# Power Policy and New Energy Technologies: Challenges and opportunities for smarter cities with smart grids

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## Electric Power Infrastructure: Interdependencies, Security, and Resilience

- Presidential Policy Directive 21: *"Energy and communications infrastructure especially critical because of their enabling functions across all critical infrastructure areas"*

- DOE: *"A resilient electric grid… is arguably the most complex and critical infrastructure."*

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

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Smart Grid: Technological Innovations

## End-to-end Electric Power System

Generation | Delivery | Customer

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## Drivers

Let's frame the issues. As I see it, here are the top 10 drivers for change in the electric power sector, in no particular order:

1. Acceleration of efficiency (energy intensity dropping 2%/yr.);
2. Distributed generation and energy resources (DG & DERs), including energy storage & microgrids;
3. More cities interested in charting their energy future;
4. District energy systems;
5. Smart Grid;

Source: M. Amin, "The Case for the Smart Grid: Funding a new infrastructure in an age of uncertainty." Public Utilities Fortnightly, March 2015, pp. 24-32 and IEEE Smart Grid, January 2014
http://smartgrid.ieee.org/january-2014/1024-the-ieee-smart-grid-initiative-what-s-ahead-in-2014

# Drivers (cont.)

6. Electrification of transportation;
7. New EPA regulations, such as for greenhouse gases under Section 111(d) of Clean Air Act;
8. Demand response (and 3rd-party aggregation of same);
9. Combined heat & power (CHP), plus waste heat recovery; and
10. The increasingly interstate and even trans-national nature of utilities (and contractors too, which leads to security concerns).

Source: M. Amin, "The Case for the Smart Grid: Funding a new infrastructure in an age of uncertainty." Public Utilities Fortnightly, March 2015, pp. 24-32 and IEEE Smart Grid, January 2014
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# Many opportunities/challenges facing the energy and power infrastructure

- Aging assets
- Confluence of multiple disruptive forces
- Severe weather events
- Physical and cyber attacks
- Dependencies and inter-relationships with other infrastructures (gas, telecommunications, etc.)
- Market and policy including recovery of investments

Source: IEEE report to the U.S. DOE for the White House's Quadrennial Energy Review (QER) to guide U.S. energy policy. See Chapter 4, on implications and importance of aging infrastructure and the options for addressing them:
http://www.ieee-pes.org/final-ieee-report-to-doe-qer-on-priority-issues

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# Key Questions

These drivers in turn lead to some important questions, both for the utility, as a business, and for regulators, as makers of policy:

1. What business models may develop, and how will they successfully serve both upstream electricity market actors and
2. What effects could these new business models have on incumbent utilities, and what opportunities may exist for other industry sectors to capitalize on these changes?
3. How will regulation need to evolve to create a level playing field for both distributed and traditional energy resources?

→

Source: M. Amin, "The Case for the Smart Grid: Funding a new infrastructure in an age of uncertainty." Public Utilities Fortnightly, March 2015, pp. 24-32 and IEEE Smart Grid, January 2014
http://smartgrid.ieee.org/january-2014/1024-the-ieee-smart-grid-initiative-what-s-ahead-in-2014

# Key Questions (cont.)

4. What plausible visions do we see for the future of the power sector, including changes for incumbent utilities, new electricity service providers, regulators, policymakers, and consumers?

5. What measures are practical and useful for critical infrastructure protection (CIP) and the security of cyber physical infrastructure? energy consumers?

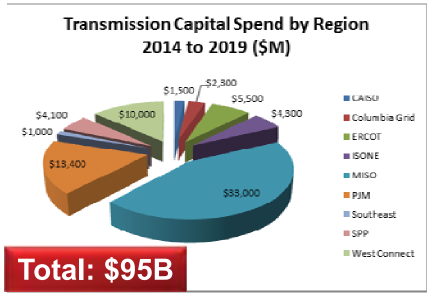
**"Today's regulatory framework is keeping us locked into the 20th century." - Anne Pramaggiore, CEO, ComEd**

Source: M. Amin, "The Case for the Smart Grid: Funding a new infrastructure in an age of uncertainty." Public Utilities Fortnightly, March 2015, pp. 24-32 and IEEE Smart Grid, January 2014
http://smartgrid.ieee.org/january-2014/1024-the-ieee-smart-grid-initiative-what-s-ahead-in-2014

# U.S. Industry Trends

Electric System Resiliency – Dept. of Homeland Security lists 17 critical infrastructures with Energy on the top as others require it

- Aging Infrastructure ***Investment*** - Electric utility industry will require up to $2 trillion by 2030, including generation (EEI)
- Reliability ***Investment*** – DOE estimates outage cost of $125B
  - White House estimates weather-related outages cost $18B to $33B annually
- Renewables and EV Integration and Microgrids ***Investment***
- Demand Side Management
- Natural Gas Interdependency
- FERC 1000 ROFR elimination




**Total: $95B**

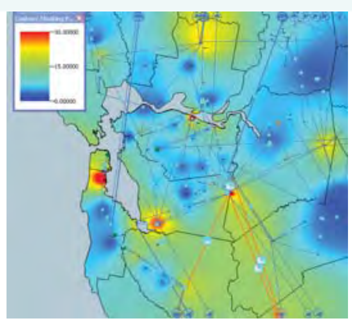


# Industry Drivers

**Grid Resiliency**
- Cost of Major Outages
- Public Safety & Security
- Critical Infrastructure Protection
- *Physical vulnerability*

**Physical Vulnerability**
- Transmission Equipment
- System - Selecting critical substations
- Standards

Equipment with gunshot damage



Source: IEEE report to the U.S. DOE for the White House's Quadrennial Energy Review (QER) to guide U.S. energy policy. See Chapter 4, on implications and importance of aging infrastructure and the options for addressing them: http://www.ieee-pes.org/final-ieee-report-to-doe-qer-on-priority-issues



## Future Power Systems…
## Substantially Larger Contribution from Renewables

- Automation aspects of integrating distributed generation and storage
  - Sources such as wind and solar characterized by intermittency of operation and inability to dispatch
- Maintain balance between instantaneous supply and demand
- Storage technologies (modeling, assessment and demonstrations)
  - Storage and Grid Integration of wind and solar
  - Impacts of plug-in electric (including hybrid) vehicles is evaluated through modeling and simulation

## 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…





## Anatomy of the Smart Grid

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

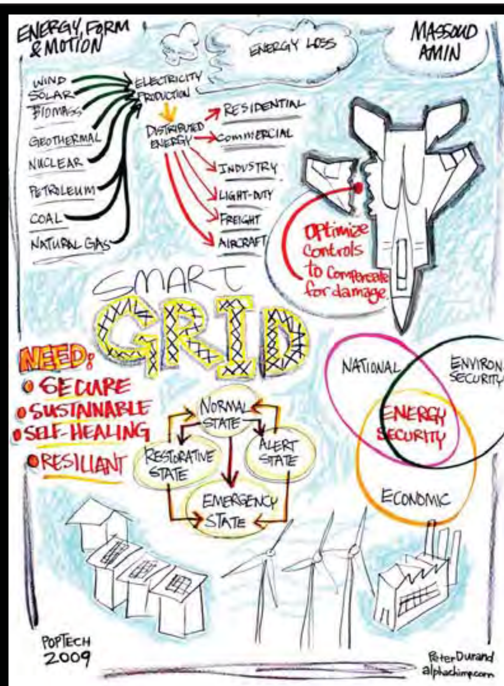
## The Emerging Smart Grid or Energy Web:
## A Complex Adaptive Infrastructure System

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

"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."

-- Wired Magazine, July 2001

http://www.wired.com/wired/archive/9.07/juice.html




## Most elements of a smarter and "more perfect" electricity system are already available

### *More perfect* SUPPLY

- Small-scale local generation (e.g. rooftop solar panels) to lessen transmission distances
- Co-generation of electricity and heating that significantly reduces waste

### *More perfect* DELIVERY

- High efficiency systems that reduce transmission losses
- Smart switches which reduce outages by automatically identifying and isolating faults and interruptions

### *More perfect* USE

- Smart meters that discount off-peak electricity
- High efficiency smart thermostats and appliances that automatically adjust to reduce costs and usage

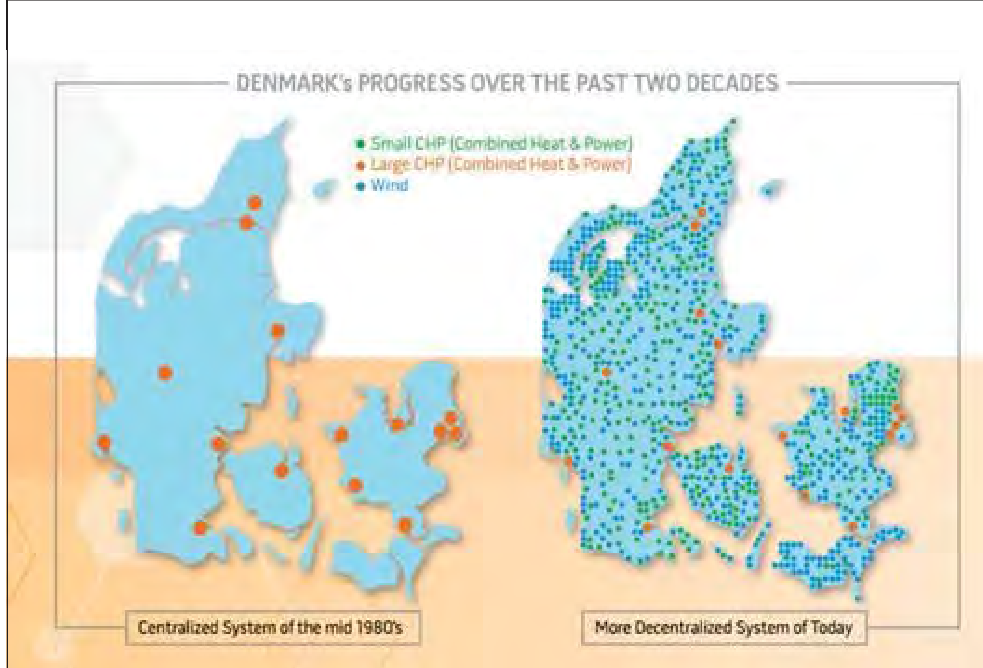
Over the next five years, **smart microgrids will play a growing role in meeting local demand, enhancing reliability and ensuring local control of electricity.** Emerging developments and challenges the smart grid community must address:


