ORIGINAL

Memorandum

From the office of
Commissioner Bob Burns
Arizona Corporation Commission
1200 W. WASHINGTON
PHOENIX, ARIZONA
(602) 542-3682

TO: Docket Control

DATE: March 25, 2014

FROM: Commissioner Bob Burns

SUBJECT: Emerging Technologies in Energy, Docket No. E-00000J-13-0375

The agenda and presentations from the March 20, 2014 Emerging Technologies Workshop have been docketed. If for some reason you cannot access eDocket, please contact my Executive Aide, Jessica Perry, to receive copies of the presentations.

As noted at the workshop, parties who want to present at the April 25th response workshop must contact my Policy Advisor, Angie Paton, by 5:00 p.m. on April 21st. Please also note that our second response workshop is scheduled for June 25th, 2014.

Original and thirteen (13) copies of
the agenda and presentations filed this 25th day of
March, 2014, with:

Docket Control
Arizona Corporation Commission
1200 West Washington Street
Phoenix, Arizona 85007

Arizona Corporation Commission
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Copies of the memo mailed
this 25th day of March, 2014, to:

Service List

NOTICE
SPECIAL OPEN MEETING
OF THE ARIZONA CORPORATION COMMISSION

Commission Workshop on Emerging Technologies
Docket No. E-00000J-13-0375

DATE: Thursday, March 20, 2014 **START TIME: 10:00 a.m.**

Arizona Corporation Commission
Hearing Room One
1200 W. Washington Street
Phoenix, Arizona 85007

This shall serve as notice of a special open meeting of the Arizona Corporation Commission at the above location for consideration, discussion, and possible vote of the items on the following agenda and other matters related thereto. Please be advised that the Commissioners may use this open meeting to ask questions about the matters on the agenda; therefore, the parties to the matters to be discussed or their legal representatives are requested, though not required, to attend. The Commissioners may move to executive session, which will not be open to the public, for the purpose of legal advice pursuant to A.R.S. §§ 38-431.03.A.2, 3 and/or 4 on the matters noticed herein. The Commissioners may also move to executive session, which will not be open to the public, for other purposes specified in A.R.S. §§ 38-431.03, including discussions, consultations or considerations of Commission personnel and salary matters, on matters noticed herein.

The Arizona Corporation Commission does not discriminate on the basis of disability in admission to its public meetings. Persons with a disability may request a reasonable accommodation, such as a sign language interpreter, as well as request this document in an alternative format, by contacting Shaylin A. Bernal, phone number (602) 542-3931, E-mail sabernal@azcc.gov. Requests should be made as early as possible to allow time to arrange the accommodations.

Jodi Jerich
Executive Director

Agenda

Presentations and discussions concerning the potential impact on emerging technologies on the current energy model, including distributed supply and storage and utility-scale storage.

Morning Session: 10:00 A.M.

Welcome and Opening Remarks

Clark Gellings, Fellow
Electric Power Research Institute
The Integrated Grid: Realizing the Full Value of Central and Distributed Energy Resources

Ahmad Faruqui, Principal
The Brattle Group
Strategies and Tactics for Dealing with Changing Consumer Energy Consumption

LUNCH

Afternoon Session: 1:15 P.M.

Josh Richman, Vice President of Business Development
Bloom Energy
Bloom Energy: Reliable, Efficient, Distributed Electricity Generation

Jeff Gates, Managing Director of Business Development
Duke Energy
Utility-Scale Battery Energy Storage

Ken Baker, Senior Manager of Sustainable Regulation and Legislation
Walmart
Renewable Energy and Energy Efficiency

Meghan Nutting, Director of Policy and Electricity Markets
SolarCity
Distributed Energy Storage

Kate Maracas, Vice President of Development, Southwest Region
Abengoa Solar Inc.
Grid Integration Challenges and the Role of CSP with Thermal Energy Storage

Glenn Meyers
Verde Sol-Air Services
Geothermal Heat Pumps/Ground Source Systems

Dr. Ben Ruddell, Assistant Professor, Department of Engineering, College of Technology and Innovation/Senior Sustainability Scientist, Global Institute of Sustainability
Arizona State University
Electrical Load Shifting for Residential and Commercial Buildings Using Thermal Storage

Wrap-up and Closing Remarks

NOTE: <u>NO VOTES ON ANY MATTER WILL BE TAKEN BY THE COMMISSION AT THIS MEETING.</u>

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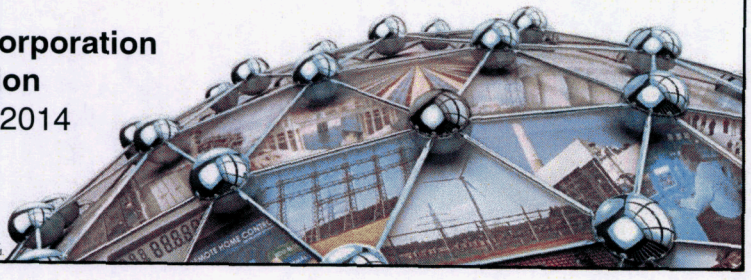
THE INTEGRATED GRID

REALIZING THE FULL VALUE OF CENTRAL AND DISTRIBUTED ENERGY RESOURCES

Clark W Gellings, P.E.
Fellow

Arizona Corporation Commission
March 20, 2014



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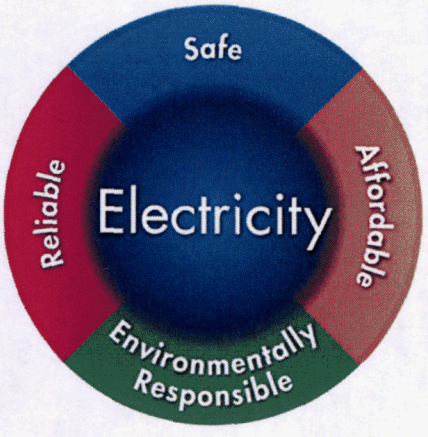

