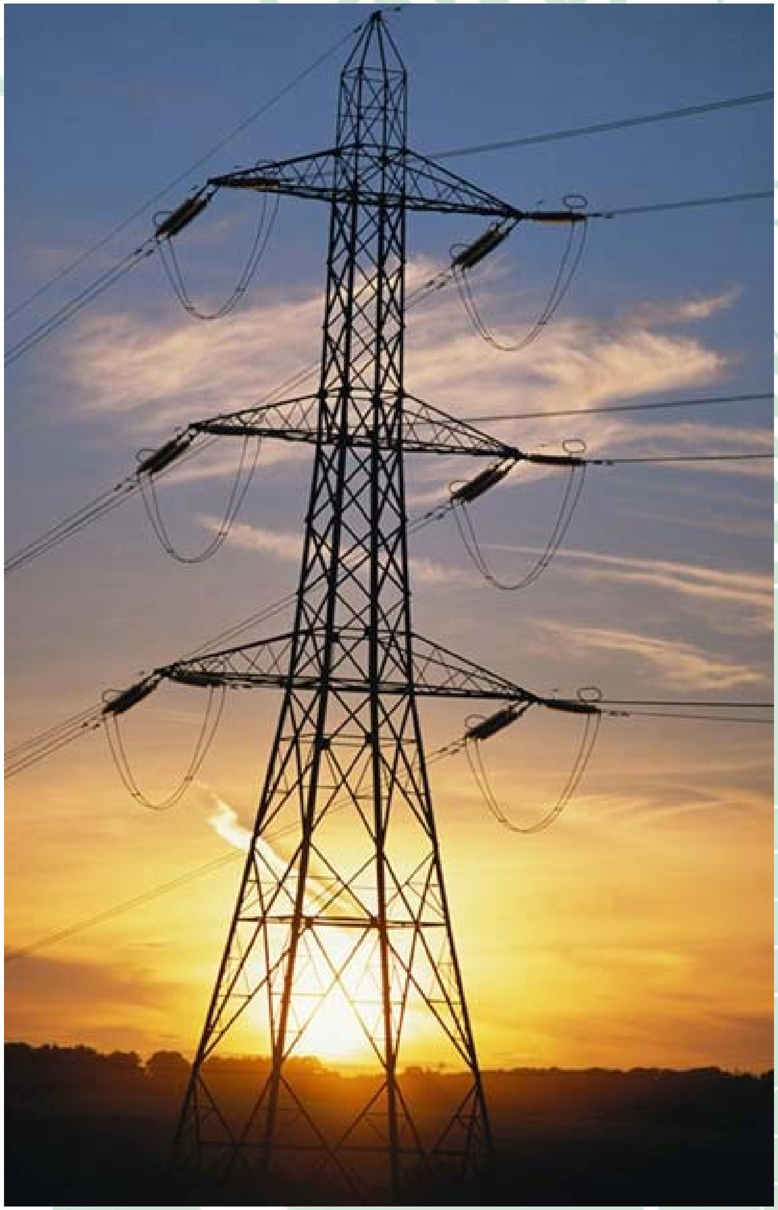


CIGRÉ U.S.
Next Generation Network (NGN)

November 9, 2015

What is the US Next Generation Network (US NGN)?

The CIGRÉ U.S. NGN was established for young engineers who have begun to progress their career within the power industry.

- US NGN Membership
  - Power systems industry experience of 10 years or less
  - Students (FREE) or professionals (50% Reduction Young member)
  - Become a CIGRÉ US NGN member
  - http://cigre.wpengine.com/membership/
- Provide opportunities for technical and personal development
  - Networking opportunities
  - Advance Technical Skills
  - Collaborate with peers across US and abroad

Ways to get involved

- Participate in webinars and tutorials
- Attend the Grid of the Future Symposium
- Participate in the International Paper Competition
- Join the NGN Executive Committee
- Expand Technical knowledge through CIGRE Working Groups

NGN Executive Committee

- Amanda Olson – Burns & McDonnell
- Chris Mertz – Dominion
- Christin Domian – MEPPI
- Diana Lee – VELCO
- Jason MacLeod – Burns & McDonnell
- Jessica Lau – ISO New England
- Josh Snodgrass – Duke Energy
- Kyle Thomas – Dominion
- Ryan Quint – NERC
- Saeed Kamalinia – S&C Electric

Join CIGRÉ!

Questions or suggestions?

Contact NGN Executive Committee at:

CIGRE.USNC.NGN@gmail.com

Visit our website for more information:

http://cigre-usnc.org/ngn

Today's speaker

Wanda Reder

- Chief Strategy Officer at S&C Electric Company
- Active CIGRE member since 2008
- Involved in CIGRE Working Groups
- Served on IEEE PES Governing Board since 2002 & 1st female president of IEEE PES Society
- Received IEEE TAB Hall of Honor Award (2013) & IEEE Richard M. Emberson Award (2014)

Power Industry Crossroads Includes Smart Grid Technologies, Renewables and Storage

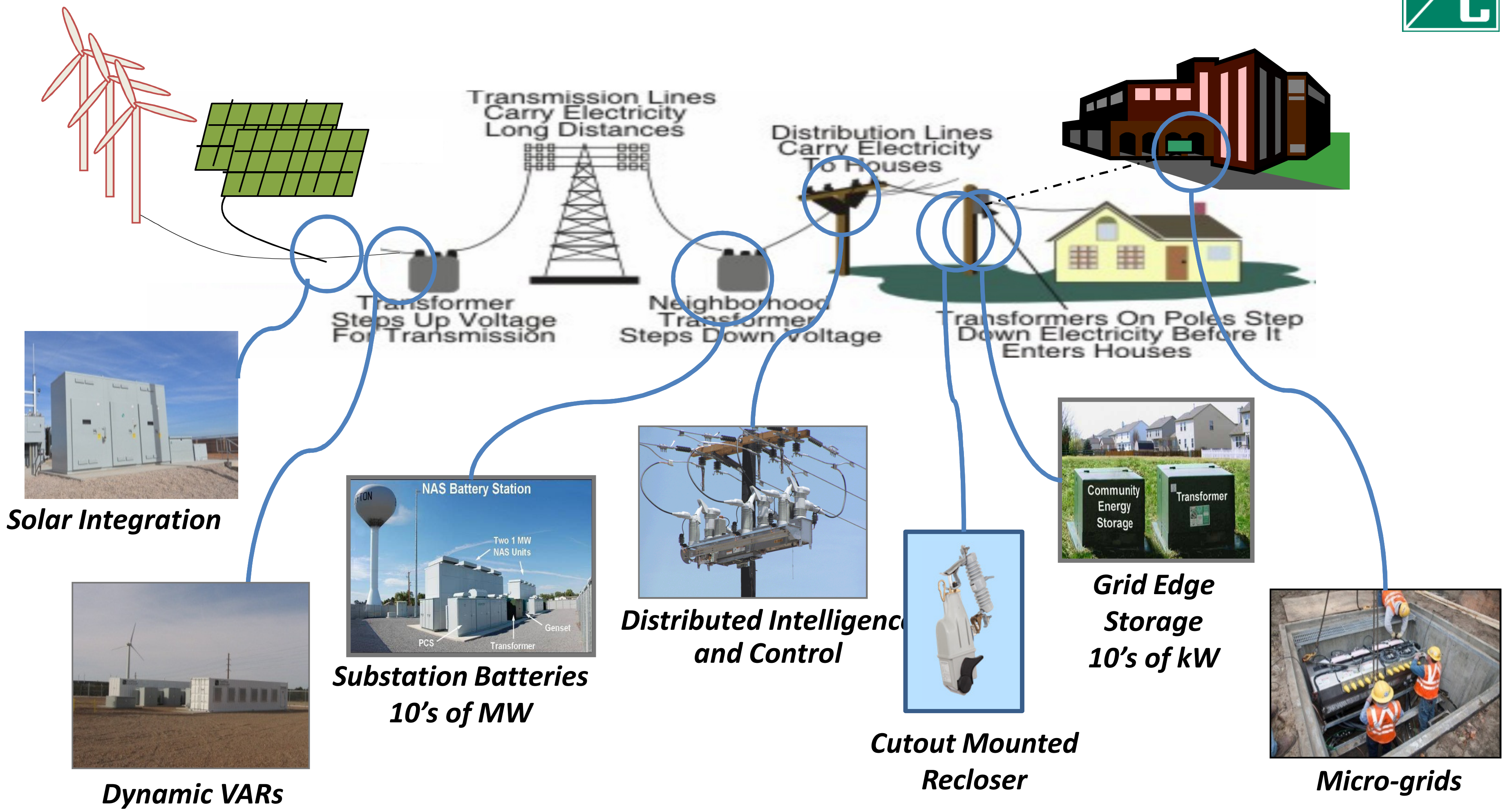
Wanda Reder

Chief Strategy Officer, S&C Electric Company

IEEE Board of Directors, Division VII

CIGRE Next Generation Network Webinar
November 9, 2015

S&C Delivers Grid Modernization



Source: Graphics adapted from an EPRI Presentation

Overview

- Grid Trends and Drivers
- Recent investments
- Modern grid improves reliability
- Technology changes things!
- Renewables and storage integration examples
- What’s next?

