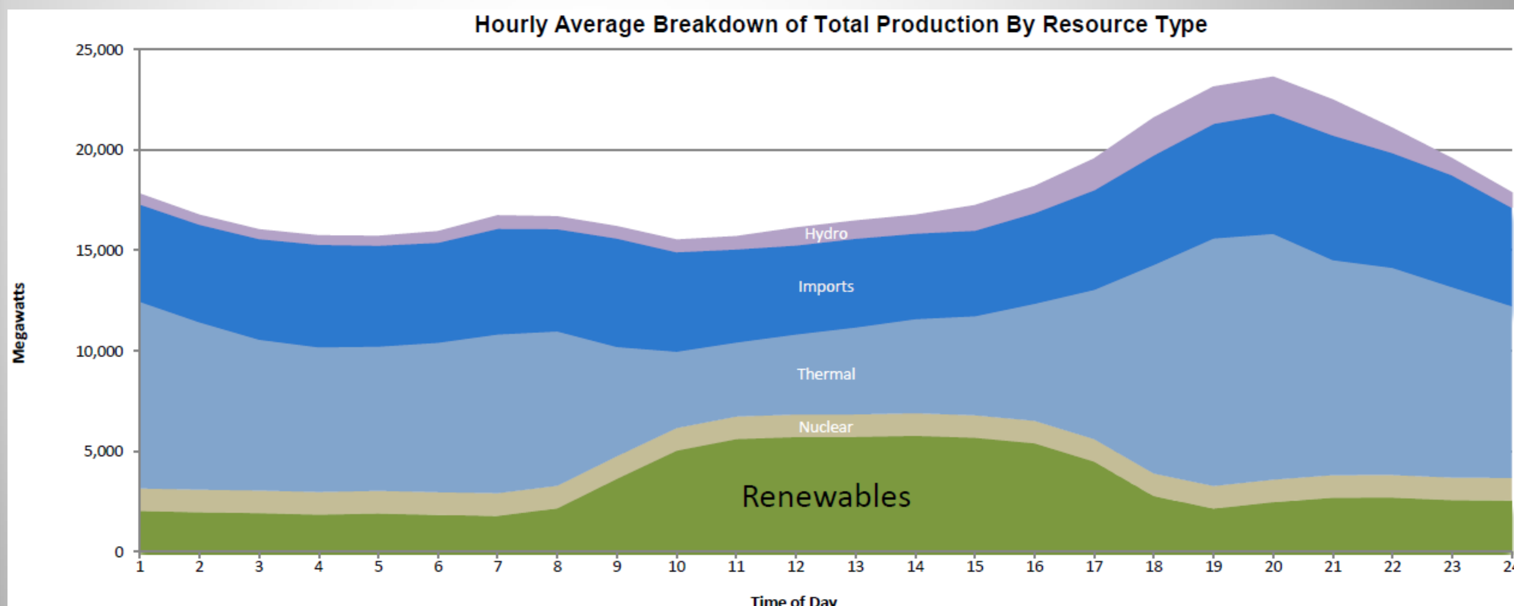
Integration of Renewables and Microgrids in Power Systems - Present and Future Challenges and Solutions



Source: content.caiso.com/green/renewrpt/20141019_DailyRenewablesWatch.pdf

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October 20, 2014

Agenda

1. Introduction and Objectives

   Julio Romero Aguero (Quanta Technology)

2. Utility perspective on Microgrids

   Shay Bharamirad (ComEd)

3. Advanced Modeling and Analysis to Support High Penetration of Distributed Solar PV

   Robert Sherick (Southern California Edison)

4. ISO perspective on Renewable Integration

   Pengwei Wu (ERCOT)

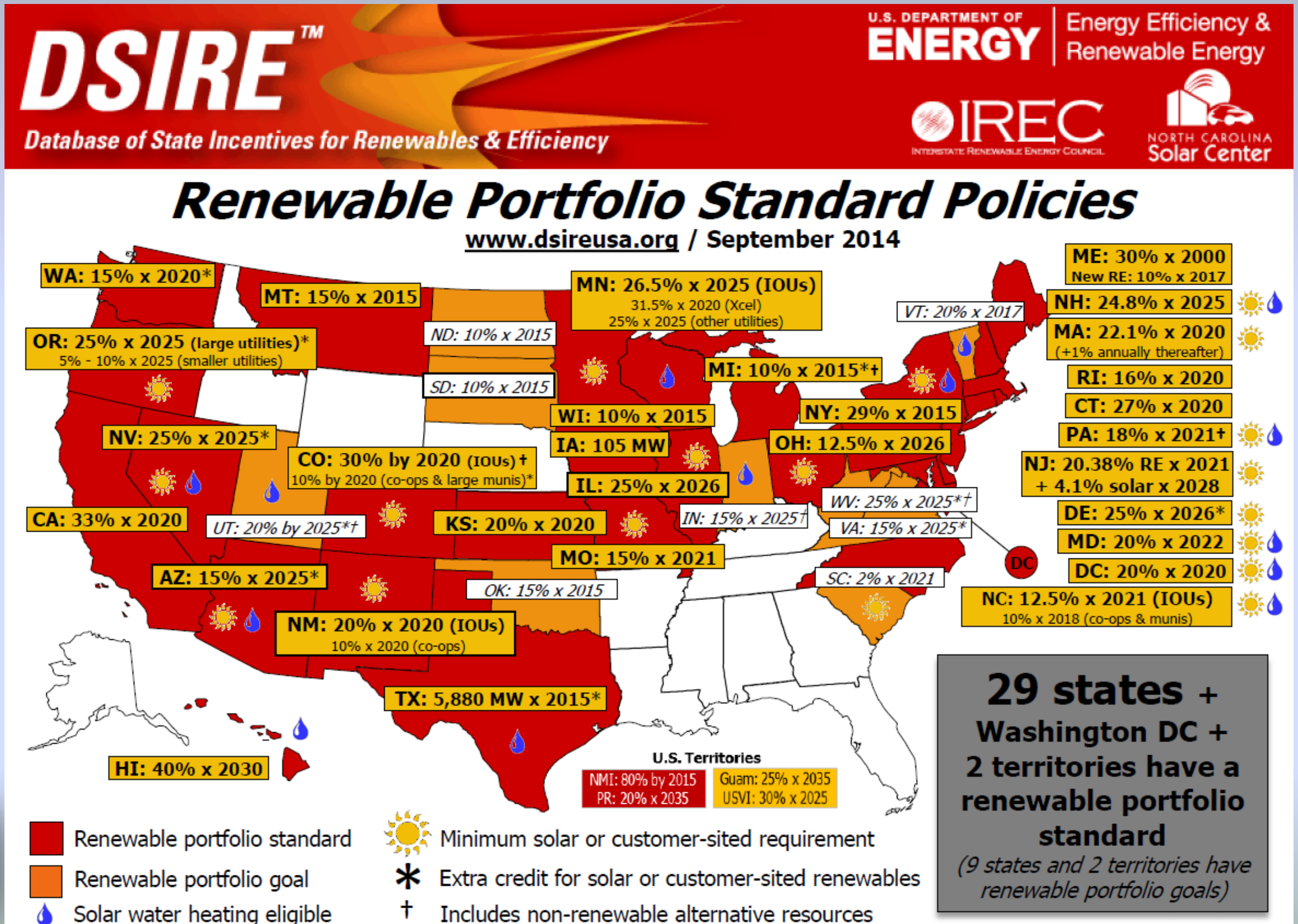
5. DER and Microgrids - A Sure thing or a Fading Myth?

   Johan Enslin (University of North Carolina at Charlotte)

QUANTA TECHNOLOGY

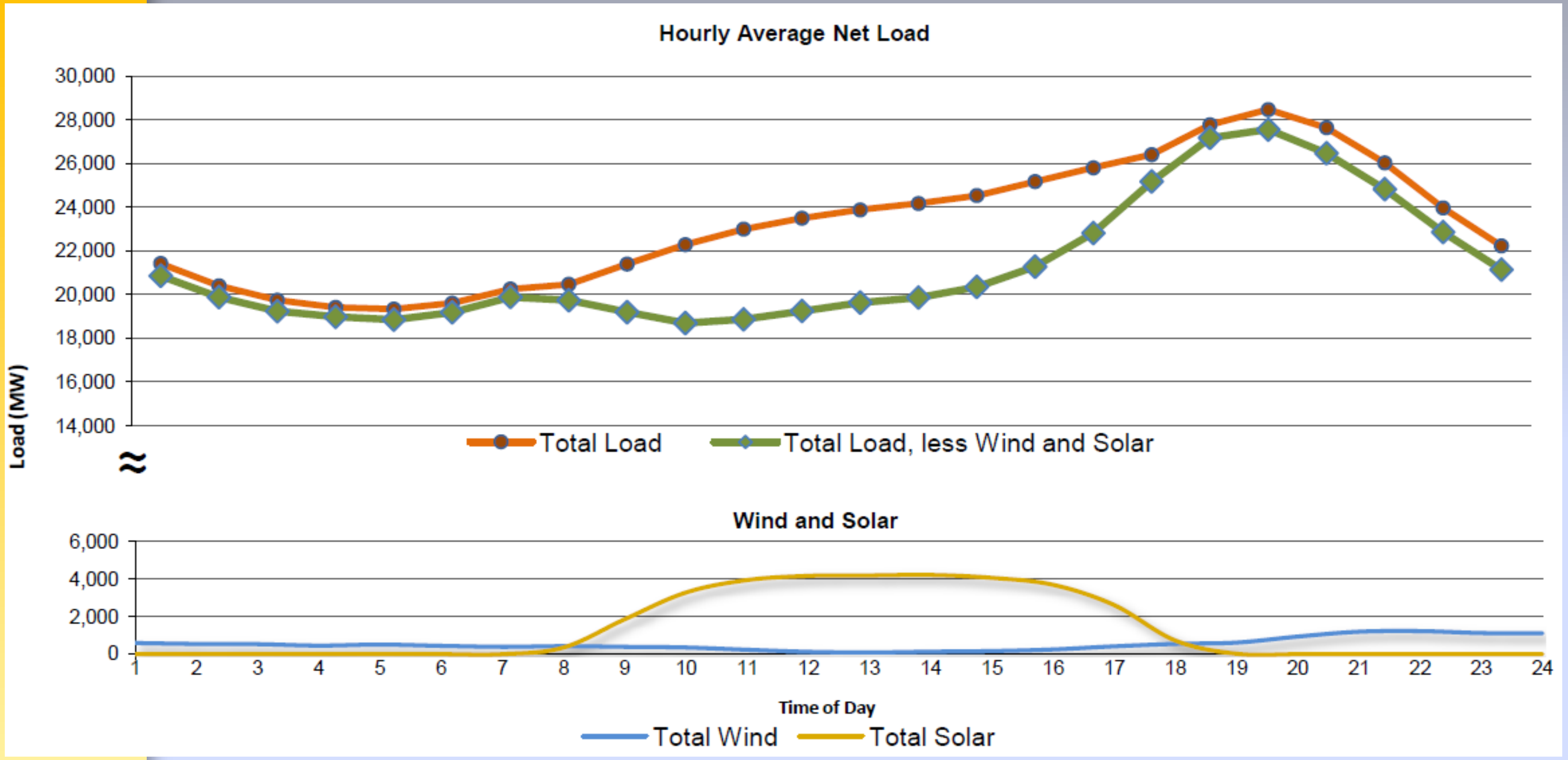
Introduction and Objectives

- Objectives:
  - Review of industry practices for integration of renewables and microgrids in T&D grids
  - Discussion of emergent trends, challenges and solutions



Introduction and Objectives

- Why is this important?



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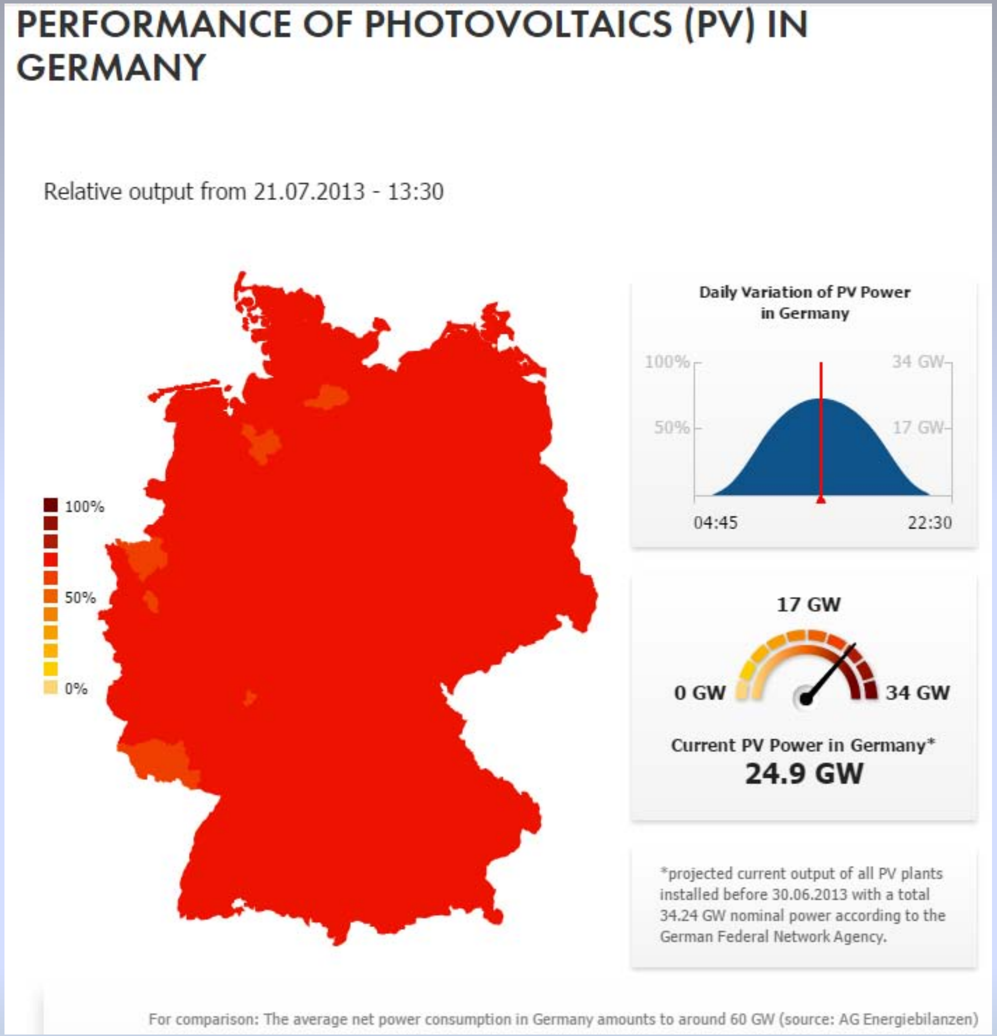
Introduction and Objectives

- Are we heading in this direction?



http://www.sma.de/en/company/pv-electricity-produced-in-germany.html

Shay Bahramirad

Shay Bahramirad is a Manager of Smart Grid and Technology at ComEd. Her responsibilities include leading the Smart Grid organization across ComEd, business case development and performance measures for Smart Grid technology deployments, and defining, developing, and implementing Smart Grid initiatives in ComEd's service territory. She is also an Adjunct Professor at the Illinois Institute of Technology. Shay holds multiple advanced degrees, including a Ph.D. in Electrical Engineering from the Illinois Institute of Technology. She is a U.S. representative of power quality monitoring in CIGRE and leads the development of the IEEE P1815 Standard: Smart Distribution Application Guide, and serves as Technical Chair of several IEEE conferences such as T&D and the Great Lake Symposium. She is the recipient of the 2014 IEEE PES Outstanding Young Engineer Award.