Together…Shaping the Future of Electricity

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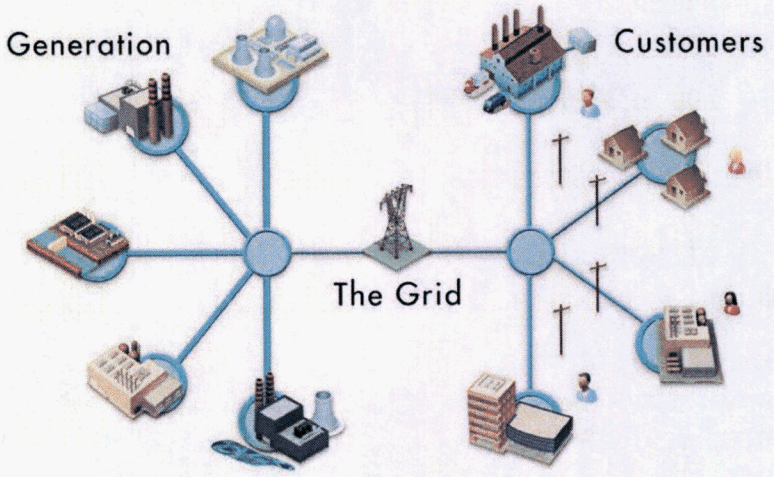
The Electric Power System



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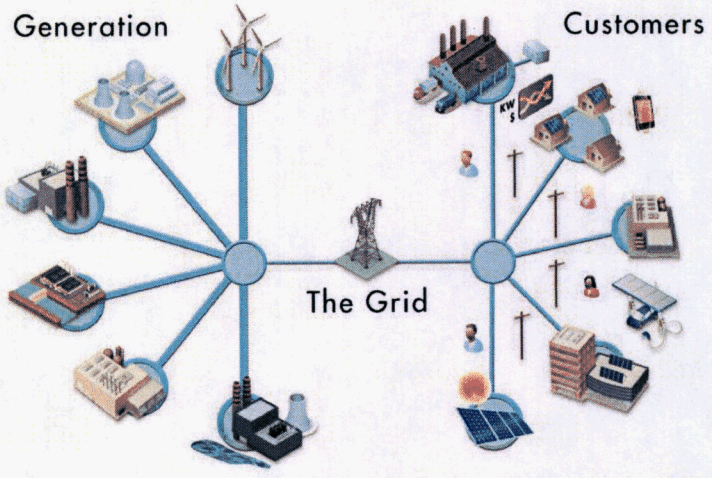
Looking Forward



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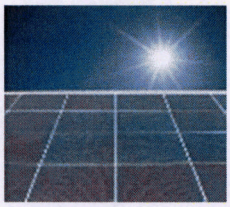
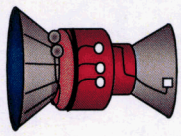
Distributed Energy Resources

Photovoltaics



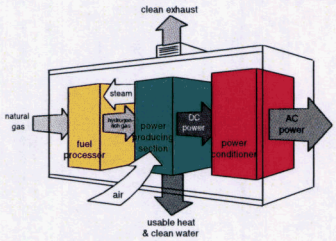
Micro-generation



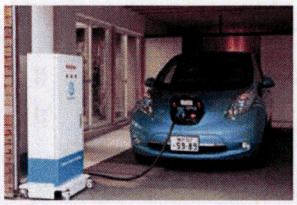
Storage

Photo courtesy of NREL

Fuel Cells



Plug-In Electric Vehicles



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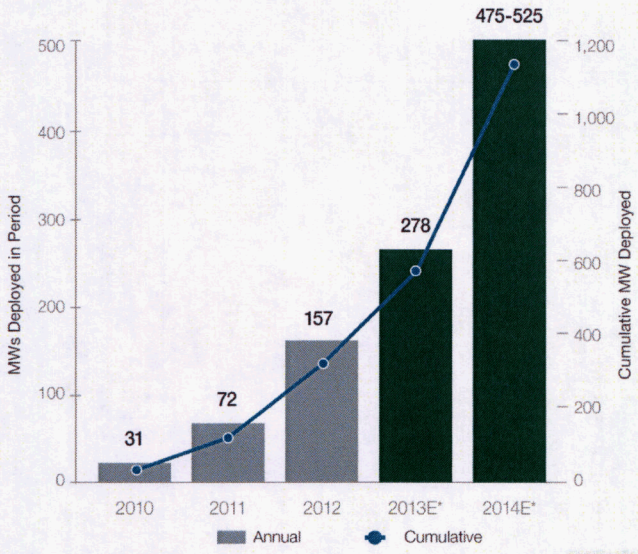
Photovoltaic Generation in the U.S.



