015

Fun Facts:

- Record-breaking **1,000+** Registrations for December Webinar with more than **500+** attendees!
- Average Registration of 500 people per webinar with more than 300+ actual attendees!
- "Past webinars page" is the second highest visited page on the IEEE Smart Grid portal

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For Reference Please See:
Conducted seven webinars in various Smart Grid related topic areas in 2014:
(1) Technological Leadership, Local to Global Strategy with Massoud Amin (June 11, 2014)
(2) The Nexus of the Smart Grid and the Internet of Things with Steve Collier (July 10, 2014)
(3) Smart Grid: Concepts, Solutions, Standards, Policy, Recent Deployments and Lessons with John McDonald (August 14, 2014)
(4) IEEE National Assessment of CVR: Preliminary Results from DOE's SVR Initiative with Kelly Warner (September 11, 2014)
(5) Putting a Value on Reliability: Iberdrola USA's Distribution Automation Cost Benefit Analysis with Laney Brown (October 16, 2014)
(6) Smart Vehicles and the Smart Grid with Lee Stogner (November 13, 2014)
(7) Enabling Smart Grids: Energy Storage Technologies, Opportunities and Challenges with Lucia Gauchia (December 18, 2014)

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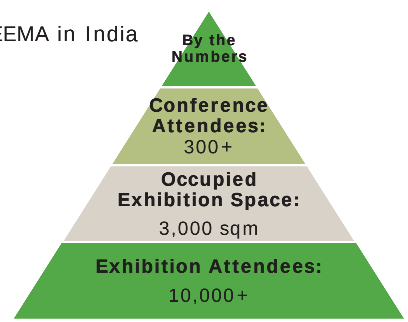
INTELECT
2015 IEEE-IEEMA INTELECT Conference and Exposition
Conference theme: Smart Electricity for Emerging Markets
22 TO 24 JANUARY 2015
BOMBAY EXHIBITION CENTRE, MUMBAI, INDIA

ieema your link to electricity

HIGHLIGHTS

- First time joint event between IEEE and IEEMA in India
- First time all IEEE-wide conference
- IEEE Financial Co-Sponsors:
  - IEEE Power & Energy Society
  - IEEE Computer Society
  - IEEE Communications Society
- IEEE Technical Co-Sponsors:
  - IEEE Smart Grid
  - IEEE Industrial Applications Society
  - IEEE Standards Association
  - IEEE SIGHT
  - IEEE Region 10
- Supported by three Ministries of Government of India
  Ministry of Power
  Urban Development
  Communications & IT
- Supported by the Government of Maharashtra



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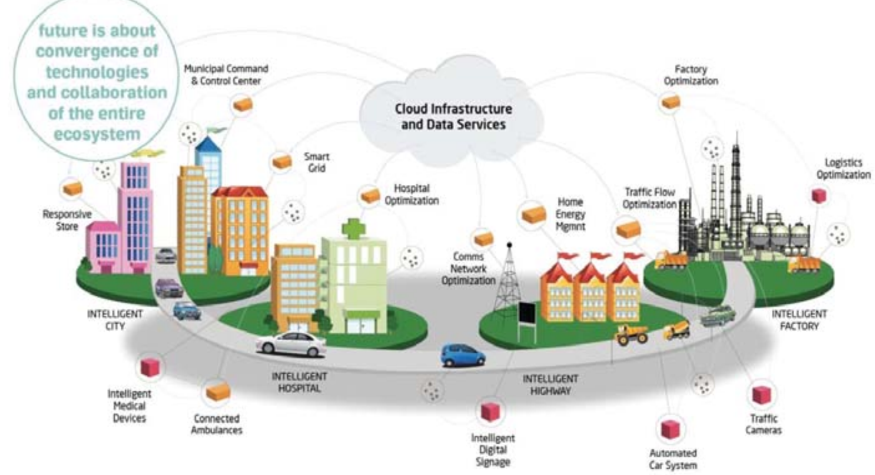
IEEE SMARTGRID

INTELECT
2015 IEEE-IEEMA INTELECT Conference and Exposition
Conference theme: Smart Electricity for Emerging Markets
22 TO 24 JANUARY 2015



The conference featured four parallel tracks:

- H3O – Smart Home, Hospital, Hotel & Office
- Microgrids, Rural Electrification and Renewables
- Smart Cities
- Humanitarian Impact of Smart Electricity

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Status Update: New products

- IEEE Smart Grid Domains and Focus Ares – Near completion, release of final version scheduled for April 2015
- Survey of IEEE Smart Grid community completed – Overall, 75% satisfaction rate with IEEE Smart Grid products and services
- IEEE Smart Grid eNewsletter Compendium – In progress, to be launched Q1 2015
- Paid ads in the IEEE Smart Grid eNewsletter - Currently selling ads, first ad sold and featured in the February issue!
- Build out of volunteers in established functional area committees – In progress, met with 20+ IEEE Society Presidents during November 2014 Board Series who are interested in promoting IEEE Smart Grid within their communities
- Strategic and Implementation Plans – In progress
- IEEE Smart Grid Policy Technical Support Committee – Confirmed by IEEE Smart Grid Steering Committee

IEEE SMARTGRID

IEEE Advancing Technology for Humanity

Quadrennial Energy Review Support

The U.S. government initiated a Quadrennial Energy Review (QER), following a Presidential Memorandum issued in January of 2014. As part of this effort, the U.S. DOE has requested IEEE to provide insights on a specific set of priority issues.