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



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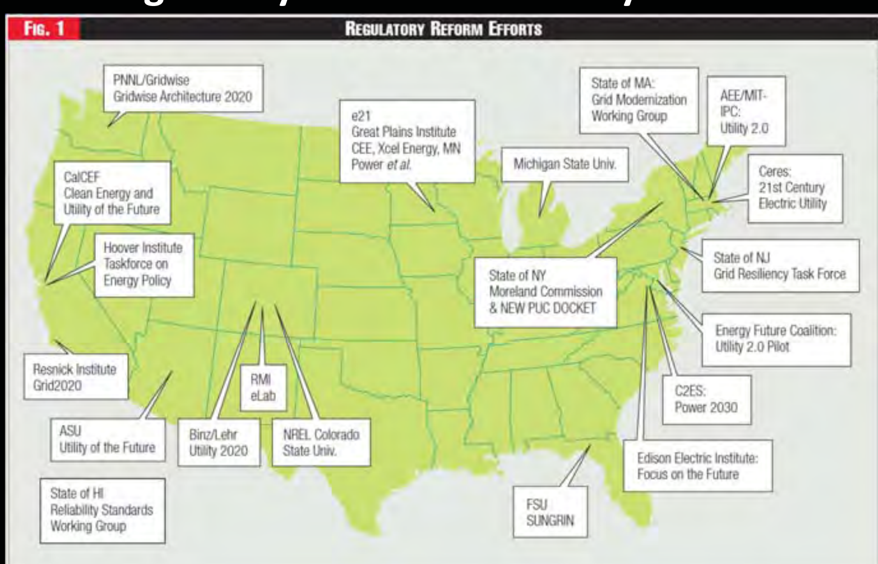
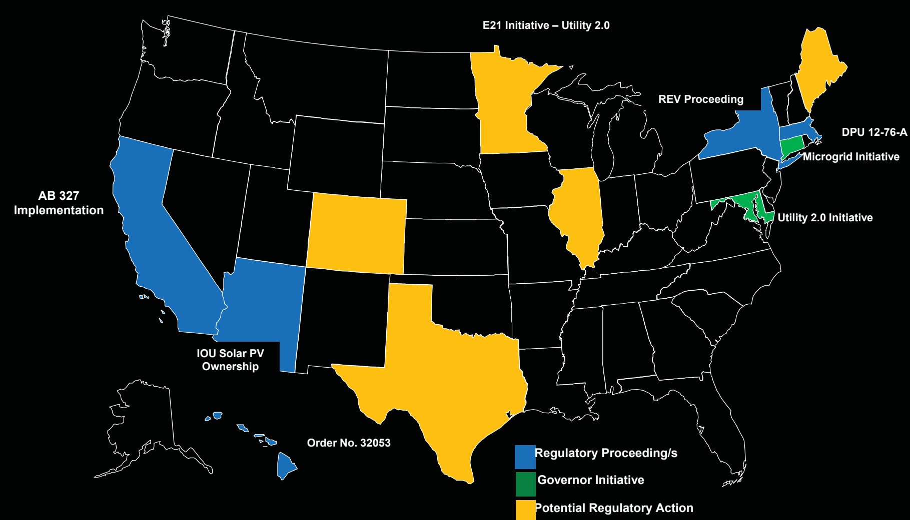
# U.S. Regulatory Reform and Utility 2.0 Efforts




Source: Massoud Amin, "The Case for the Smart Grid: Funding a new infrastructure in an age of uncertainty." Public Utilities Fortnightly, March 2015, pp. 24-32. Map adapted from the Energy Foundation

## 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 )



# Utility of the Future (UoF): Initiative Status

FIG. 2 UTILITY OF THE FUTURE: STATUS OF VARIOUS INITIATIVES

| 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 |
| 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 service and DR as a resource |
| NV Energy | Customer service 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 |
| Tuscon 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 |

Source: Massoud Amin, "The Case for the Smart Grid: Funding a new infrastructure in an age of uncertainty." Public Utilities Fortnightly, March 2015, pp. 24-32. Map adapted from Mr. Erich Gunther, EnerNex

| Utility | Location | Rating | Technology |
|---|---|---|---|
| **Battery Storage For Utility Load Shifting Or For Wind Farm Diurnal Operations And Ramping Control** | | | |
| Duke Energy | Goldsmith, TX | 24 MW | Proprietary |
| Modesto Irr. District | Modesto, CA | 25MW / 75MWh | Zn-Cl Flow |
| SoCal Edison | Tehachapi, CA | 8MW / 32MWh | Lithium Ion |
| **Frequency Regulation Ancillary Services** | | | |
| PPL Corp/Midwest Energy | Tyngsboro, MA; Hazle Township, PA | 20MW / 5MWh | Flywheel |
| **Distributed Energy Storage For Grid Support** | | | |
| Painesville Municipal | 5 locations in OH, PA, VA, IN, MA | 1MW / 6-8MWh | Vanadium Redox |
| Detroit Edison | Hanover, MA; West | 25kW / 50kWh (20 | Lithium Ion |



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# TRANSFORMING the chaos

TRANSFORMATION
Overhauling business models, standards, regulatory, policy, funding opportunities



EMERGENCE
Emerging leaders and technologies

CONVERGENCE
Bringing it all together—ne participants, systems and infrastructure, national and international



HUMANS
Humanizing infrastructure

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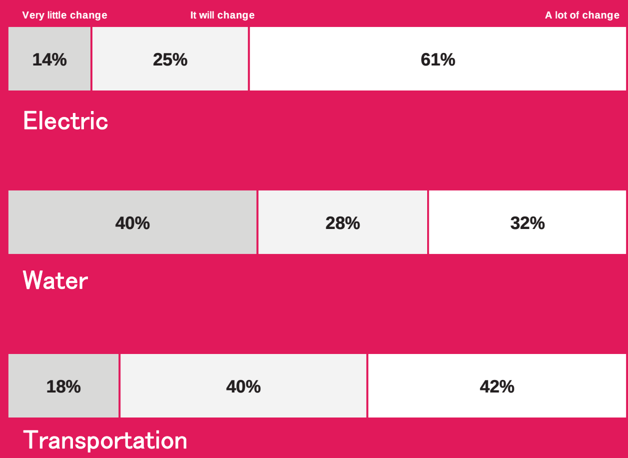
# TRANSFORMATION

Overhauling business models, standards, regulatory, policy, funding opportunities

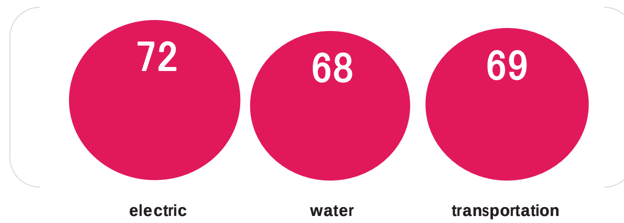
ets

# CHANGE for current business models




# REGULATORS ready?

Percent of respondents who think regulators are doing a poor job of supporting business model transformation

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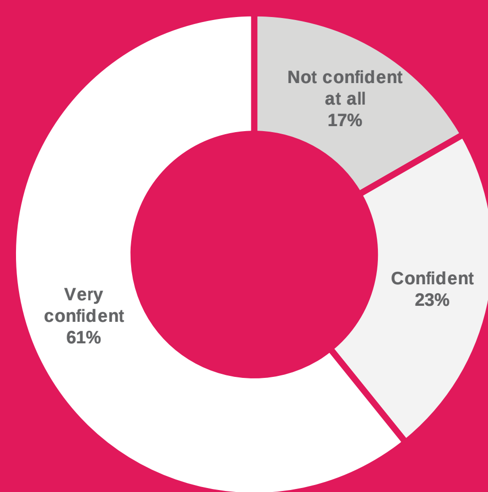
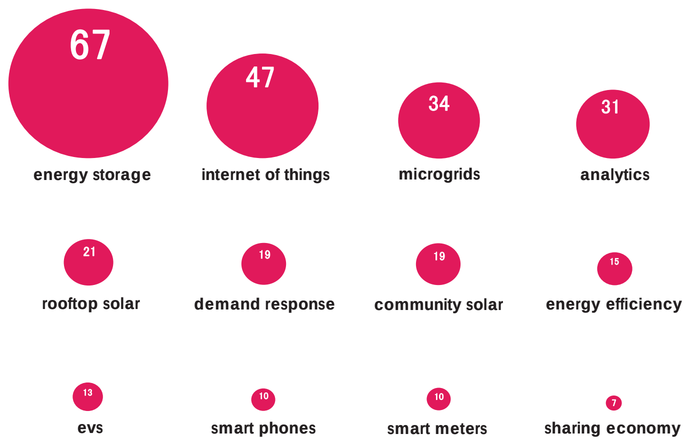
# EMERGENCE

Emerging leaders and technologies

# TECHNOLOGY disrupt infrastructure?



# MOST DISRUPTIVE technologies




Question: Select the top three technologies do you think will be the most disruptive for smart infrastructure?

Figure show percent of respondents who put a technology in their top three.



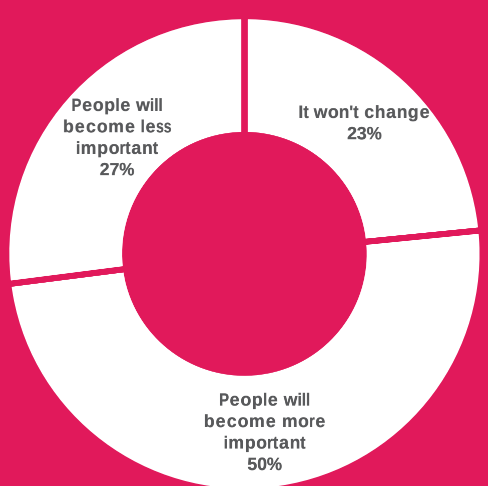


# HUMANS

Humanizing infrastructure

ets

# PEOPLE as new technologies rollout

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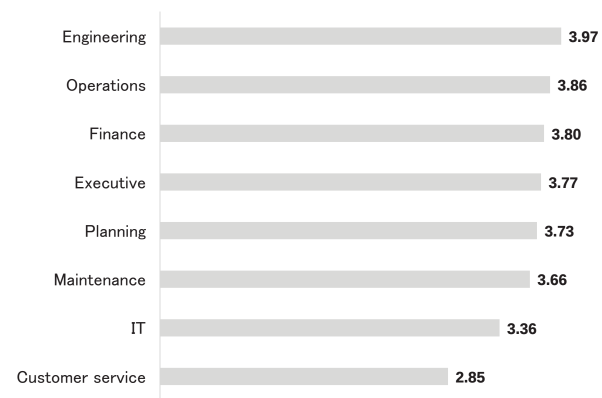
# A VARIETY of people are needed…




## …for a variety of things

(like asset management)

Role of groups in asset management (1 = no role, 5 = significant role)

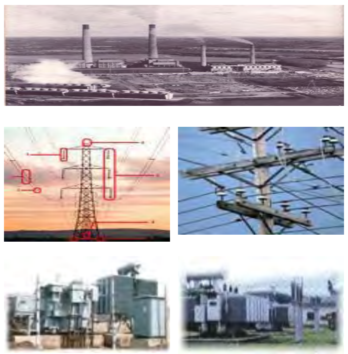
Source: ABB – Zpryme survey of 150 utility executives, 2015-2016.

