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The Future of Smart Grid:
Embrace Change – Power Progress

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IEEE SMARTGRID

TECHNOLOGICAL LEADERSHIP INSTITUTE

UNIVERSITY OF MINNESOTA

Driven to Discover℠

Embrace Change?

- Build Smarter, More Secure, Resilient, and Sustainable Lifeline Infrastructures
- Develop World-Class Human Capital
- Create Jobs - Grow The Economy - Power Progress

100 Years of Power Generation Development

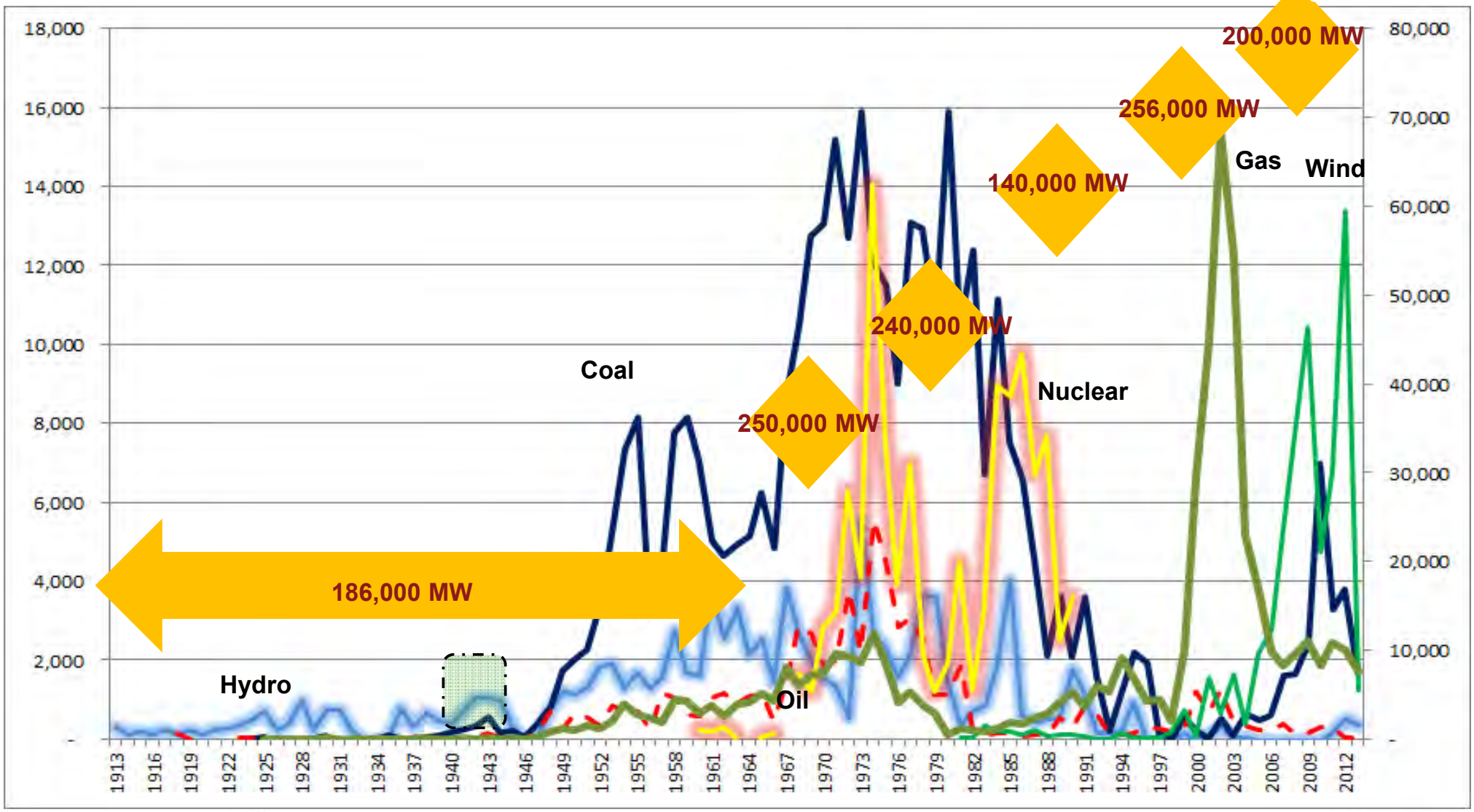
97 million

92 million population increase

189 million

131 million population increase

320 million



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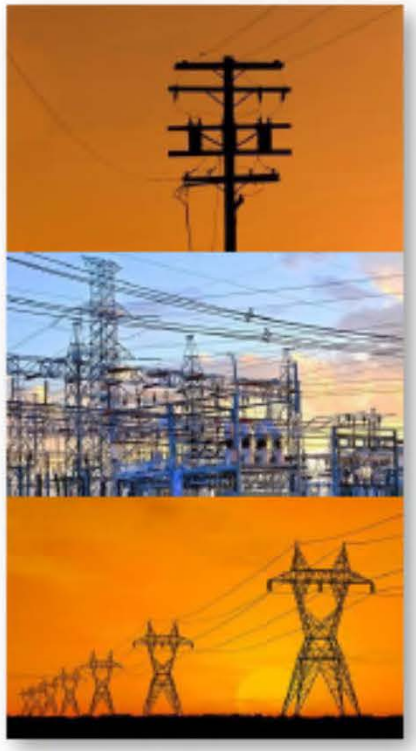
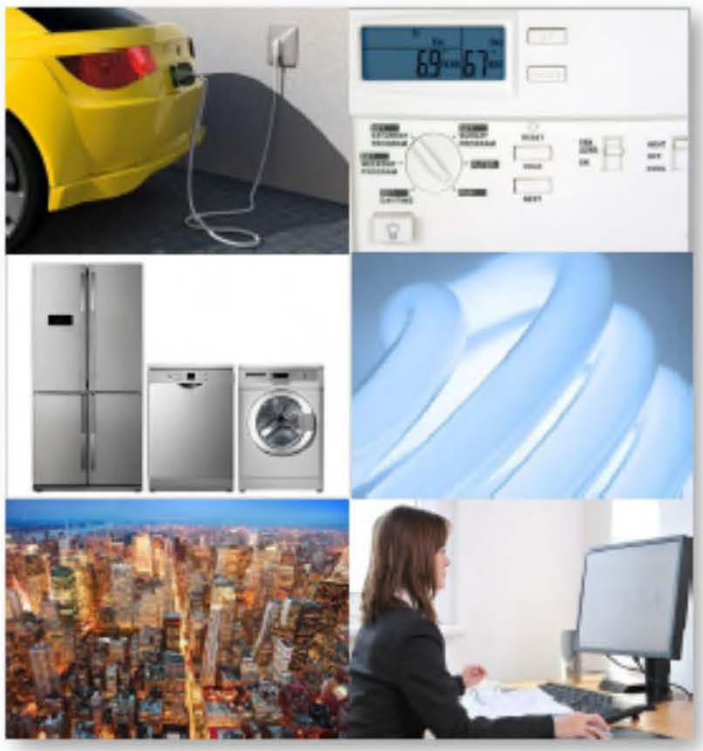
Source: Adopted from Siemens

End-to-end Electric Power System

Generation



Delivery

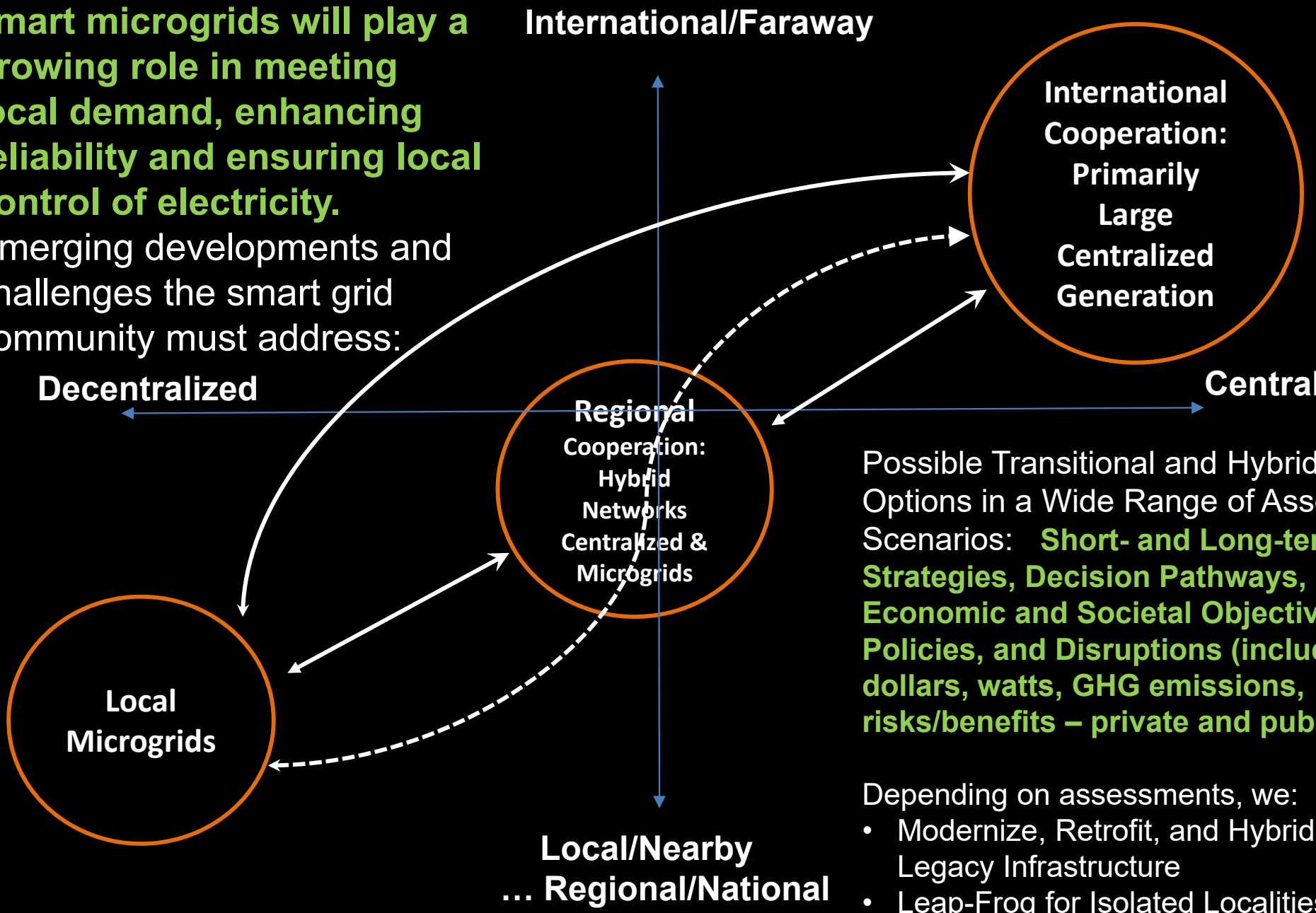


Customer

Power of Smart Resilient Networks: 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.