- The IEEE Power and Energy Society (PES) and the IEEE-USA organizations have led the IEEE response.
- IEEE leaders engaged a large IEEE volunteer community, including IEEE PES Technical Committees, to support this initiative.
- **Each section addressed in the document addressed the DOE QER priority topics, including:**
  1. Effects of renewable intermittency on the electric power grid and the potential role of storage in addressing these effects
  2. Utility and other energy company business case issues related to microgrids and distributed generation (DG), including rooftop photovoltaics
  3. The technical implications for the grid (bulk and local distribution) of electric vehicle (EV) integration - and the timing you see as necessary to avoid having the grid status slow down any potential progress
  4. The implications and importance of aging infrastructure and the options for addressing these challenges, including asset management
  5. Recommendations for metrics for addressing Smart Grid issues, especially to help policy makers determine the importance and necessity of protocols
  6. Skilled workforce issues

- **The IEEE has delivered to the DOE QER:**
  - The summary report consisting of individual summaries for each topic, including key findings and recommendations.
  - The overall report with detailed information on each topic.

This document has been extensively reviewed by the IEEE membership, IEEE PES Technical Committees, representatives from various industry organizations, utilities, RTOs, academia, and private companies. The IEEE team has incorporated those extremely valuable comments to the best of its abilities while assuring document consistency.

IEEE SMARTGRID

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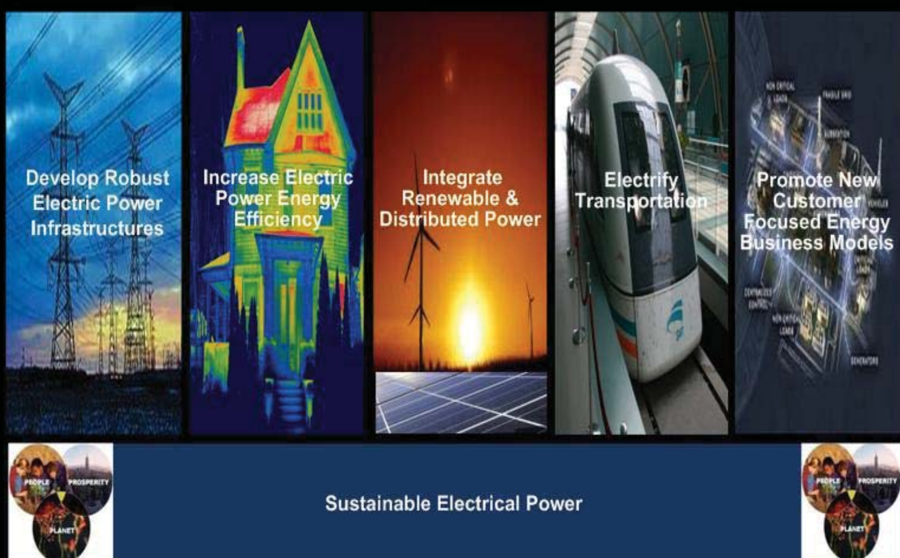
Smart Grid Goals



IEEE Smart Grid http://smartgrid.ieee.org

IEEE smart village

Empowering Off-Grid Communities

Short Summary: An IEEE Foundation Signature Program Est. 2014

(Formerly IEEE Community Solutions Initiative)

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Smart Village Mission

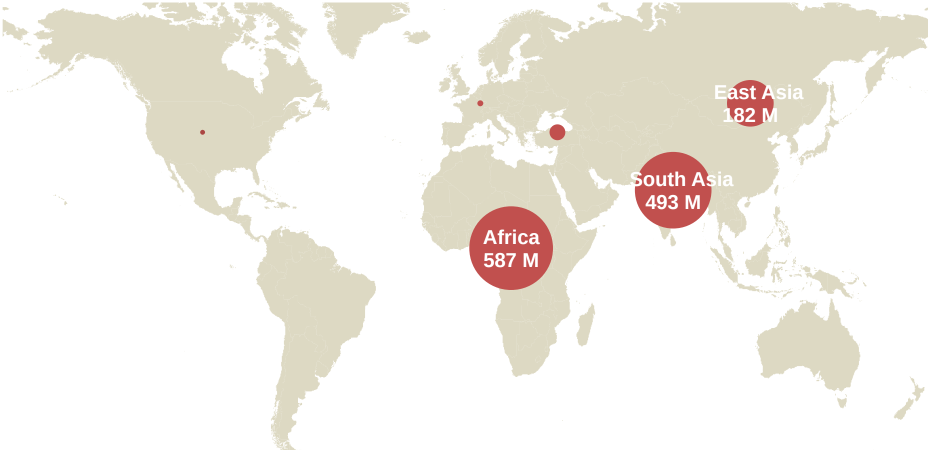
- Dedicated to incubating energy technology partnerships and advanced learning among people earning <$2/day
- Based on unique community owned and operated entrepreneurial businesses *plus* community based accredited education models
- *Not a charity but sustainable, growing economy*
- *Not just vocational training*
- *“Learning beyond the light bulb”*