Presentation: Utility Perspective on Microgrids

QUANTA TECHNOLOGY

Robert Sherick

Robert Sherick is a Principal Manager in SCE's Advanced Technology Group. Robert manages a group of engineers working on renewable integration analysis, real-time digital simulations of the power system, and situational awareness technologies. His prior experience includes working as the Director of Power Supply for Pasadena Water and Power, Product Manager for Sungard Energy Systems, a Manager at Deloitte Consulting, and various engineering and operational roles at the Los Angeles Department of Water and Power. Robert has a Masters in Business Administration from the Claremont Graduate School and a Masters in Electrical Engineering from the University of Southern California.

Presentation: Advanced Modeling and Analysis to Support High Penetration of Distributed Solar PV

QUANTA TECHNOLOGY

Yunzhi Cheng

Yunzhi Cheng is Senior Planning Engineer at ERCOT (Electrical Reliability Council of Texas). He received his B.S. and M. S. degrees from Shanghai Jiaotong University, Shanghai, China, and Ph.D. degree from the University of Texas at Arlington, Arlington, TX, USA, all in electrical engineering. During 2003 to 2006, he worked as a Transmission & Generation Planning Engineer at East China Electric Power Design Institute, focusing on power system planning for East China Power Grid. From 2009 to 2014, Dr. Cheng worked as a Manager of Power System Studies at PwrSolutions, a DNV GL company at Dallas Texas. His areas of interest include renewable energy modeling and integration, power system stability, dynamic parameter identification, state estimation, blackout restoration, hydrogen economy, and power market.

Presentation: ISO Perspective on Renewable Integration

Johan Enslin

Johan H Enslin PhD, is the Director for the Energy Production and Infrastructure Center (EPIC) and the Duke Energy Distinguished Chaired Professor in Power System at UNC Charlotte. Enslin has combined a 33-year career with leadership in industry and academia; in the US, Europe and South Africa. He served as an executive for private business operations and a professor in electrical engineering. Dr. Enslin initiated and led renewable energy teams, companies and executed multi-disciplinary power system projects. Johan worked for more than 80 US, European, Asian and African power utilities, governments and industries. He authored more than 280 journal and conference papers for IEEE and other organizations, and has written several chapters in scientific books. Johan is a leader in IEEE and CIGRÉ. He holds more than 21 provisional and final patents. He is a registered Professional Engineer, IEEE and SAIEE Fellow.

Presentation: DER and Microgrids - A Sure thing or a Fading Myth?

Utility perspective on Microgrids

Shay Bahramirad, PhD

Manager of Smart Grid & Technology

October 2014

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An Exelon Company

COMED OVERVIEW

- The service territory covers 11,400 mi^2 in Northern Illinois
- Serving about 3.8 million (70%) of the customers in Illinois
- ComEd delivers electricity to 400+ municipalities, including the **City of Chicago**
- 23,750 MW all-time system peak (summer 2011)
- Transmission lines at 138, 345, 765 kV
- About 5,700 miles of transmission (69 -765kV) lines and about 66,000 miles of primary distribution (4 - 34kV) lines
- 225 HV, 526 MV distribution substations
- 5400 Distribution Feeders at 4, 12.5, 34.5 kV

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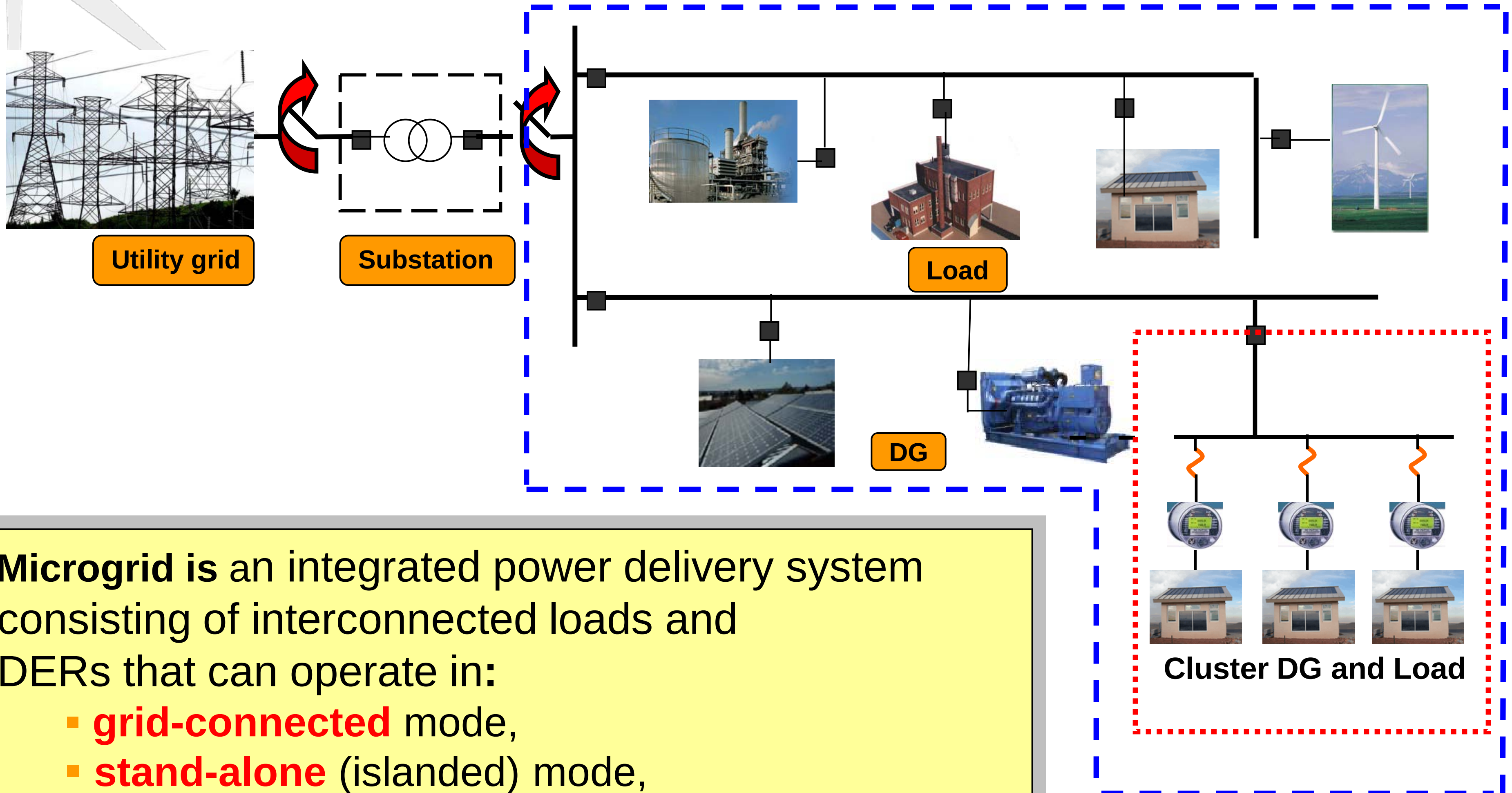
ELECTRIC UTILITIES ARE FACING SIGNIFICANT CHANGES

- **Stressed and Aging Infrastructure**
  - **Climate change resulting in increased weather volatility**
    - Demand for grid hardening and off-grid solutions
  - **Grid security and resiliency**
    - Concerns are driving operating expenses and capital expenditure
  - **Constrained delivery of gas and power**
    - Creates a need for transmission and gas storage
  - **Increasing utilization of natural gas**
    - Driven by low supply costs, new infrastructure, and the desire for clean and resilient energy
    - Improving CHP and Fuel Cell technologies enable gas to replace network-delivered electricity
- **Shifting Customer Expectations & Segmentation**
  - **Increasing customer expectations and segmentation**
    - Cleaner, more affordable, more reliable, and secure energy
    - Lower tolerance for outages
  - **Internet of Options**
    - Increase in big data driving an increase in customer options
- **To meet these challenges new technologies will have to implemented, such as microgrids**

SIMPLIFIED MICROGRID



Microgrid is an integrated power delivery system consisting of interconnected loads and DERs that can operate in**:**

- **grid-connected** mode,
- **stand-alone** (islanded) mode,
- **ride-through** between the above modes.

- Operates within clearly defined boundaries
- Appears as a single controllable entity wrt. to the grid

Definition: DOE Microgrid Exchange Group

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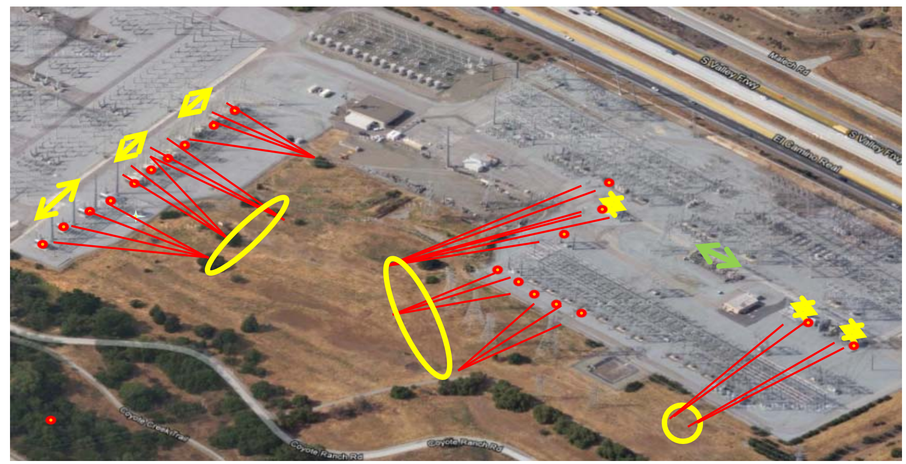
MICROGRIDS

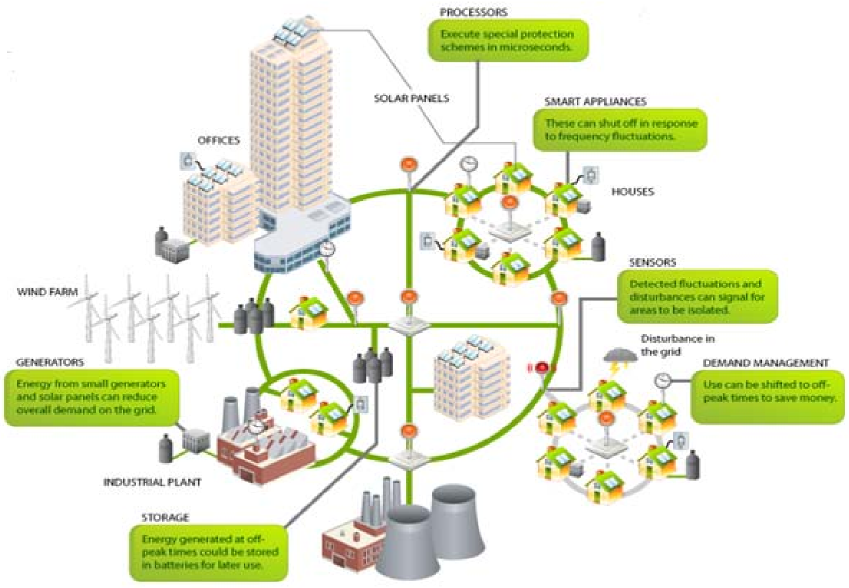
- **Why a microgrid?**
  - o Improved capacity, resiliency, reliability, efficiency and power quality
    - ▪ Storms and terrorism
  - o Improved physical and cyber security
  - o Increased sustainability
  - o Smaller environmental impact
    - ▪ Cleaner DG (distributed generation)