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, we:

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

Energy Independence and Security Act

- Passed by U.S. Congress in 2007.

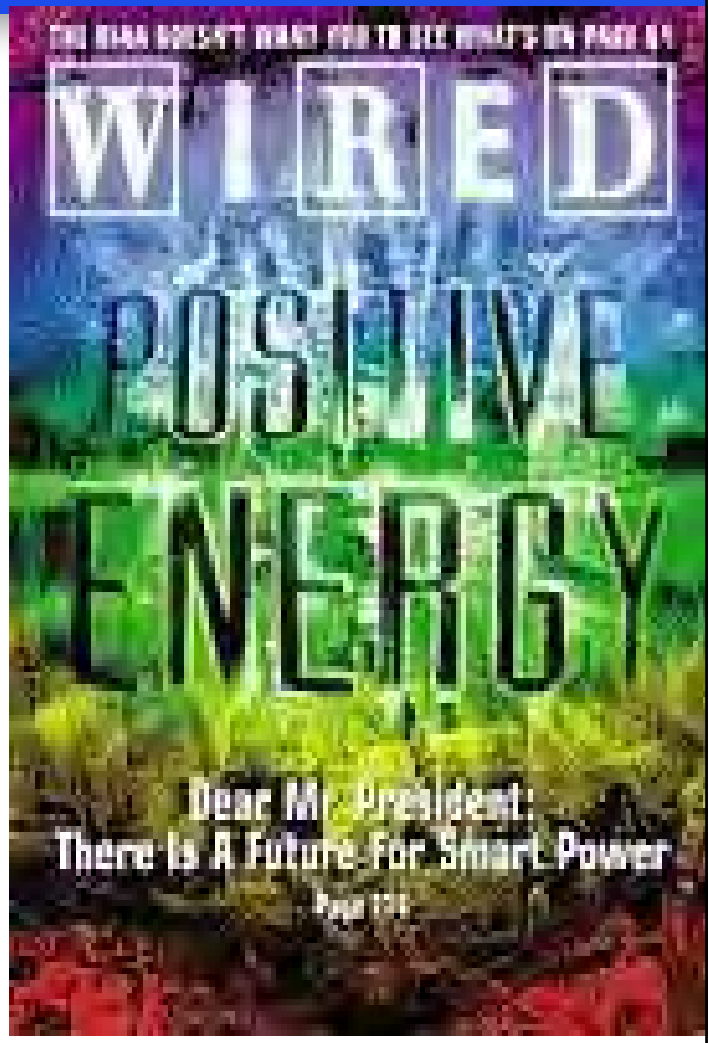
- "It is the policy of the United States to support the modernization of the Nation's electricity transmission and distribution system … that can meet future demand growth and to achieve each of the following, which together characterize a Smart Grid:
  1. **Increased use of digital information and controls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

Smart Grids: Two Decades in the Making

"… 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."

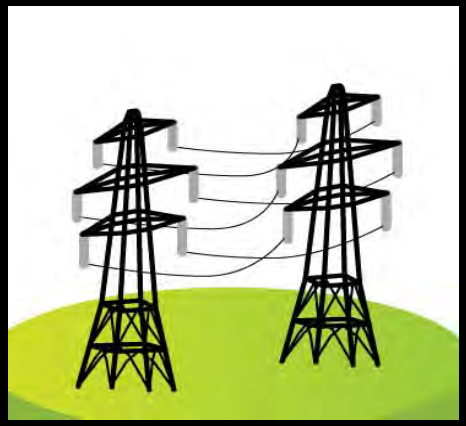


-- **The Energy Web,** Wired Magazine, July 2001
http://www.wired.com/wired/archive/9.07/juice.html

EPRI

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

Smart Grid



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

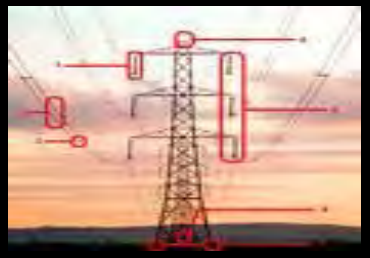
Smart meters that discount off-peak electricity

High efficiency smart thermostats and appliances that automatically adjust to reduce costs and usage

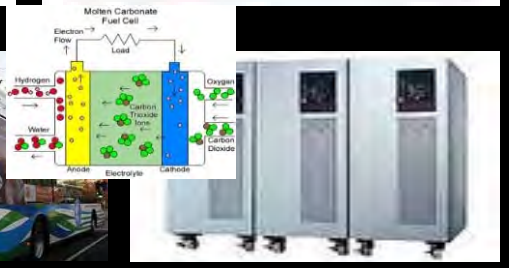
Smart Grid: Options, Costs and Benefits

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



Customer

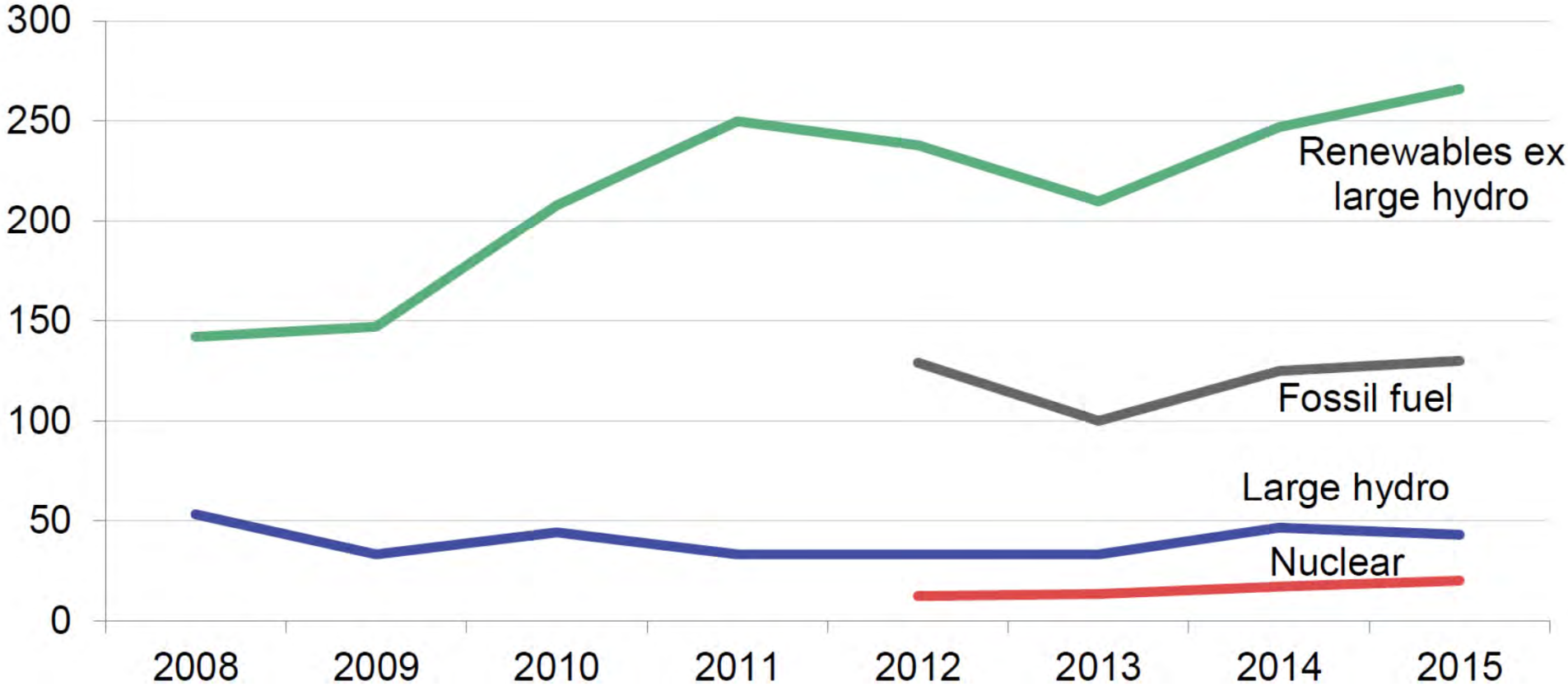
Smart Grid: Technological Innovations

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

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

INVESTMENT IN POWER CAPACITY, 2008–15 ($BN)



Source: UNEP, Bloomberg New Energy Finance

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WORLD RECORD: 3-CENT WIND, SUB-4-CENT SOLAR (UNSUBSIDISED)

ONSHORE WIND

Location:	Morocco
Bidder:	Enel Green Power
Signed:	January 2016
Price:	US$ 3.0 c/kWh

SOLAR PV

Location:	Coahuila, Mexico
Bidder:	Enel Green Power
Signed:	March 2016
Price:	**US$ 3.6 c/kWh**