Grid Trends and Drivers

Growing Population, More Electronics

Infrastructure is more prone to failure

Increasing Environmental Requirements

Escalating Security Concerns

Heightened Investor Demands

Driving Technology & Policy Decisions

Recognizing the need for Power

Sources: "The Ampere Strikes Back: How Consumer Electronics Are Taking Over The World," Energy Saving Trust, June 2007; "The Rise of The Machines: A Review of Energy Using Products In The Home From The 1970s to Today" Energy Saving Trust, June 2006; "Electric Power – The Next Generation: The Intelligent Grid," CenterPoint

How Can We Not Change?

- Customer expectations are increasing, and yet…
- Vulnerabilities are increasing
  - ✓ Climate Change
  - ✓ Aging Assets
  - ✓ Physical and Cyber security
  - ✓ Need for flexibility

Grid modernization is a MUST for increased resiliency!

'Frankenstorm' Sandy hits US
October 29, 2012

Source: US DOE (2013) Energy Sector Vulnerabilities to Climate Change

Vulnerability from Climatic Conditions

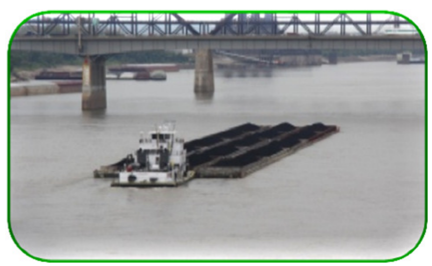
Lower water levels: Reduced hydropower

Flooding: Impacts on inland power plants

Cooling water intake or discharge too hot: Reduced generation from power plants

Intense storms: Disrupted power generation, distribution and oil /gas operations

Lower river levels: Restricted barge transportation of coal and petroleum products



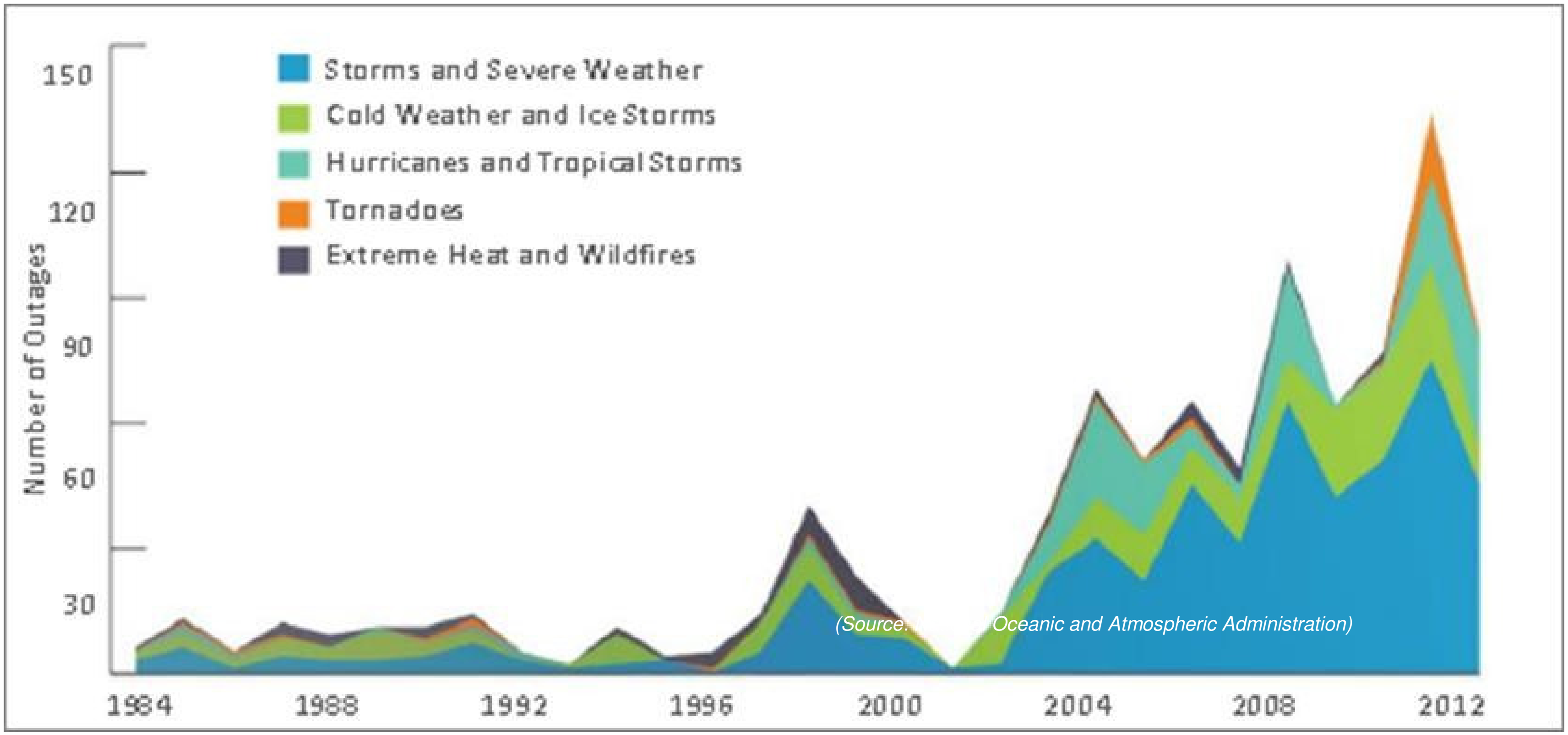
Wildfires: Damaged transmission lines

Water restrictions due to drought: Limiting shale gas and power production

Source: U.S. DOE (2013), U.S. Energy Sector Vulnerabilities to Climate Change and Extreme Weather.

Can We Afford To Not Change?

U.S. Power Outages Affecting 50,000 Customers Caused by Extreme Weather



(Source: National Oceanic and Atmospheric Administration)