SunBlazer I - 2011

- Mobile 1.5kW Generator, lighting for 80-100 homes



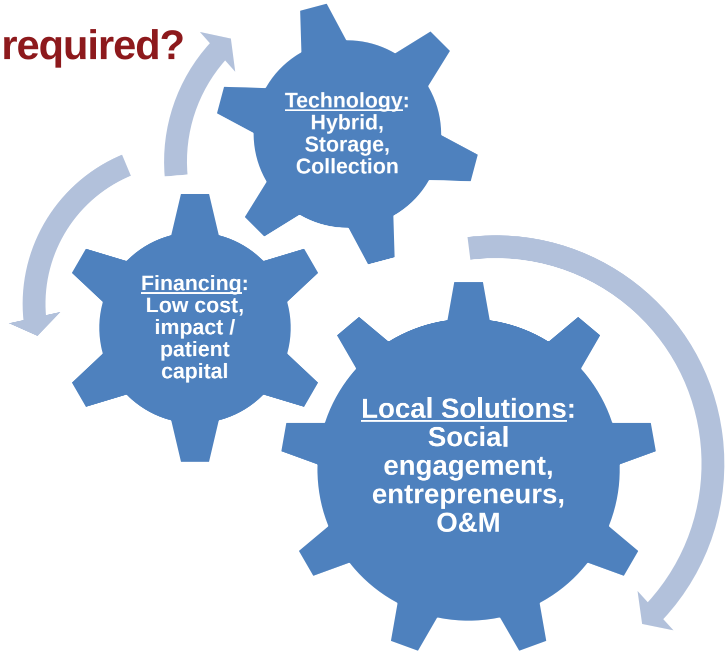
1.3B Worldwide Lack Access to Electricity



Millions: IEA 2014 World Energy Outlook

Macro Areas and Clusters for Best Practices

What is required?



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smartgrid.ieee.org

JOIN US: linkedin.com/groups/IEEE-Smart-Grid

FOLLOW US: twitter.com/ieeesmartgrid

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Multi-Objective Optimization Model

Objective 1: Minimize aggregate customer outage cost
Objective 2: Minimize capital cost of storage systems

$$\underset{X,Y}{\text{minimize}} \quad \alpha \sum_{i=1}^{n} N_i * CDF_i\,(t_o - Y_i t_s) + (1-\alpha) \sum_{j=1}^{t} C_j X_j \qquad s.t.$$

(1) $t_s = \frac{\sum_{j=1}^{t} X_j S_j}{\sum_{i=1}^{n} Y_i D_i}$

(2) $X_j \in \mathbb{Z}_n \forall j$

(3) $Y_i \in \{0,1\} \forall i$

(4) *Power System Operating Constraints*

Where,
i: Load index ϵ {1 ….n}
j: Storage type Index ϵ {j …. s}
Y_i : Emergency service indicator variable for load i
X_j : Number of storage systems of type j selected
N_i: Number of customers of given type at load i
CDF_i(*): Non-linear customer damage function
t_o: Duration of system outage (min)
t_s: Duration storage to serve emergency loads
S_{cap}: kWh capacity of storage facility
D_i: kW demand of load i
C_j: Capital cost of storage unit type j

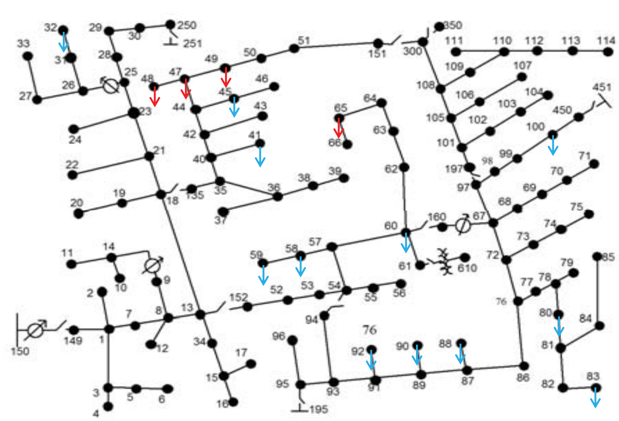
Prioritizing Emergency Backup Service

SYSTEM CHARACTERISTICS	
Voltage (kV)	4.16
Number of Loads	85
Peak Load	3490 kW at 0.88 PF
Number of Customers	513
Large C&I Customers	10
Medium C&I Customers	62
Residential Customers	441

Simulated Outage
- 120 minute outage on bulk power system
- 1500 kWh backup-storage a distribution substation (nod 150)
- Loads selectively served for outage ride-through

LOADS SERVED
- Small C&I
- Large C&I

123 IEEE Test Feeder Model



Customer Outage Costs (2008$)	Large C&I	Med C&I	Res.	Total	Loads Served
No Storage	95,900	98,260	3,550	197,710	0
With Storage - All Loads	88,610	91,400	3,390	183,450	All 85
With Storage - Selective Service	35,900	84,980	3,550	124,430	19

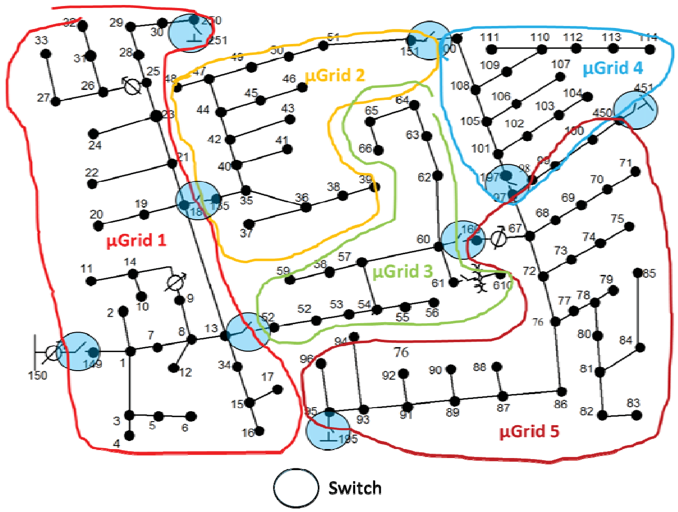
Feeder Reconfiguration/Intentional Islanding