Source: Bloomberg New Energy Finance; ImagesSiemens; Wikimedia Commons

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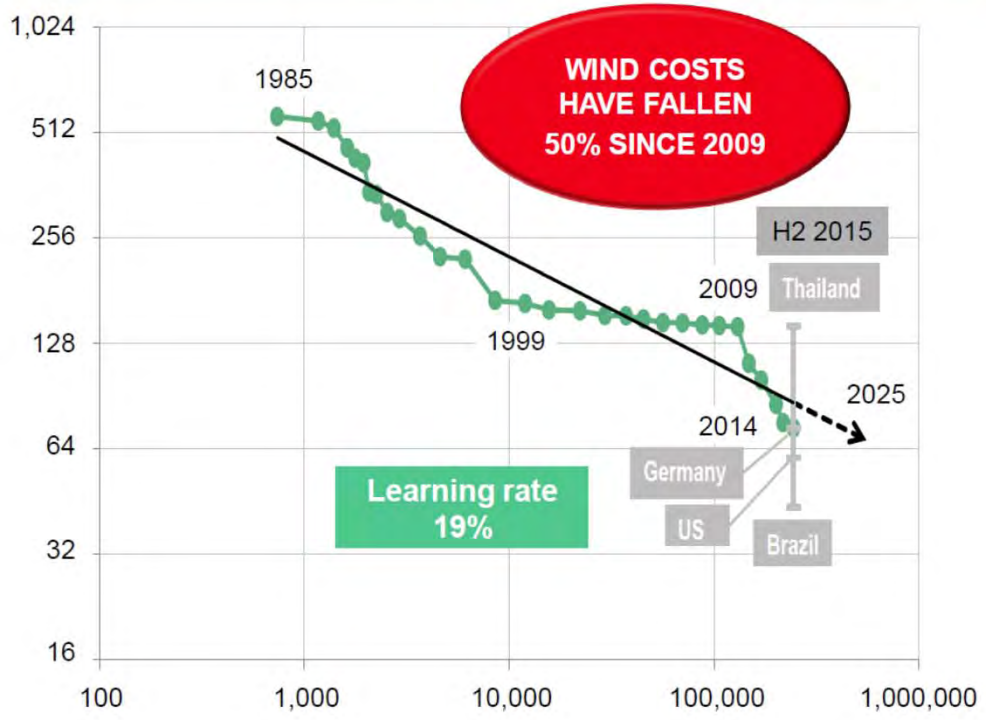
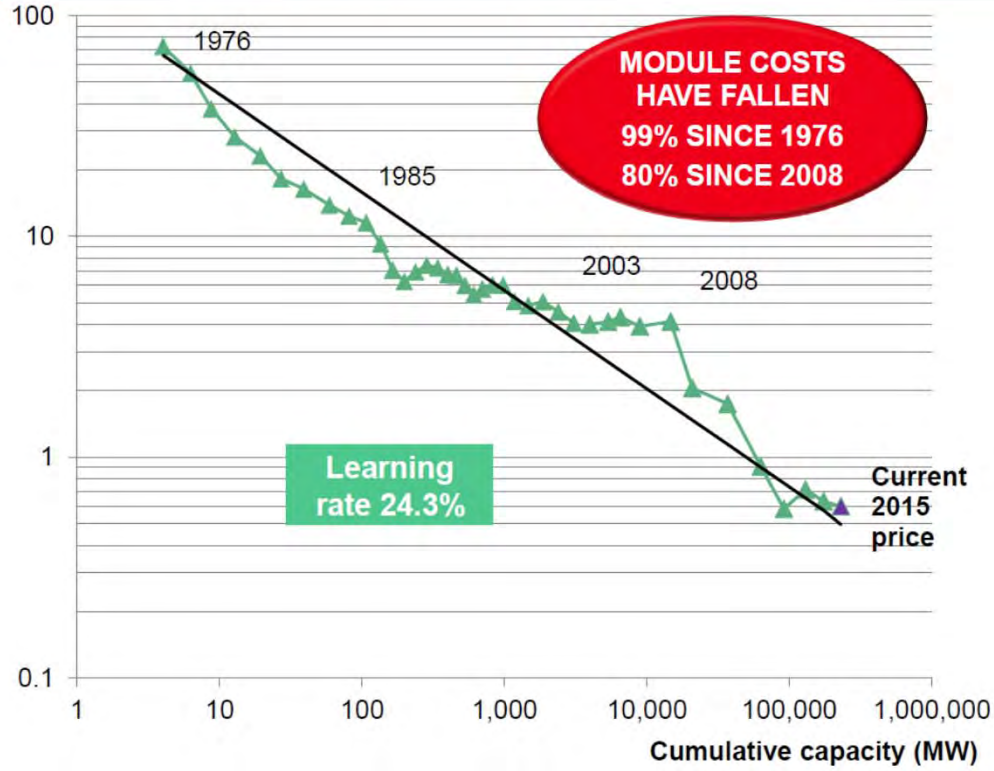
Wind & Solar Experience Curves

ONSHORE WIND LEVELISED COST ($/MWh)



Note: Pricing data has been inflation corrected to 2014. We assume the debt ratio of 70%, cost of debt (bps to LIBOR) of 175, cost of equity of 8% Source: Bloomberg New Energy Finance

SOLAR PV MODULE COST ($/W)



Note: Prices are in real (2015) USD. 'Current price' is $0.61/W Source: Bloomberg New Energy Finance, Maycock

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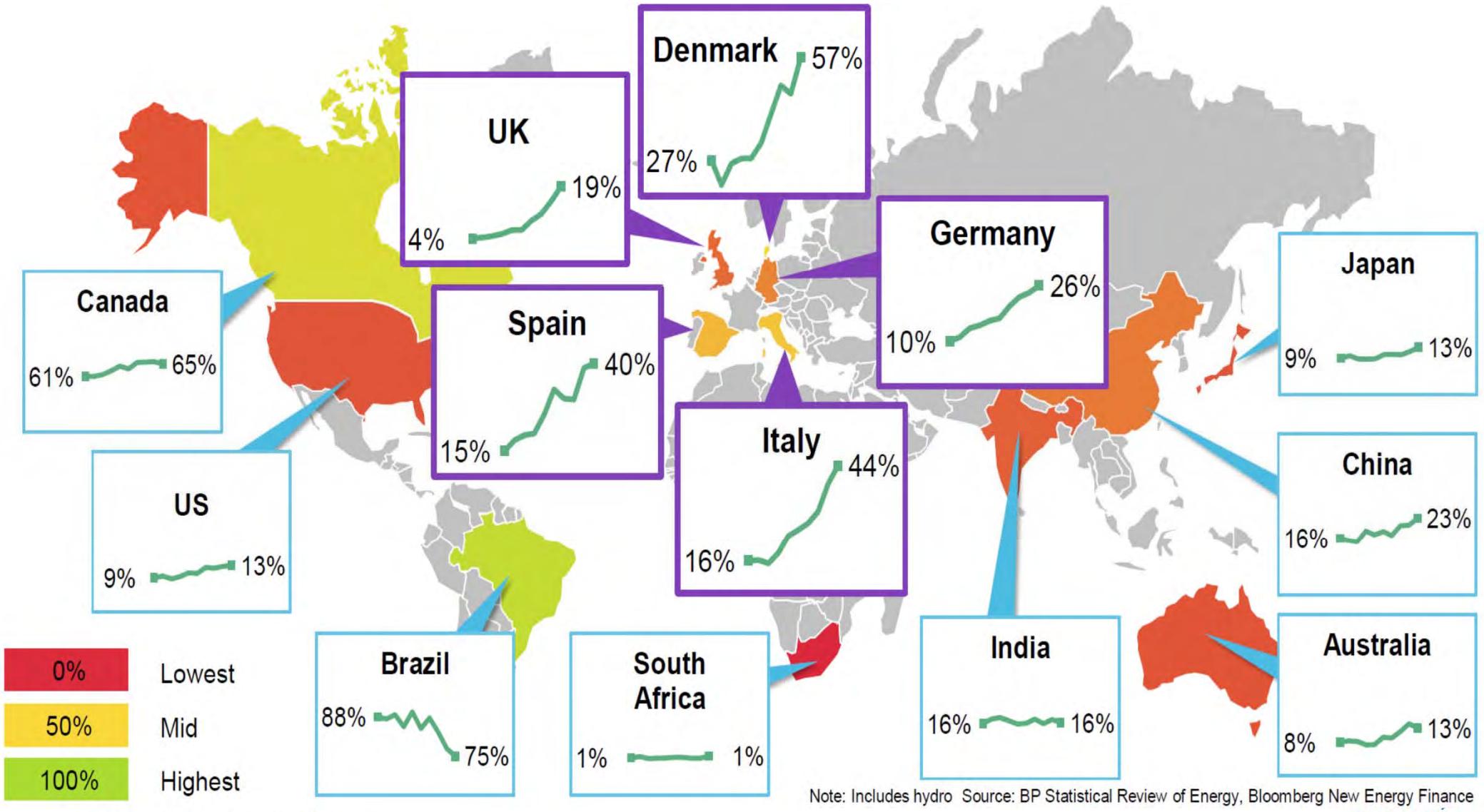
RENEWABLE ENERGY PROPORTION OF POWER GENERATION, 10 YEARS TO 2014 (%)



Note: Includes hydro Source: BP Statistical Review of Energy, Bloomberg New Energy Finance