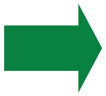
Smart Grid: Options, Costs and Benefits

## Interface of Smart Grid and Microgrids

- Fossil Fuel
- Long Distance Central Station
- An Aging Infrastructure
- Out of Capacity

- Renewable Power
- On-site
- Zero Energy Building
- Smart Grid

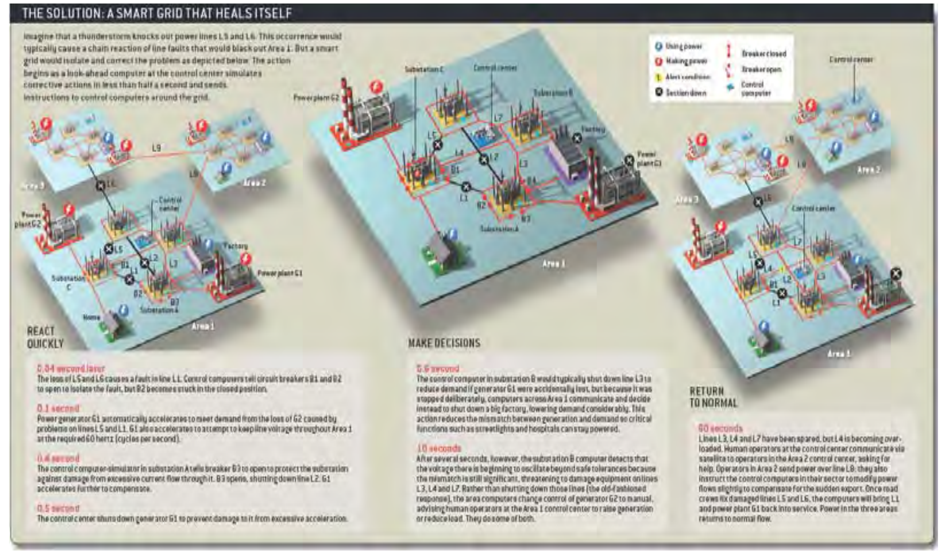








## Smart Self-Healing Grid

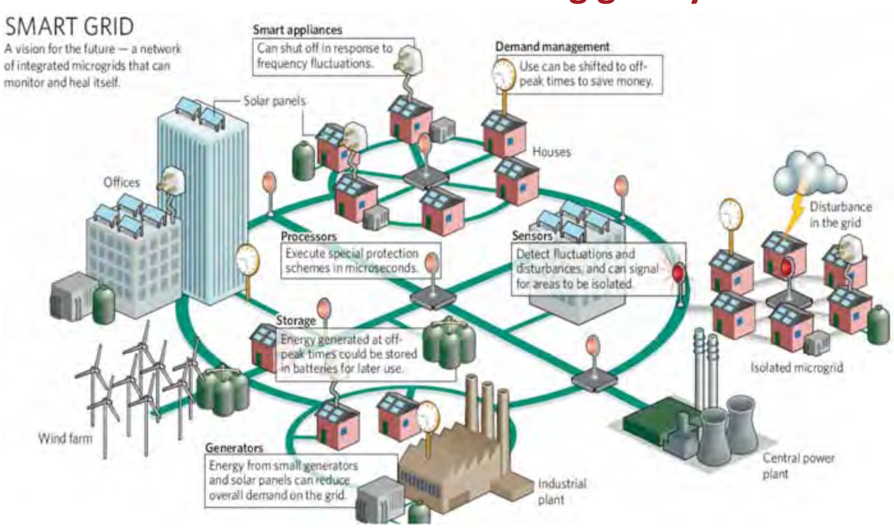



Source: Amin & Schewe, "Preventing Blackouts," Scientific American, May 2007





## Integrate microgrids, diverse generation and storage resources into a smart self-healing grid system




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

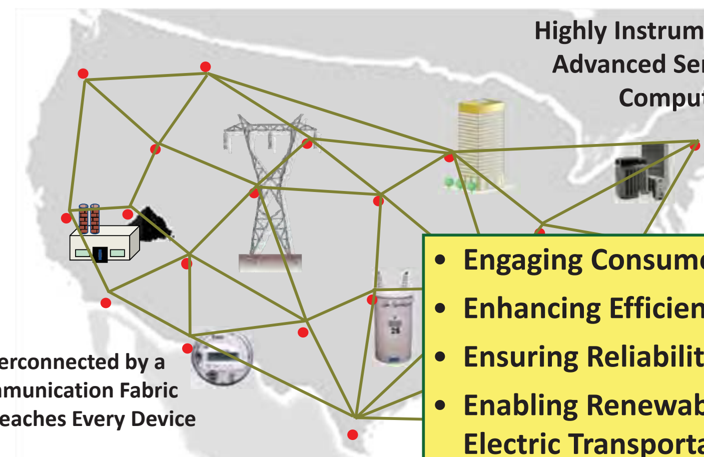




Many Definitions – But One VISION

## Visualizing the Smart Grid

Highly Instrumented with Advanced Sensors and Computing



Interconnected by a Communication Fabric that Reaches Every Device

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

# Smart Grid: Technological Innovations

- Intelligent Sensors, Communication and Analysis
- Increase and Flexible Power Flow
- Secure From Cyber and Physical Attack



# Key Technology Areas: Management

| Technology Area | Description |
|---|---|
| Integrated Communications | High-speed, fully integrated, two-way communication technologies will make the modern grid a dynamic, interactive "mega-infrastructure" for real-time information and power exchange. Open architecture will create a plug-and-play environment that securely networks grid components to talk, listen and interact. |
| Sensing and Measurement | These technologies will enhance power system measurements and enable the transformation of data into information. They evaluate the health of equipment and the integrity of the grid and support advanced protective relaying; they eliminate meter estimations and prevent energy theft. They enable consumer choice and demand response, and help relieve congestion. |
| Advanced Control Methods | New methods will be applied to monitor essential components, enabling rapid diagnosis and timely, appropriate response to any event. They will also support market pricing and enhance asset management and efficient operations. |
| Improved Interfaces and Decision Support | In many situations, the time available for operators to make decisions has shortened to seconds. Thus, the modern grid will require wide, seamless, real-time use of applications and tools that enable grid operators and managers to make decisions quickly. Decision support with improved interfaces will amplify human decision making at all levels of 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 | |

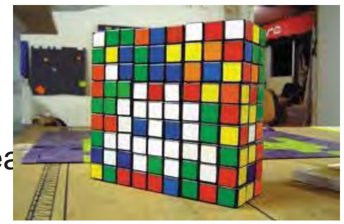


# Examples of SG Technologies & Systems

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

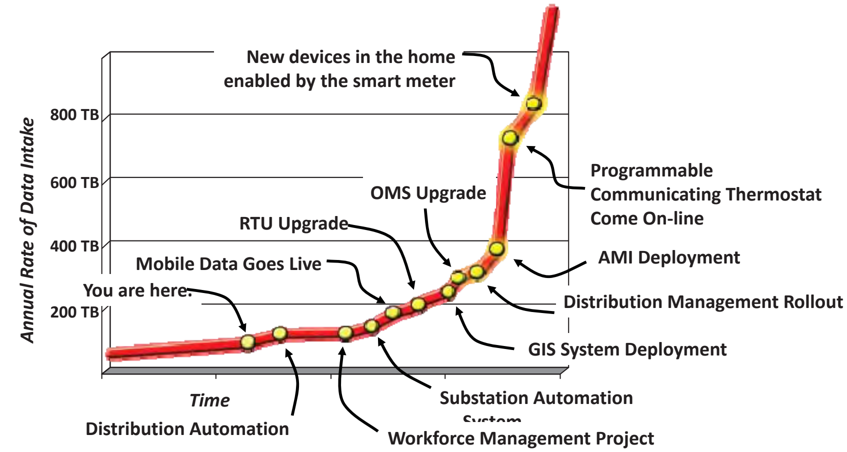
# Paradigm Shift - Data

- 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 yea





# Smart Grid: Tsunami of Data Developing

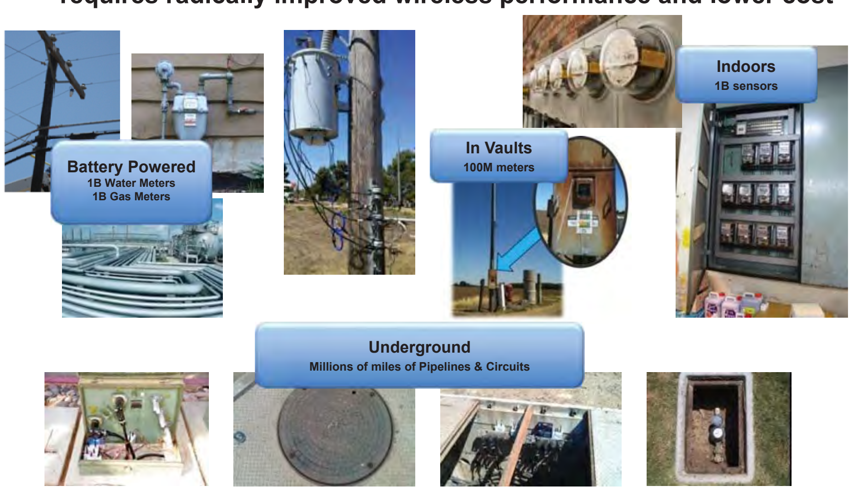



**Tremendous amount of data coming from the field in the near future - paradigm shift for how utilities operate and maintain the grid**