Outline

- System divided into sub-networks joined by controllable switches
- The fault is isolated for a given outage situation
- Non-faulted sub-networks are intentionally islanded to supply back-up service to local loads

Simulation

- Perform Sequential Monte-Carlo simulation to simulate outages
- Determine optimal locations to place storage elements



Energy Storage for C&I Applications

Energy Storage for Commercial and Industrial Applications

	Maturity	Capacity (kWh)	Power (kW)	Duration (hrs)	Efficiency (%)	Cycle Life (cycles)	Total Cost ($/kW)	Cost ($/kW-h)
Advanced Lead-Acid 1	Demo-Commercial	5000	1000	5	85	4500	3000	600
Advanced Lead-Acid 2	Demo-Commercial	1000	200	5	80	4500	3600	720
NaS	Commercial	7200	1000	7.2	75	4500	3600	500
Zn/Br Flow 1	Demo	625	125	5	62	>10000	2420	485
Zn/Br Flow 2	Demo	2500	500	5	62	>10000	2200	440
Vanadium Flow	Demo	1000	285	3.5	67	>10000	3800	1085
Li-Ion	Demo	625	175	3.5	87	4500	3800	1085

* Rastler D., "Electricity Energy Storage Technology Options – A White Paper Primer on Applications, Costs and Benefits", EPRI, 2010

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Single Customer Multi-Objective Optimization Model

Objective 1: Minimize Outage Costs

$$\underset{Y}{\text{minimize}} \sum_{n=1}^{N_{outage}} CDF\left(t_o - P_{load,n} \sum_{j=1}^{J_{types}} \frac{X_j}{S_{BESS,j}}\right)$$

Objective 2: Minimize Energy Costs

$$\underset{SOC}{\text{minimize}} \sum_{t=1}^{T} (P_{load,t} - P_{gen,t} + P_{BESS,t}) C_{e,t} \Delta t$$

Objective 3: Minimize Demand Costs

$$\underset{SOC}{\text{minimize}} \sum_{p=1}^{P} \left(max\left(P_{load,t} - P_{gen,t} + P_{BESS,t}\right)_p + PF_p\right) C_{d,p}$$

Objective 4: Minimize Capital Costs

$$\underset{X}{\text{minimize}} \sum_{j=1}^{t} C_j X_j$$

Where,
n: Outage index $\epsilon \{1 \dots . N_{outage}\}$
$CDF_i(*)$: Customer damage function
t_o: Duration of outage (min)
j: Storage type index $\epsilon \{j \dots . s\}$
X_j : Number of storage systems of type j selected
$P_{load,n}$: Ave. load during outage, n
$S_{BESS,j}$: kWh storage capacity
S_{cap}: kWh capacity of storage facility
Cj: Capital cost of storage unit type j

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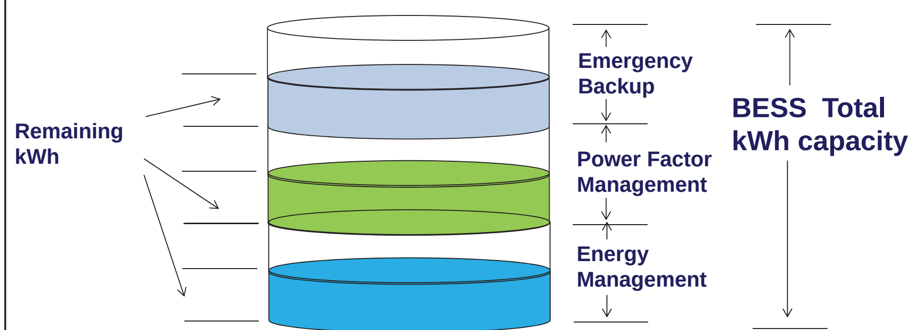
Multi-Application Energy Storage

Approach: Partition energy storage capacity according to application



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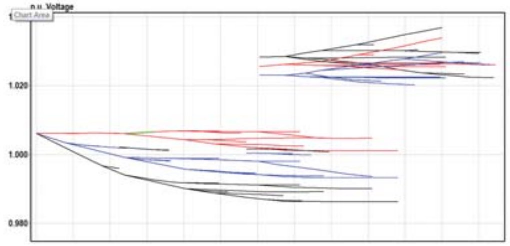
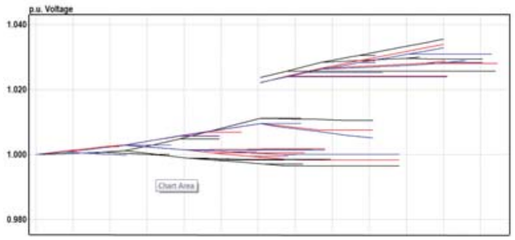
Voltage Profiles