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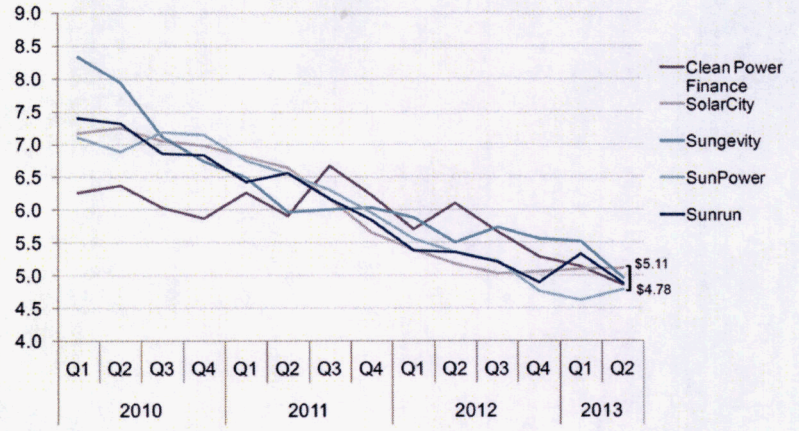
Installed PV Costs ($/ Watt)



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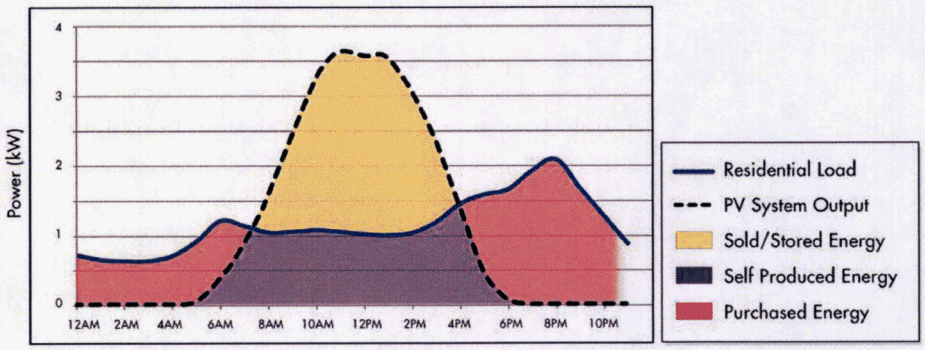
The Grid Provides Transactional Value



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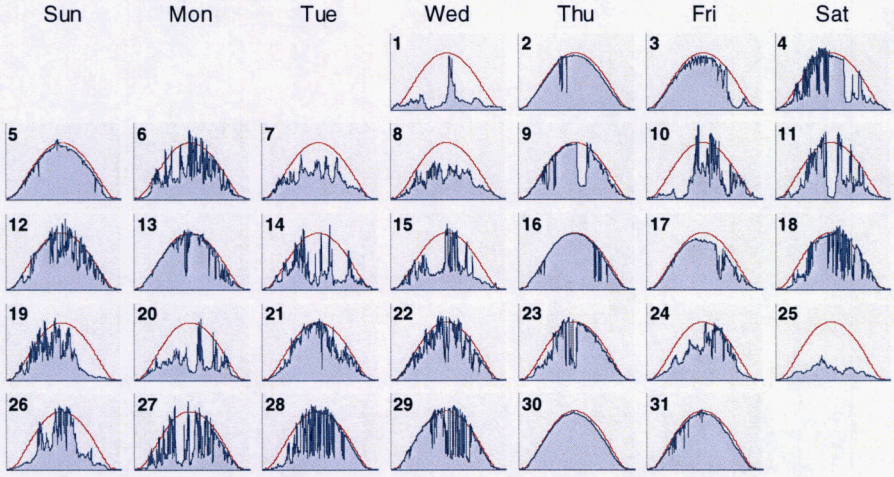
Grid Delivers Balancing Resource

Solar resource calendar for August 2012 shows irradiance profiles in NJ



Blue area: measured irradiance

Orange line: calculated clear sky irradiance

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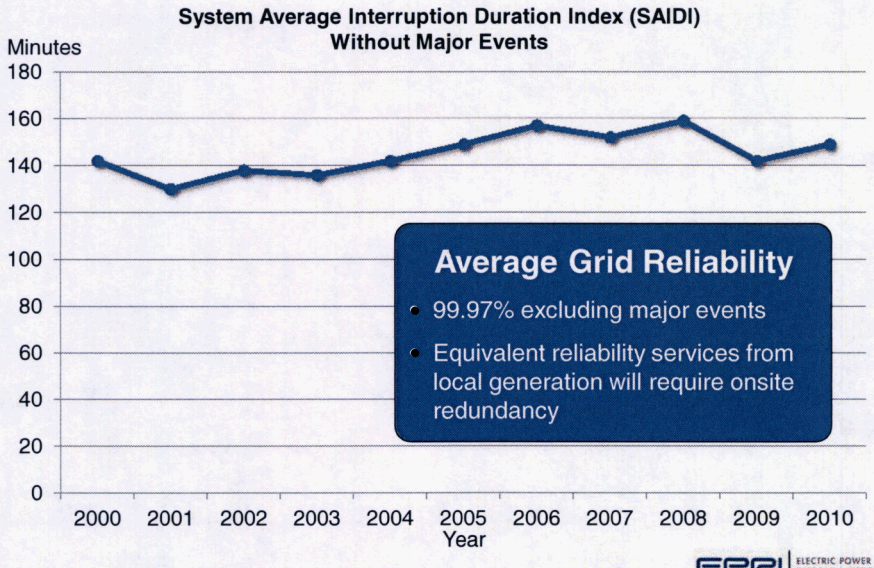
Grid Provides Reliability Service



Average Grid Reliability

- 99.97% excluding major events
- Equivalent reliability services from local generation will require onsite redundancy

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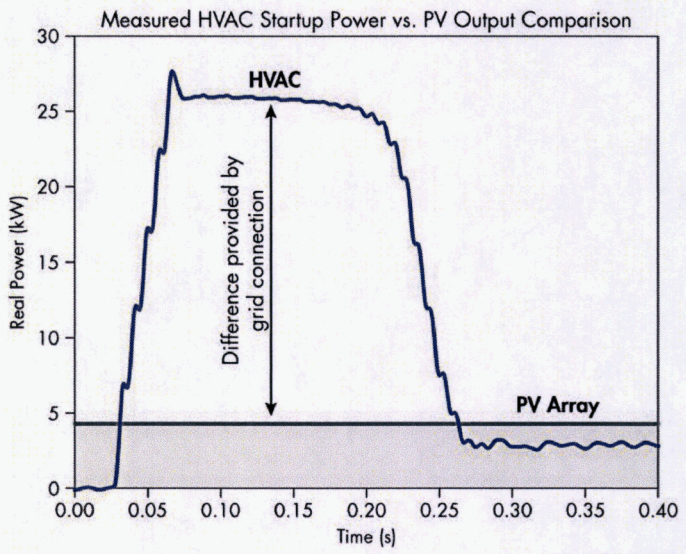
The Grid Provides Startup Power