Sniper attack on PG&E's Metcalf substation

MICROGRID CONTROLLER

- U.S. Department of Energy announced $8 Million in grant funding to improve grid resiliency
- DOE awarded approximately $1.2 million to ComEd and it's partners to develop and test a commercial-grade microgrid controller capable of managing two or more interconnected microgrids
- ComEd's project includes a diverse mix of facilities and critical loads, including police and fire department headquarters, major transportation infrastructure, healthcare facilities for seniors, and private residences



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COMMUNITY MICROGRID

Evaluation of a potential project could cluster two microgrids in a community

ComEd is evaluating Chicago's Bronzeville neighborhood for implementation of a potential microgrid

- The potential location is adjacent to Illinois Institute of Technology (IIT) which has a microgrid
- Would create the first clustered microgrid in the world.
- Location is a great cross section of the City of Chicago, with a diverse set of critical loads
  - High tech manufacturing
  - Educational facilities
  - Police headquarters
  - Healthcare and senior residences
  - Other private residences

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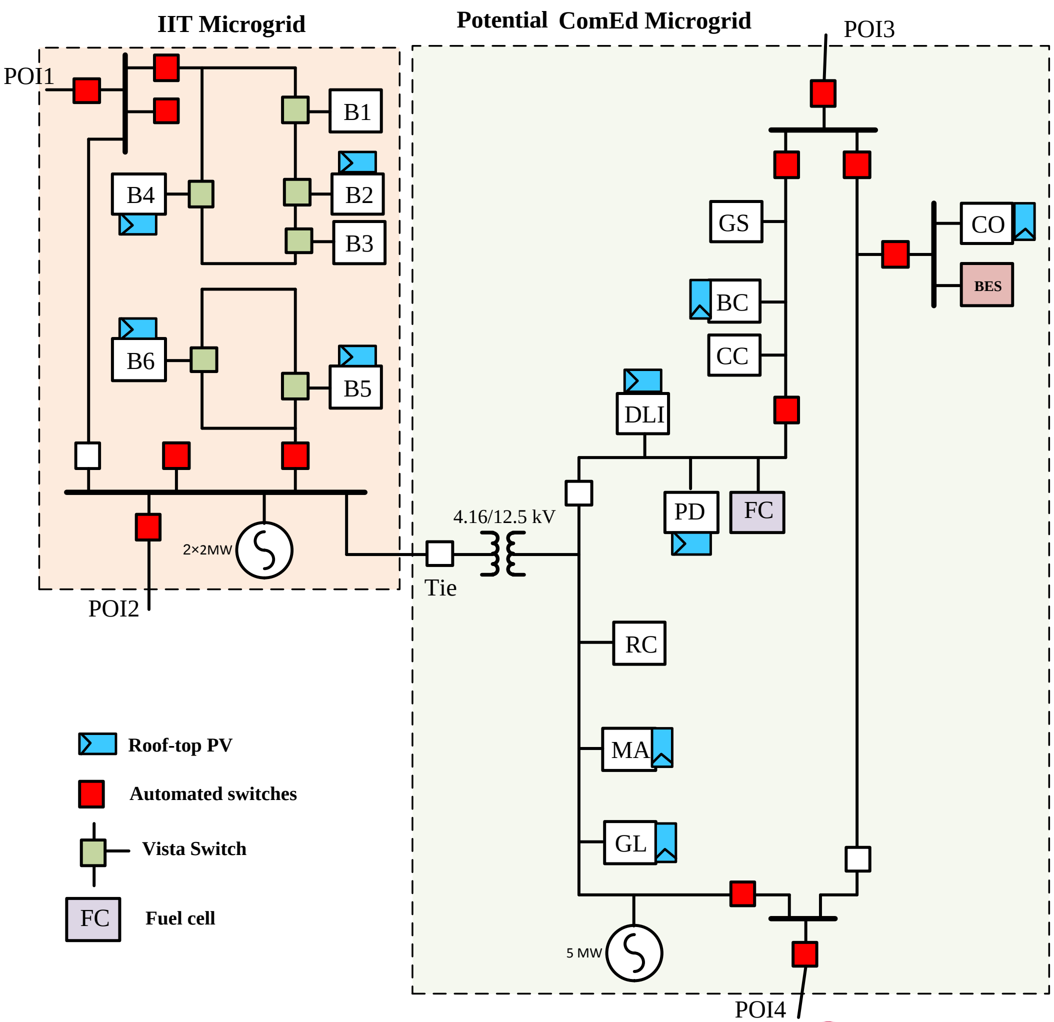
COMMUNITY MICROGRID

- Feeders would be reconfigured in a loop scheme which ties to the IIT microgrid
- Mix of generation sources would be required – could include fuel cells, solar, natural gas generator(s), storage, etc.
- It would provide a decentralized distribution model that does not depend on the rest of the ComEd system availability



MICROGRID REGULATORY ISSUES

- In Illinois utilities and power generation are separated – utilities do not typically own generation assets.
- Generation assets are allowed for back-up purposes only
  - Utilities are to provide strictly power distribution and transmission services

- Options to study microgrids with generations assets for pilot purposes:
  - Classify microgrid, including distributed generation assets, as R&D asset
  - Operating lease of generation assets from third party
  - Third party ownership of generation

- Microgrids are emerging technology:
  - Lack of regulatory framework specifically devoted to microgrids

MICROGRID – FUTURE APPLICATIONS

- Future microgrid deployments would focus on locations with critical infrastructure, such as hospitals and airports
- Clustering multiple microgrids together would improve the resiliency and power quality delivered to the loads
- Other potential applications could be business districts, universities and park districts
- Premium service – customer willing to pay more for improved reliability/resiliency

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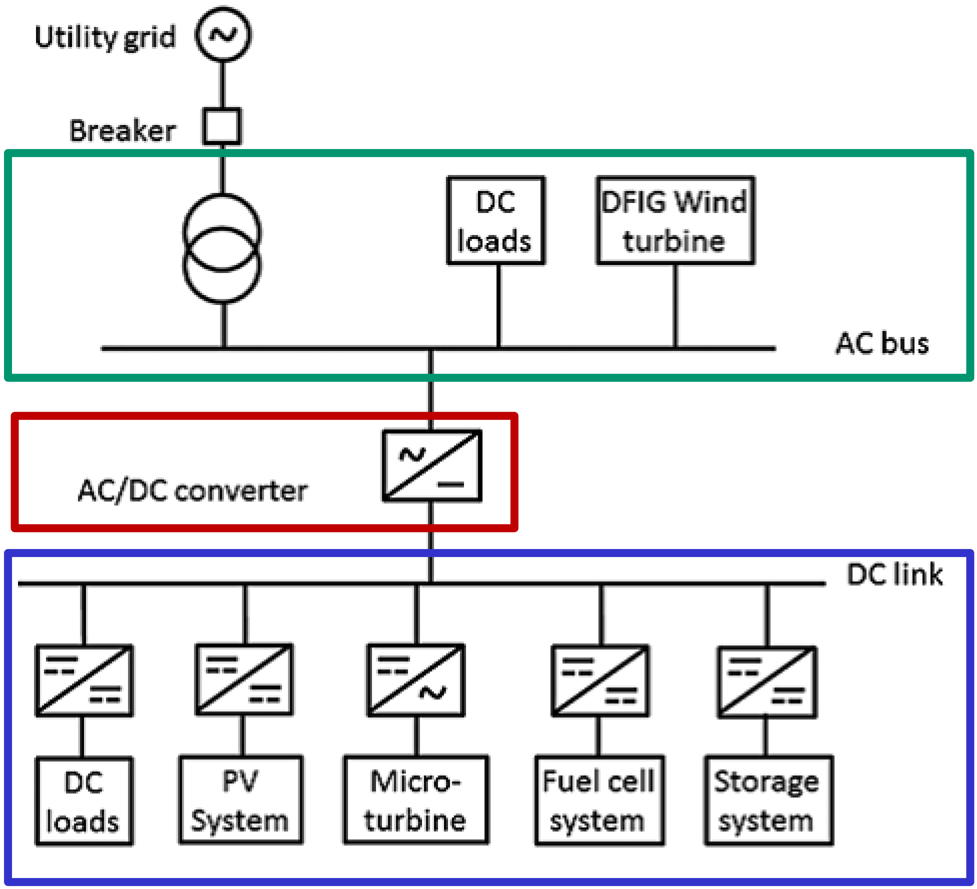
MICROGRID – FUTURE APPLICATIONS

AC/DC Hybrid Microgrids

- Future application that combines AC and DC power systems
  - AC bus
    - Natural gas, wind turbines etc.
    - Conventional AC loads
  - DC bus
    - Solar, fuel cells, batteries etc.
    - DC loads (data centers, variable frequency drives)
  - Coupled through a three-phase converter that operates as either an inverter or a rectifier
- Can operate in grid connected or islanded orientation
- ComEd is currently evaluating areas within which this technology could be deployed in



MICROGRID FUTURE

- Microgrids are becoming a high profile and highly visible market
- North American microgrid capacity is projected to reach almost 6GW by 2020
  - Six times the existing microgrid capacity
- Annual investments in building microgrids worldwide are expected to quadruple from $10B to $40B by 2020
  - 50% of microgrids being formed in North America
- Utilities should be prepared for a range of roles in developing, installing, and operating microgrids
  - Depends on the customer situation and ability to own DG resources
- Spectrum of utility ownership:
  - Ability to sell generation into the market and use of DG for economic dispatch
- Microgrid investments:
  - Transmission and distribution upgrades as well as the microgrid controllers typically account for less than 40% of the microgrid's cost.
  - DG accounts for rest of the costs, but varies based on technology.

IN SUMMARY

- Microgrids are becoming more popular because the reliability and resiliency improvements they can provide
- ComEd is working on several microgrid related projects:
  - Microgrid controller development
  - Evaluating areas for public good microgrids
  - Evaluating potential locations for microgrid clusters and AC/DC hybrid microgrids
- Microgrid challenges
  - Lack of regulatory standards
  - Interconnection procedures
  - Standby rates and tariff treatments
  - Valuation of benefits, especially for value of reliability and resiliency
  - Customer education and expectations

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Southern California Edison

Advanced Modeling and Analysis to Support High Penetration of Distributed Solar PV

October 21, 2014
Robert Sherick

GO solar CALIFORNIA

Itron CSI RD&D Program Manager

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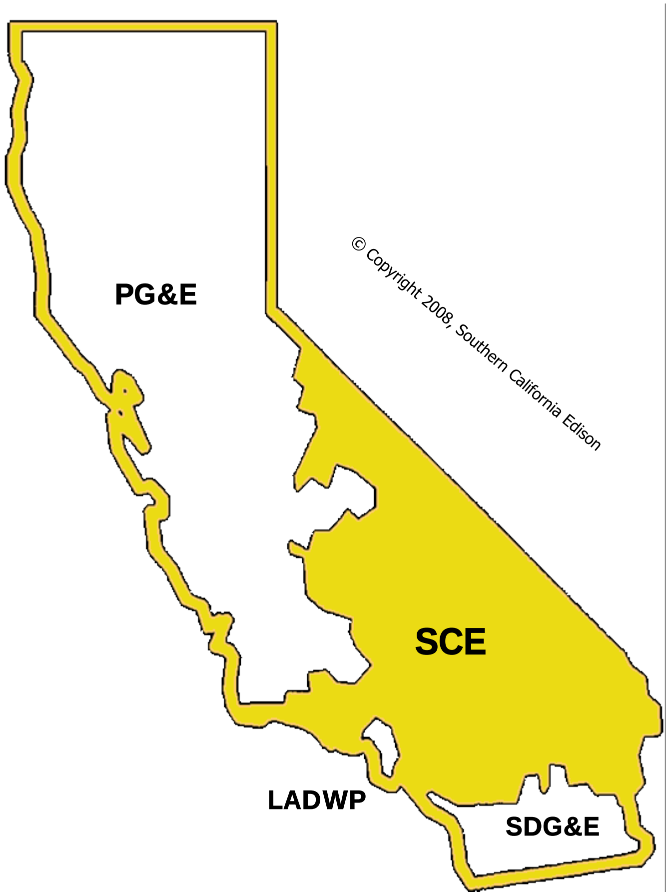
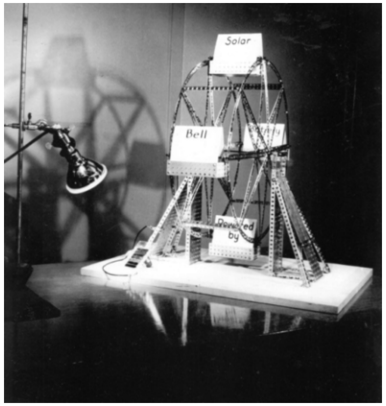
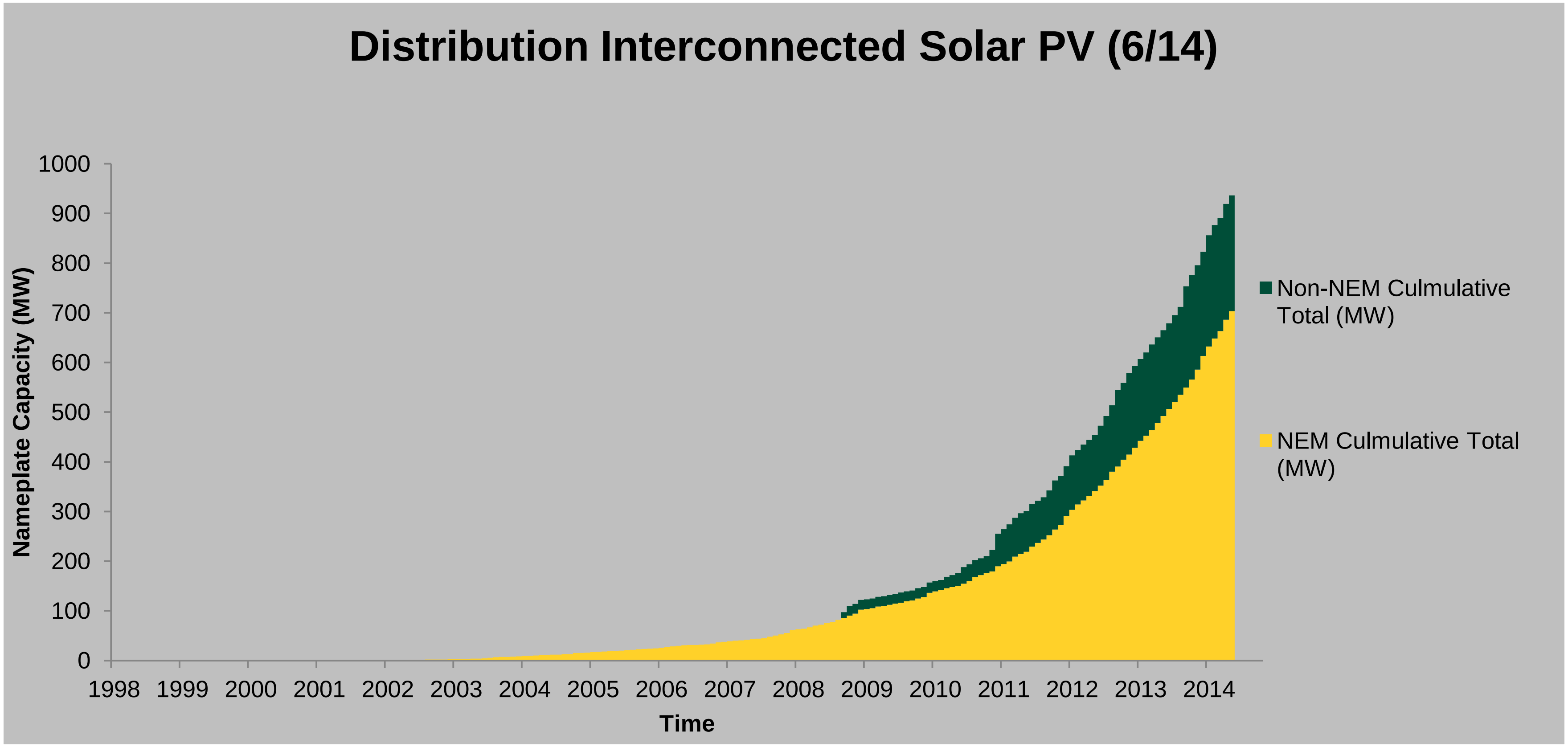