Normal Operation:
1.04 – 0.98pu voltages



Priority Ride-Through:
1.04 – 0.99pu voltages



Distribution Reliability Analysis

- **Failure rate, λ**: expected # of failures per year for network component
- **Repair time**, **r**: average number of hours to repair network component
- **N_s**: Number of customers at load point s
- **System Average Interruption Frequency Index (SAIFI)**
- $SAIFI = \frac{\sum N_s \lambda_s}{\sum N_s} = Average\ number\ of\ interruptions\ per\ customer\ served$
- **System Average Interruption Duration Index (SAIDI)**
- $SAIDI = \frac{\sum N_s \lambda_s r_s}{\sum N_s} = System\ wide\ average\ interruption\ duration$
- **Customer Average Interruption Duration Index (CAIDI)**
- $CAIDI = \frac{\sum N_s \lambda_s r_s}{\sum N_s \lambda_s} = Average\ outage\ duration\ experienced\ by\ a\ customer$

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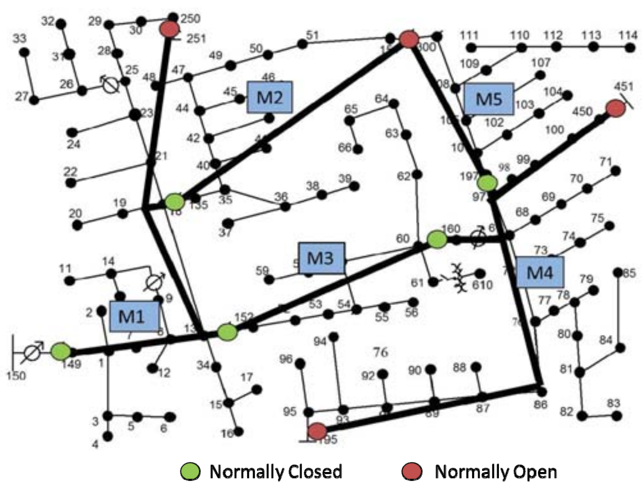
Feeder Main Reliability Analysis



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Optimal Mix and Placement

No. Units Selected	BESS Selected	Location	Capital Cost	Added Savings	Annual Outage Costs	Payback Period
0	None	--	$ 0	--	$ 1,435,814	---
1	Zinc Bromine 1	M4	$ 303,125	$ 285,776	$ 1,150,038	*1.06 years*
2	Zinc Bromine 1	M4	$ 606,250	$ 207,749	$ 942,289	*1.23 years*
3	Zinc Bromine 1	M4	$ 909,375	$ 224,758	$ 717,531	*1.27 years*
4	Zinc Bromine 1	M4	$ 1,212,500	$ 225,395	$ 492,136	*1.29 years*
5	Zinc Bromine 1	M3	$ 1,515,625	$103,449	$ 388,687	*1.45 years*

Index	M1	M2	M3	M4	M5
Total Cust.	200	85	44	72	112
Cust. Served	0	0	4	35	0
SAIDI: 3.93 (down 0.44)		*SAIFI: 5.90 (down 0.66)*		*CAIDI: 1.5 (same)*	

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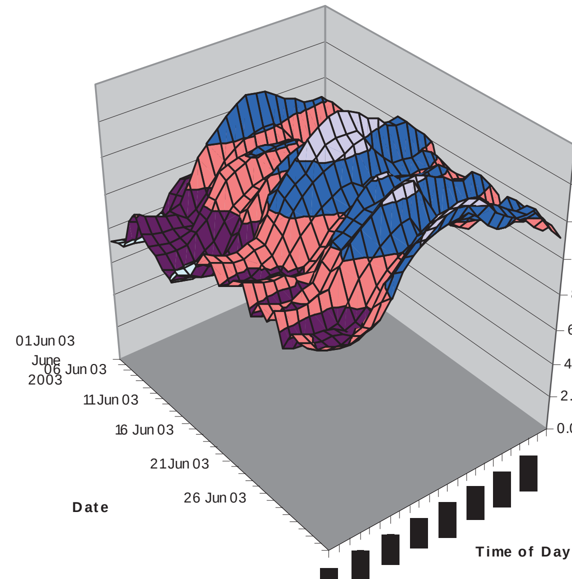
Smart Grid U™

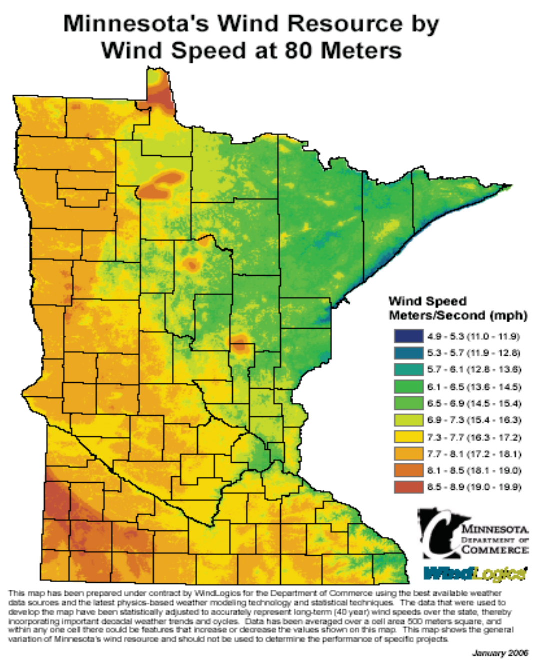
- Goal: transform the University of Minnesota's Twin Cities' campus into a *SmartGridU.*
  - Develop system models, algorithms and tools for successfully integrating the components (generation, storage and loads) within a microgrid on the University of Minnesota campus.
  - Conduct "wind-tunnel" data-driven simulation testing of smart grid designs, alternative architectures, and technology assessments, utilizing the University as a living laboratory.
  - Roadmap to achieve a "net zero smart grid" at the large-scale community level – i.e., a self contained, intelligent electricity infrastructure able to match renewable energy supply to the electricity demand.