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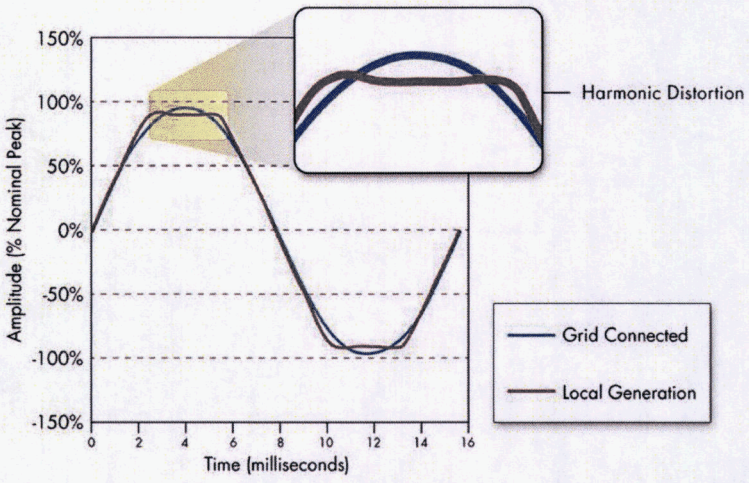
Grid Connectivity Reduces Harmonic Impact



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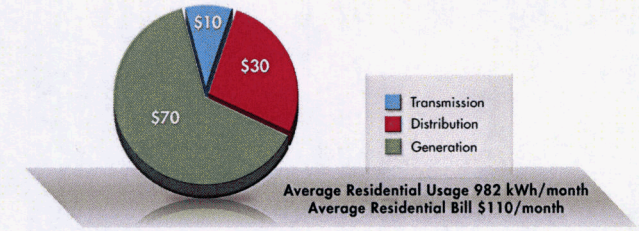
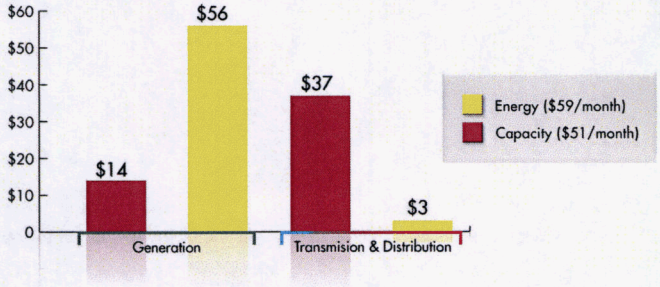
Cost of Grid Connectivity for Local Resources





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Cost Projection for Off-Grid Local Energy Resource

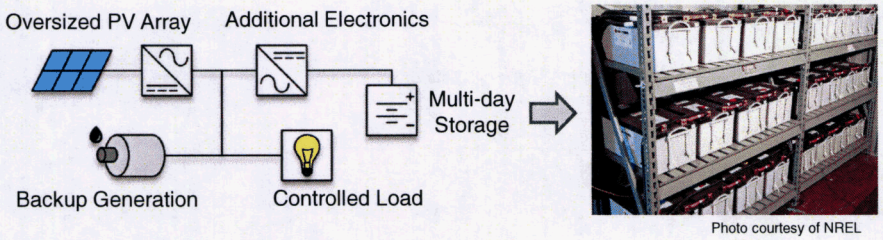
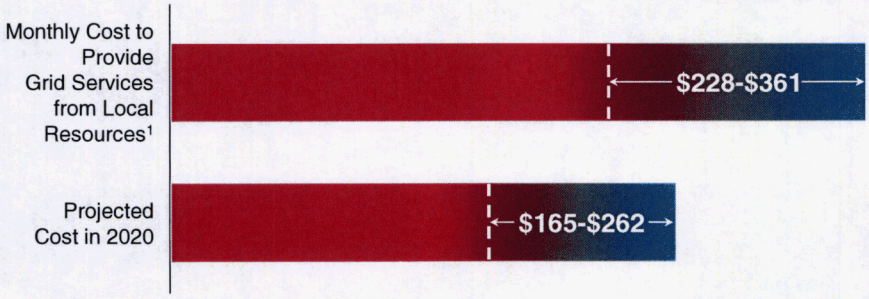


Photo courtesy of NREL



[1] *Does not include additional cost of energy from local resources*

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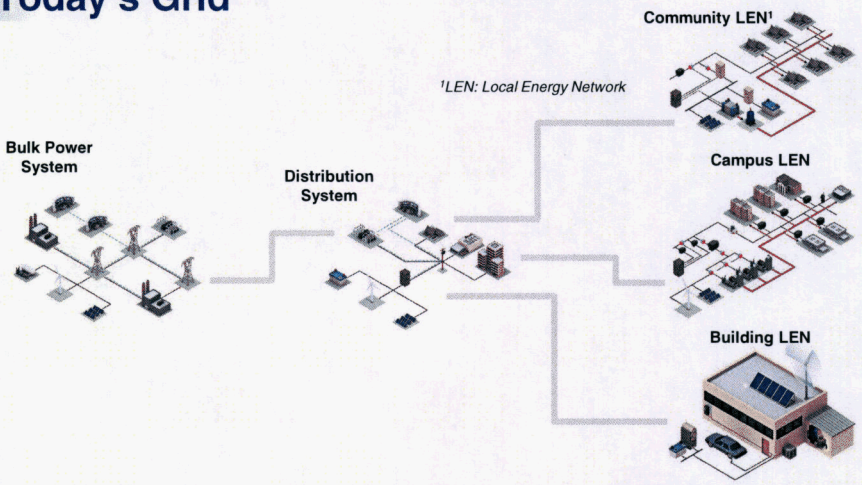
Distributed Energy Resource Deployment in Today's Grid