Operation of Borrego Springs Microgrid

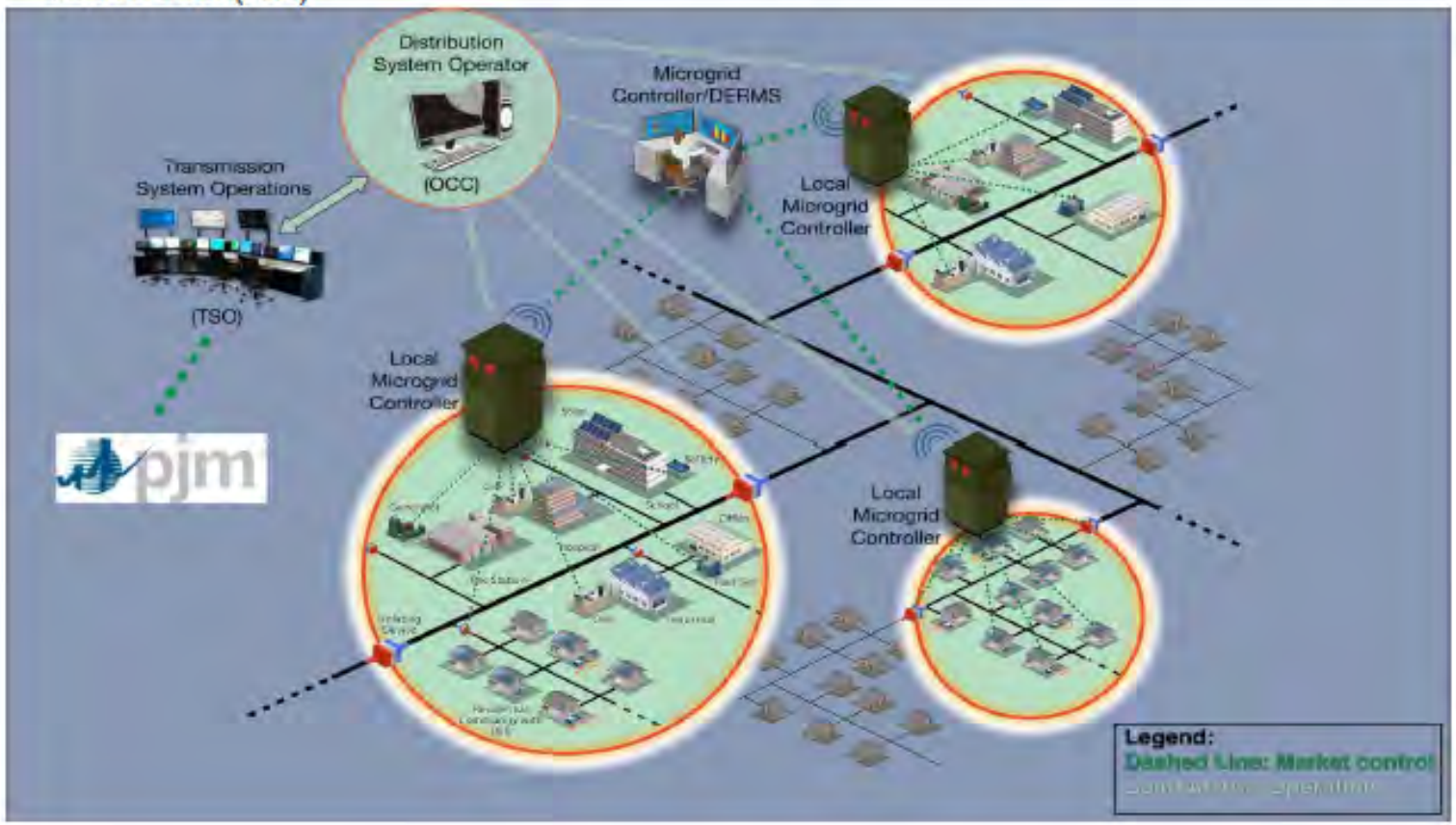
- 10 hour outage to entire community required to perform compliance-driven transmission maintenance and to replace 2 suspect transmission poles
- Utilized Borrego Springs Microgrid to keep all 2800 customers energized during transmission outage
- Base load was fed by the solar facility, using the batteries and distributed generation to “follow the load”
- Customers experienced a brief 10 minute planned outage to reconnect to the transmission grid

Source: David Geier, SDG&E

Utility Initiatives – ComEd (Exelon)

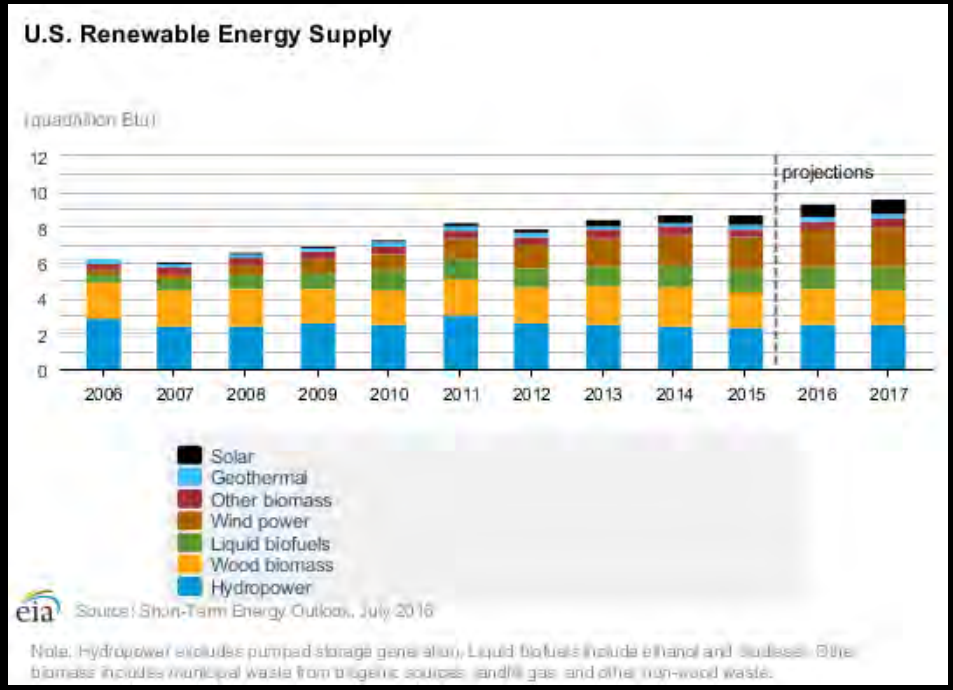
WHAT'S NEXT.....OPERATIONAL VISION OF THE GRID OF THE FUTURE

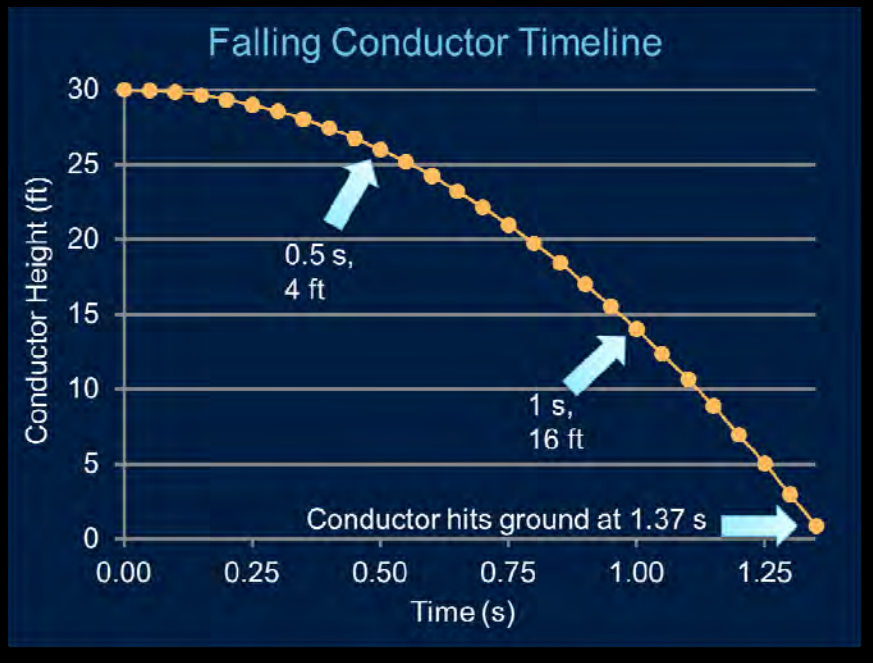
- Currently in the process of developing transformational grid control algorithms and architectures that optimize the usage of flexible load and DERs.
- The expected system level benefits of reliably managing dynamic changes in the grid by leveraging the additional grid resources, while having minimal impact on customer quality of service.
- Additional savings are expected to be achieved by supporting higher penetration of Distributed Generation (DG)



Grid Transformation Drivers

- Asset Management
  - Aging Infrastructure, Reliability, Hardening, Security (Physical & Cyber)
  - Natural Gas and Electrical Interdependency
- Distributed Energy Resources, Microgrids, Energy Storage, and Electrical Vehicles
- Smarter Grid Investments & Transformation
  - GPS Synchronized Measurements
  - Wide Area Protection coordination
  - Distribution Management Systems, automation, Volt-VAR control, etc.
  - Demand response w/smart meters
- Need for robust, hybrid T&D grid – Grid connection for reliability and market reach
- Smart Cities - Improve the livability, workability and sustainability w/ electricity





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 http://smartgrid.ieee.org/january-2014/1024-the-ieee-smart-grid-initiative-what-s-ahead-in-2014

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?

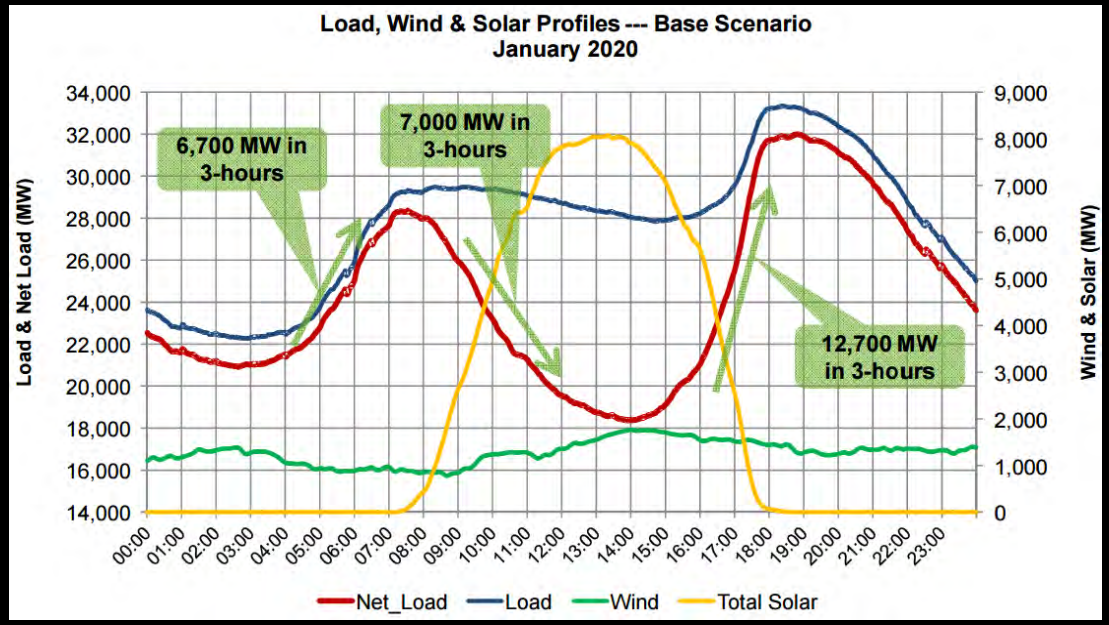
5. What measures are practical and useful for critical infrastructure protection (CIP) and the security of cyber physical infrastructure? energy consumers?