- SCE Service Area
  - 50,000 square miles
  - Over 400 cities and communities
  - 13.5 million residents
  - 4.9 million customer accounts
- Electric Revenues of $10 billion



Solar PV



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Demonstration and Studies

Irvine Smart Grid Demonstration

Tehachapi Storage Project

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NREL National Renewable Energy Laboratory

High Penetration PV Integration

arpa-e CHANGING WHAT'S POSSIBLE

California Institute of Technology 1891

Distributed Volt/VAR Control

Public Utilities Commission State of California

Battelle The Business of Innovation

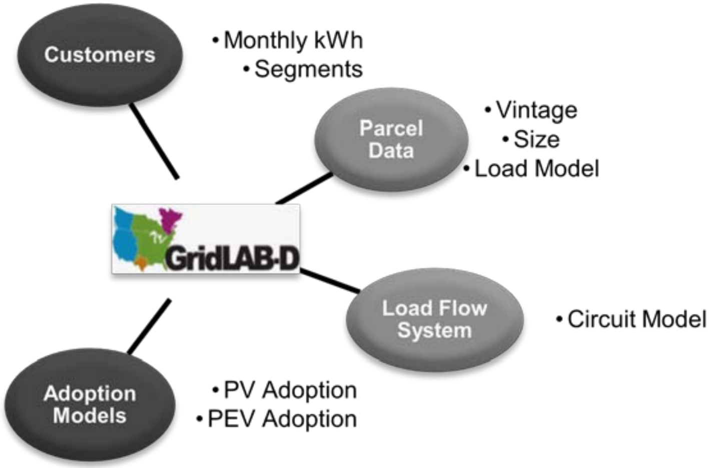
Distribution Planning & Analysis

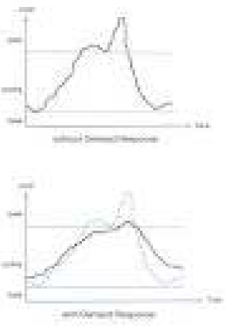
GO solar CALIFORNIA

EPRI ELECTRIC POWER RESEARCH INSTITUTE

Screening Distribution Feeders

Advanced Distribution Analytics





From advanced modeling and analysis …

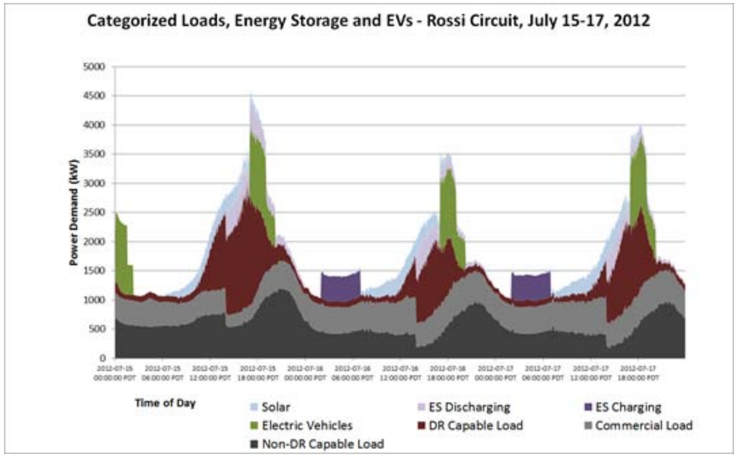
… to streamlined interconnection

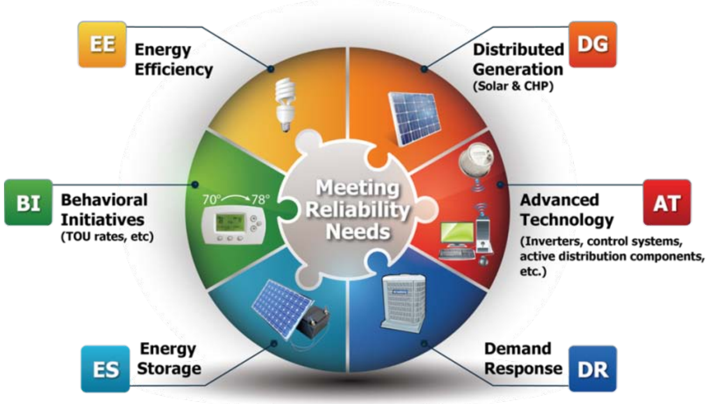
Project Objectives

- Understand distribution feeder native capability
- Develop a common framework to extend capability
  - Improve mitigation plans
  - Increase transparency of mitigation strategies
  - Improve siting decisions
  - Improve cost estimates
- Increase overall PV adoption rate
  - Streamline the process and improve the quality of interconnection applications
  - Enhance collaboration with stakeholders through on-line systems
- Evolve the planning process
  - People, process, and technology

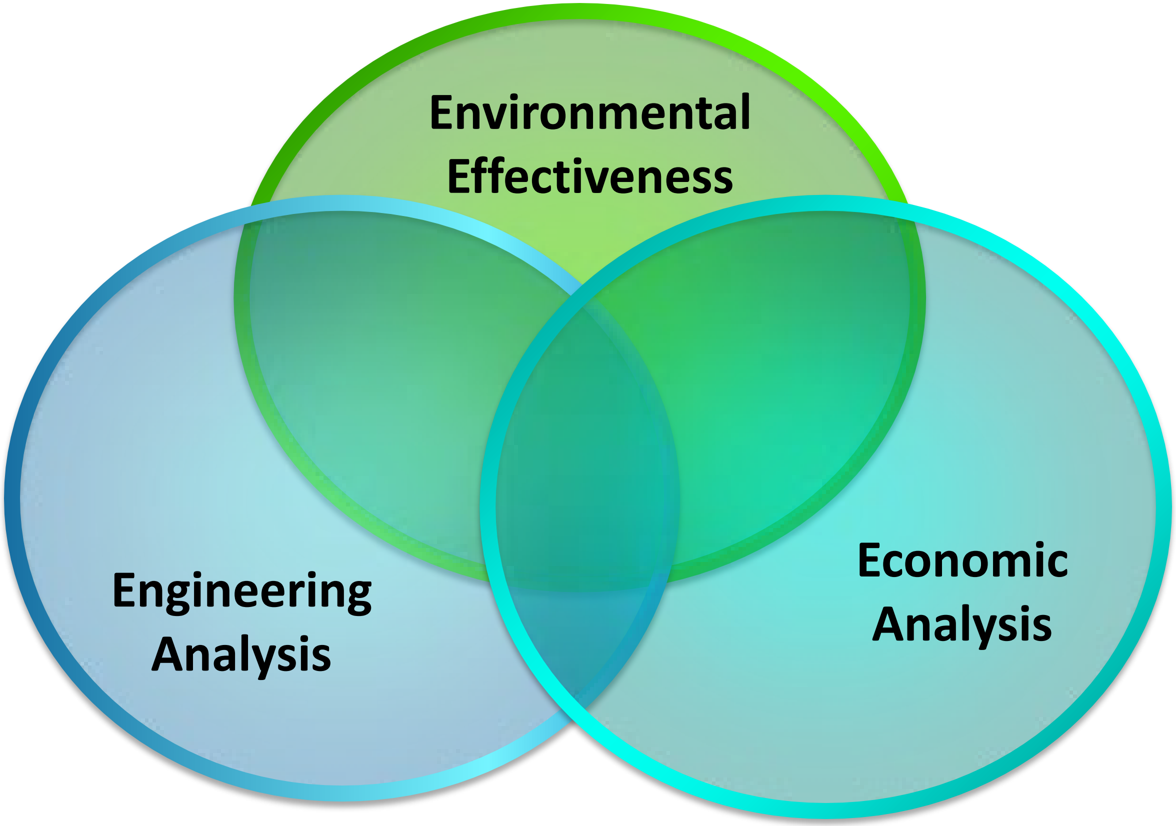
Different Type of Analysis

- Level of Detail
  - ✓ Behind-the-Meter
  - ✓ Forecasting Adoption
  - ✓ Behavioral Understanding
- Holistic Analysis
  - ✓ Interactions
  - ✓ Coordination
- Optimization of Interconnectedness
  - ✓ Locational Value
  - ✓ Temporal Considerations





What we want



Internet of things provides the beginnings of an opportunity…
Interconnected devices that interoperate…
Enabling innovation…

What we don't know (not a comprehensive list)

- Planning for safe/reliable/affordable with uncertainty
  - Lifecycle of assets
  - Forecasting technology adoption
- Interconnection Protocols to Enable Value
  - What are the dynamics of interconnected devices?
  - Are there real benefits and at what cost?
  - What framework creates device synergies?
- What Value for How Long?
  - Mark-to-Market technology
- Flexibility of the System through Design
  - Value of flexibility – real options
- Capturing the value without dictating a technology

Questions

Robert Sherick

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ISO Perspective on Renewable Integration

Prepared by Pengwei Du
Pengwei.Du@ercot.com

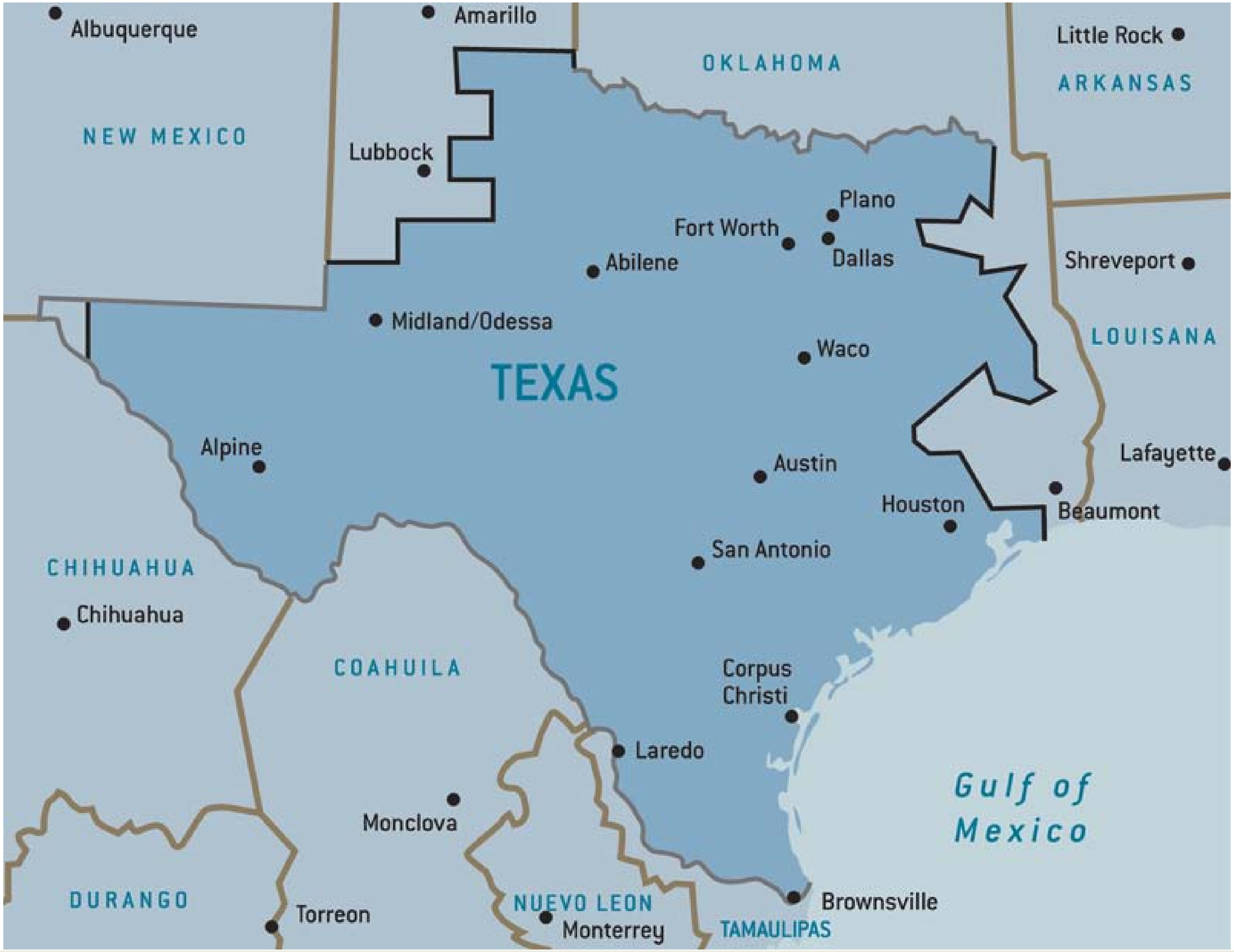
Presented by Yunzhi Cheng
Yunzhi.Cheng@ercot.com