Changing Energy Landscape

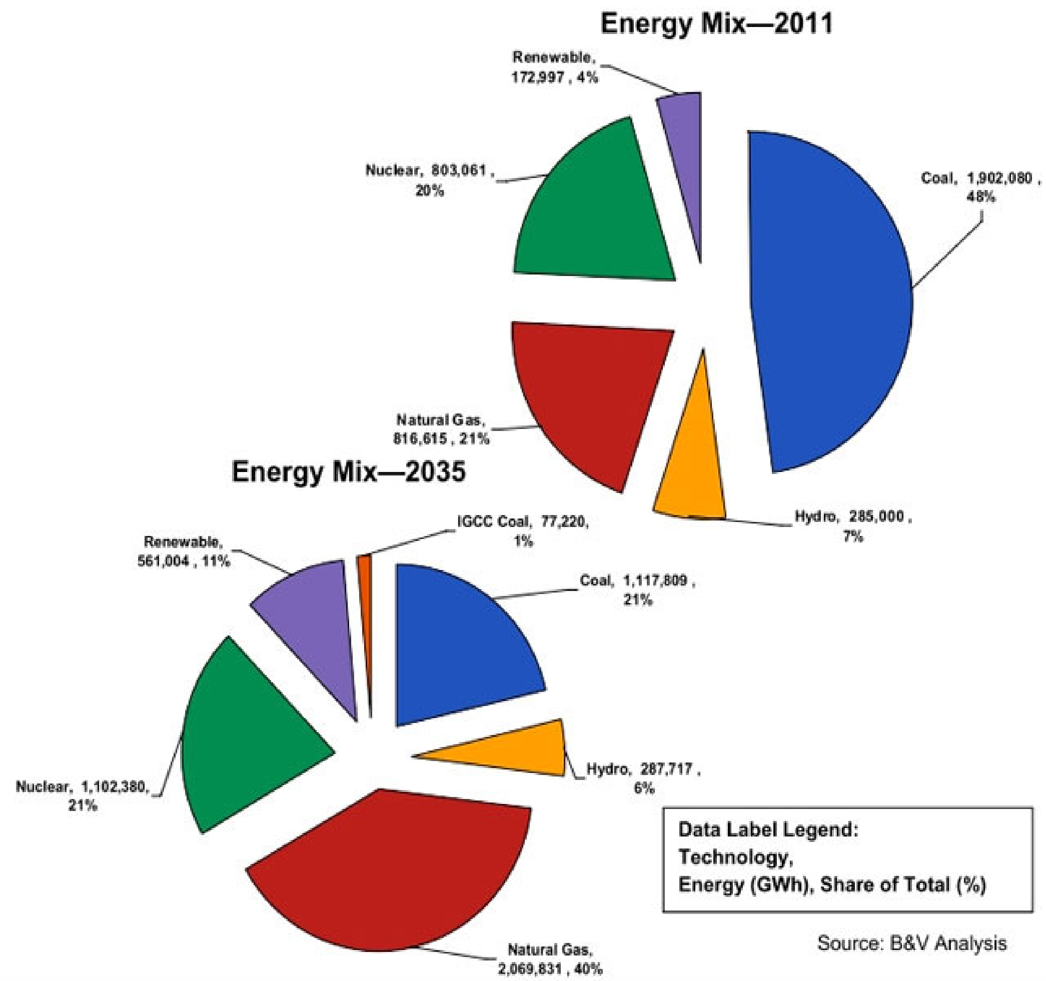
Energy mix: 2011 - 2035

- ⇧ Natural gas: 21% to ?%
- ⇩ Coal: 49% to 25%
- ⇧ Renewables: 4% to ?%

Energy Security Changes

Policy Developments

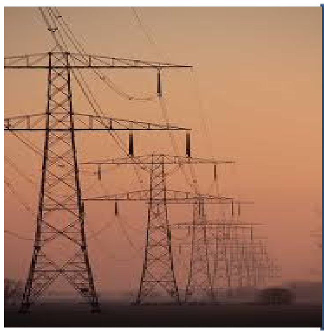
Implications…



Source: Black & Veatch Analysis - Energy Market Perspective

The Future Grid **Changes** Things…

Make Energy:
- More distributed supply
- Accommodate growth



Move Energy:
- More flexible, adaptable, intelligent, resilient
- Increase visibility

Use Energy:
- Integrate end-use activity
- Empower customers

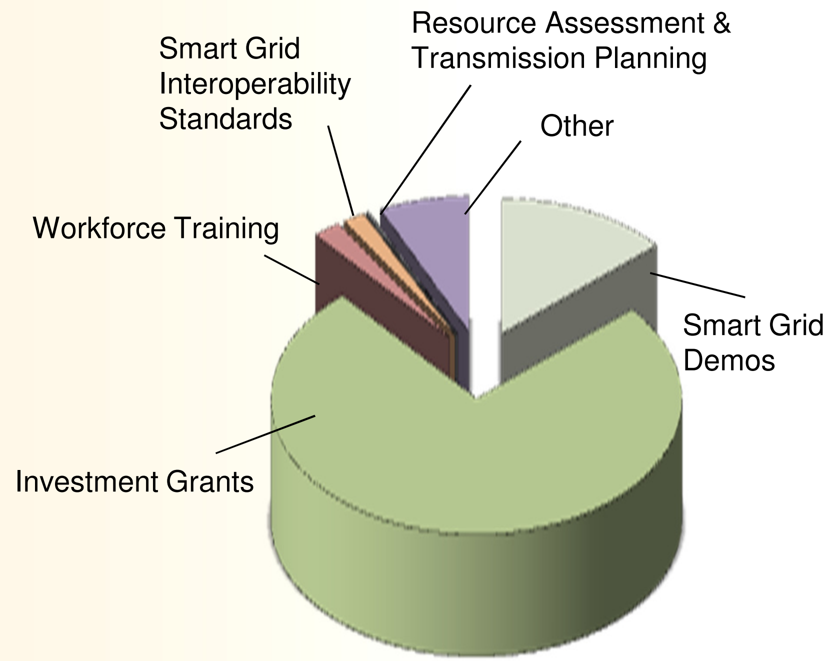
Apply Technologies:
- Energy storage
- Power electronics
- Distributed intelligence
- Adaptive protection
- Layered architecture
- Self-diagnostic, healing
- Data, cyber, analytics

Source: IEEE GridVision 2050

US Recovery Act: Grid Modernization

- US Spent $7.9B in ARRA Smart Grid Projects
  - Includes $4.5B Federal stimulus and industry matching funds
  - Five year grants starting in 2010
- Results are posted
  - www.smartgrid.gov
- Developing a platform for significant grid modernization investment

One-time Appropriation
$4.5B of Recovery Act Funds



Source: US Department of Energy Office of Electricity and Energy Reliability: Results and Findings from the ARRA Smart Grid Projects, May 2013

Modern Grid Improves Reliability

TripSaver® II Cutout Mounted Recloser

- Single phase
- Avoid truck rolls

IntelliRupter® PulseCloser

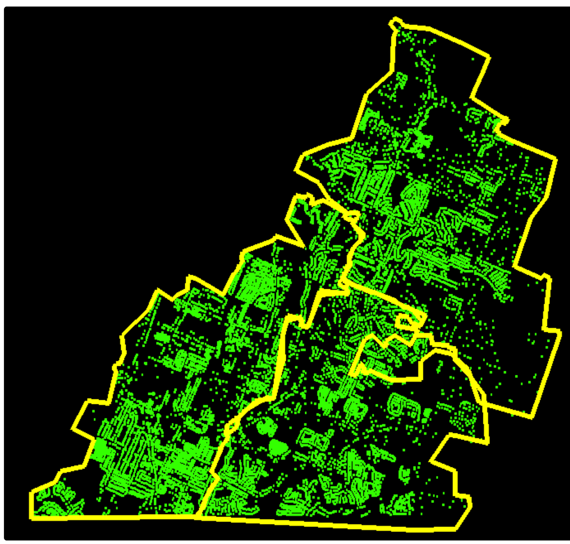
- Interrupt fault current
- Segments load
- Two-way sensing
- Adaptive protection
- Detects power quality events

EPB Chattanooga's Smarter Smart Grid

EPB Chattanooga
500,000 customer municipal

Smart Grid
Started with fiber everywhere

Smart Switches
1200 units on all 12kV



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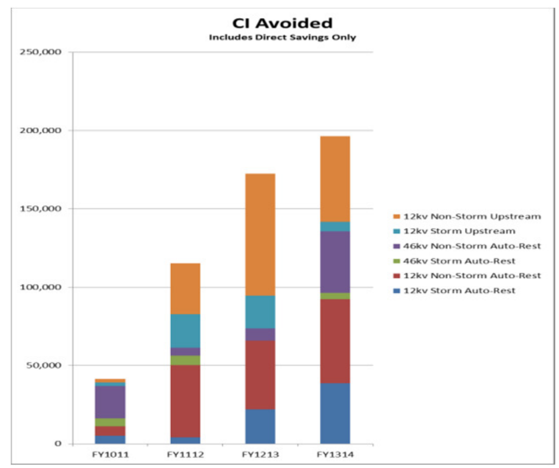
All customers restored

Storm Jan, 2013

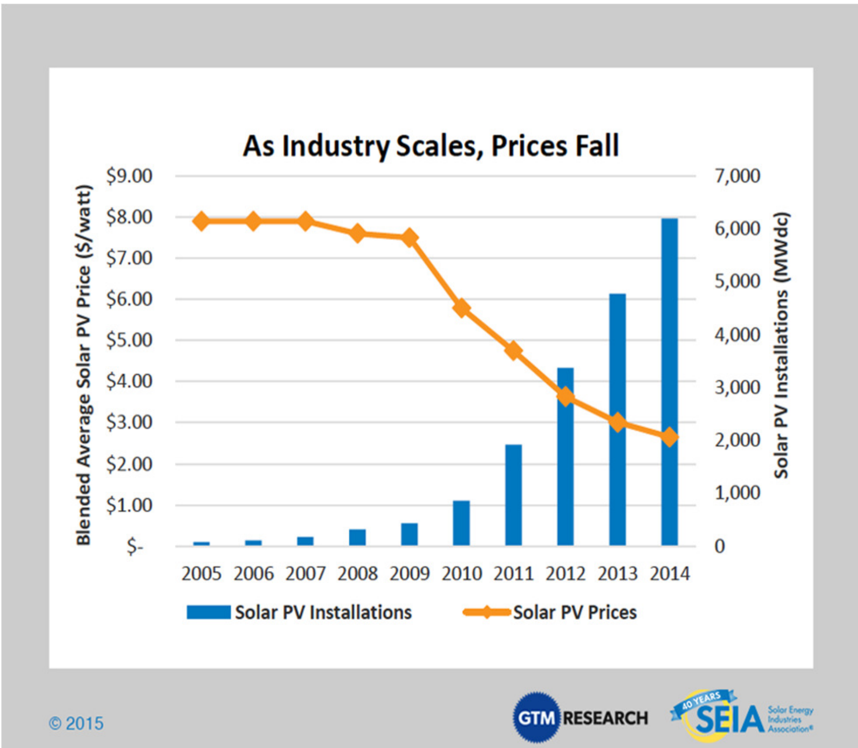


Interruptions Avoided: 2011 - 2014

Source: David Wade, EPB Chattanooga, presented for DOE, Dec. 2014 "EPB's Smarter Smart Grid"

Technology Changes Things!