# Industry Needs to Connect 50 Billion Devices by 2020

**An unsolved problem costing billions per year in wasted resources requires radically improved wireless performance and lower cost**





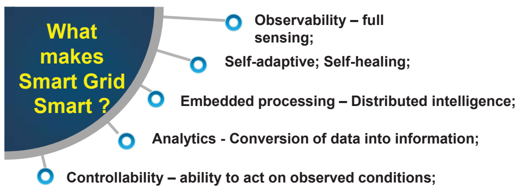

# ICT Infrastructure for Vertical Industries

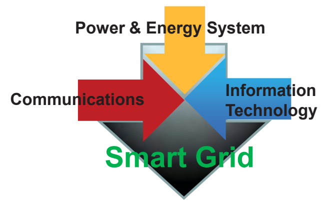

**Integration , Adaptation , Partnership**

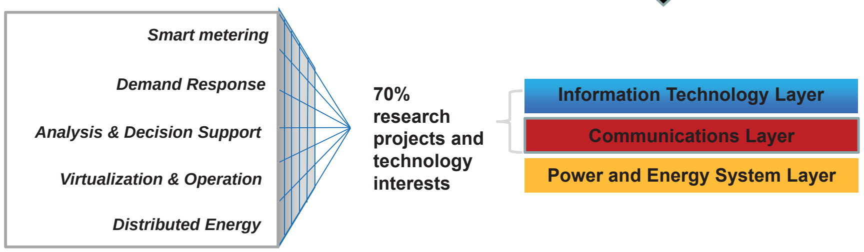
| | | |
|---|---|---|
| Unified Communication & Collaboration | Cloud CC, UC, VC/TP, IVS, VDI | Efficient |
| Information & Security | xDC Security, Network Security, Mobile Security, Data Loss Prevention, Compliance, Security OM | Secure |
| Cloud-based Green Data Center | Data Center, Server, Storage, Cloud Software Platform | Reliable |
| Enterprise Network Infrastructure | DCN, IP Network, Transmission Network, Wireless Network | Flexible |

Shared platform & Chipsets

## Nerve System and Enabler of Smart Grid







## ICT Challenges in Smart Grid

### Service Requirement

**Power transmission and transformation**
- Strong, Long range, high capacity, and low line-loss

**Dispatch and Control**
- Intelligent, precise , on-demand resource allocation;

**Distribution and Consumption**
- Intelligent, diversified widely distributed terminals;
- Differentiated services: EMS, Protection, AMI, Video, etc.

**Management Information System**
- heterogeneous information ,Multiple data stream, High bandwidth,
- Cloud computing, Big Data, Disaster Recovery;

**New Services**
- Distributed power generation, Micro-grid;
- E-vehicle charging network,
- Mobility with live video and data services
- NAN, HAN, smart home, energy efficiency management;

### Challenges

**Reliability and Security**
- High reliability of network structure
- QoS for real-time services
- Network security risks

**Network coverage and scalability**
- Network coverage and service bearers should match fast development of the Grid along with new services

**Flexible Access Network**
- Multiple scenarios for distribution, AMI and new services
- Flexible access technologies
- Economic efficiency

**Bandwidth and Capacity**
- Fast increasing broadband applications for production and management

**Network Management**
- Complex network structure and increasingly large capacity
- Hierarchical and cross-platform management




## A Better Connected Smart Grid

**Grid data sharing**

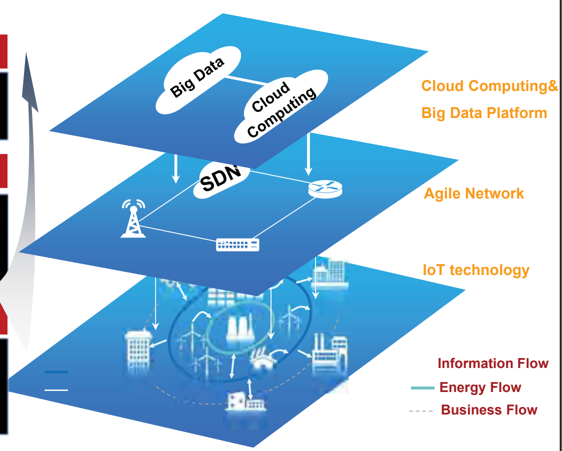
Resource-sharing cloud data centers provides an effective IT platform for business applications like BI, Big Data, decision support & analytics;

**Agile communication networks**

Fast and robust backbone network , flexible and converged access network offers ubiquitous access to smart devices, achieving real-time bi-directional interaction

**Better-connected smart terminals**

With rich interface the IoT gateway implements high-speed two-way interconnection for intelligent meters, sensors, and controllers everywhere, providing communication channel to an open M2M platform

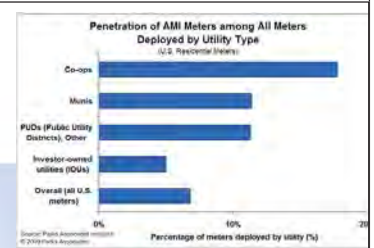


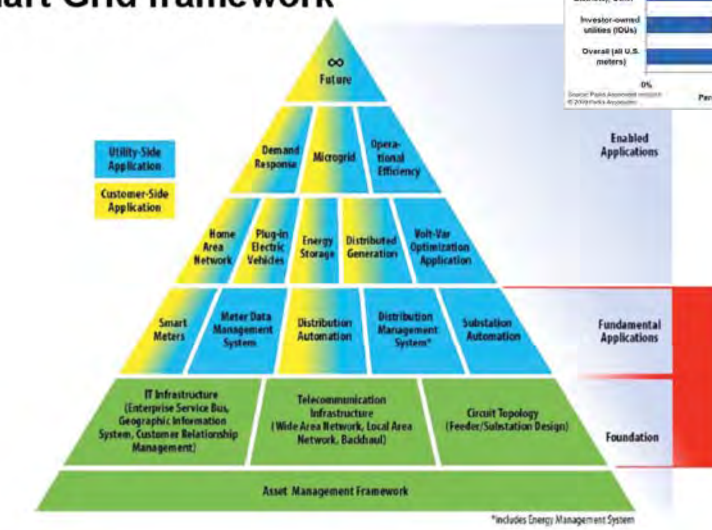




## End-to-End Smart Grid Opportunities

### Smart Grid framework




Source: BC Hyrdo

## Unlocking Smart Grid Benefits Requires

- Intelligent Technology
- Intelligent Policy
- Empowered Consumers & Communities

•INTELLIGENCE = the ability to understand and deal successfully with new situations

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## "The Integrated Grid"

- The Electricity Industry is in the midst of profound change.
- The Dynamic, Secure, Electronic grid systems are needed for precise control and 2-way power flow.
- Grid Performance Criteria requires a fully integrated grid with full substation microgrids.

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## Utility Business Challenge

- Change is inevitable
- Utilities must focus on customer service
- Microgrids are the key enabler

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## Utility Frustration

- "It's all about the customer today and we know very little; and we have no regulatory incentive."
- "Customer price transparency is the key with education and automation."
- "Our infrastructure, policies and incentives are legacies of the 1930s."

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## Gaining Customer Acceptance

- ENGAGE through dynamic rates, technology and education
- MOTIVATE through savings and automated control
- DELIGHT through easy, enjoyable, fulfilling experiences

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## New Business Opportunities

- Turnkey Smart Buildings
- Web-enabled Energy Systems
- Residential DR
- Turnkey Perfect Power Retailing
- Turnkey AMI
- Commercial Perfect Power Retailing
- Enhanced Distribution Reliability Zones
- Entrepreneurial Microgrids

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## Characteristics of Smart Grids

- Enables Informed Customer Participation
- Accommodates all Generation & Storage Options
- Enables New Products, Services & Markets
- Provides the Power Quality to meet all needs
- Optimizes Asset Utilization & Efficiency
- Provides Resiliency to all Manner of Interruptions

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## How could the Smart Grid Improve Competitiveness and Create Jobs?

- Enable municipalities and utilities to increase reliability for residents
  - Improve safety and reduced economic losses
  - Eliminate hidden costs
- Enable residents to manage costs
  - Avoid higher priced peak electricity
  - Protects residents from rising fuel and new capacity costs
  - Leverages lower cost off-peak electricity through real time or hourly pricing
  - Generate revenue by providing ancillary services to the system operator
- Enable municipalities and utilities to improve the environment
  - Provide residents access to lower carbon generation sources
  - Enable municipalities to improve esthetics and increase the overall value of real estate
- Enable new service offers to residents
  - Backup power, renewable power, low carbon power

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# Distribution Systems Consumers Microgrids




## Pivotal and Emerging Technologies

1. **Energy storage**
2. **Microgrids**
3. **Cyber-Physical Security**
4. **Advanced Controls with Secure Communications**
   - Operating Platform – Advanced EMS/DMS
   - Sensors, Monitoring, and Diagnostics
   - Smart Breakers
5. **In-home Technologies**
   - Smart homes and Demand Response

**The next phase of power grid evolution is managing demand through consumers as part of a well-managed, secure, and smarter grid**




## The Microgrid Revolution

- **Nearly all Utilities now see Microgrids as an important business opportunity.**
- **Utilities and Independent Power Producers both are viewing Microgrid Partnerships as the best ownership model.**
- **Regulations must be changed to better incentivize Microgrids and allow them to cross public rights-of-way.**




## The Role of the Microgrid

– **Optimize distribution performance and service value**
– **Maximizing DC Power**
– **Seamlessly integrate electricity supply and demand**
– **Convert buildings from Power Pigs to Power Plants**
– **Provide user-friendly consumer empowerment**
– **Open the door to entrepreneurial innovation**
– **Enable local green enterprise zones**

## Microgrids Significantly Improve Centralized Grids

- Microgrids provide utilities the ability to enhance security, reliability, and reduce outages without total grid redesign.