Table of Contents

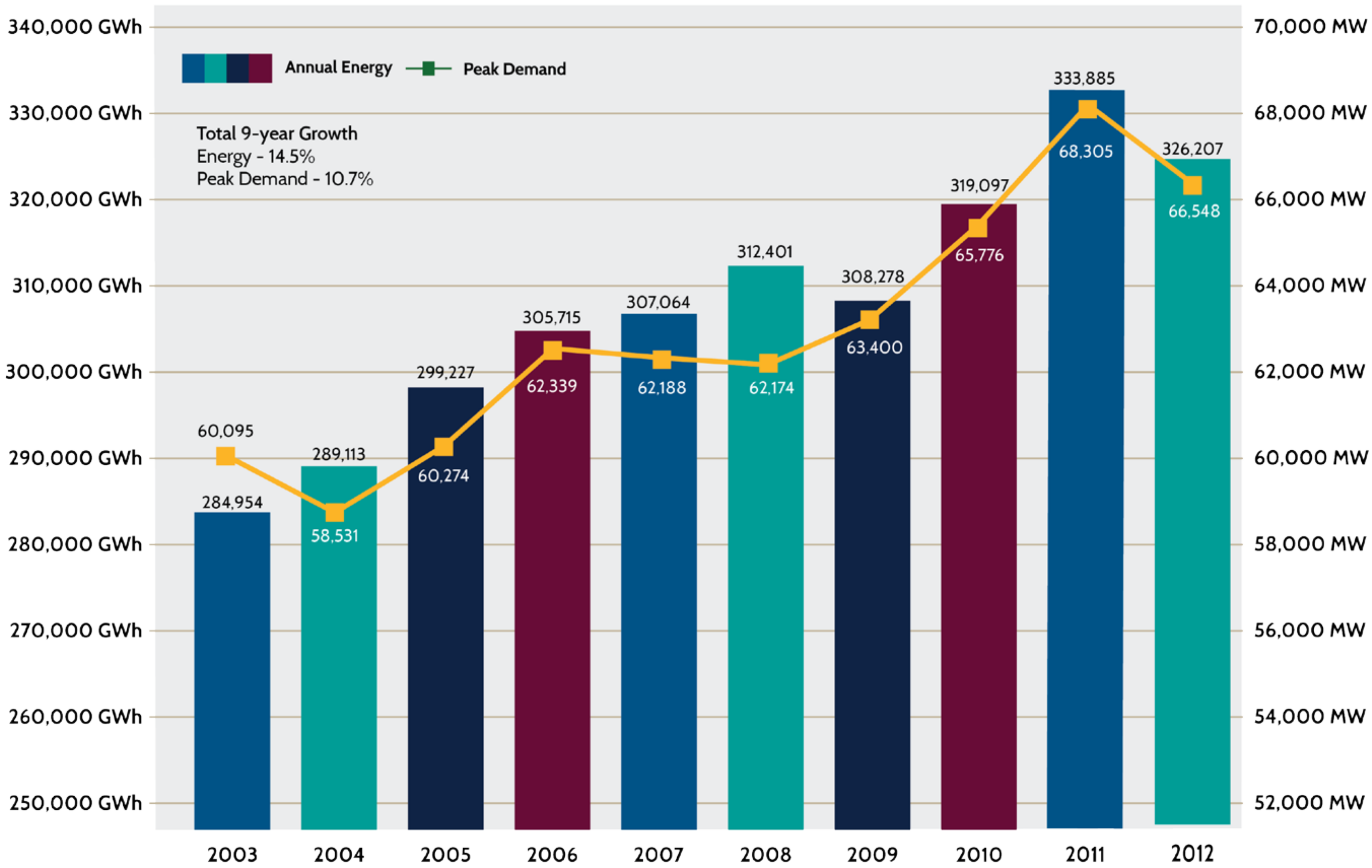
– Load and Wind resources in ERCOT
– Short-term Wind Potential Forecast and ERCOT Large Ramp Alert System
– Solar Integration
– Summary

- **Acronyms for this presentation:**
  - WGR: Wind-powered Generation Resource
  - AS: Ancillary Service
  - STWPF: Short-term Wind Power Forecast
  - COP: Current Operating Plan
  - RUC: Reliability Unit Commitment
  - ELRAS: ERCOT Large Ramp Alert System

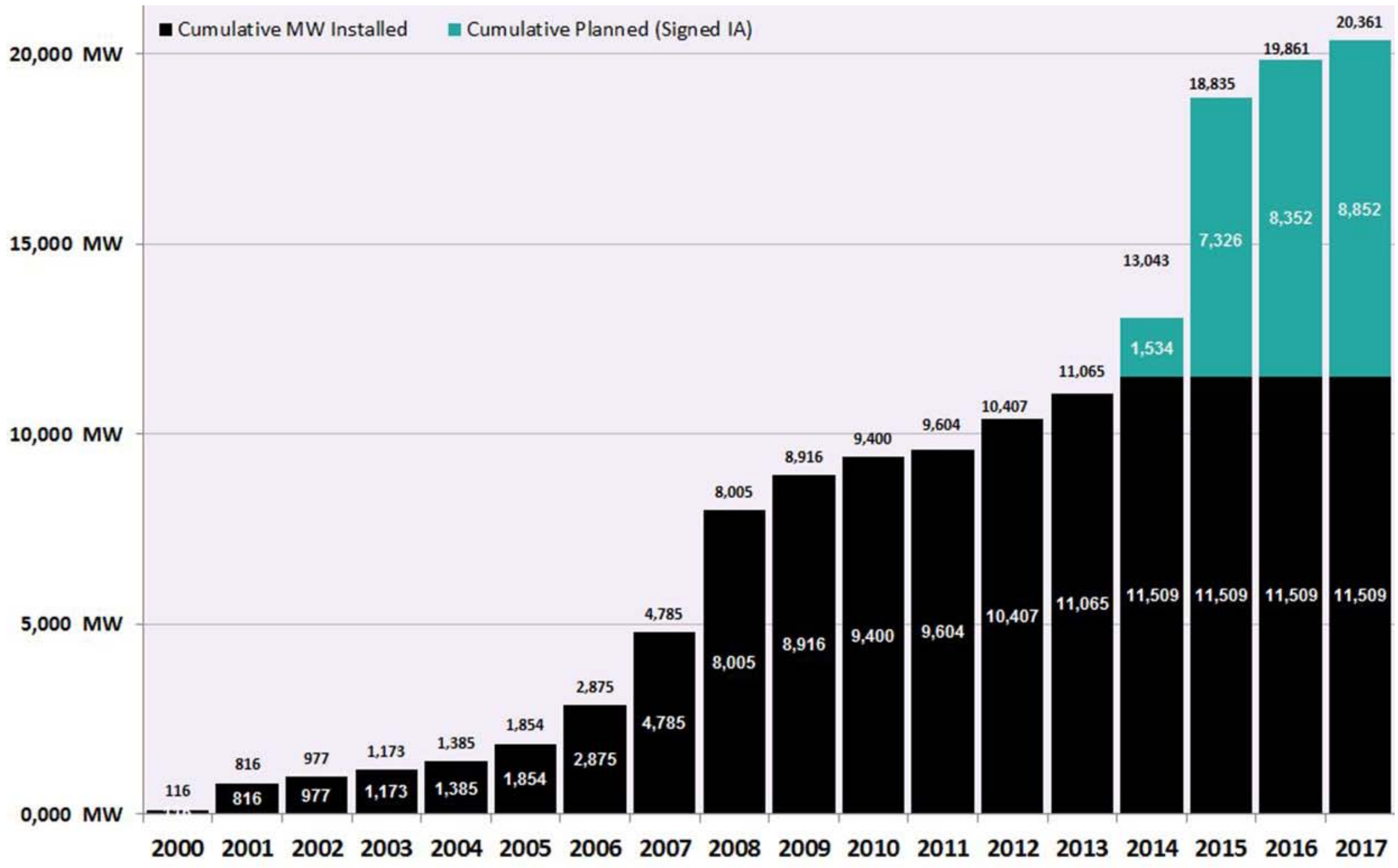
ERCOT MAP


Albuquerque
Amarillo
OKLAHOMA
Little Rock
ARKANSAS
NEW MEXICO
Lubbock
Plano
Fort Worth
Dallas
Abilene
Shreveport
Midland/Odessa
LOUISANA
Waco
TEXAS
Alpine
Austin
Lafayette
Houston
Beaumont
San Antonio
CHIHUAHUA
Chihuahua
COAHUILA
Corpus
Christi
Laredo
Gulf of
Mexico
Monclova
DURANGO
Torreon
NUEVO LEON
Monterrey
TAMAULIPAS
Brownsville

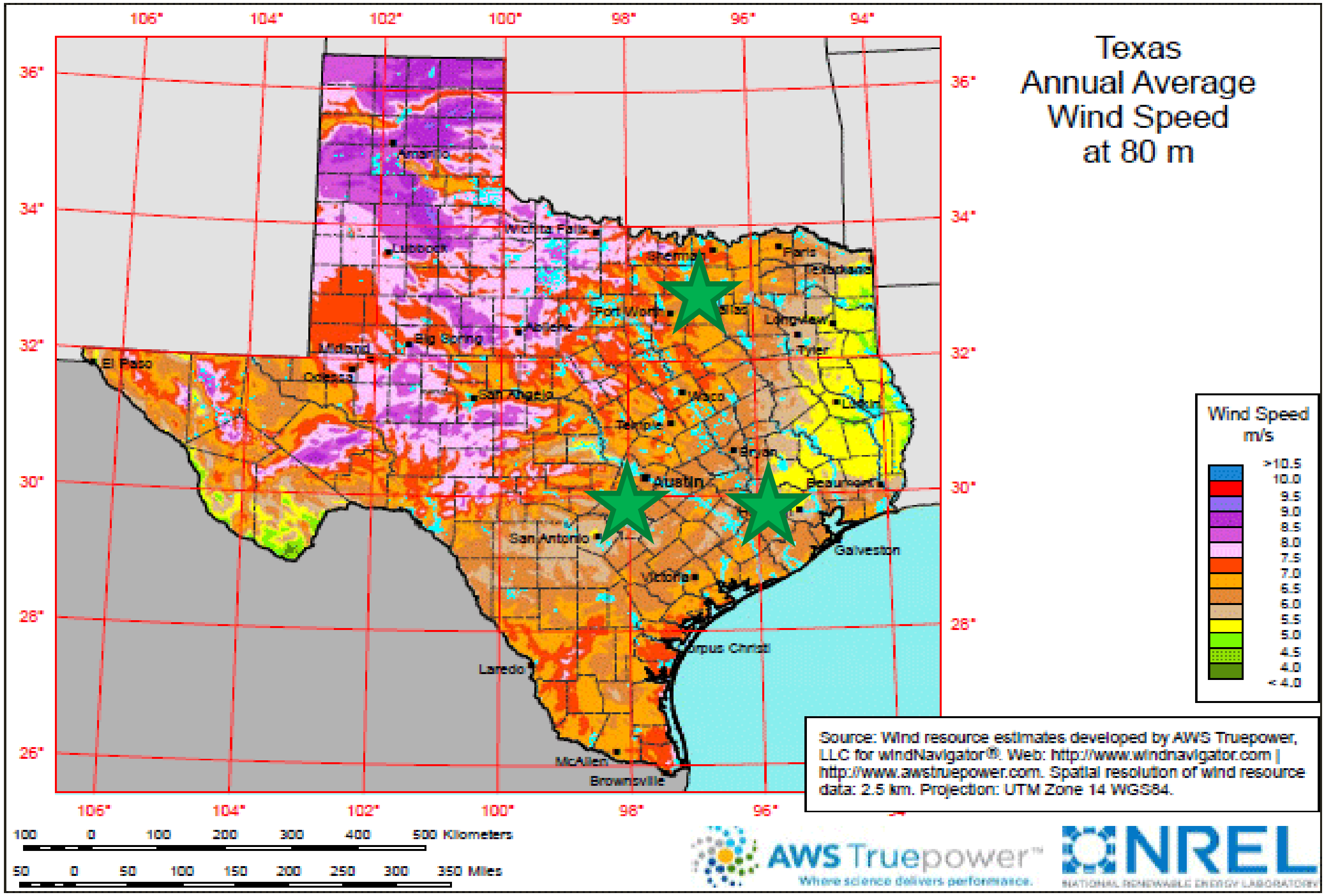
Annual Energy & Peak Demand (2003-2012)