Distributed Solar is Here to Stay



Source: Mark McGranaghan, EPRI "International Game Changers" Denver CO July 2015

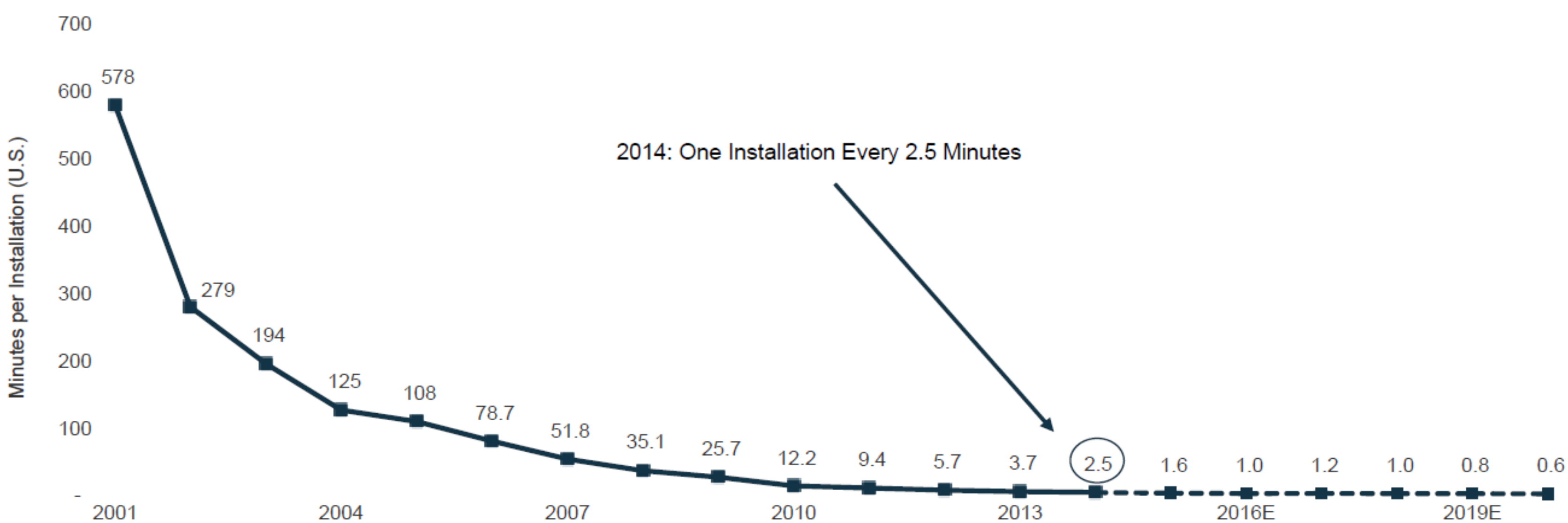
Google Map Snapshot of Ikea in Frisco, Texas

US Rate of Solar Installs per Minute is Declining

PV Growth

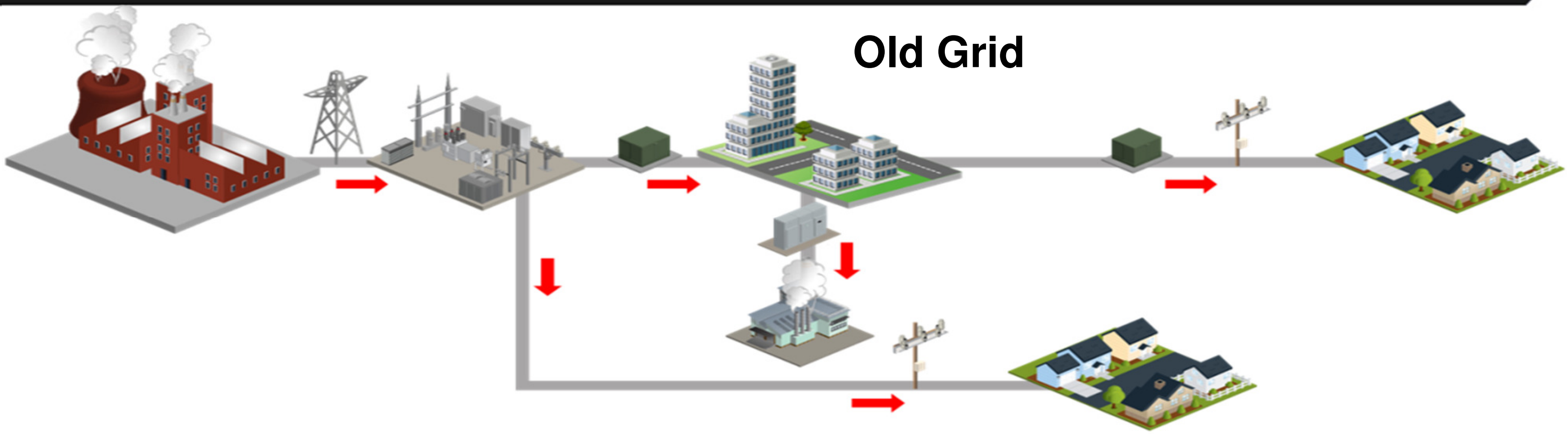
Accelerated growth and declining costs bring distributed solar and storage closer to grid parity: Especially in remote locations or islands with high electricity costs, the cost-competitiveness of PV makes renewable generation an increasingly favorable microgrid option when compared to strictly fossil fuel alternatives.

U.S. Solar PV Installation per Minute

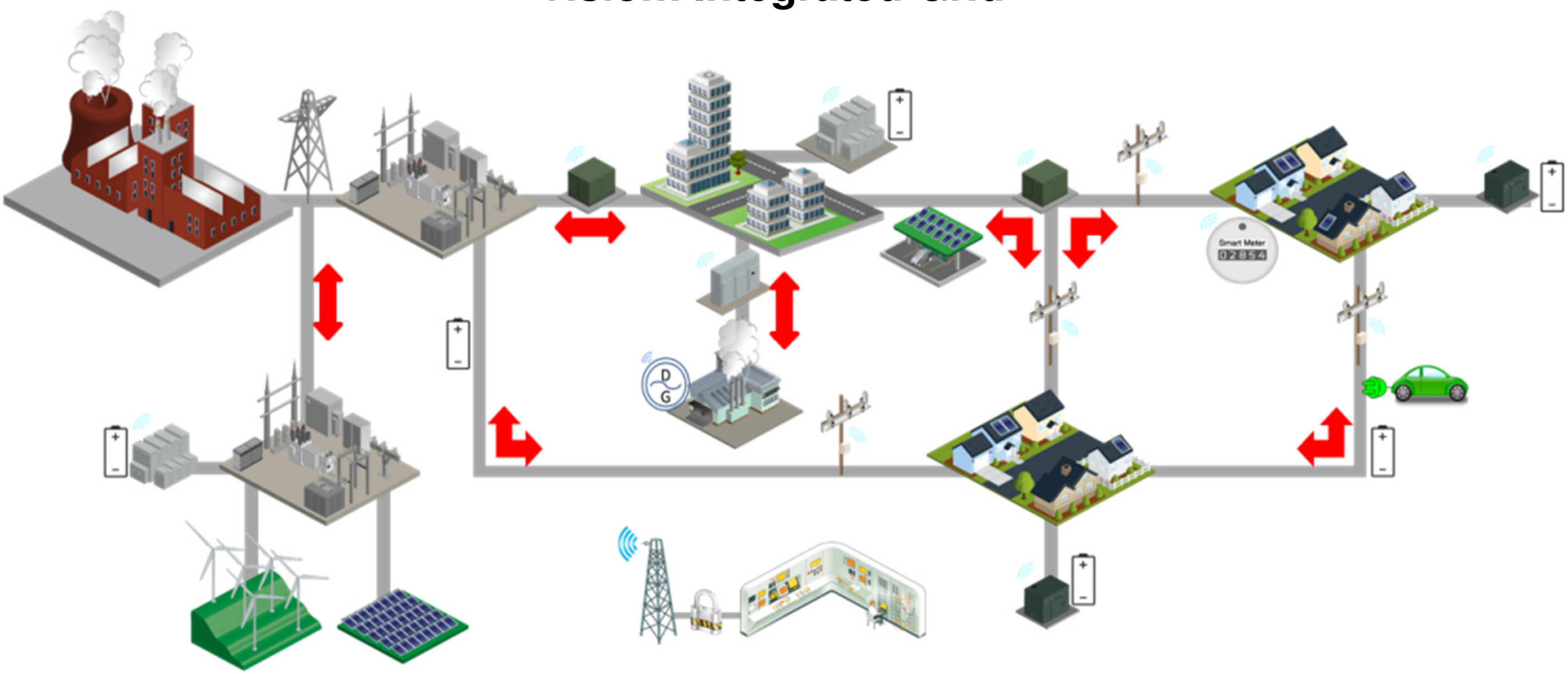


GTM RESEARCH
A Greentech Media Company

Old Grid

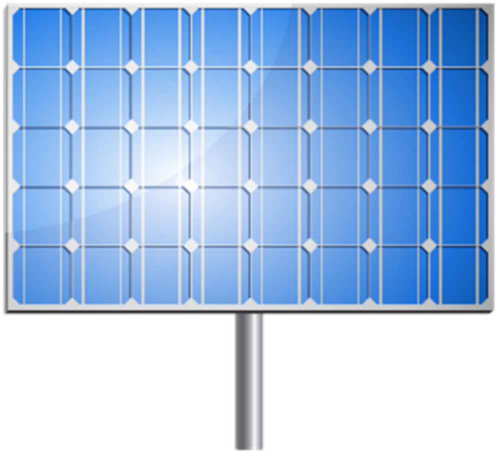


Vision: Integrated Grid



Interconnecting Renewables

- Intermittent and uncertain output
  - Voltage control, equipment impacts, protection, thermal limits
  - How much can we integrate?
- Often inverter based having harmonic contribution
- Interconnection requires power export considerations
- Involves negative load modeling