Smart Grid U™



- Control algorithms and interfaces for turning individual energy components (storage, generation and loads) into an integrated, optimized energy system.
  - E.g., demand surface plots of raw data for demands, emissions, & efficiency

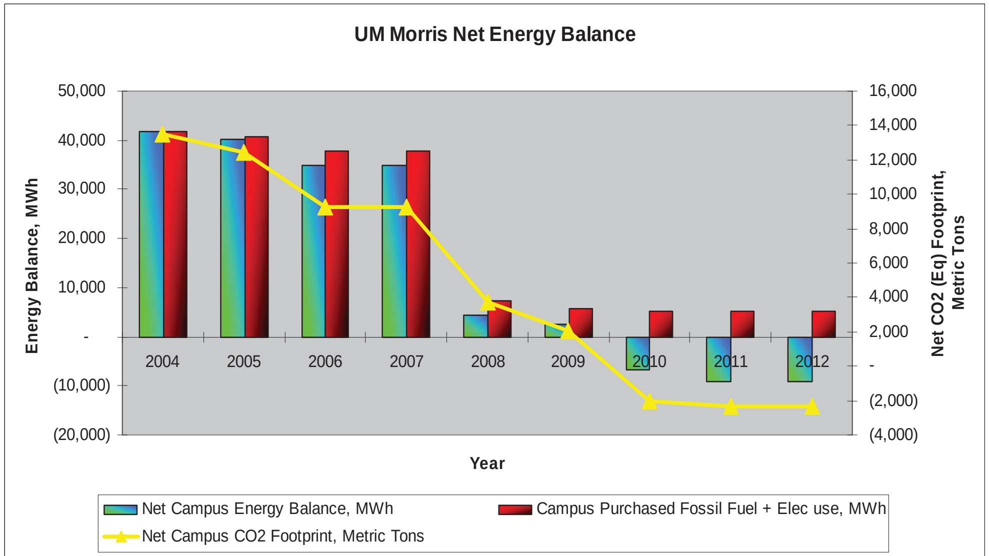
Next steps: demonstrate ability to integrate renewables/storage, cogeneration and achieve NZE status.



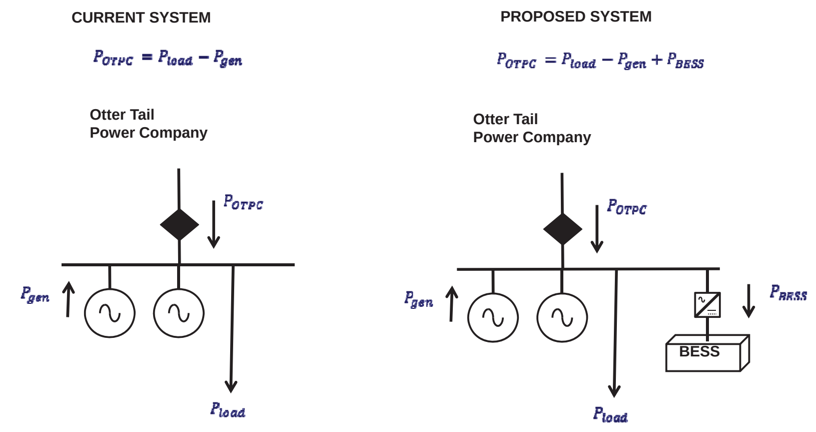
UM-Morris Potential Smart Grid projects

- Location: Morris, MN
- Size: 1,800 student residential campus
- Energy Sources:
  - Biomass gasification plant
  - Solar thermal panels
  - Solar photovoltaic system
  - Two 1.65MW wind turbines (provides ~70% of campus's electricity needs)
- Load 300,000-750,000 kWh/month

Going Carbon Negative…



University of Minnesota - Morris



Pgen = 2 x 1.65 MW Wind Turbines
Pload = 1.5 MW Peak

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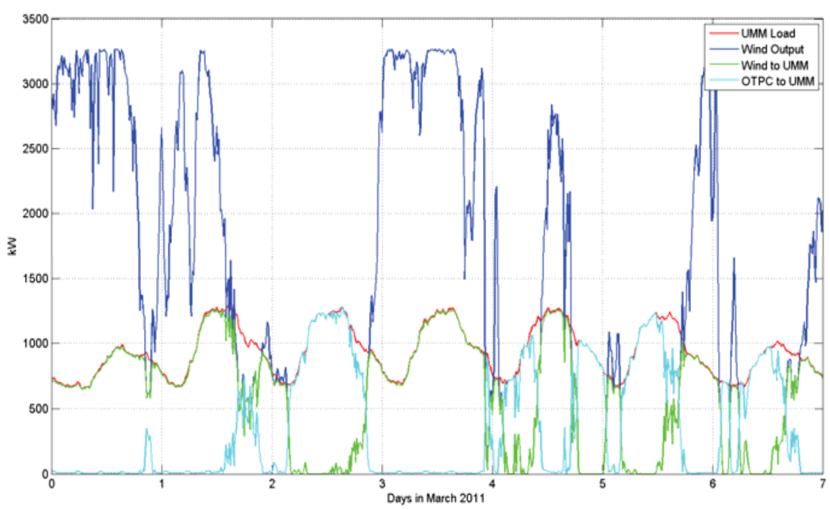
UMMorris – Typical Week in 2011