Installed Wind Generation in ERCOT

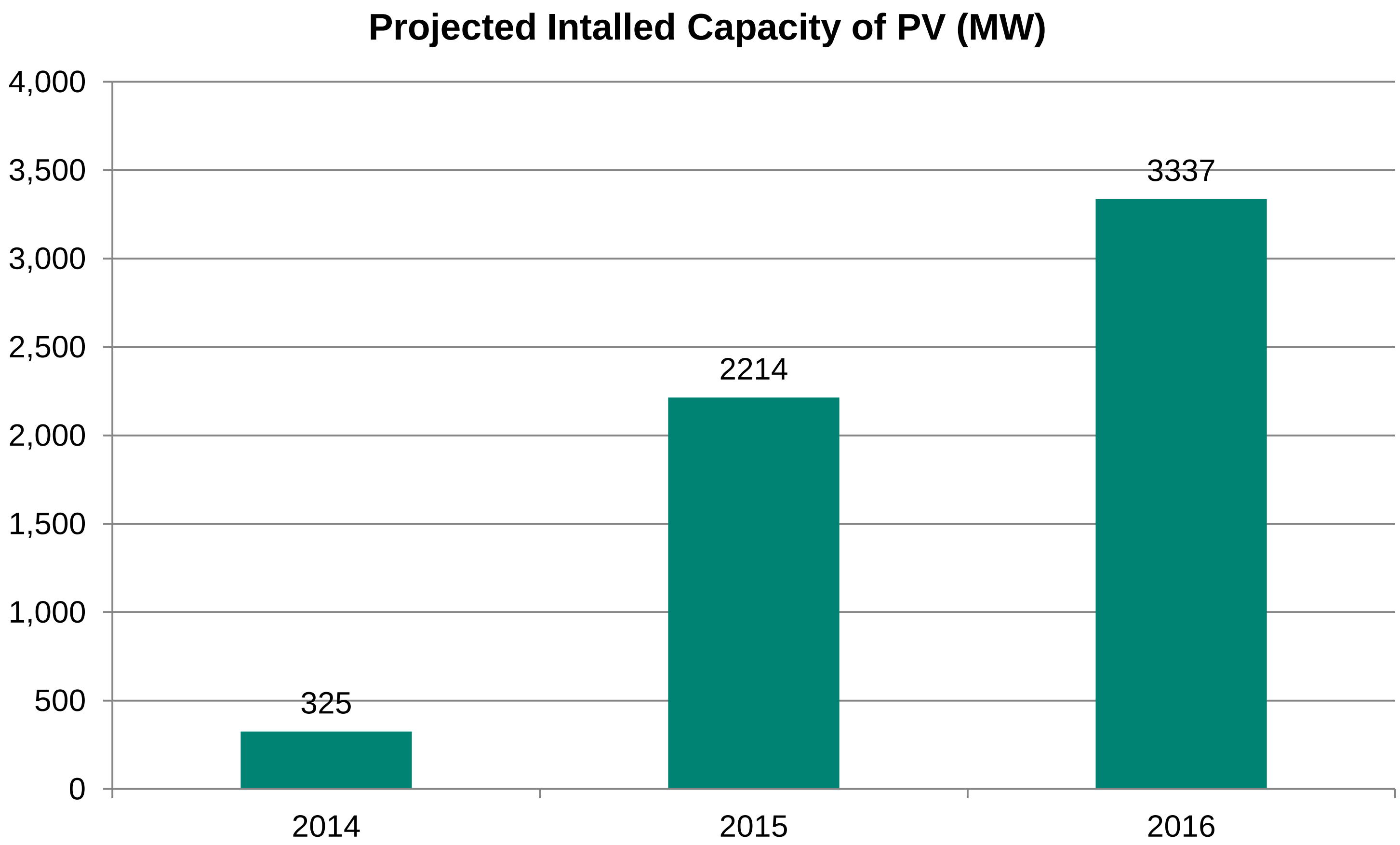


NREL map of wind resource in Texas

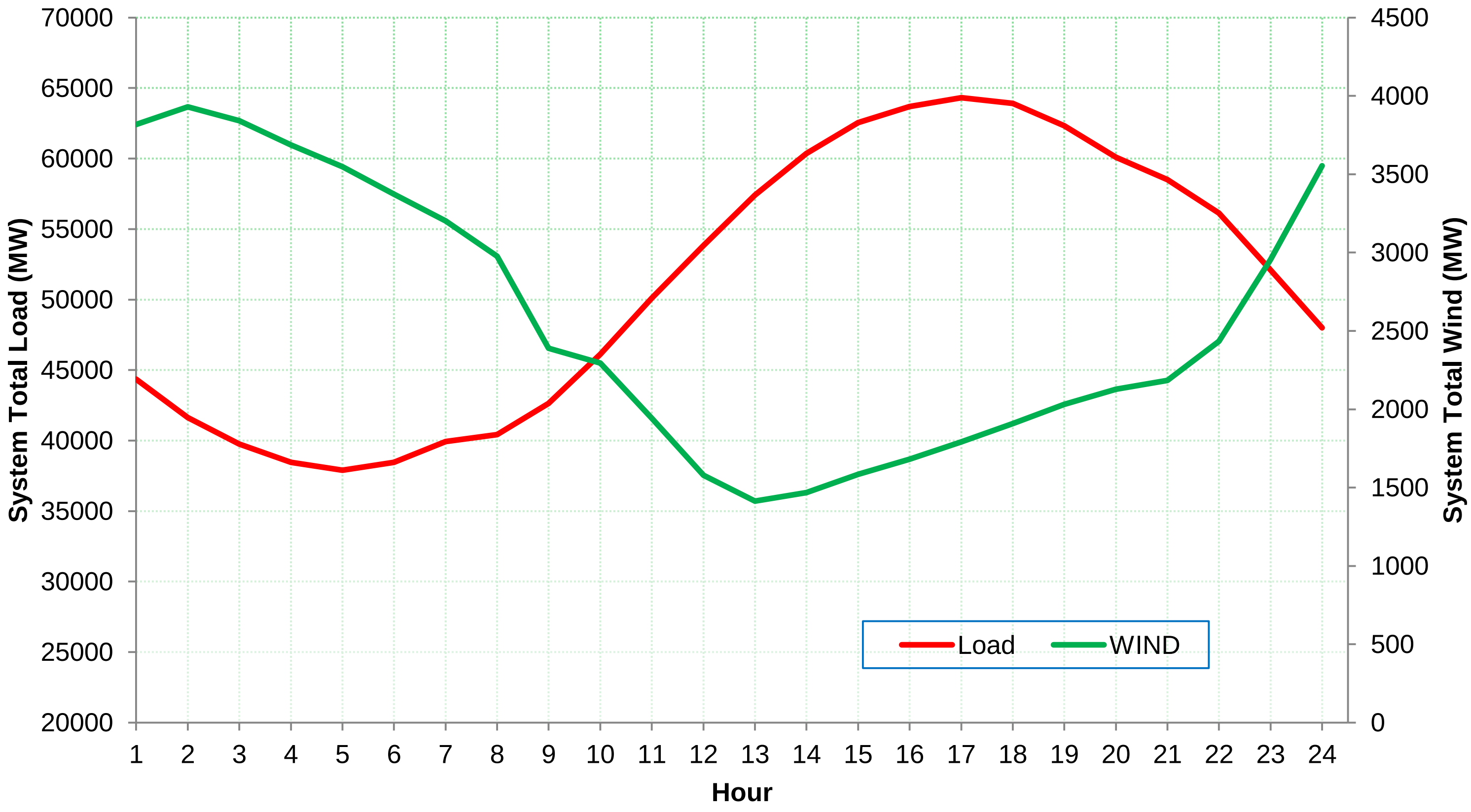


Source: National Renewable Energy Laboratory

Projected Installed Capacity of PV in ERCOT



Correlation between Wind and Load



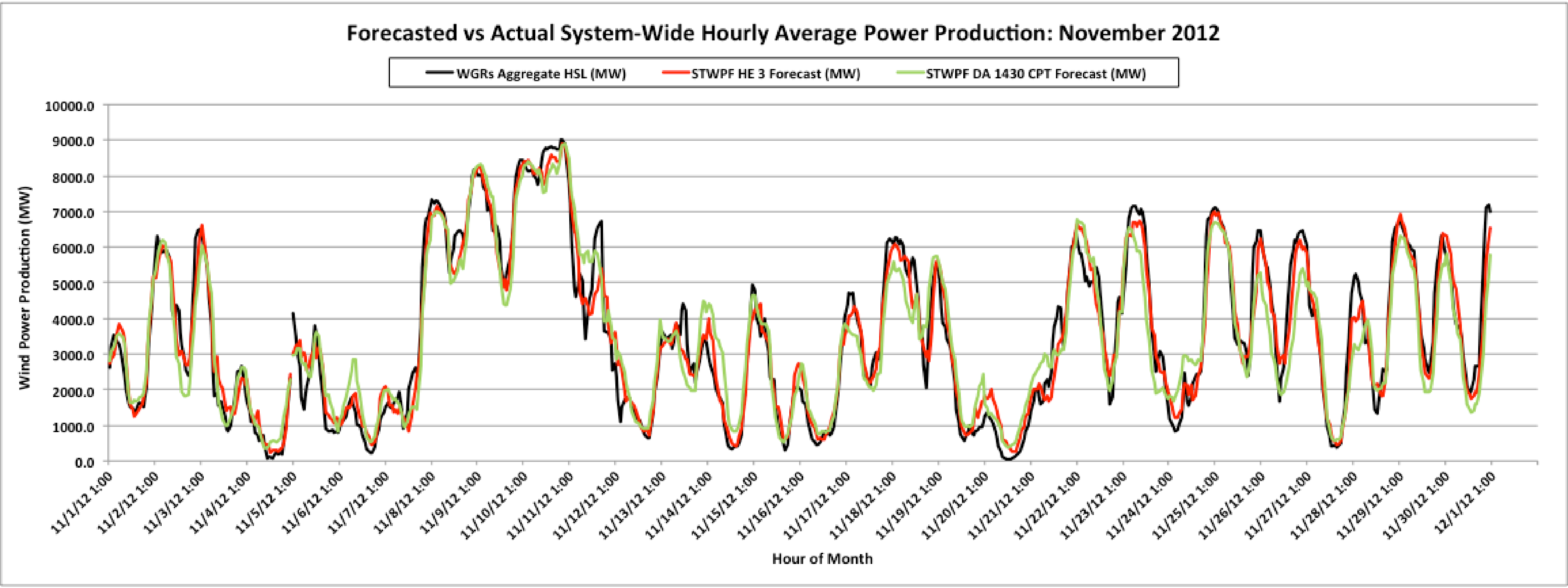
ERCOT

Importance of Wind Forecast

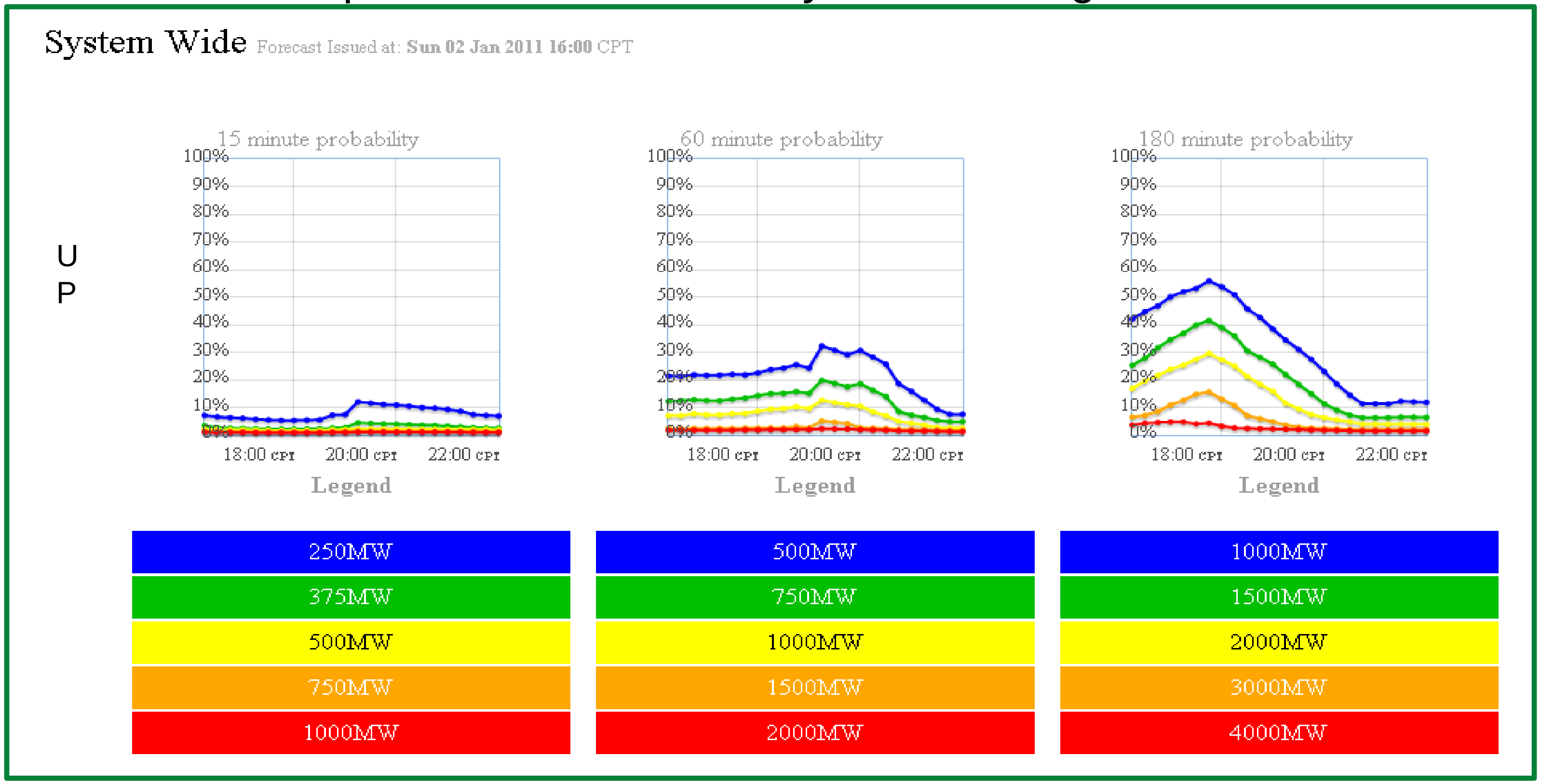
“the seamless integration of **wind plant output forecasting** – into both power market operations and utility control room operations – is a critical next step in accommodating large penetrations of wind energy in power systems”