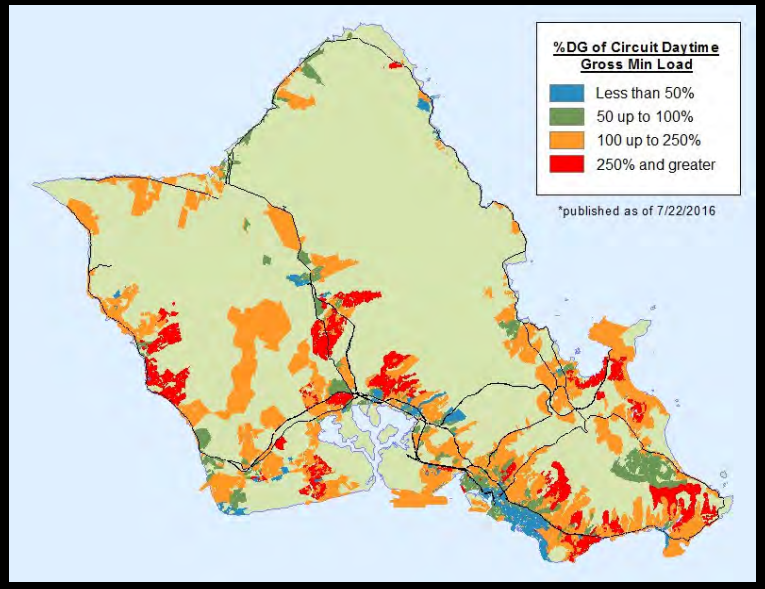
"Today's regulatory framework is keeping us locked into the 20th century." - Anne Pramaggiore, CEO, ComEd

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

Grid of the Future?

- How to value the use of the grid in the presence of renewables?
- How best to deliver remote renewable energy sources to load centers? Is it realistic to build cities close to renewable resources?
- Is it more reliable and cost efficient to independently manage local generation (e.g. PV), microgrids, or to manage then in an integrated way?
- Does storage provide full solutions to renewable intermittency?
- What are the benefits and conditions for Distribution System Operator?



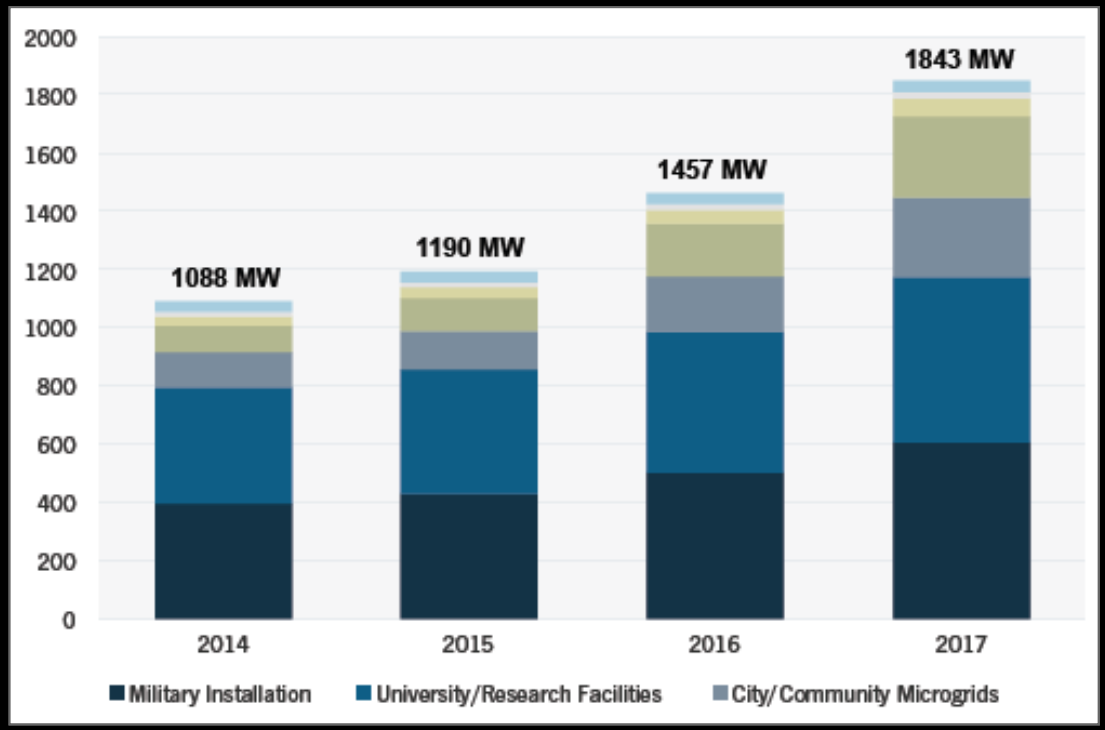


http://www.hawaiianelectric.com/heco/Clean-Energy/Integration-Tools-and-Resources/Locational-Value-Maps

Optimized Hybrid Microgrids

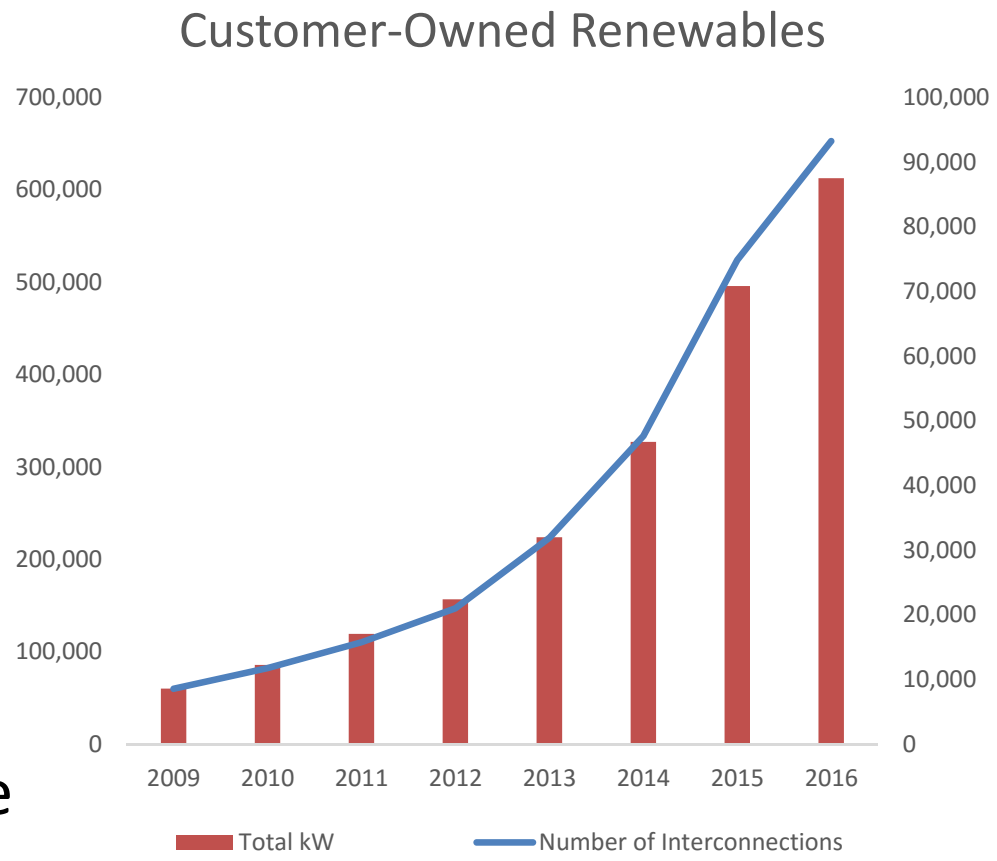
- Utility grid and microgrids must work synergistically to fulfill all the needs - serving all the load all the time
- Assessing costs should include efficiency, reliability, safety, optimizing life-cycle costs, and system resilience
- New tools and Standards, e.g. IEEE 1547 Series, Microgrid Controller
  - Frequency regulation
  - Voltage control

IEEE JOINT TASK FORCE ON QUADRENNIAL ENERGY REVIEW



Preparing for the Grid of the Future

- Developing business and technology roadmaps
- Addressing and preparing for various scenarios
- Deploying pilot projects to test and prepare for changes
- Developing and applying industry standards
- Developing a skilled workforce



Source: David Geier, SDG&E

Speed and success will depend on clear and balanced regulatory policies to promote safe, cost-effective, and reliable deployment of technologies

Future Grid Roadmap

- Demand For Electricity and G, T&D Will Increase - Population growth, electric vehicles, renewables, etc.
- Fuel Transformation is Occurring
- More Resilient, Safe, Reliable, & Efficient Grid
  - Advancements in technology and processes
  - Need for clear and balanced regulatory policies
- Electricity Value Beyond Commodity
  - Increased choices, digital reliability, comfort value
  - Societal and Economic goals to meet sustainability and support of growing economy

Key for Smarter Grid is in educated workforce, developing & applying standards, and sharing global best practices