Lack of Visibility, Control, Frequency Support Challenges Grid Reliability at Higher Penetration Level of Local Resources

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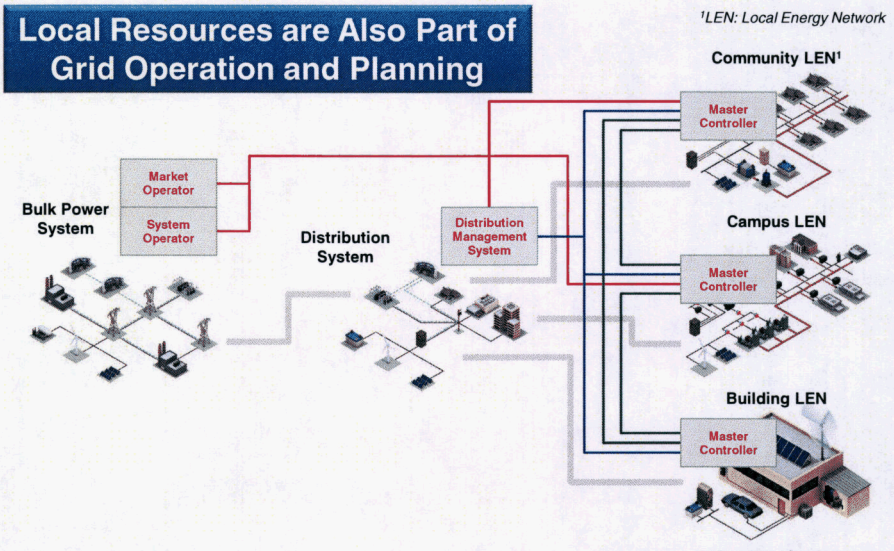
The Integrated Approach

Local Resources are Also Part of Grid Operation and Planning



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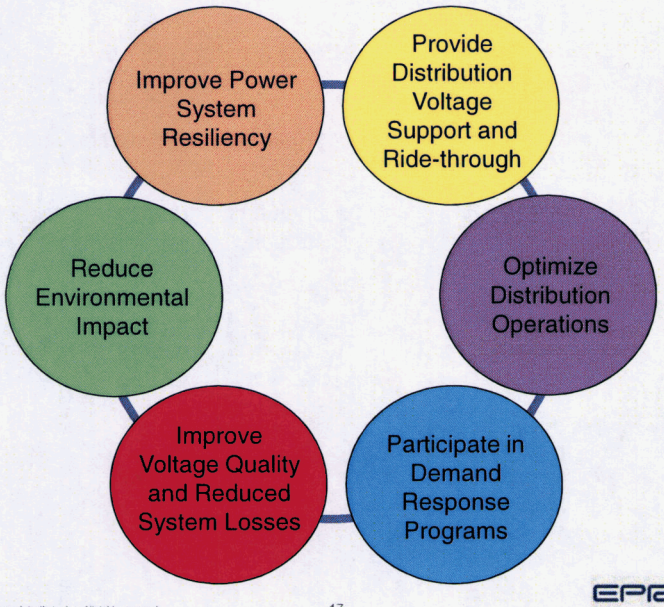
Value of DER to the Integrated Grid



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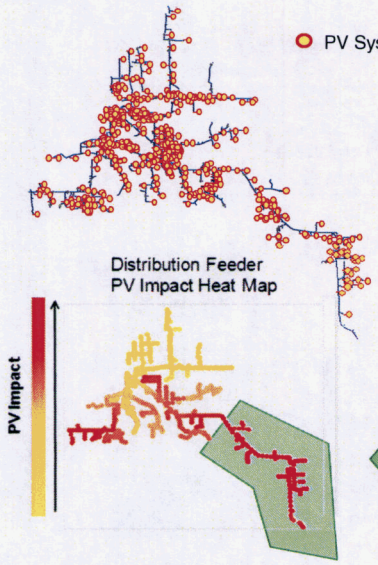
Distribution Feeder Hosting Capacity



Baseline – No PV
PV Penetration 1
PV Penetration 2
PV Penetration 3
Beyond…

Process is repeated 100's of times to capture many possible scenarios

Increase Penetration Levels Until Violations Occur

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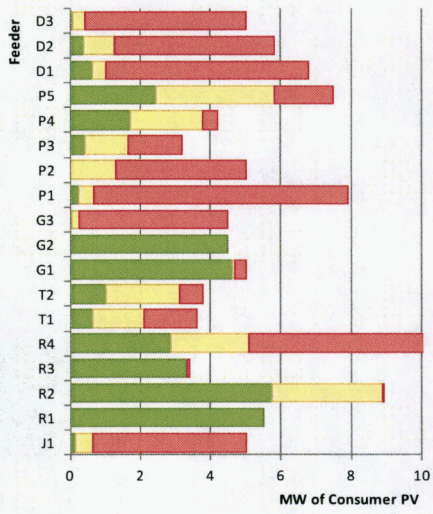
Sample High-Level Results



Each feeder has

- a unique hosting capacity
- a unique "range" that can be accommodated
- unique constraint that limits hosting capacity