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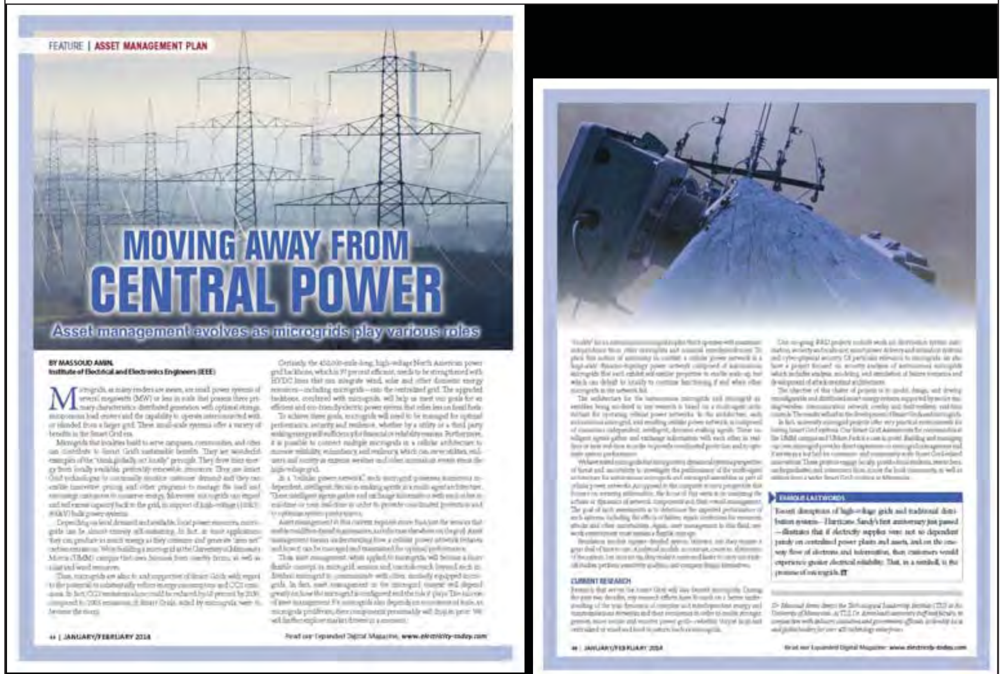




## In-home Technologies:
## Smarter homes and Demand Response

- **Smarter Homes**
  - Defer demand
  - Optimize supply
- **Electric vehicles and interface with grid**
  - Defer charging to off-peak times
  - Manage those times among a EV population
  - Use as energy source during periods of peak demand
- **Education**
  - Needs to be part of the technology shift
  - Results in lowered peak usage

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## Pivotal Technology 1

- **Smarter Homes and Meters**
  - Sense power requirements
  - Demand Response
  - Allow consumers to be aware of power use
  - Reduces downtime associated with outages
  - Integrate renewables onto the grid
  - Consumer services

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# Pivotal Technology 2

- Smart Energy Distribution Management Systems (SEDMS)
  - Monitors consumer demand requirements
  - Signals generating capacity changes
  - Manage via accurate, real-time measurement
  - Respond faster to demand changes

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# Pivotal Technology 3

- Integrated Communications
  - Allows up and downstream interface
  - Can use multiple transports
    - Wireless
    - Broadband over Powerline
    - Broadband
    - Cellular

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FEATURE | STATE OF INDUSTRY

HOW TO SAVE AGING ASSETS

Applying limited resources to critical infrastructure

PRACTICAL STEPS

NIST: Enterprise-Wide Risk Management

- Multi-tiered Risk Management Approach
- Implemented by the Risk Executive Function
- Enterprise Architecture and SDLC Focus
- Flexible and Agile Implementation

TIER 1 Organization (Governance)

TIER 2 Mission / Business Process (Information and Information Flows)

TIER 3 Information System (Environment of Operation)

STRATEGIC RISK FOCUS

TACTICAL RISK FOCUS

Figure 1



# Customer

- Smart Appliances
- Electric Vehicles
- Energy Efficiency
- Demand Response
- Distributed Energy Resources

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# "Customers are the Utility's Greatest Untapped Reserve" *Schneider Electric USA, Inc.*

- **Educate**: Dynamic pricing & home energy management value
- **Engage**: Get customer's attention and hold it by making a difference
- **Empower**: Enable automatic, real-time customer control
- **Emphasize**: The smart grid is a win-win for everyone
- **Equip**: Give Customers what they want – customer choice is the key



# SMART GRID POLICY IMPLICATIONS

- **Focus on Consumer-Societal Benefits**
  - Seamless Supply/Demand Interconnect
  - Consumer Empowerment
  - Reliability Transformation
- **Help Utilities Deal with the Inevitable**
  - Universal Real Time Pricing
  - Distributed Generation Microgrids
  - Retail Service Competition

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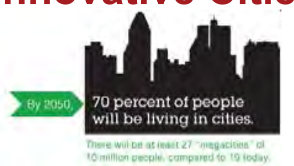
# Smarter about education, safety, energy, water, food, transp., e-gov… Innovative Cities:

- **Smarter transportation**
  **Stockholm, Dublin, Singapore and Brisbane are working with IBM to develop smart systems ranging from predictive tools to smart cards to congestion charging in order to reduce traffic and pollution.**
- **Smarter policing and emergency response**
  **New York, Syracuse, Santa Barbara and St. Louis are using data analytics, wireless and video surveillance capabilities to strengthen crime fighting and the coordination of emergency response units.**
- **Smarter power and water management**
  **Local government agencies, farmers and ranchers in the Paraguay-Paraná River basin to understand the factors that can help to safeguard the quality and availability of the water system. Malta is building a smart grid that links the power and water systems, and will detect leakages, allow for variable pricing and provide more control to consumers. Ultimately, it will enable this island country to replace fossil fuels with sustainable energy sources.**
- **Smarter governance**
  **Albuquerque is using a business intelligence solution to automate data sharing among its 7,000 employees in more than 20 departments, so every employee gets a single version of the truth. It has realized cost savings of almost 2,000%.**




"Cities are perfect for promoting change and renewable energies. Cities can serve as innovation platforms, creating clusters of business around green energy."

**Top 10 cities**

| Rank | Country | City | Rating |
|---|---|---|---|
| 1 | Canada | Vancouver | 98.0 |
| 2 | Austria | Vienna | 97.9 |
| 3 | Australia | Melbourne | 97.5 |
| 4 | Canada | Toronto | 97.2 |
| 5 | Canada | Calgary | 96.6 |
| 6 | Finland | Helsinki | 96.2 |
| 7 | Australia | Sydney | 96.1 |
| 8= | Australia | Perth | 95.9 |
| 8= | Australia | Adelaide | 95.9 |
| 10 | New Zealand | Auckland | 95.7 |

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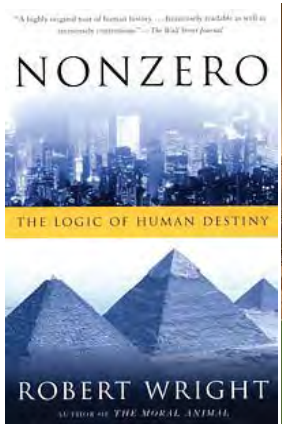
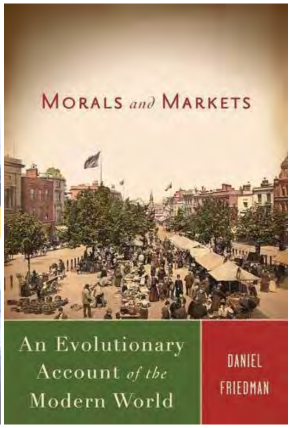
# Cities are just the right scale for smart technologies to enable diverse value creation





Source: IBM, please also see Paul Romer's Charter Cities Video: http://www.ted.com/talks/paul_romer.html

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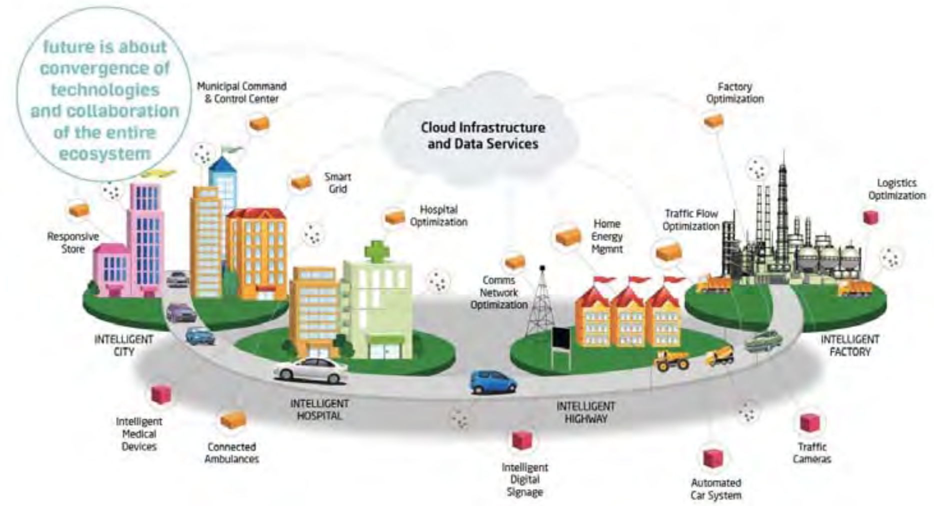



**The conference featured four parallel tracks:**

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

INTELECT 22 TO 24 JANUARY 2015

IEEE SMARTGRID




# Building a MN Smart Grid Coalition

- The Smart Grid Working Group foci:
  - Consumer preferences
  - Systems
  - Duluth Demonstration
  - SmartGrid U Demonstration*
- – Key elements of Smart Grid Roadmap and potential timetable for implementation:
  - Identified appropriate smart grid pilot projects/demonstrations
  - Develop the generation/transmission/utility/customer model
  - Develop a portfolio for Minnesota Smart Grid capabilities
  - Articulate the story for stakeholders
  - Develop state regulatory model to support this market

*- Phase 0: "Smart Room"
- Phase I: "SmartGrid School"
- Phase II: "SmartGrid U"
- Phase III: "SmartGrid City"

Evolve from "Smart Room" to "Smart Building" to "Smart Campus"

Create a "Smart Grid Sandbox" at the U of M where companies could contribute their SG technologies and expertise to see what works - and what works together – a CoLab and "skunkworks" projects.