Reactive Power Requirements

- Capability of synchronous generators forms basis for wind interconnection requirements
- Often grid codes specifies reactive power capability at Point Of Interest (POI)
  - To maintain power flow limits on transmission lines, voltage limits at bus bars, utility system voltage control
  - Typically -0.95 to +0.95, but unity power factor (zero vars) is sometimes needed at POI
  - Entire range is often applied

Reactive Power Compensation

- Inverter-based dynamic Var Compensation
- Modules provide reactive support for Low Voltage Ride Through and dynamic range
- Use with mechanically switched devices

DSTATCOM:
1.25 MVAR modules provide 264% of continuous rating for 2 to 4 seconds

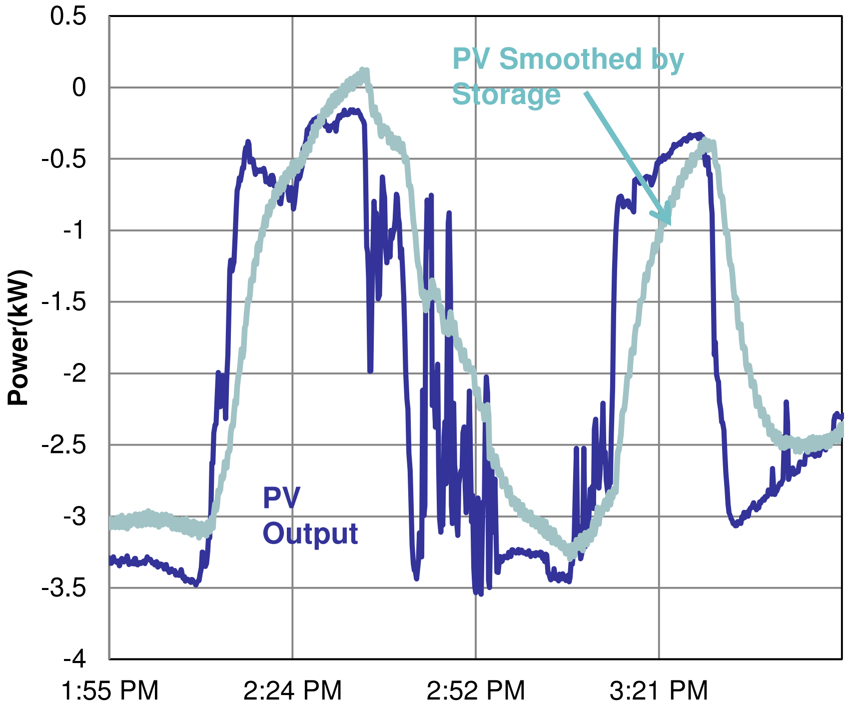
New Mexico Installation proivdes +/- 12 MVAR for 90 MW Wind Park that also includes 91 MVAR of switched capacitors.

Solar Integration

- Pre-engineered to save time
- Smaller footprint
- Integrates meters and relays
- Compact, sealed design
- Easily operated
- Enhanced safety: visible open gap, internal grounding, no exposure to medium voltage during operation

20 MW Solar installation with System VI in Tuscon, AZ

Using Storage to Manage Chaos



Batteries smooth intermittent solar generation

Source: SDG&E, June 2014 - Thomas Bialek

Characteristics of Storage and Renewables

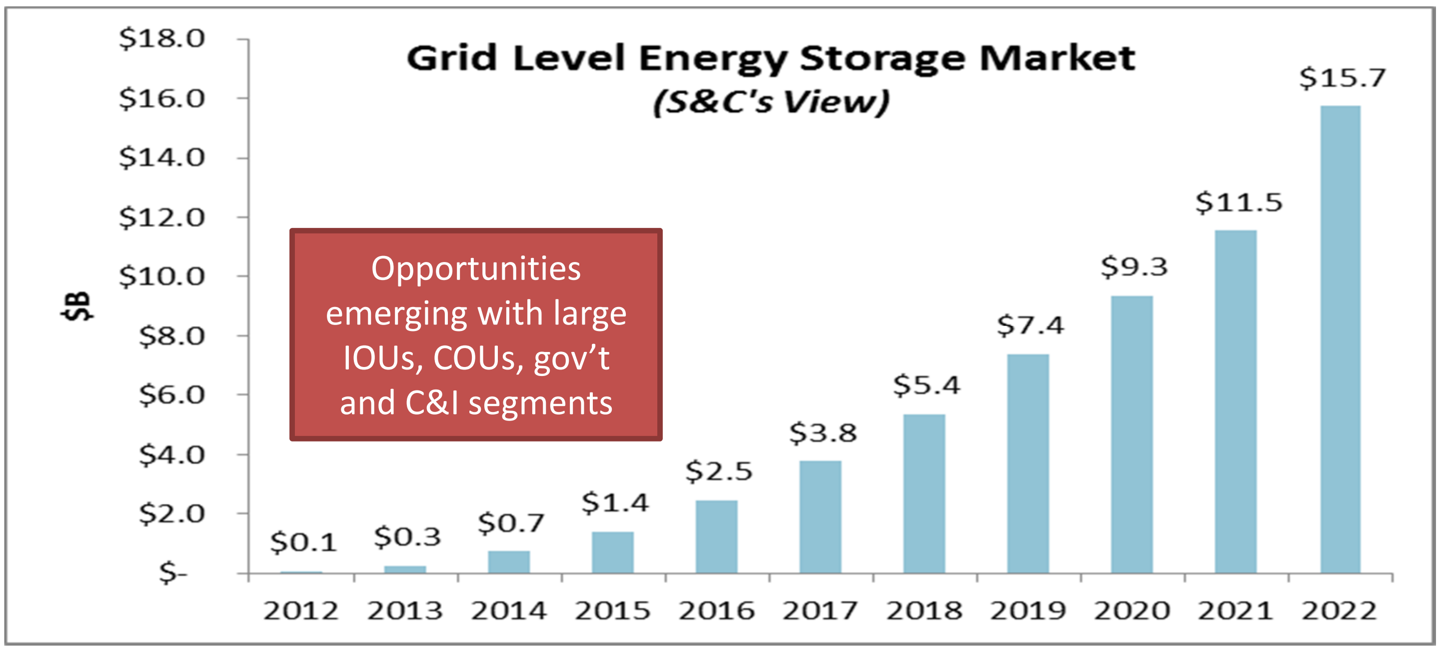
- Smooth intermittency
- Minimize reverse power flow, keeps voltage within limits
- Store output and release coincidental with local load
- Control ramp rate