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

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

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

Terry Ward

Heidi Hamilton

Val Svensson

Joe Nietfeld

Technological Leadership Institute

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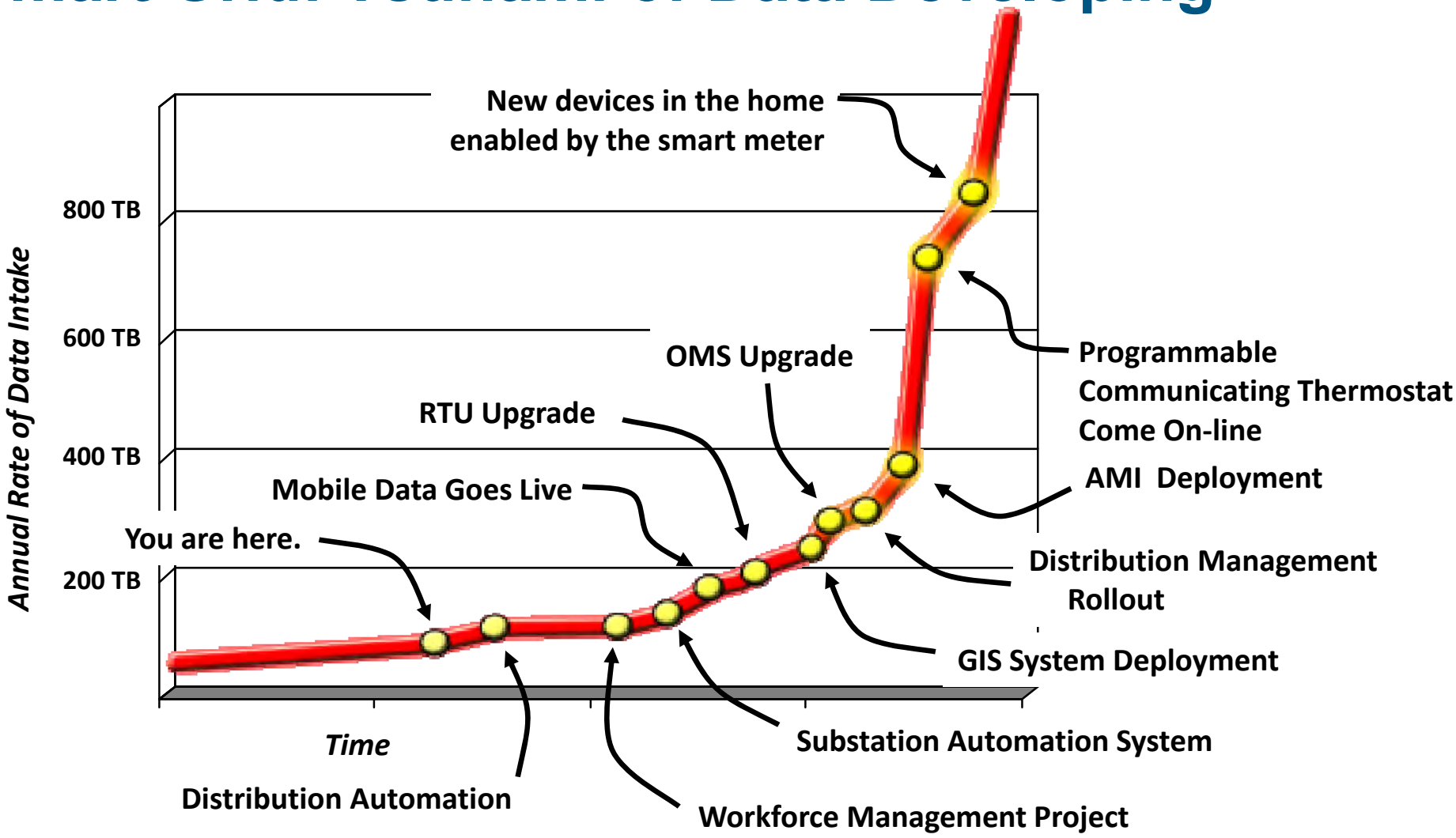
Not Just Utilities … Our Role in Minnesota:

2015 MN2050 Survey

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**

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

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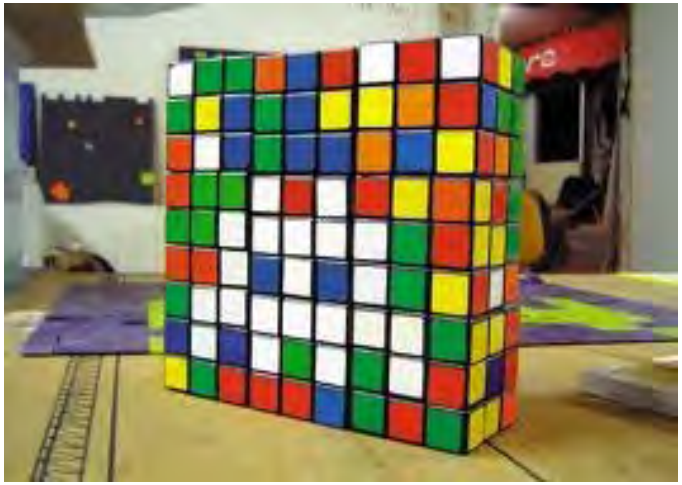
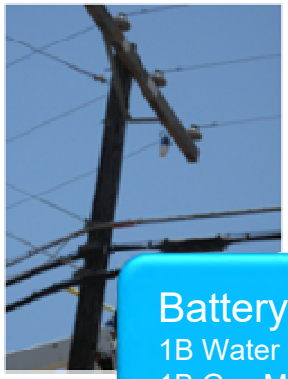
Paradigm Shift – Data at MN Valley Coop

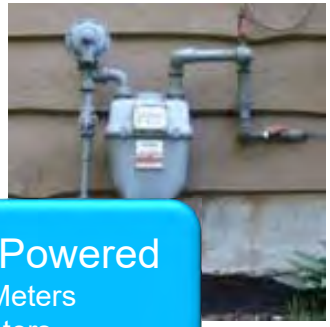
- Before smart meters
  - –Monthly read
  - –480,000 data points per year
- After smart meters
  - –15-60 minute kWh
  - –Peak demand
  - –Voltage
  - –Power interruptions
  - –480,000,000 data points per year



Industry Needs to Connect 50 Billion Devices by 2020

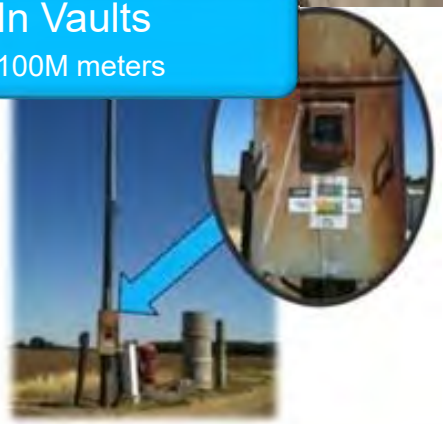
An unsolved problem costing billions per year in wasted resources requires radically improved wireless performance and lower cost



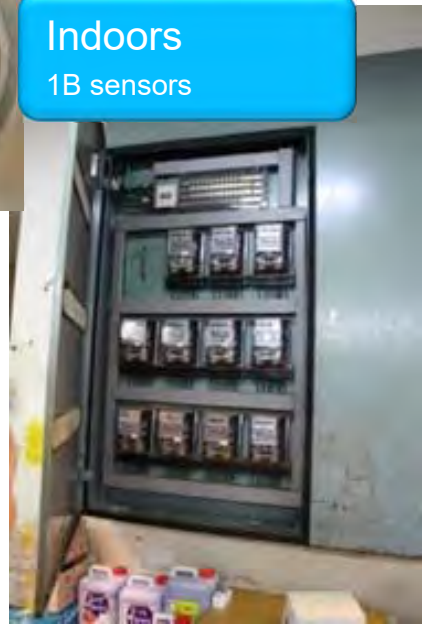


Battery Powered
1B Water Meters
1B Gas Meters

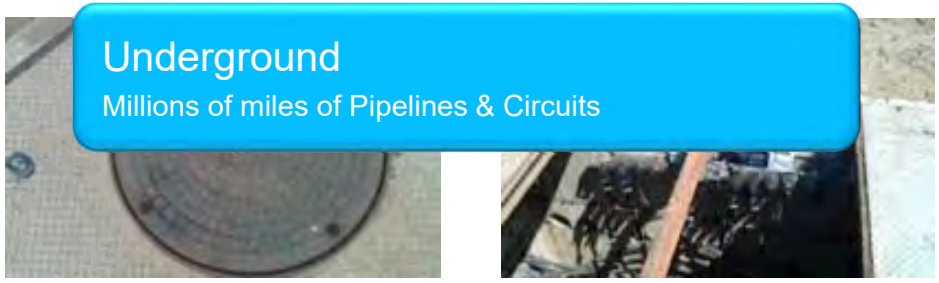
In Vaults
100M meters



Indoors
1B sensors



Underground
Millions of miles of Pipelines & Circuits



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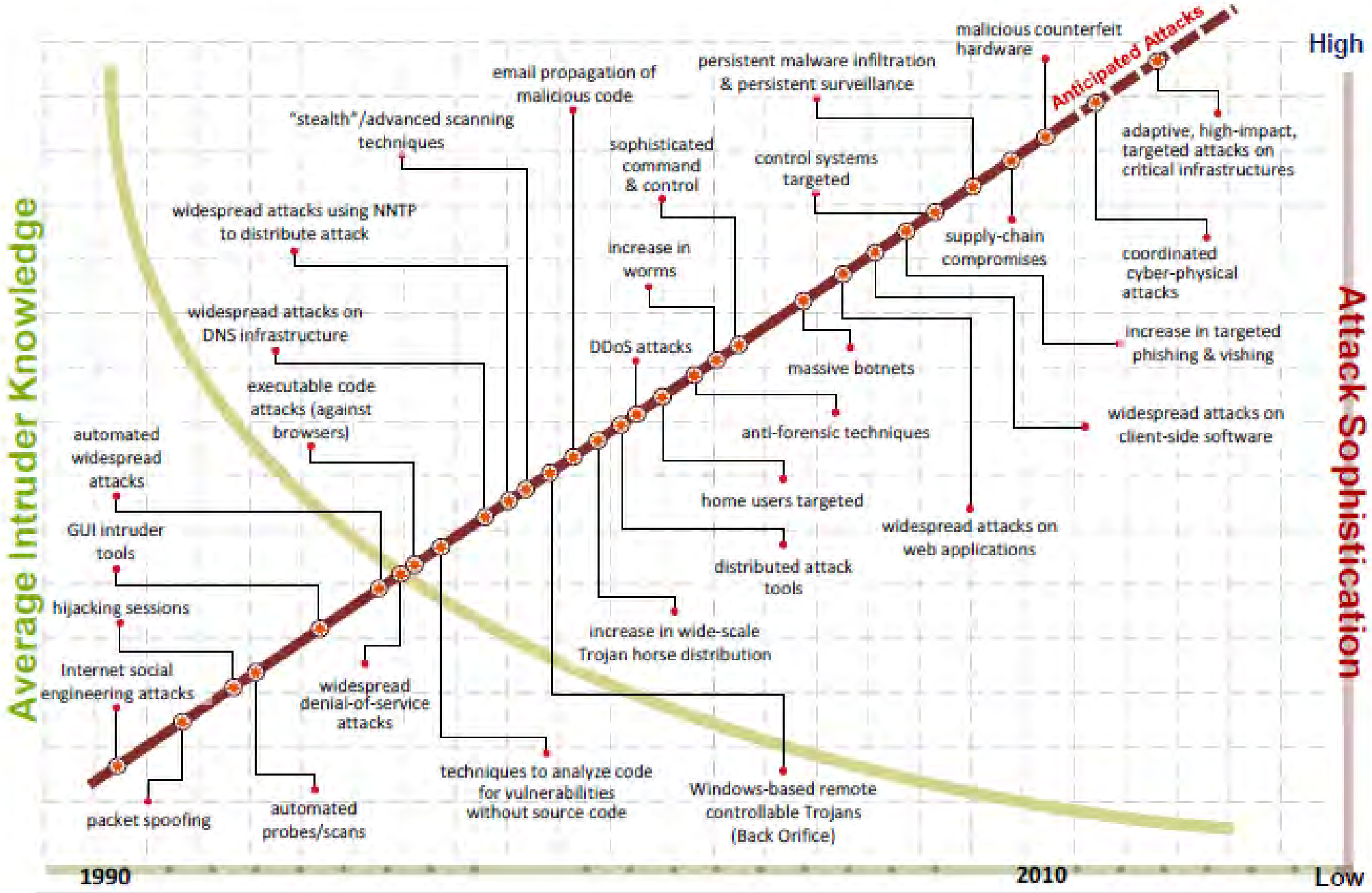
Cyberattacks – Power Grid Intruder Knowledge