# Background: Building a MN Smart Grid Coalition

- July 8, 2009: **"Building a Smart Grid Coalition in Minnesota"** forum hosted by the University of Minnesota–Institute of Technology, in collaboration with the Midwest Energy Technology Alliance (META) which attracted over 100 participants.
- November 18, 2008 **Smart Grid Workshop** offered in conjunction with the Initiative for Renewable Energy and the Environment's E3 Summit in November. **Focused on challenges and opportunities in Energy and Cyber Security, Energy Efficiency, and Integration of Renewables** (with over 160 participants representing a broad spectrum of industry, academia, and government).
- February 11, 2010: The **Smart Grid Roundtable** -- A select group of 30 participants chosen for their interest and expertise in the development of smart grid technologies. Support and hosting from IREE, IoE, MN Office Energy Security, and TLI)

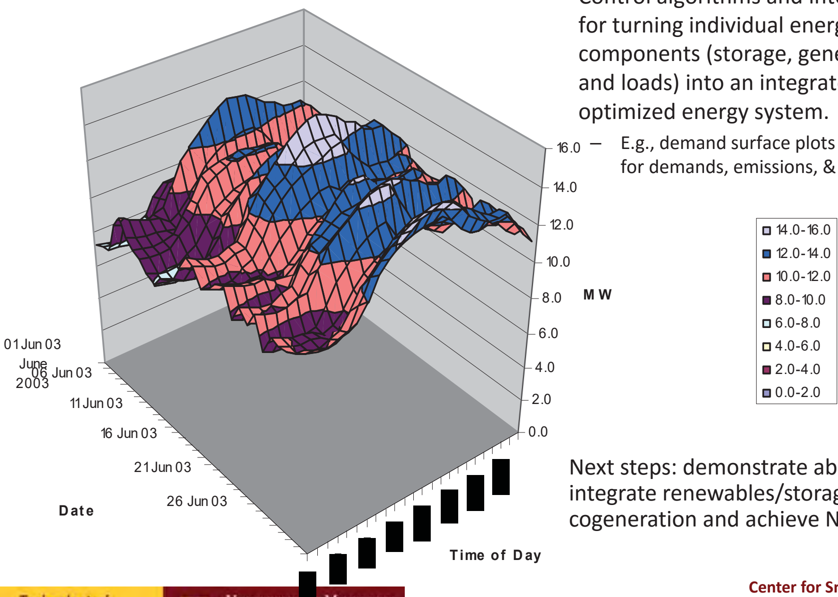
…




# Smart Grid U™

- Goal: transform the University of Minnesota's Twin Cities' and the Morris campuses into *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.





# 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.**





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

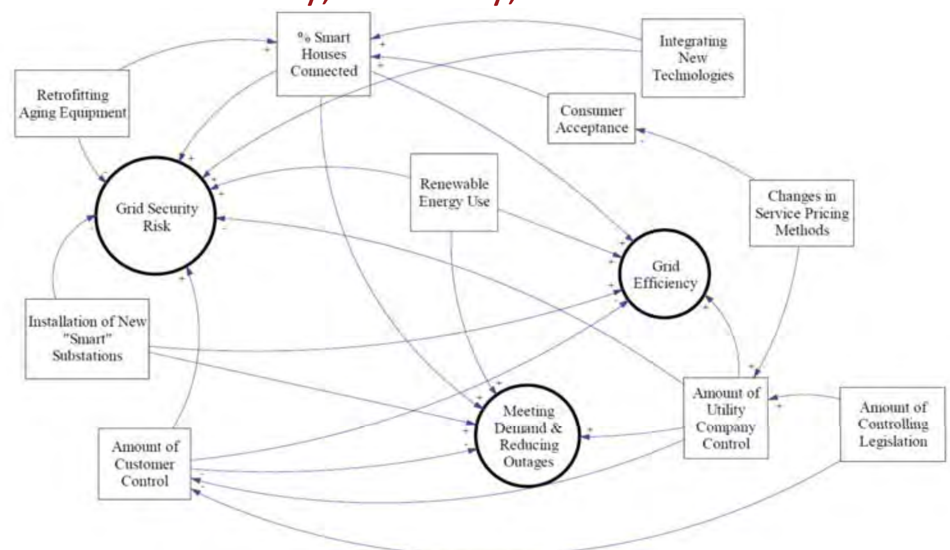
- Integration and optimization of storage devices and PHEVs with the electric power grid
- Grid agents as distributed computer
- Fast power grid simulation and risk assessment
- Security of cyber-physical infrastructure: A Resilient Real-Time System for a Secure & Reconfigurable Grid
- Security Analyses 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




# Smart Grid Interdependencies

## Security, Efficiency, and Resilience



# Four Broad Functions

- **Monitor:** Take data and get it out to be read and analyzed.
- **Control:** Use the analysis to control the monitored system.
- **Optimize:** Use the data and analysis results to best deploy multiple devices/systems/processes in a way that globally optimizes the entire system.
- **Automate:** Using machine learning/AI/ automation to perform the above in a timely manner.



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# Fast Power Systems Risk Assessment

**1987**

**Connection Machine 2**

**2010**

**$5,000,000**

**Only a dozen built**

**$350**

**100 million sold**

Doctoral Dissertation: Laurie Miller (June 2005-2013) ORNL contract, the U of MN start-up fund (2005-2008), and NSF grant (2008-2009), PI: Massoud Amin

# Fast Power Grid Simulation

**CRAY Supercomputer**

**Nvidia GeForce GPU card for PC**


*Use Nvidia GeForce GPU card to gain 15 times faster power flow calculation on PC*

# Smart Grid Assessment for UMore Park

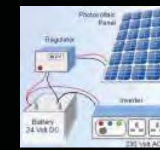
# Smart Grid assessment for UMore Park

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

# Estimated Prices for Energy-Efficient, Smart Grid Ready Homes in UMore Park

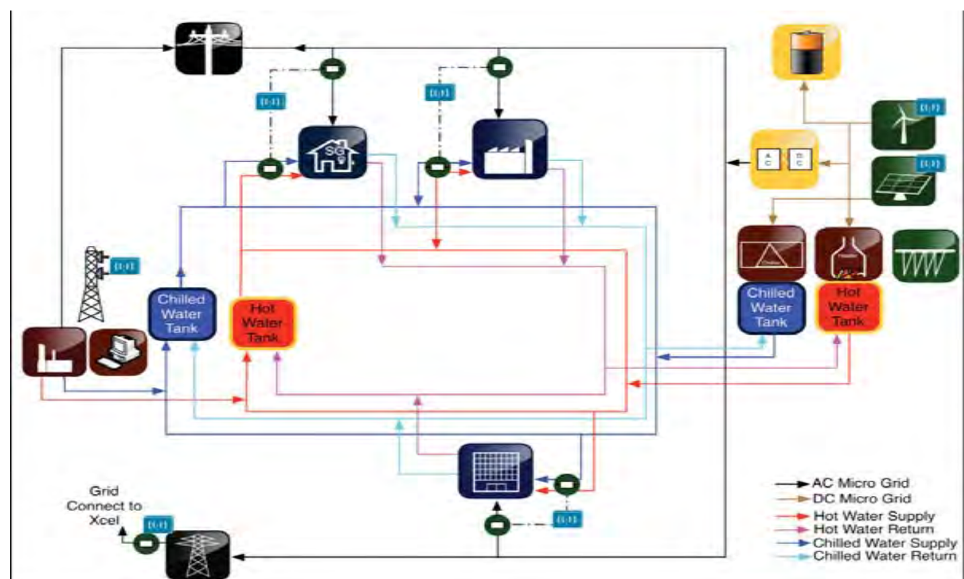
| Estimates for Lot Sizes and Home Prices in UMore Park (Maxfield Research, Inc., 2010) | | | | | | |
|---|---|---|---|---|---|---|
| | Square Foot Range | | | Estimated Home Pricing | | |
| | Low | High | Average | Low | High | Average |
| Small Lot | 1,600 | 2,500 | 2,050 | $225,000 | $350,000 | $287,500 |
| Traditional | 1,800 | 2,800 | 2,300 | $225,000 | $410,000 | $317,500 |
| Large Lot | 2,800 | 4,500 | 3,650 | $450,000 | $725,000 | $587,500 |

| Estimates for Energy-Efficient, Smart Grid Ready Homes in UMore Park | | | | | | |
|---|---|---|---|---|---|---|
| | Price Ranges | | | Cost Over Traditional Home | | |
| | Low | High | Average | Low | High | Average |
| Small Lot | $244,920 | $379,920 | $312,420 | $19,920 | $29,920 | $24,920 |
| Traditional | $244,920 | $444,720 | $344,820 | $19,920 | $34,720 | $27,320 |
| Large Lot | $487,920 | $784,920 | $636,420 | $37,920 | $59,920 | $48,920 |

Average prices are within range of the low-high estimated home prices for UMore Park

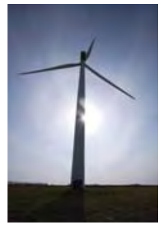



# A District Energy Model



# 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





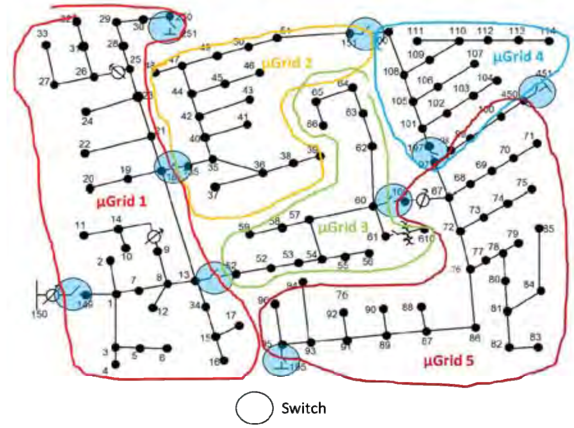

# Feeder Reconfiguration/Intentional Islanding

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**







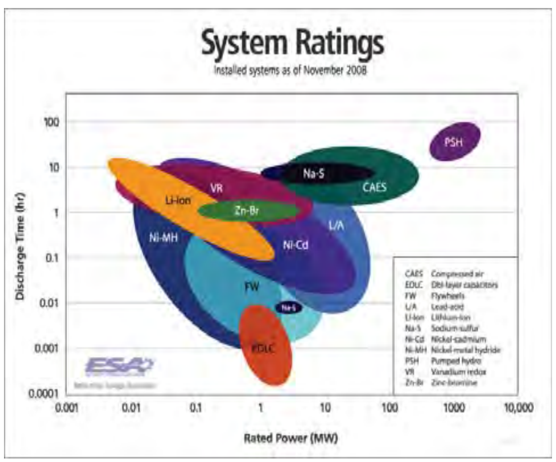
# Energy Storage Technologies

**Electrochemical**
- Lead Acid
- Ni-MH / NI-Cd
- Li-Ion
- Sodium Sulfur (NaS)
- Flow Batteries
  - Vanadium Redox
  - Zinc Bromine