All penetrations in this region are acceptable, regardless of location

Some penetrations in this region are acceptable, site specific

No penetrations in this region are acceptable, regardless of location

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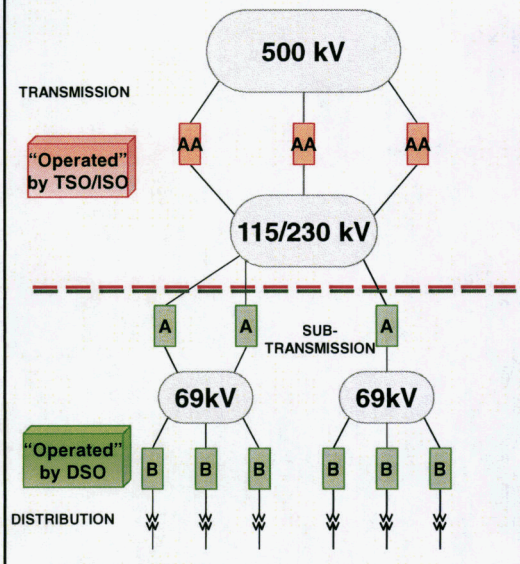
Understanding System Impacts of DER



Voltage and Frequency Stability

Increasing Re-dispatch Transmission Constraint

Reverse power flow Reactive Power flow Balance

Prevalent Overvoltage and Overcapacity and Protection Coordination Issues

Localized Overvoltage and Overcapacity in long circuits

Increasing Penetration Level

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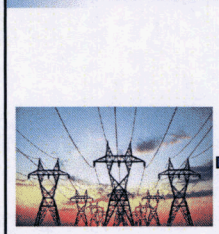
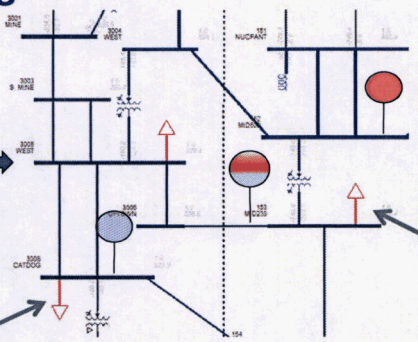
Transmission Impact Assessment & Modeling

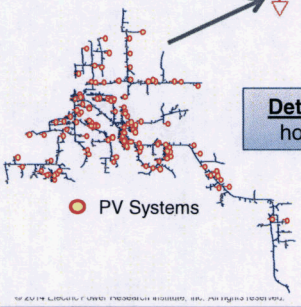




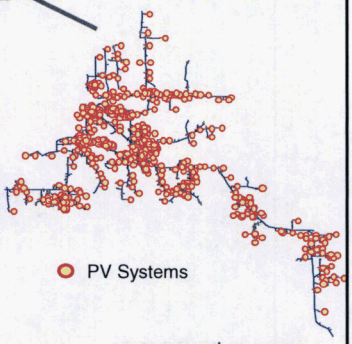
Replace Generation

Reduce Generation

Detailed Dist Models: Max. PV hosting capacity (P,Q) at sub.



PV Systems



PV Systems

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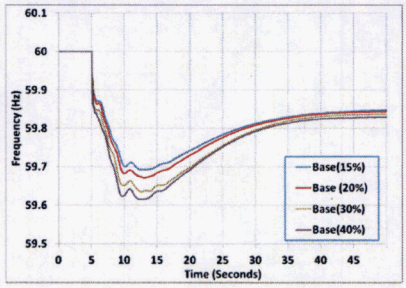
Bulk System Impacts of Distributed PV

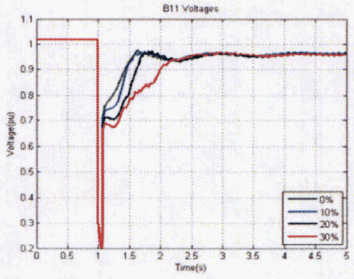
Impact on Frequency:

- Reduction in system inertia due to change in generation mix
- PV drop out due to large voltage disturbance (as per IEEE 1547)



Impact on Voltages :

- Delay in voltage recovery
- Degradation of load power factor
- Change in Active/Reactive Power Margins



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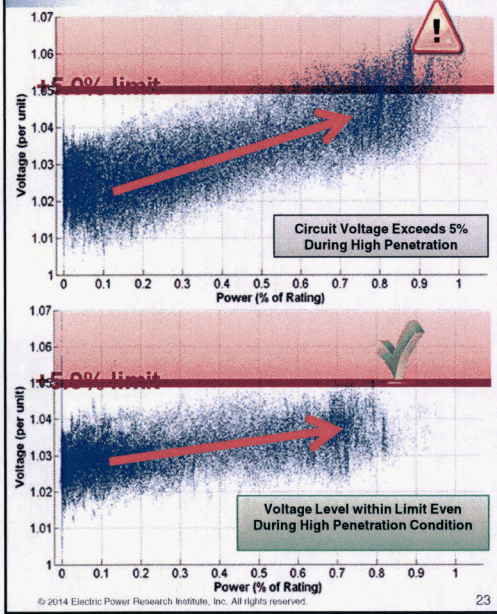
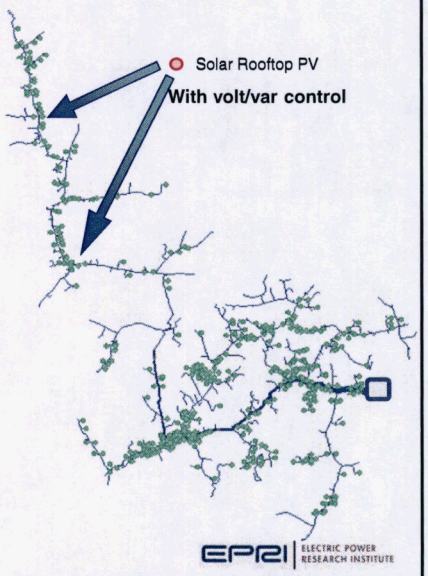
Example Technology Option to Increase DER