Energy Storage - Solar Hybrid Project

Energy Storage – Wind Hybrid Project

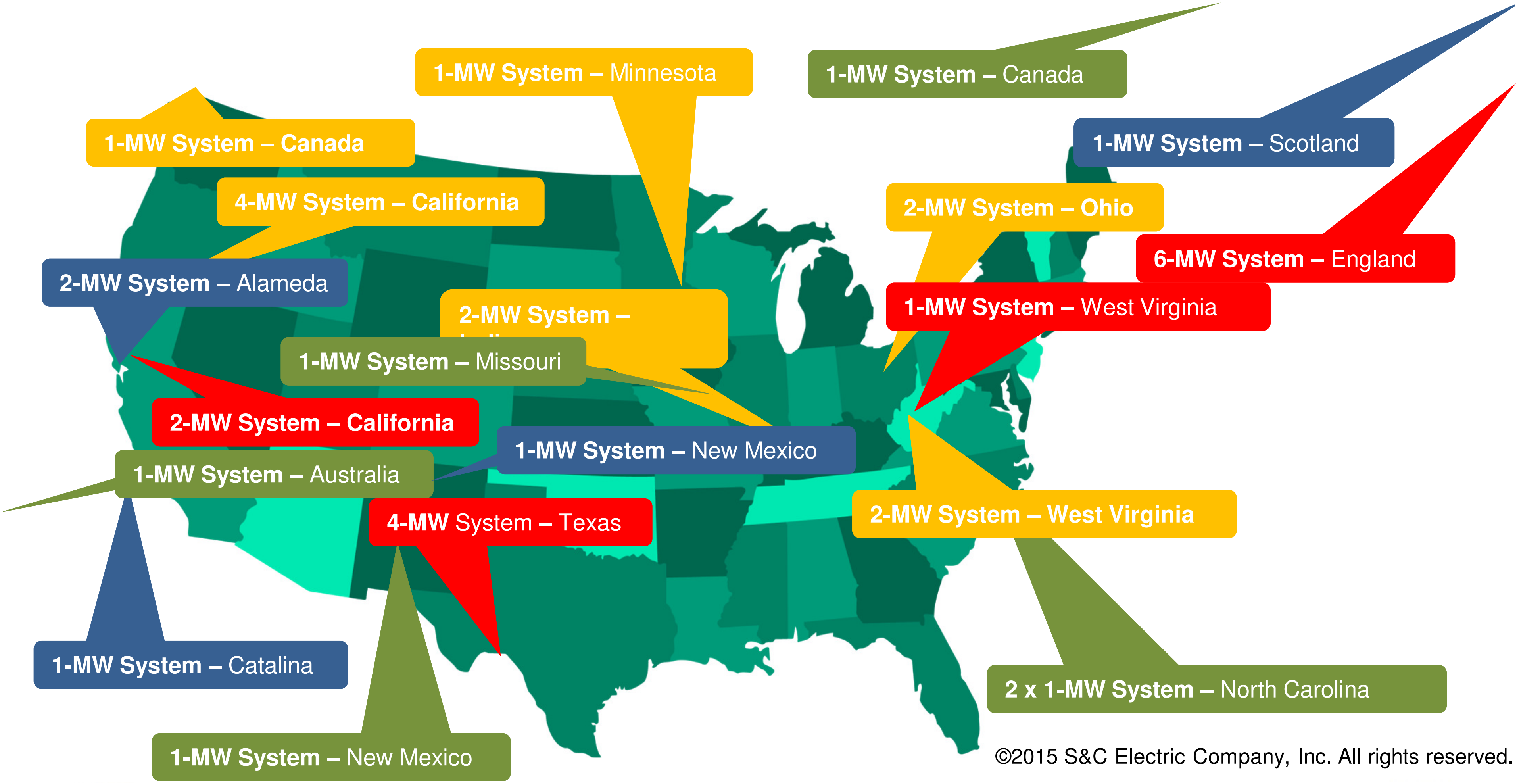
Grid-Connected Energy Storage is Growing

- Demand Drivers
  - Renewable energy penetration
  - Heavily loaded infrastructure
  - Microgrids
  - Policy/Regulations
- Supply Drivers
  - Decreasing costs
  - New chemistries
  - Better financing options



S&C's Storage Use Cases

Islanding
Ren Integration
MicroGrid
T&D Deferral



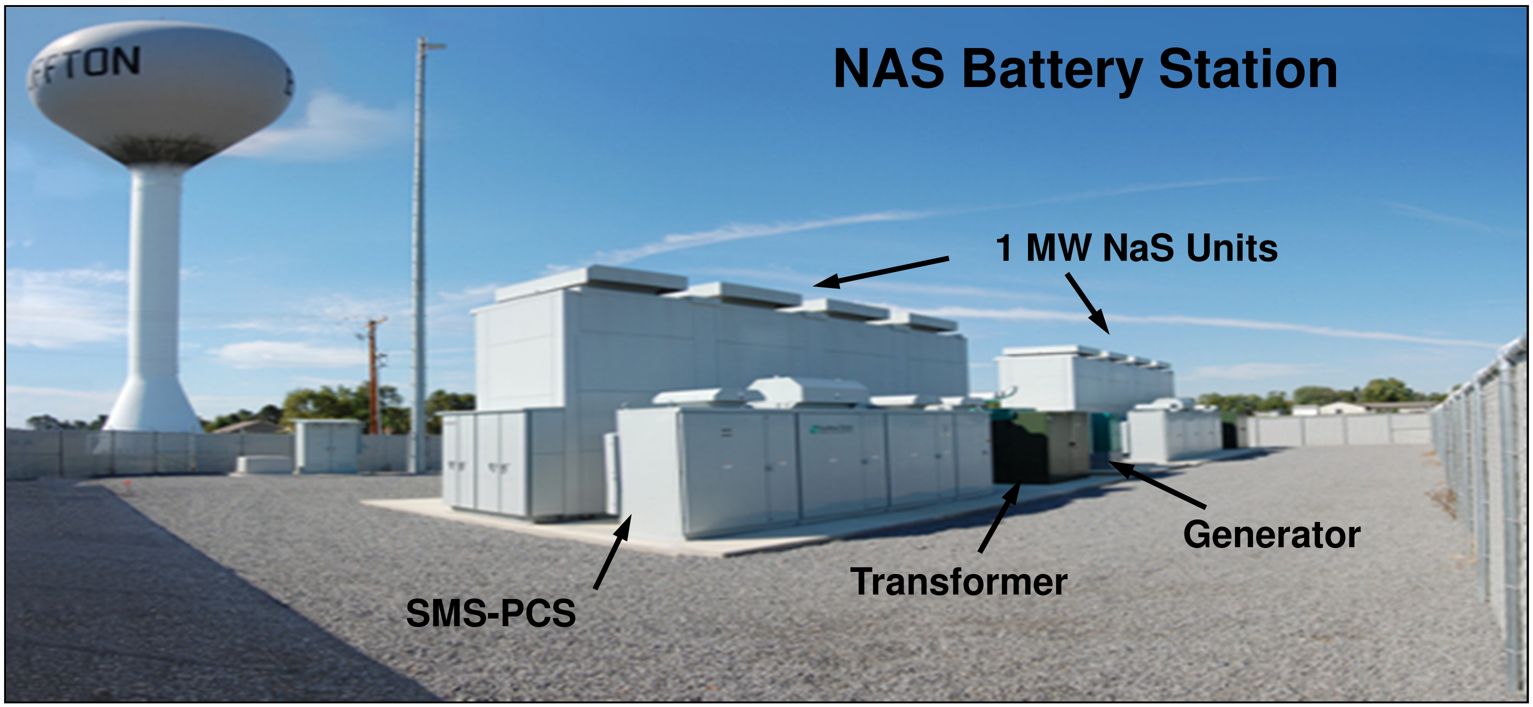
Energy Storage Systems

- Energy Storage Benefits
  - Cost deferral of new substations
  - Improved service reliability
  - Less stress on aging infrastructure
  - Integration of renewable energy
  - Energy market value
  - Frequency regulation

Luverne, MN
NaS Battery Installation
1.0 MW for 6 hours
Used for wind farm smoothing to facilitate dispatched wind and peak shaving

AEP Storage in Bluffton, Ohio

- 2.0 MW, 14.4 MWH outdoor installation in Bluffton, Ohio
- Includes dynamic islanding and triggered peak shaving
- Generator for heater backup power
- Two other identical sites in West Virginia and Indiana