**Electrical**
- Supercapacitors (EDLC)

**Magnetic**
- Super-conducting electromagnets (SMES)

**Mechanical**
- Pumped Hydro
- Compressed Air (CAES)
- Flywheel



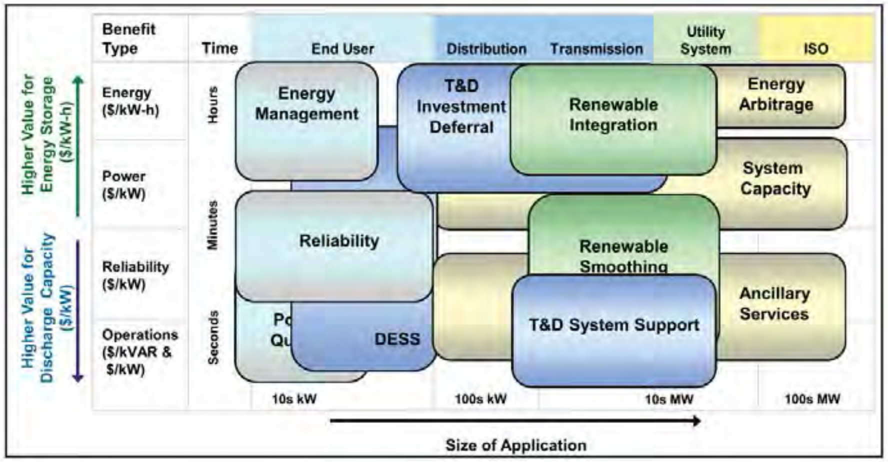

**Source:** *Electricity Storage Association, www.electricitystorage.org*




# Energy Storage - Drivers

- **Economic**: Higher price differences between on-peak and off-peak power due to congestion, limited capacity
- **Regulatory**: Federal Regulatory Energy Commission (FERC) mandate to support fast-ramping regulation resources
- **Technological**: Investments in battery technology R&D for consumer and transportation applications
- **Regulatory/Economic**: 2007 U.S. Energy Storage Competiveness Act and ARRA Demonstration Grant
- ***And many more…***

# Energy Storage - Benefits & Applications




**Source:** *Electricity Energy Storage Technology Options – A White Paper Primer on Applications, Costs and Benefits, EPRI, Palo Alto, CA, 2010, Report #1020676*





# 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




# 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)* | |




# I-35W bridge

Just after 6:00 p.m. on Aug. 1, Prof. Massoud Amin was at work in his office on the University of Minnesota's West Bank, where he heard and watched the unthinkable happen—the collapse of the I-35W bridge about 100 yards away.

"As an individual, it was shocking and very painful to witness it from our offices here in Minneapolis," says Amin, director of the Center for the Development of Technological Leadership (CDTL) and the H.W. Sweatt Chair in Technological Leadership. Amin also viewed the tragedy from a broader perspective as a result of his ongoing work to advance the security and health of the nation's infrastructure.

In the days and weeks that followed, he responded to media inquiries from the BBC, Reuthers, and the CBC, keeping his comments focused on the critical nature of the infrastructure. He referred reporters with questions about bridge design, conditions, and inspections to several professional colleagues, including Professors Roberto Ballarini, Ted Galambos, Vaughan Voller, and John Gulliver in the Department of Civil Engineering and the National Academy of Engineering Board on Infrastructure and Constructed Environment.

For Amin, Voller, and many others, the bridge collapse puts into focus the importance of two key issues—the tremendous value of infrastructure and infrastructure systems that help make possible indispensable activities such as transportation, waste disposal, water, telecommunications, and electricity and power, among many others, and the search for positive and innovative ways to strengthen the infrastructure.

## To improve the future and avoid a repetition of the past:

**Sensors built in to the I-35W bridge at less than 0.5% total cost by TLI alumni**



## Not Just Utilities … Our Role in Minnesota:
## 2015 MN2050 Survey

MN 2050 Infrastructure planning, long term success

| | 2015 Values | | | | |
|---|---|---|---|---|---|
| | Small City | Large City | County | State | Total |
| Roads | $4,174,022,424 | $10,517,476,430 | $27,647,815,260 | $29,338,312,840 | $71,677,626,954 |
| Bridges | $1,151,894,172 | $807,350,570 | $1,456,009,206 | $6,592,940,562 | $10,008,194,510 |
| Transit | $0 | $0 | $0 | $0 | $0 |
| Traffic | $14,168,440 | $138,820,460 | $59,985,398 | $0 | $212,974,298 |
| Buildings | $7,583,657,510 | $13,724,959,690 | $4,869,723,674 | $501,696,056 | $26,680,036,930 |
| Water | $1,499,020,952 | $6,279,799,230 | $0 | $0 | $7,778,820,182 |
| Waste Water | $1,704,463,332 | $4,244,983,540 | $0 | $6,494,782,638 | $12,444,229,510 |
| Storm sewer | $0 | $2,085,960,070 | $0 | $0 | $2,085,960,070 |
| Storm ponds | $150,185,464 | $65,757,060 | $5,453,218 | $0 | $221,395,742 |
| Airports | $1,240,446,922 | $1,344,366,560 | $0 | $0 | $2,584,813,482 |
| Ports | $0 | $0 | $0 | $0 | $0 |
| Rail | $0 | $0 | $3,173,772,876 | $0 | $3,173,772,876 |
| Electrical | $0 | $10,564,967,640 | $0 | $0 | $10,564,967,640 |
| Solid Waste | $0 | $94,982,420 | $796,169,828 | $0 | $891,152,248 |
| Natural Gas | $2,056,549,066 | $2,747,183,840 | $0 | $0 | $4,803,732,906 |
| Total | $19.5B | $52.6B | $38.0B | $42.9B | $153B |

## How do we Train for Mission Critical Jobs?




## Background

- Increased dependence on electricity
- Aging workforce
- Power System going through rapid changes
- Renewal generation and storage operations
- New technologies
- Growing threats: Cyber and Physical
- Increased use of automation
  - But need to train when automation fails

# TLI Strategic Road Mapping Results

- Our 2004-2009 strategic plan narrowed 18 original areas of focus to a critical few that most reflect market need and build on TLI core strengths
- Extend MOT DNA to the technological management of:
  - Master of Science in Security Technologies (est. 2010)
  - Master of Science in Medical Device Innovation (est. 2013)
  - Energy Technologies (in development, 2017)




# Energy Technologies
# Soft Skills are Critical

- Agile Reasoning
- Ability to Plan
- Attention to Detail
- Grasps Big Picture Overview
- Excellent Communicator
- Team Player
- Capability to Lead
- Flexible
- Has Emotional Control under Stress
- Adapts to changing environment

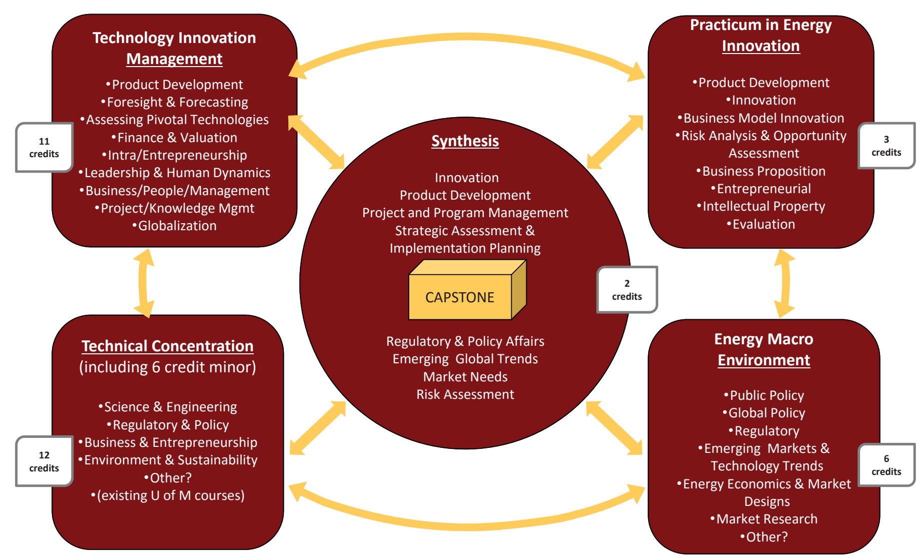



# 1. Market Need / Target Segments (Draft)

| Student Segment | Potential Demand | Specific Challenges |
|---|---|---|
| **1. Recent grads** (employed with 2-5 years experience) | | • Funding sources?<br>• Desire to participate full vs. part-time? |
| **2. Career changers?** (want to transition into Energy industry) | | • Desire to attend class during work day vs. evenings or weekends or virtually?<br>• Employment: where do they end up? |
| **3. New grads** with little or no experience? (this will be an exception) | | • Project for Capstone?<br>• Funding if no TA / RA? |
| • Can we accommodate interest in entrepreneurship / new ventures as well as intrapreneurship within established companies?<br>• How can we achieve a "best of both worlds": best of in-class discussion AND flexibility of some virtual elements; value of f/t cohort experience AND flexibility to accommodate p/t students? | | |
| Prerequisites:<br>•1 year physics + proficiency in differential equations or equivalent experience?<br>•May have technical or non-technical BS/BA if prerequisites are met | | |




# 3. Curriculum Focus and Mix (Draft)



# Curriculum Focus and Mix

**Capstone -2 Credit**

Innovation, Management, Assessment, Regulatory, Market Needs
Product Development, Planning, Implementation, Policy, Emerging Trends

**Practicum in Energy Innovation -3 Credits**

Product Development, Business Model Innovation, Assessment, Entrepreneurial
Innovation, Risk Analysis & Opportunity, Business Proposition, Intellectual Property
Evaluation

**Concentrations/Tracks from Existing U of M Courses -12 Credits**
(Including 6 credit minor)
Science & Engineering
Administration/Management
Analytical: Product/Process Development and Systems Analyses
Regulatory & Policy
Business & Entrepreneurship including New Business Development

**Core Courses - 17 Credits**

<u>Technology Innovation Management</u> (11 Credits)
- Product Development
- Project Management
- Foresight & Forecasting
- Assessing Pivotal Technologies
- Finance & Valuation
- Intra/Entrepreneurship
- Leadership & Human Dynamics
- Quality, Process, and Knowledge Management

<u>Energy Macro Environment</u> (6 Credits)
- Public Policy
- Global Policy & Globalization
- Law & Ethics
- Regulatory
- Environment & Sustainability
- Emerging Markets & Technology Trends
- Energy Economics & Market Designs
- Market Research