- *DOE, 20% Wind Energy by 2030 (Washington, DC: DOE, 2008), http://www.20percentwind.org/20p.aspx?page=Report.*

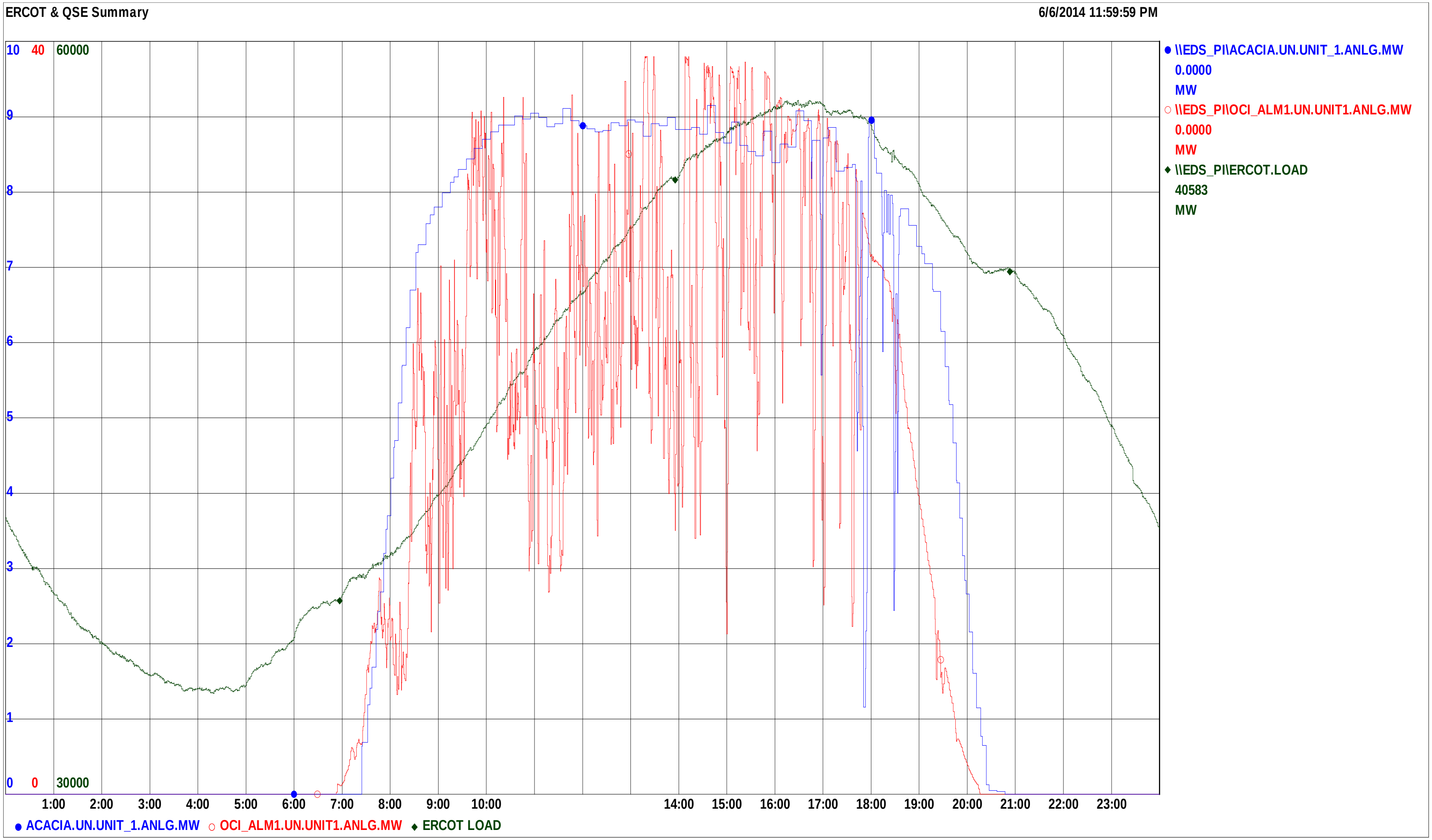
Forecast vs. Observed Time Series – November 2012 (Low MAE month despite high wind variability)



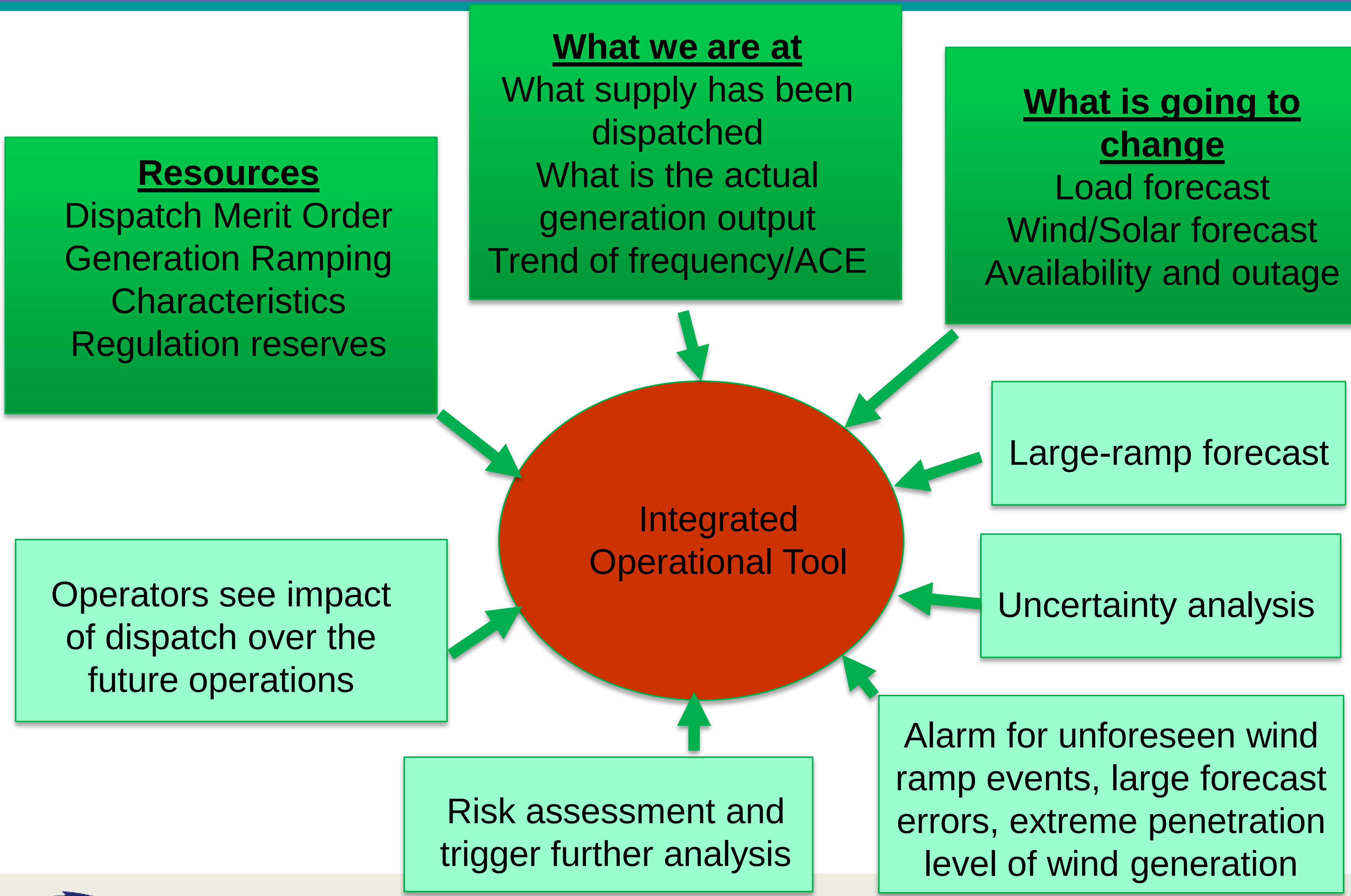
- **The main focus of ELRAS is to provide the probabilities of Wind Power ramp events of various MW changes over various time frames**
  - The far right graph shows that there is a 30% chance of the wind output changing by 2000 MW or more between 18:00 and 21:00
  - Information is provided for both the system and region levels



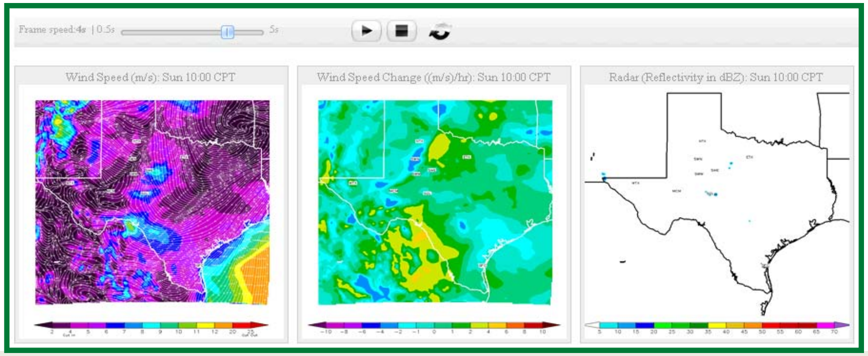
Power Produced from Two PVGRs



Integrated Framework in Operation



- **As the Operators enter the Operating Day, they are able to execute hourly RUC studies**
  - The Operators would like to wait as close to real-time as possible to commit a Resource
- **The Operator is also able to begin using the ERCOT Large Ramp Alert System (ELRAS)**
  - ELRAS provides probabilistic forecast information for the next 6 hours
  - The displays include animated graphics of weather conditions
- **Probabilistic forecast information will very likely play a key role in Grid Operations in the near future**
  - There is still work to be done in the incorporation of the probabilistic forecasts in the control room



Questions

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Grid of the Future

DER and Microgrids - A Sure thing or a Fading Myth?

Johan H Enslin, PhD, FIEEE, PrEng

Director, Energy Production & Infrastructure Center (EPIC)

Duke Energy Distinguished Chaired Professor

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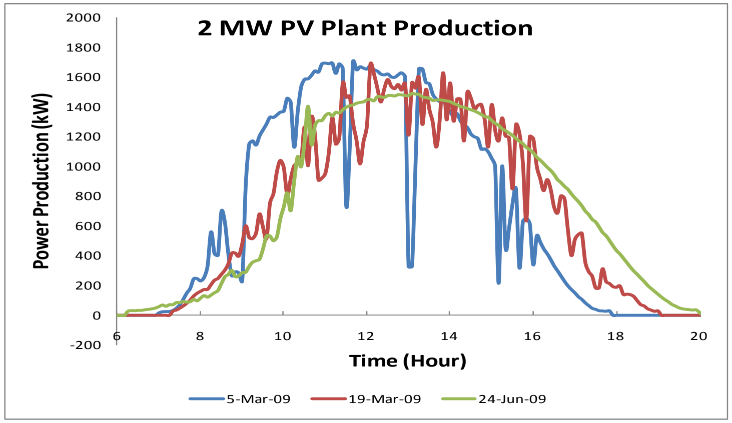
UNC CHARLOTTE

ENERGY PRODUCTION AND INFRASTRUCTURE CENTER (EPIC)

Challenges to (PV) DER Integration
- Driven by Incentives?