Distribution Voltage Regulation





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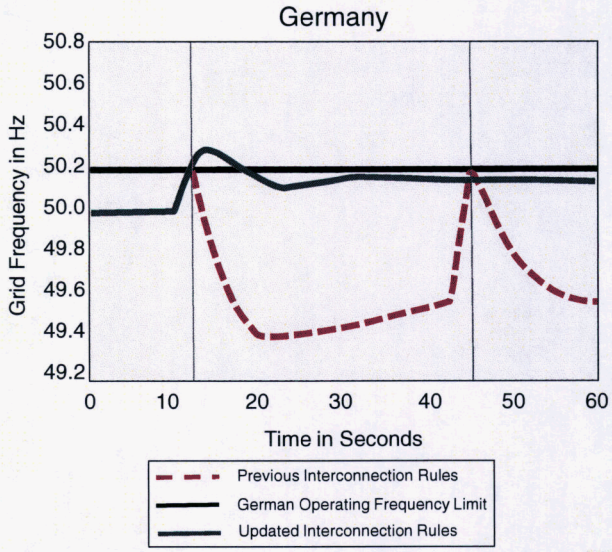
Example: The Right Interconnection Rules



Source: T. K. Vrana (2011)

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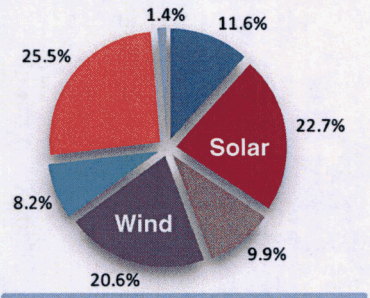
Germany: Higher Penetration of Local Generation Necessitates an Integrated Approach

Installed Capacity (2013)



~63GW of Installed Wind and PV – mostly connected to LV and MV grid

Interconnection Rules

- Grid frequency support

Grid Infrastructure Upgrade

- ~$27.5B-$42.5B upgrade

Two Way Communication

- Enabled by Advanced Distribution Management

Recent Changes in Germany to Address Concern of Grid Reliability

Source: Fraunhofer Institute, Germany

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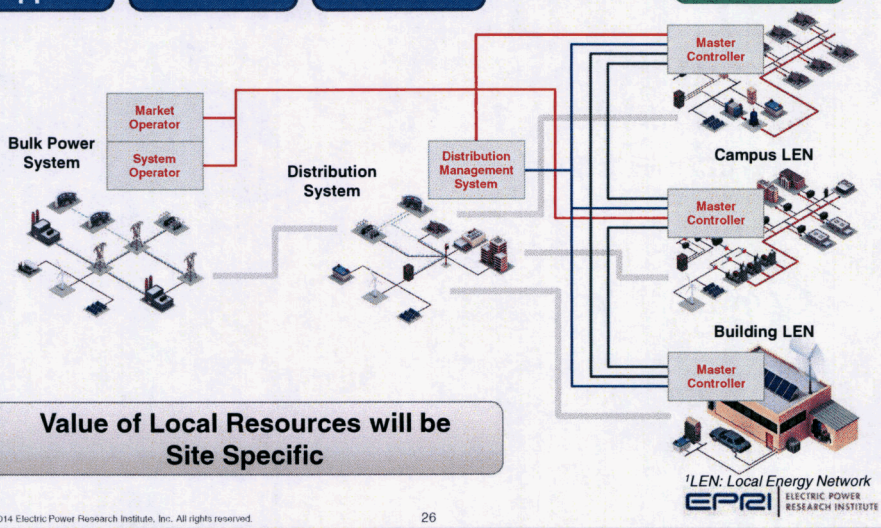
Potential Value of Distributed Energy Resources in an Integrated Grid

Volt/Var Support | **Loss Reduction** | **Capacity Services** | **Increased Resiliency**



Value of Local Resources will be Site Specific

[1]LEN: Local Energy Network

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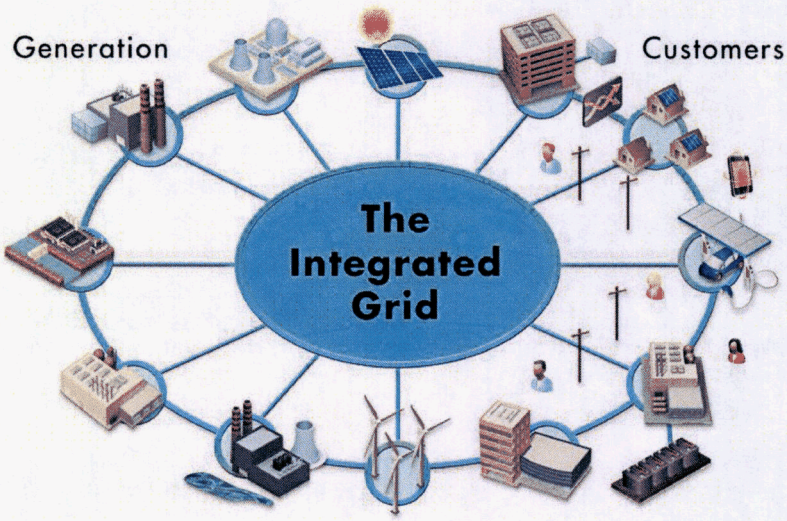
Meet the Challenge