IEEE Smart Grid Collaboration Across IEEE

- Total of 14 IEEE partner organizational units
- Working with all partners on the following:
  - Co-branding on each others' websites
  - Webinars, newsletter articles, interviews, white papers
  - Collaboration within the 6 functional committees

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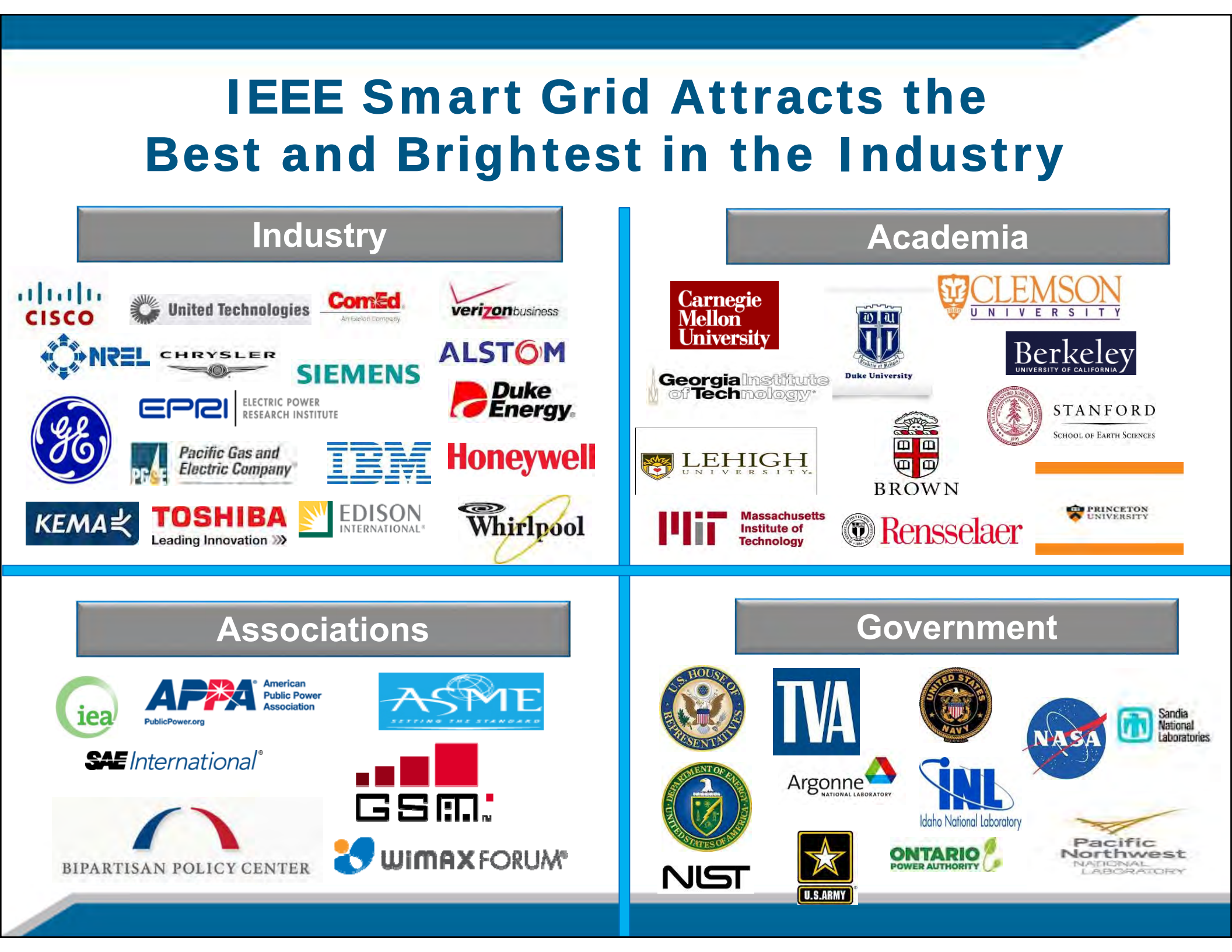
IEEE Smart Grid Attracts the Best and Brightest in the Industry



IEEE Smart Grid Attracts the Most Influential Media and Analysts

Technology & Mainstream

EE Times
examiner.com
GOVERNMENT TECHNOLOGY
CIO INSIGHT
FierceTelecom
WHAT'S NEXT FOR TELCOS
GCN
electronic design
THE WALL STREET JOURNAL.
npr
ZDNet
theenergycollective
The world's best thinkers on energy & climate
InformationWeek
THE BUSINESS VALUE OF TECHNOLOGY
Forbes
NETWORKWORLD
WORLDnews

Smart Grid

SmartGridToday
ClimateWire
greentechmedia
SMARTGRID
RENEWABLE ENERGY WORLD.COM
FierceSmartGrid
SMART GRID NEWS.COM
renewGRID

Utilities

PUBLIC UTILITIES FORTNIGHTLY
ENERGY, MONEY, POWER
Pipeline | Volume 9 | Issue 10
Pipeline
Electric Energy ONLINE.com
ELECTRICITY TODAY
intelligentutility
WHERE THE SMART GRID MEETS BUSINESS AND REALITY
POWERGRID INTERNATIONAL

Industry Analysts

IDC
Analyze the Future
FORRESTER
ABIresearch
PikeResearch
Cleantech Market Intelligence
FROST & SULLIVAN
yankee group
In-Stat
experts™
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Gartner

IEEE Smart Grid Dashboard

Marketing Channel	2013	2014	2015	2016 (as of 31 August 2016)	2016 Year End Goal
Collabratec				1,862	
Facebook			717	1,392	2,500
Flip board			10,631	18,425	20,000
Linkedin	20,800	24,695	30,070	34,888	42,000
Newsletter	10,800	13,769	16,767	18,284	20,500
Technical Community	5,300	5,970	8,179	9,643	11,000
Twitter	6,500	9,255	12,905	14,735	17,000
Webinar registrants			7,236	11,670	9,000
TOTAL	43,400	53,689	86,505	110,899	122,000

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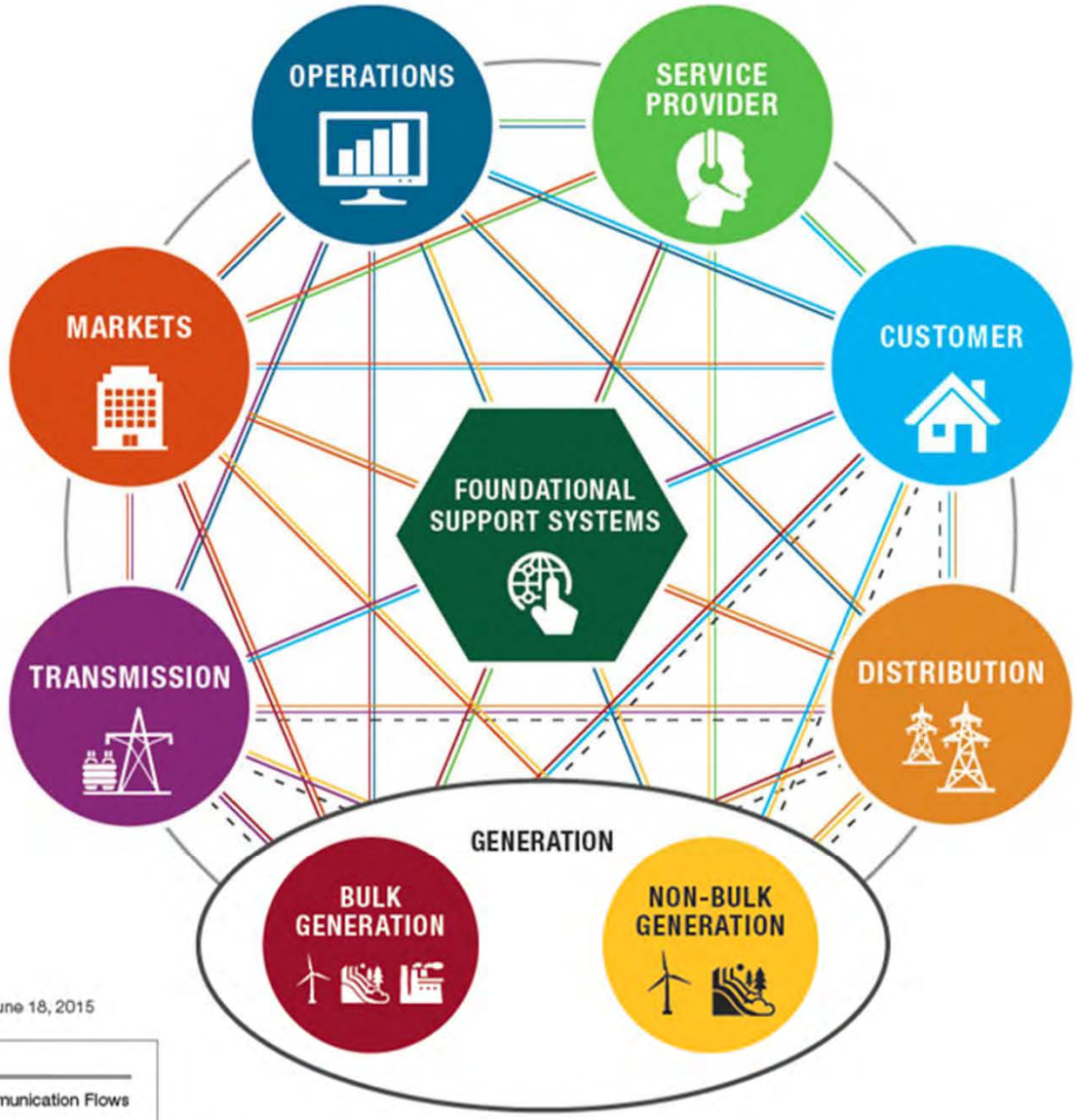
See ITEM 3 in Google Drive