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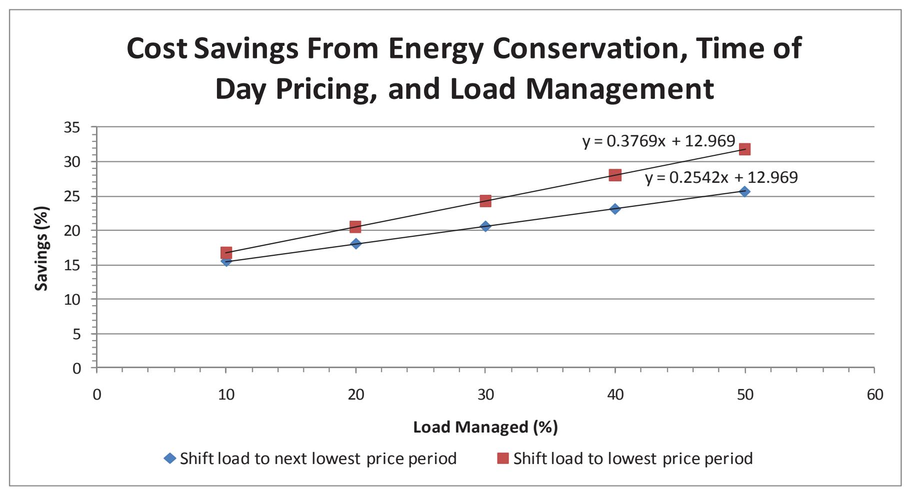
DR: Total Cost Savings



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DR: Total Cost Savings (cont.)

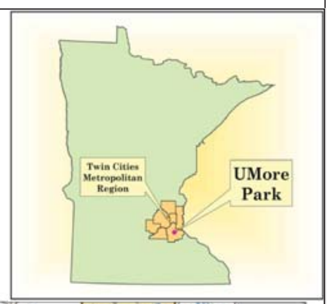
Load Managed (%)	Savings ($)	Savings (%)
Load Shifted to Next Lowest Price Period		
10	51,398	15.5
20	59,823	18.1
30	68,247	20.6
40	76,671	23.1
50	85,096	25.7
Load Shifted to Lowest Price Period		
10	55,463	16.7
20	67,952	20.5
30	80,442	24.3
40	92,931	28.0
50	105,420	31.8

Smart Grid Assessment for UMore Park

Smart Grid assessment for UMore Park

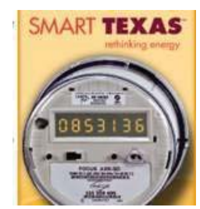
Can the application of smart grid technologies, and more broadly, smart systems provide a better method and designs for managing the energy needs of the community?

Massoud Amin and his team of graduate MOT assistants, Eric Bohnert, Andrew Fraser, Hope Johnson and Shanna Leeland

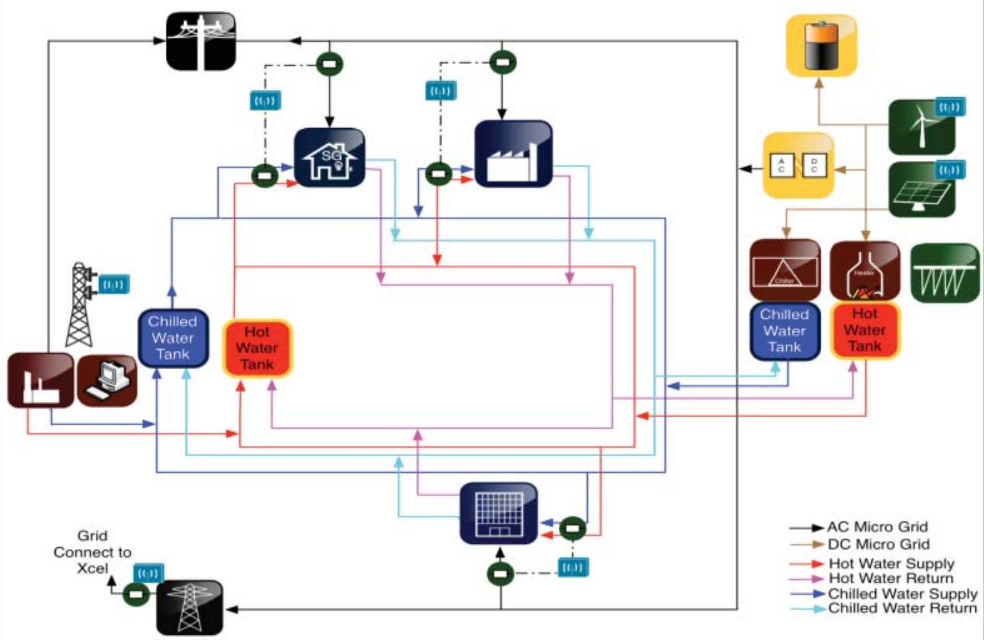


UMore Park: Smart Grid Technologies for Homes

- Photovoltaic inverters
- Smart meters, in-home displays
- Grid-ready appliances
- Electric vehicle power charging station
- Battery storage backup
- Estimated costs: $10,670 to $27,190 per home
- About 4-5% of total cost