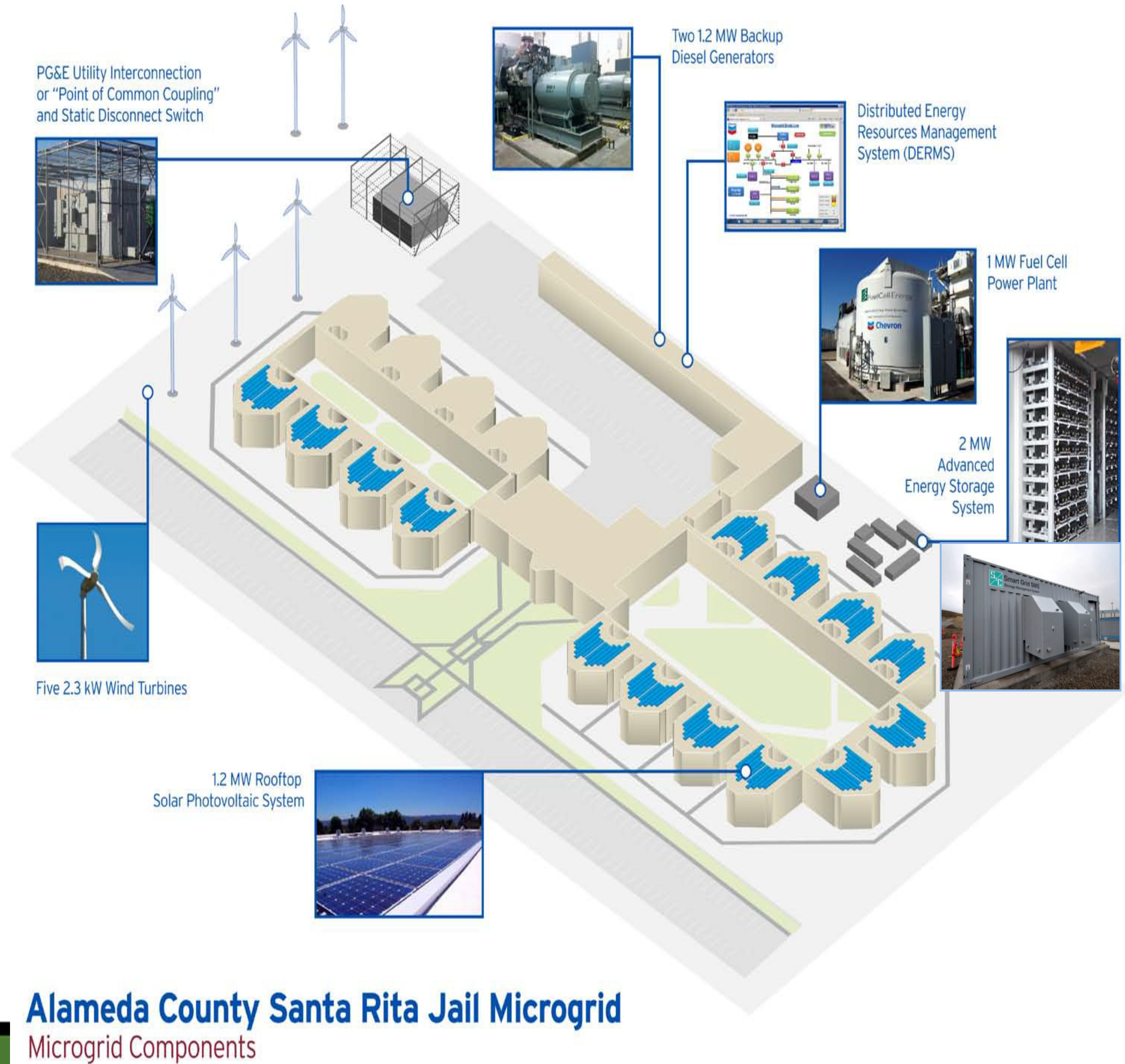
Dynamic Islanding from Storage and DA

- Load data is captured by automated distribution devices
- Dynamic islanding with power loss
- The maximum number of customers are restored serviced by the battery based upon:
  – Last load information
  – Energy in the battery
- The island can be minimized as the battery depletes
- Customer load served until battery is exhausted or power is restored

IntelliRupter: Self Powered, Self Contained, Fault-Interrupting Switch

Micro-grid: Santa Rita Jail, California

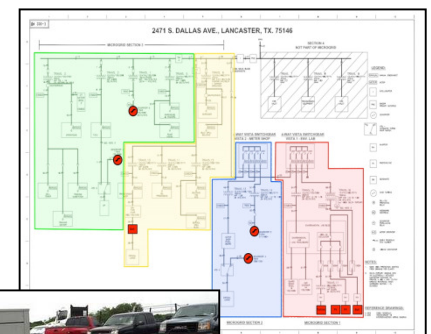
- 2 MW, 4 MWh, lithium-ion batteries with S&C Storage Management System
- Time shifts solar and wind to cure mismatch between generation and consumption
- No critical outages since its dedication 3/22/2012




Santa Rita Jail - 2012
Smart Grid SMS
Storage Management System
Chevron
Energy Storage | PV | Wind | Fuel Cells | Diesel Generators

ONCOR Microgrid


- Engineered to maximize energy storage, renewable generation and improve reliability
- Consists of 4 interconnected micro-grids
- Utilizes distributed generation
  - two solar photovoltaic arrays
  - one micro-turbine
  - two energy storage units
  - four generators
- Energy storage is the backbone



Modern Grid Uses Energy Storage

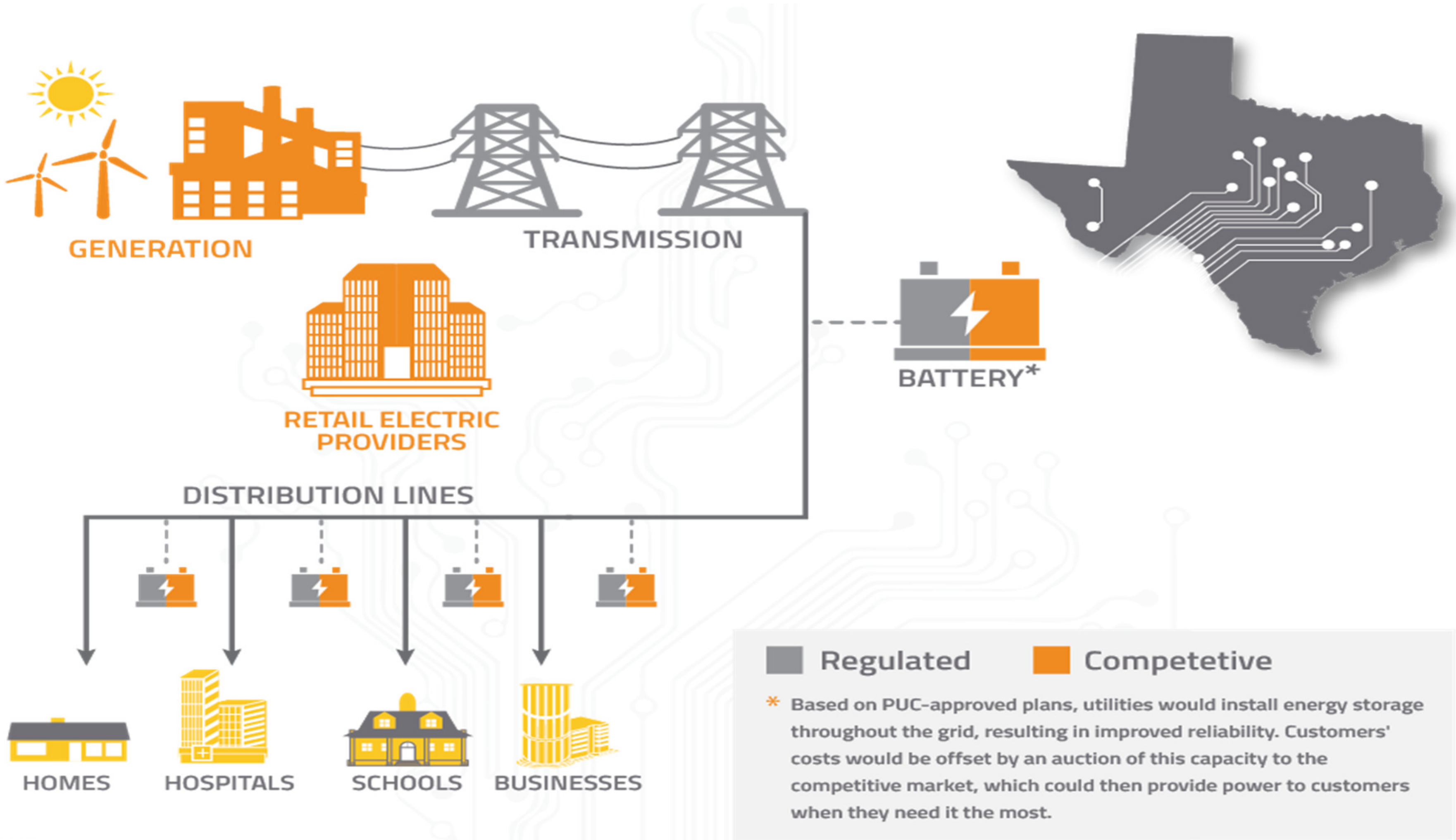
- Brattle report:
  - Analysis shows that ~5,000 MW of distributed electricity storage is most cost-effective across ERCOT at $350/kWh storage cost.
  - Payback dependent on regulated investment deferral and merchant/market value of the energy