# 4. Program Names

- MS in Sustainability and Environmental Management (Harvard)
- MS in Energy and Environmental Sustainability (MIT)
- Master's of Engineering in Energy Systems Engineering (Michigan)
- MA/MS in Energy and Resources (UC Berkeley)
  - Four concentrations including MS in Engineering Approaches to Energy, Resources and the Environment
- MS in Energy Science, Technology & Policy (Carnegie Mellon Univ.)
- MS in Energy Policy and Climate (Johns Hopkins Univ.)
- MS in Global Energy Management (Univ. of Colorado, Denver)
- MS in Energy Systems (Northeastern Univ.)
- MS in ME with certificate in Energy Systems Engineering (U of Illinois, Champaign-Urbana)
- MS in Energy Management (NY Institute of Technology)
- Master's in Renewable Energy (EU)

<u>U of MN Names Under Consideration</u>:
- MS in Energy Technologies
- MS in Energy Technology Innovation




# Technology development, transition and Implementation: … the really hard part

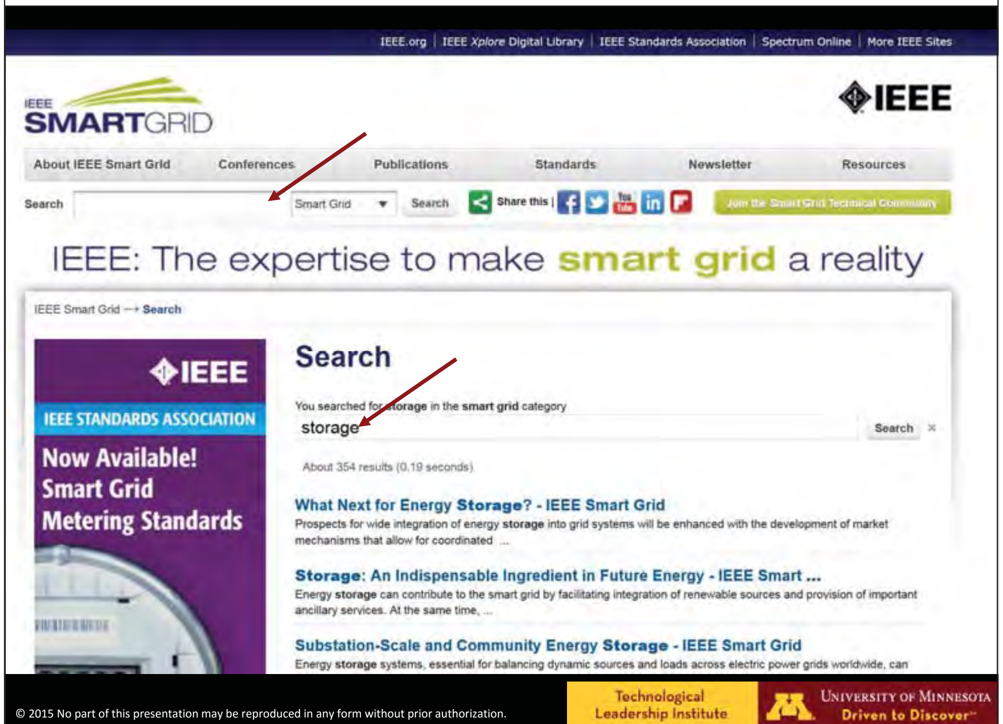
- Steps in STEM-based R&D to enable secure, efficient, resilient and adaptive infrastructure
- Markets and Policy framework, implementation, and evaluation
- Wind-tunnel testing of designs, markets and policy
- Making the business case for the opportunity
- Decision Support Dashboard: Have a plan …





# Summary of my team's at the UofM:

- Storage and Renewables integration
  - Controller architecture
  - Resiliency and Cyber-Physical Security
  - Dollars and watts -- Prices to devices
  - Autonomous and Grid-connected Microgrids
  - Big Data and Predictive Analytics
- Microgrids
  - U of M - Morris campus project
  - UMore Park Project
- Technological Leadership Institute (TLI), est. 1987
  - Science & Technology assessments
  - Master of Science Energy Technologies
- MN Smart Grid Coalition (2008-11) /Governor's Summit '14
  - Smart Grid U™
- MRO and TexasRE Boards of Directors
- Complementary: Please sign up for IEEE Smart Grid
  - Implementations
  - Global projects, results and lessons learned, what's next?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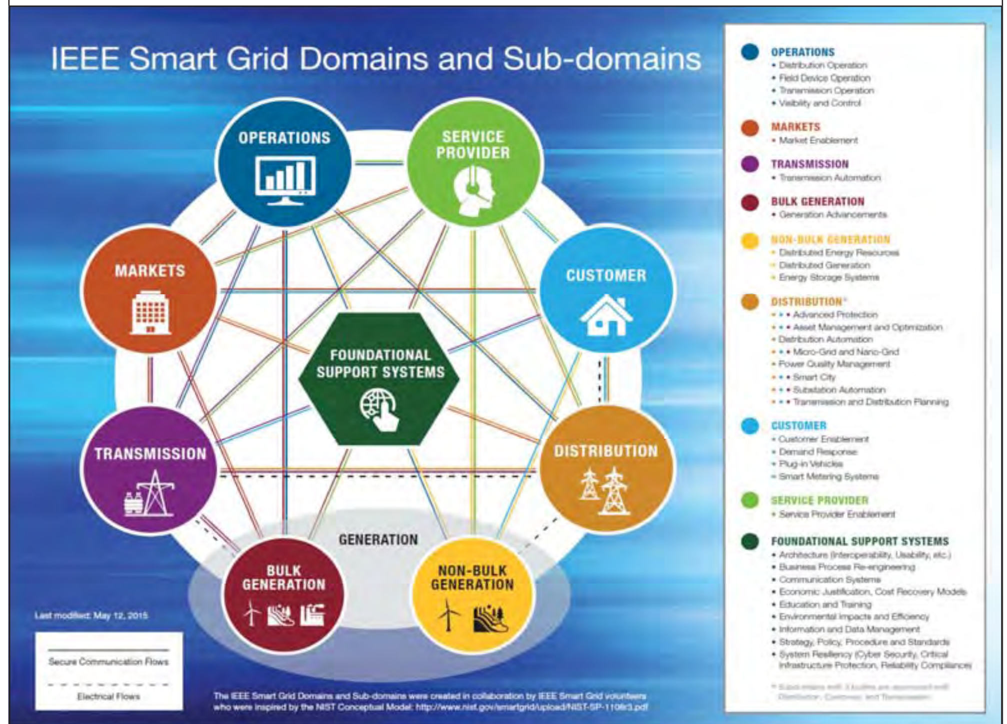
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SERVICE PROVIDER
MARKETS
CUSTOMER
FOUNDATIONAL SUPPORT SYSTEMS
TRANSMISSION
DISTRIBUTION
GENERATION
BULK GENERATION
NON-BULK GENERATION
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Secure Communication Flows
Electrical Flows
OPERATIONS
MARKETS
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BULK GENERATION
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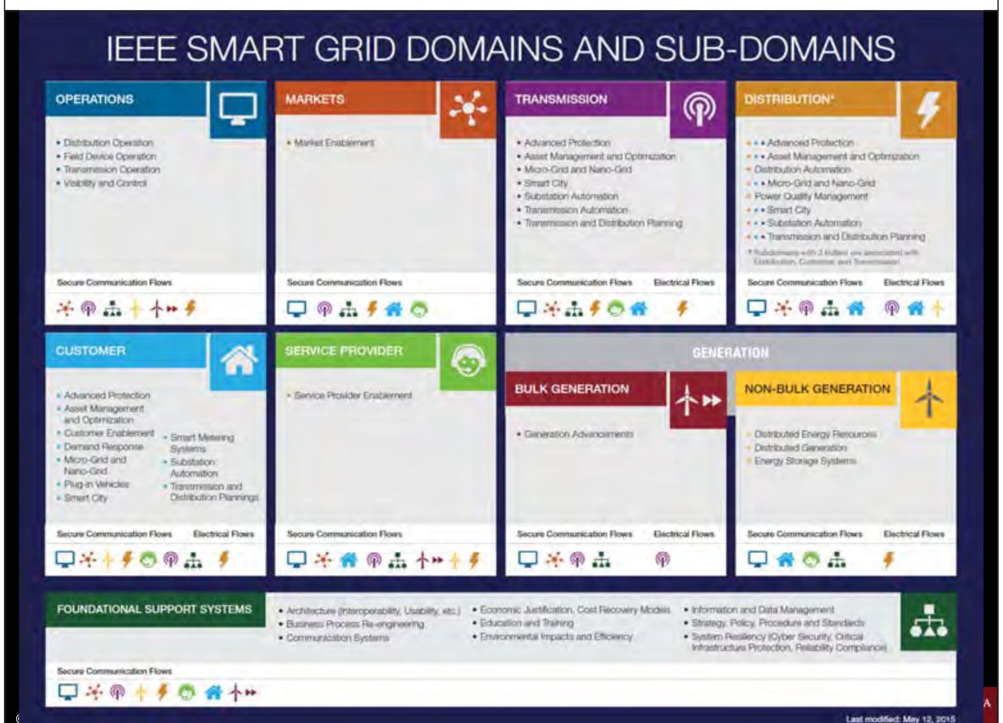
CUSTOMER
SERVICE PROVIDER
FOUNDATIONAL SUPPORT SYSTEMS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OPERATIONS
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CUSTOMER
SERVICE PROVIDER
GENERATION
BULK GENERATION
NON-BULK GENERATION
FOUNDATIONAL SUPPORT SYSTEMS
Secure Communication Flows
Electrical Flows
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LEADERSHIP

## What to do? Pathways forward

1. **Create National Infrastructure Banks:**
   - ➢ Focused on addressing both the much-needed repairs today (to modernize existing aging infrastructure) AND also to bridge to more advanced, smarter, more secure and sustainable lifeline infrastructures envisioned for the next 10-20 years.
   - ➢ Created as public/private partnership enterprises that lend money on a sustainable basis and has clear cost/benefit, performance metrics and include fees for quality of services provided by the modernized infrastructures.
2. **Retool/re-train our best and brightest for this call to action:**
   - ➢ Some of the best talents to help rebuild our critical infrastructure are our veterans of the Armed Forces.
3. **Renew/Update the American Model:**
   ➢Align innovation and policy: Focus, Alignment, Collaboration, and Execution to revitalize leadership in education, R&D, innovation and entrepreneurship.

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