- Technology and devices are mostly there – Focus on:
  - BOS systems - racking, permits, installation, etc.
  - Smart inverters - need to be standardized and required in all
  - Virtual Power Plant control and communications.
  - Dispachability of DER systems – Storage, ramping control and DR
  - Energy Analytics – Load, capacity and resource forecasting, DR, etc.
- What is the business model when FTC and RPS are lifted?
  - Focus on grid parity with dispatched DER
  - Capture multiple revenue streams with different entities into one
  - Market for DER grid support – Volt-VAR; frequency; capacity, spinning reserves, etc.
- Regulatory challenges – Utility of the future business models?
  - Capacity and reliability markets.
- Applications
  - Mainly RPS driven with 30% FTC

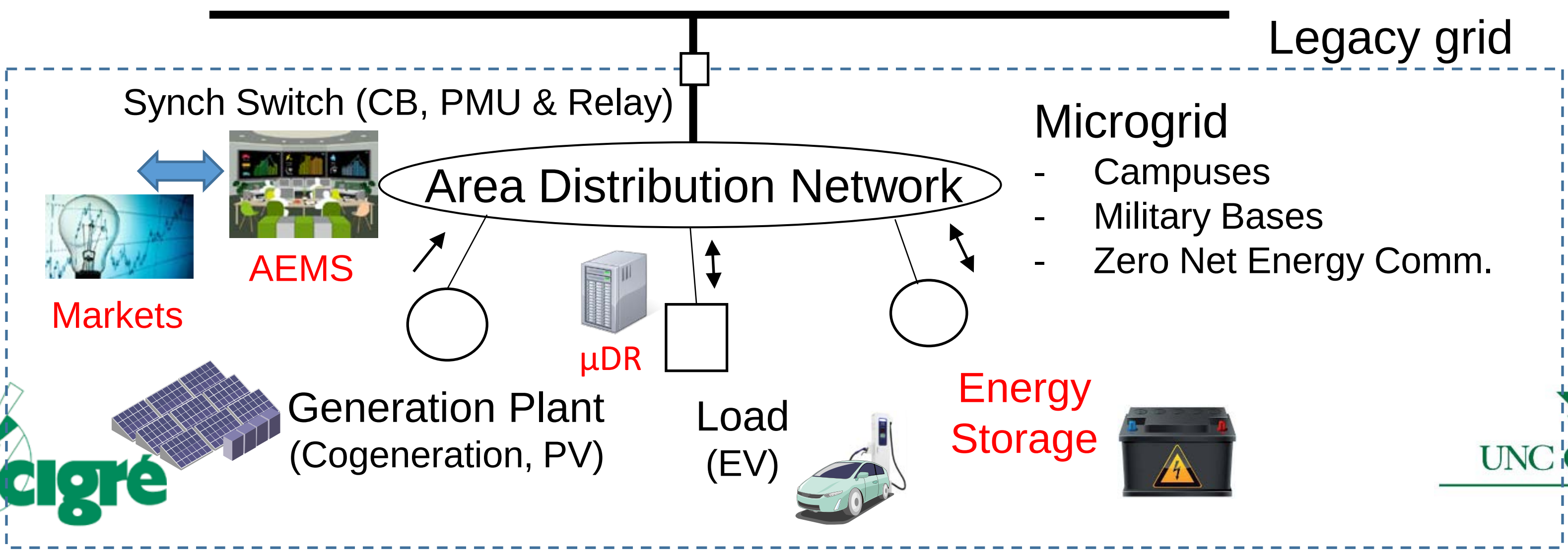


2 MW PV Solar generation profiles during 3 days in southern California

UNC CHARLOTTE EPIC

Challenges to Microgrid Integration
- What is the business case?

- Technology and devices are mostly there – Focus on:
  - Area Energy Management Systems (AEMS) and Visualization
  - Micro-Demand Response systems (μDR)
  - Energy Storage dispand Ancillary Services tie-ins
- What is the business model?
  - Multiple revenue streams with different entities
- Regulatory challenges – Utility of the future business models?
- Grid resiliency and energy security funded by Federal Agencies



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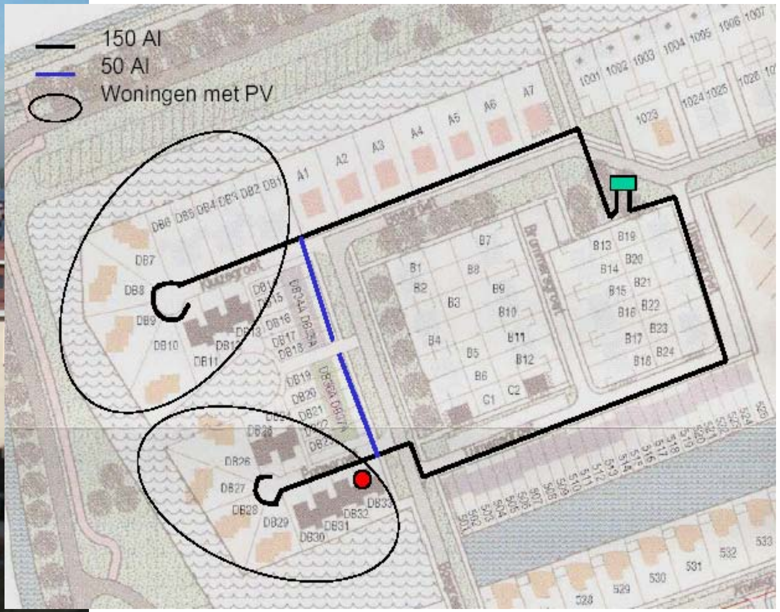
Interconnection of DER at Dense Populations



Ouddorp, The Netherlands

Technical DER and Microgrid Interconnection Issues

- Short circuit ratings change over wide range through operation
- Voltage Regulation and Flicker:
  - May exceeding voltage limits and inverters trip
  - Voltage fluctuations and flicker due to intermittency
- Harmonics:
  - Inverters individually satisfy PQ standards
  - PQ standards can temporarily be exceeded.
  - Inverters trip unexpectedly
- Attention Points on Standards and Interconnections
  - Smart inverter settings and closed-loop control
  - Coordinated control of VAR resources and smart inverters
  - Effect of background supply distortion
  - Increased distortion due to a system resonance
  - Microgrids and weak networks
  - Islanding times and algorithms
  - Natural damping

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Conclusions & Recommendations

- DER and Microgrids business case needs to show value proposition
- Regulatory support and policy for DER and Microgrid rollout
- Future Utility Business Models to encourage value proposition
- Smart Inverters, emulating synchronous machine characteristics, can mitigate power quality issues
- Evaluate and test inverters with real-time HiL Testbeds
- Need to develop guidelines and standards for weak, Microgrid, DER or islanded network operations with variable impedances.

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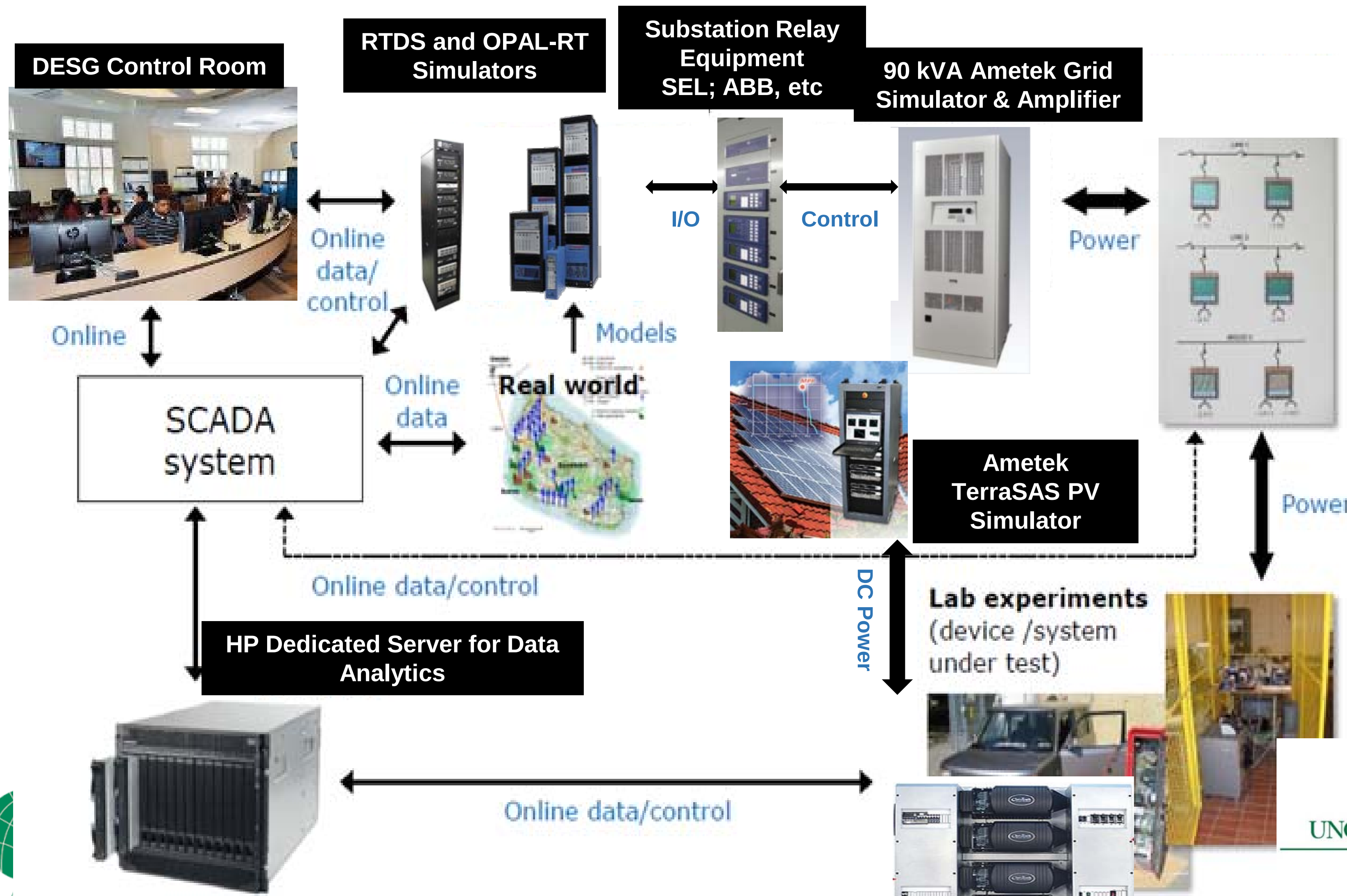
Duke Energy Smart Grid Lab.



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Duke Energy Smart Grid Lab

- Real Time Digital Simulator (RTDS) – 3 enhanced racks
- 32 core OPAL-RT real-time power simulator
- 90 kVA Ametek Grid Simulator and Amplifier
- 150 A with 120V, 208V, 480V 1&3 phase power supplies
- Amatek TerraSAS 10 kW PV SImulator
- High speed fiber connections between labs and server room
- Dedicated and secured private LAN for external data streams
- Raised floor access for power, communication and control cables
- 6 fast response large LCD Screens and image control
- Data storage devices and SCADA gateways
- Communications - Private HP Server for data analytics
- HP X820, 16-Core, Dual Processor Xeon Workstation
- Simulation tools including - PSS/E; ETAP; EMTP-RV;
  RSCAD; PSCAD; Hypersim, RTLAB, etc.

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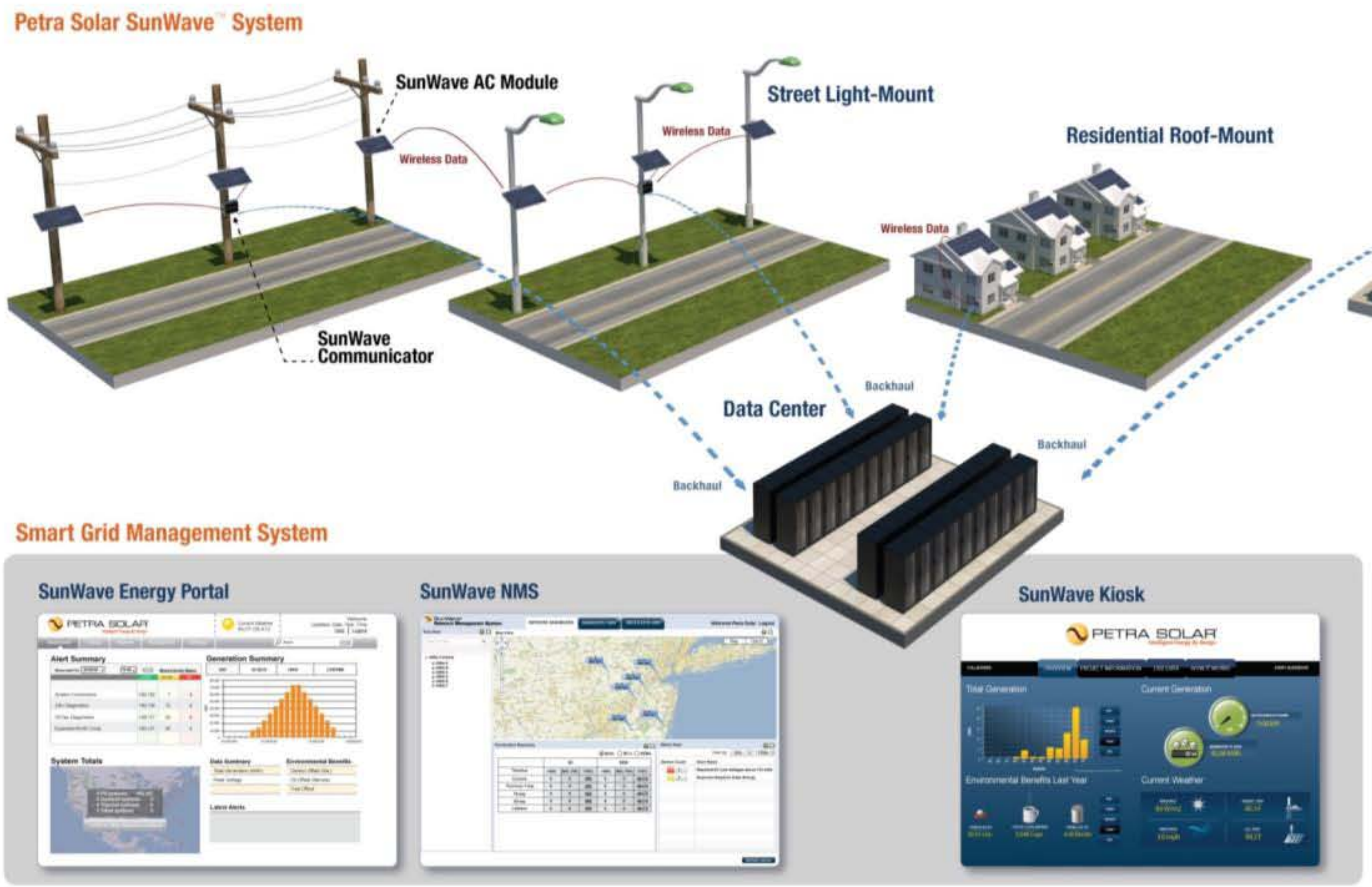
The Emerging Virtual Power Plant



Source: Petra Solar, NJ USA