Community Energy Storage
25 kW; 50 kWh
Lithium-Ion

Mid-Sized Energy Storage
250 kW; 250 kWh
Lithium-Ion

"Utility Marketplace with a Texas Twist" Tim Hein, Oncor, April 2015

Oncor Anticipates Market Development



Source: D.Treichler, ONCOR “ONCOR Energy Storage and Microgrid” for DOE in June,


CATALINA ISLAND (SCE) - 2012
DIESEL INTEGRATION

BC Hydro – Field, BC

- 1 MW NAS System for back-up
  - Small town (300 people)
  - Long feeder, extended outages
  - Battery provides 6+ hours of islanding
- System tweets alert to town residents when on battery power
- S&C equipment/services
  - PureWave SMS 1MW
  - IntelliTeam® II Automatic Restoration
  - Turnkey installation

http://www.youtube.com/watch?v=s9RRp4psqvQ

Distributed Intelligence is Key

Operations

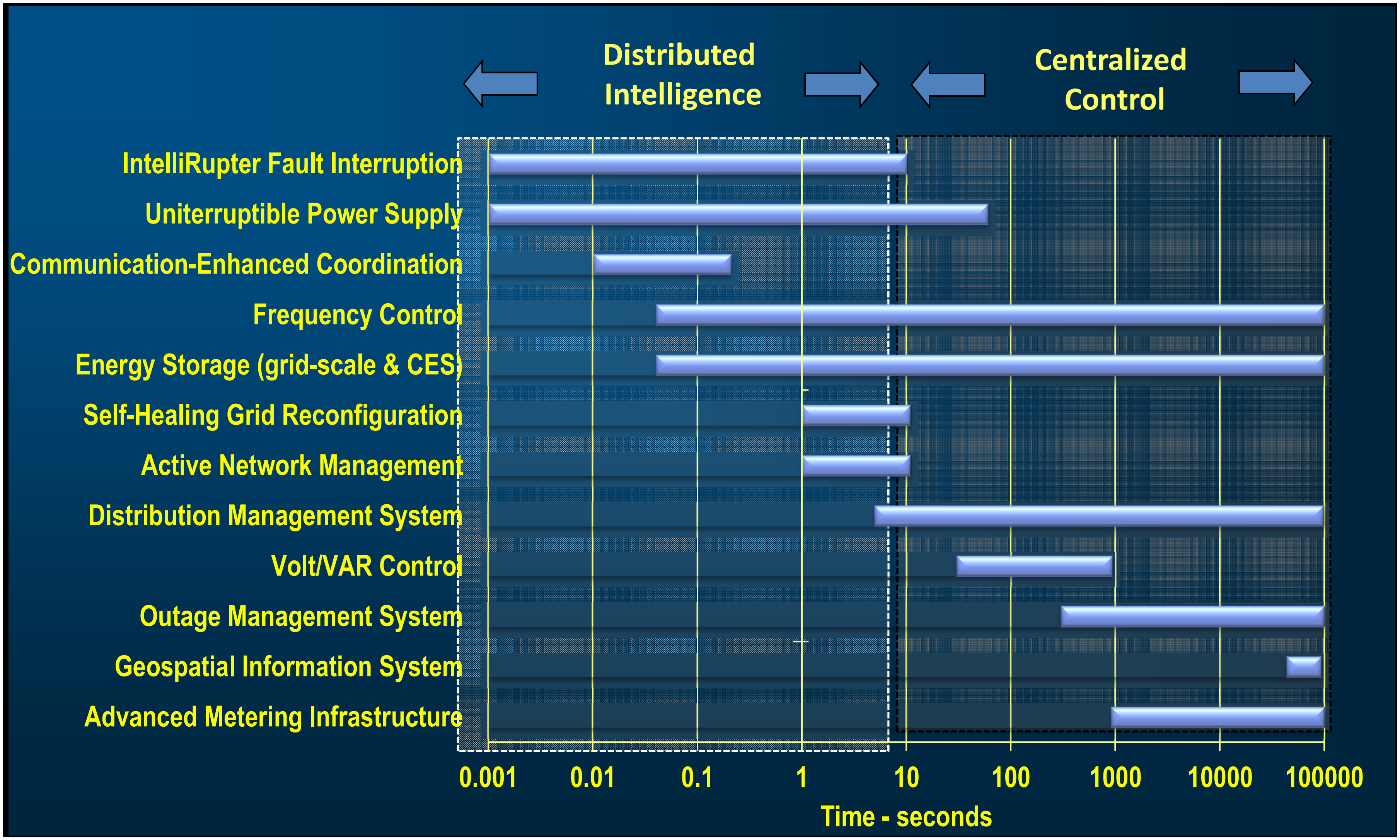
- Less Certainty
- More Choices
- Less Time to React

Intelligence

- Layered architecture
- More distributed

More Difficult to Manage Centrally

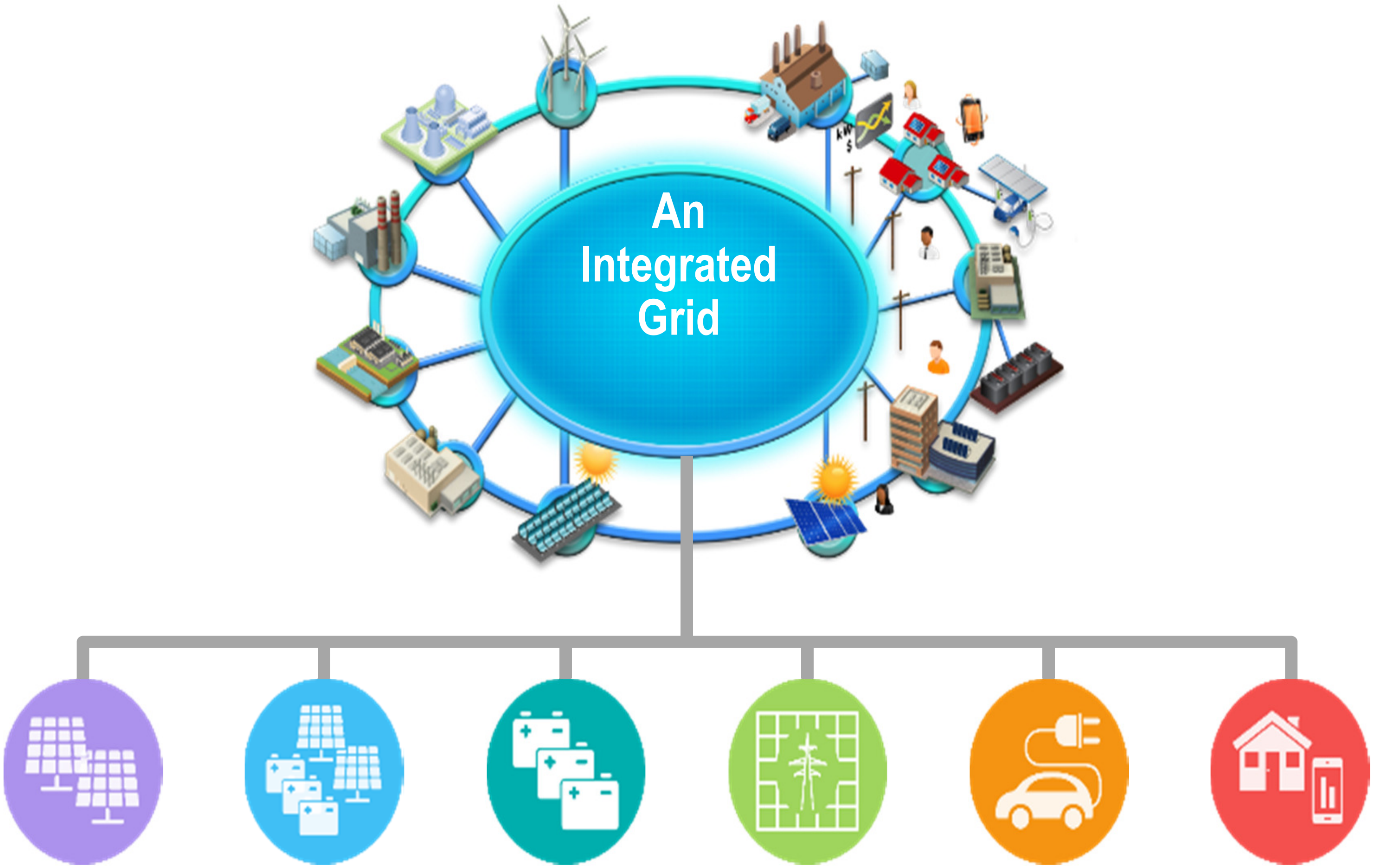
Operational Time: The *Need for Speed*…



Model Development Needed

- Tools:
  - Multi-phase power flow analysis with fine time resolution data
  - Data Bases that are “accepted” by the financial community
- Simulation:
  - Mitigate renewables impacts: over-voltages, power quality
  - Track operational parameters - voltages, operations, charge state
  - Model battery capacity fade predictions
- Market Applications (combinations and trade-offs):
  - Day Ahead Energy, Spinning Reserve, Real-Time Balancing
  - Co-Locate PV+ Storage in Conventional and Ancillary Markets
  - Bundled Use Case: Substation Deferral and Market Participation
  - Scope certainty for various connections points

An Integrated Grid is Next



Graphic Source: Mark McGranaghan, EPRI "International Game Changers" July 2015

Changing the Conversation with Storage

- Recognize the trends and drivers
- Enable the future with a modern grid
- Storage and renewables are key components for advancement
- Changes how we make, move and use power
- An integrated grid is next
- Much more to be done

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