IEEE Smart Grid Domains and Sub-domains



Last modified: June 18, 2015

Secure Communication Flows

Electrical Flows

The IEEE Smart Grid Domains and Sub-domains were created in collaboration by IEEE Smart Grid volunteers who were inspired by the NIST Conceptual Model: http://www.nist.gov/smartgrid/upload/NIST-SP-1108r3.pdf

OPERATIONS
- Distribution Operation
- Field Device Operation
- Transmission Operation
- Visibility and Control

MARKETS
- Market Enablement

TRANSMISSION
- Transmission Automation

BULK GENERATION
- Generation Advancements

NON-BULK GENERATION
- Distributed Energy Resources
- Distributed Generation
- Energy Storage Systems

DISTRIBUTION*
- • • Advanced Protection
- • • Asset Management and Optimization
- Distribution Automation
- • • Micro-Grid and Nano-Grid
- Power Quality Management
- • • Smart City
- • • Substation Automation
- • • Transmission and Distribution Planning

CUSTOMER
- Customer Enablement
- Demand Response
- Plug-in Vehicles
- Smart Metering Systems

SERVICE PROVIDER
- Service Provider Enablement

FOUNDATIONAL SUPPORT SYSTEMS
- Architecture (Interoperability, Usability, etc.)
- Business Process Re-engineering
- Communication Systems
- Economic Justification, Cost Recovery Models
- Education and Training
- Environmental Impacts and Efficiency
- Information and Data Management
- Strategy, Policy, Procedure and Standards
- System Resiliency (Cyber Security, Critical Infrastructure Protection, Reliability Compliance)

* Subdomains with 3 bullets are associated with Distribution, Customer, and Transmission

IEEE SMART GRID DOMAINS AND SUB-DOMAINS

OPERATIONS

- Distribution Operation
- Field Device Operation
- Transmission Operation
- Visibility and Control

Secure Communication Flows

MARKETS

- Market Enablement

Secure Communication Flows

TRANSMISSION

- Advanced Protection
- Asset Management and Optimization
- Micro-Grid and Nano-Grid
- Smart City
- Substation Automation
- Transmission Automation
- Transmission and Distribution Planning

Secure Communication Flows | Electrical Flows

DISTRIBUTION*

- • • Advanced Protection
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Secure Communication Flows | Electrical Flows

CUSTOMER

- Advanced Protection
- Asset Management and Optimization
- Customer Enablement
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- Transmission and Distribution Plannings

Secure Communication Flows | Electrical Flows

SERVICE PROVIDER

- Service Provider Enablement

Secure Communication Flows

GENERATION

BULK GENERATION

- Generation Advancements

Secure Communication Flows | Electrical Flows

NON-BULK GENERATION

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Secure Communication Flows | Electrical Flows

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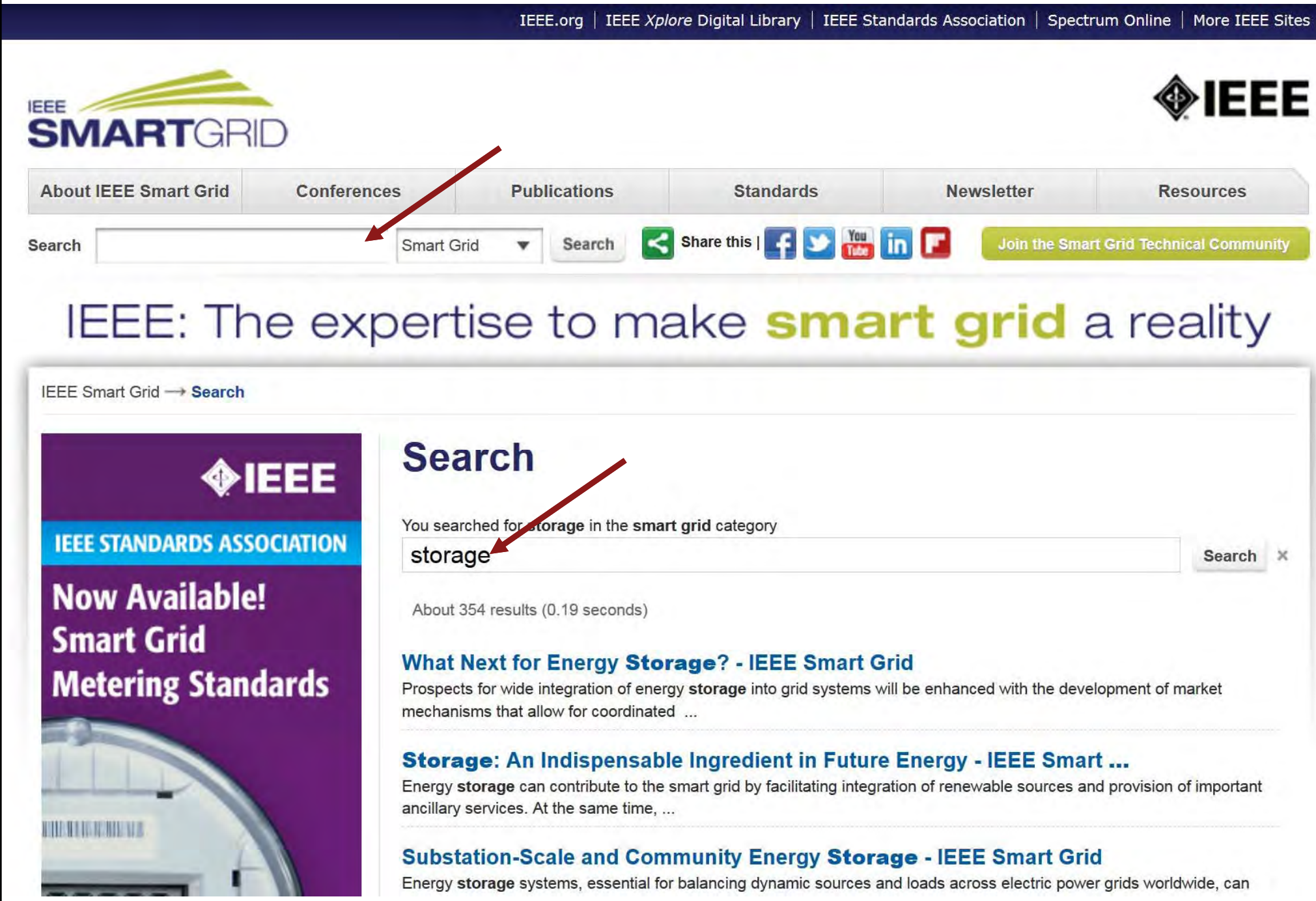
Secure Communication Flows

Last modified: May 12, 2015



Thank you for joining us today. Please be informed that the meeting will begin at 2:00pm Central Time. Please stay tuned.

Join the IEEE Smart Grid Community

smartgrid.ieee.org

LIKE: facebook.com/IEEESmartGrid

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

FOLLOW: twitter.com/ieeesmartgrid

COLLABORATE:
ieee-collabratec.ieee.org/app/community/88/activities

EXPLORE: flip.it/Tk5PH

For any questions, comments or concerns, please email
Project Manager Angelique Rajski Parashis at a.rajski@ieee.org

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High Level Update

- Date: October 16-18, 2016
- Location: Paris, France
- Financial Sponsor: IEEE Smart Grid
- 18 technical co-sponsors secured
- Nouredenie Hadjsaid and Laurent Schmitt serve as Co-Chairs
- Doug Houseman serves as the Technical Program Chair
- **Visit www.ieeesg4sc.org to register!**

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Observations and Concluding Remarks

- We all believe that we're in the middle of a movement, albeit slow (and even behind Europe)…
- We know we are going somewhere but there are practical considerations:
  - **9 Ps: People, Physics, Price, Pollution, Psychology, Public Education, Prosperity, Policies, and Politics**

Top ten strategies for success:

10. Really ***REALLY*** Know Your Customer – Policy connected to the will and desire of customers

9. We need a Comprehensive Energy Policy (Holistic Data-Driven Policy – with corners of Reliability/Security, Safety, Sustainability, and Cost)

8. Electricity IS THE "DISRUPTIVE" force – electrification of transportation, port of Savannah going all electric, airport baggage handling, services, electro-technologies

Concluding Remarks (cont.)

7. Treat/Think of the grid as a valuable resource

6. We are far under-served with infrastructure (need to build a lot more infrastructure; 140 GW by 2030)

5. In the future of the grid, all essential services – electronic resources, demand & supply, frequency control, inertia (first few seconds for stability) will need modernized control systems.

4. Who owns what? And provider of the last resort – e.g., neighborhood transformer blowing up… what if you own it?

3. Storage will be (is) a critical resource (need for control services as well as intermittency accommodation)

2. All severe events are going to get more critical and more extreme

1. Winner will be those who take advantage of data and predictive analytics (from acquisition of data, to customers … to equipment maintenance & operations).

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.**

BASIS OF FUTURE COMPETITION

The speed at which an Enterprise can

- Gather
- Collate
- Analyze
- Apply information

Embrace Change?

- Build Smarter, More Secure, Resilient, and Sustainable Lifeline Infrastructures
- Develop World-Class Human Capital
- Create Jobs - Grow The Economy - Power Progress


LEADERSHIP


THANK YOU
MINNESOTA