UMore Park: District Energy and Smart Grid Options

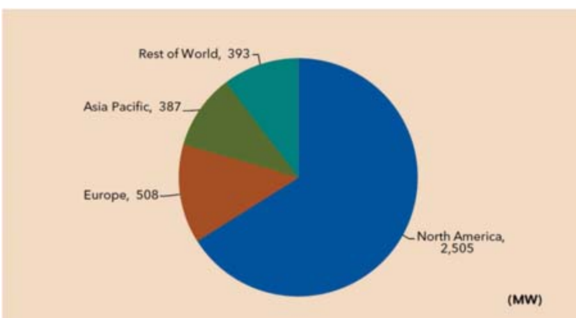


Smart Grid U™

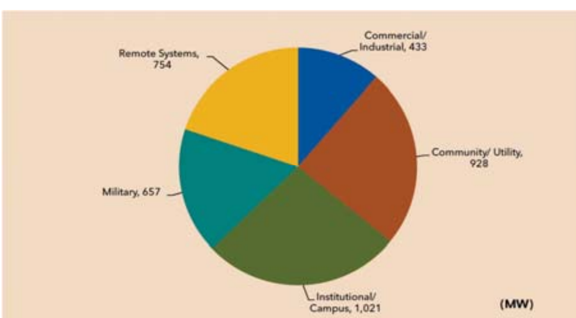
- Lessons learned and key messages:
  - Consider all parts together (Holistic Systems approach)
  - Focus on Benefits to Cost Payback
  - Remove deficiencies in foundations
  - The University as a Living laboratory
  - Education and Research → Implement new solutions
- **Consumer engagement critical to successful policy implementation to enable** end-to-end system modernization
- If the transformation to smart grid is to produce real strategic value for our nation and all its citizens, our goals must include:
  - Enable **every building and every node to become an efficient and smart energy node.**

Microgrids:

Total Microgrid Capacity by Region, World Markets
(Navigant Research, 2013)



Total Microgrid Capacity by Segment, World Markets

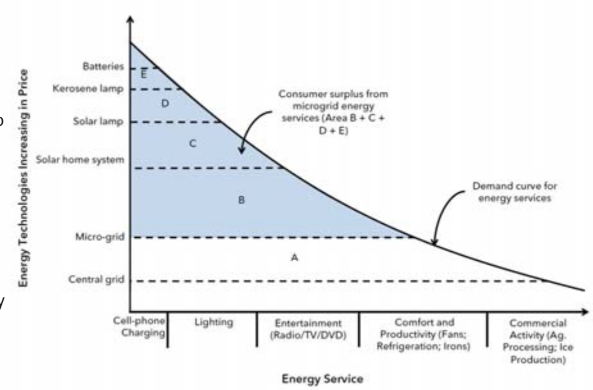


Price of Energy Services Provided by Energy Fuels and Technologies

Microgrids deliver benefits through cost savings relative to lower quality energy fuels and technologies.

- In Haiti, for example, rural house-holds spend an average of $10/month on kerosene and candles, and an additional $4/month on cell-phone battery charging (EarthSpark International, 2009).
- In Bangladesh, rural families use approximately half a liter of kerosene every night for lighting, which amounts to $11/month (Sovacool and Drupady, 2012).
- These high costs are reflective of the importance of lighting and phone charging services, and the exorbitant prices of each.
- Those prices work out to approximately 20-45 $/kWh for kerosene lighting on a CFL and LED equivalent basis, respectively and 60-115 $/kWh for cell-phone charging depending on the size of the phone battery.

Microgrids, when combined with efficient end-use technologies – deliver these services at far lower prices, as shown:



Examples of a few tools/templates for your use

Short-term Moves

BS = Business Strategy
CS = Corporate Strategy
IS = Innovation Strategy
GS =Government Strategy

Short-term focus is addressing high risks,
or defining the market niche and addressing its early needs

Strategy/Move	Who	What/Why	How	When	Cost/Risk

Long-term Moves

BS = Business Strategy
CS = Corporate Strategy
IS = Innovation Strategy
GS =Government Strategy

Long-term focus is satisfying strategic security (or customer) needs and reducing vulnerabilities (or expanding niche market for corresponding products)

Strategy/Move	Who	What/Why	How	When	Cost/Risk

Probability
L = < 20%
H = > 50%

Risks

Risk	Prob	Impact	Mitigation Plan
	M	M	
	M	H	
	M	M	
	L	M	
	H	H	

The R-W-W Screen

George Day, "Is it real? Can we win? Is it Worth Doing? Managing risk and reward in an innovation portfolio." Harvard Business Review, Dec. 2007

Is it Real?	Is the market real?	•Is there a need or desire for the product?
		•Can the customer buy it?
		•Is the size of the potential market adequate?
		•Will the customer buy the product?
	Is the product real?	•Is there a clear concept / value proposition?
		•Can the product be made?
		•Will the final product satisfy the market?
Can We Win?	Can the product be competitive?	•Does it have a competitive advantage?
		•Can the advantage be sustained?
		•How will the competitors respond?
	Can our company be competitive?	•Do we have superior resources?
		•Do we have appropriate management?
		•Can we understand and respond to market dynamics?
Is It Worth Doing?	Will the product be profitable at an acceptable risk?	•Are forecasted returns greater than costs?
		•Are the risks acceptable to all stakeholders?
	Does launching the product make strategic sense?	•Does the product fit with our overall growth strategy (and core competencies)?
		•Will top management support it?

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