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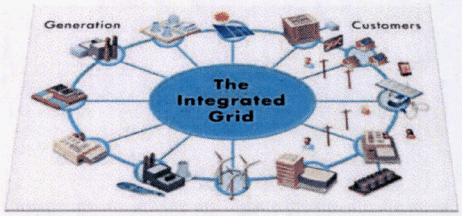
Foundation of An Integrated Grid

1. Grid Modernization
2. Communication Standards and Interconnection Rules
3. Integrated Planning and Operations
4. Informed Policy and Regulation



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Technology Options & Solutions

System Operator Solutions	Interactive Solutions	DER-Owner Solutions
Network Reinforcement	Price-Based Demand Response	Distributed Storage (customer system)
Centralized Voltage Control	Direct Load Control	Self-Consumption
Static VAR Compensators	On-Demand Reactive Power	Power Factor Control
Distributed Storage (distribution system)	On-Demand Curtailment	Direct Voltage Control
Network Reconfiguration	Wide-Area Voltage Control	Frequency-based Curtailment

The coordinated assessment of technology combination across different types of distribution system feeders is needed

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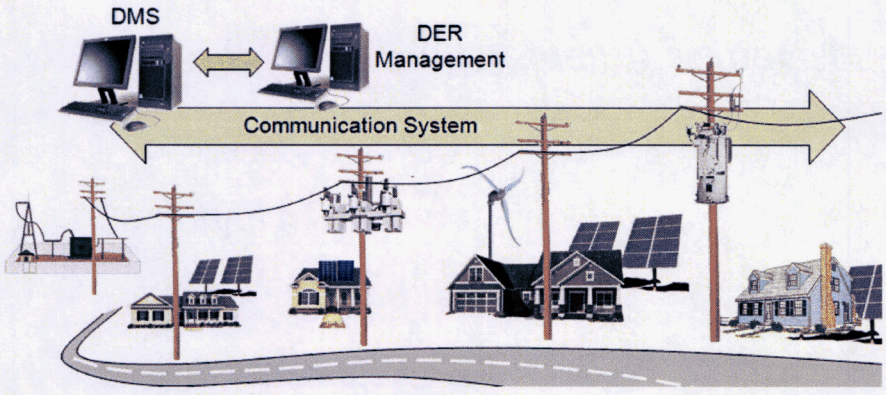
Grid Modernization

Communication-Connected Distributed Solar and Storage Systems as **Beneficial Distribution System Assets**



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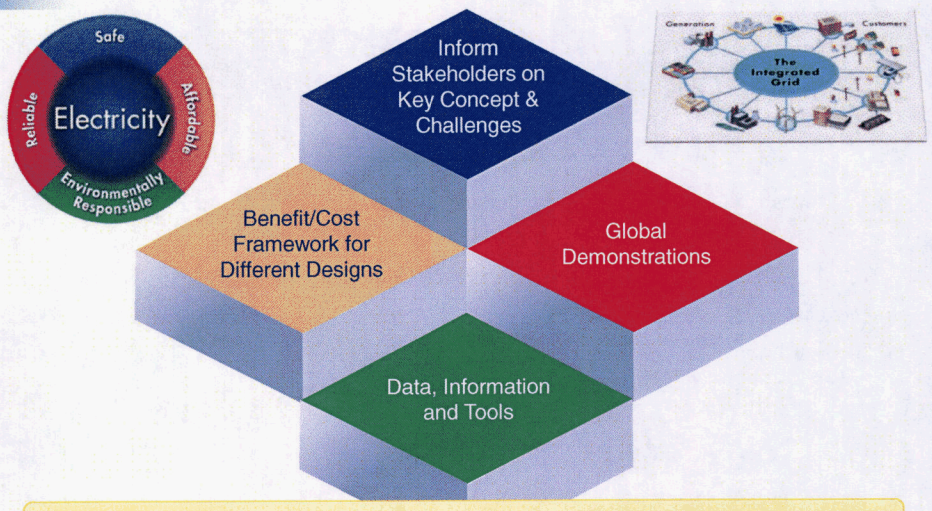
Action Plan



Global Collaboration to Establish the Science, Engineering and Economics

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Together…Shaping the Future of Electricity

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Strategies and tactics for dealing with changing customer energy use patterns

ACC Workshop
Phoenix, Arizona

Ahmad Faruqui , Ph.D.

March 20, 2014

THE Brattle GROUP

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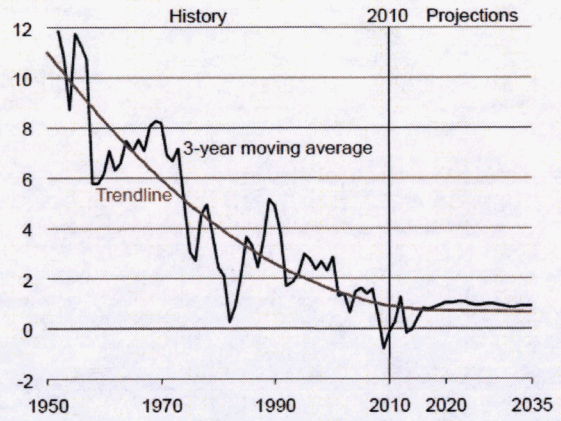
Normal electricity growth has not resumed four years after the Great Recession ended

- According to Dr. John Caldwell of the Edison Electric Institute, normal growth usually resumes within five months after the recession ends; the longest it has ever taken has been twelve months
- The EIA's March 2013 Short-Term Energy Outlook (STEO) projects that electric retail sales will grow by ~0.7% in 2013 and 2014; in the residential sector, the corresponding growth rates will be ~0.3% and ~0.8%
- The EIA also projects that total electricity sales will not return to the weather-adjusted pre-recession levels until 2014

Of course, declining growth has been the norm and not the exception since 1950

U.S. Electricity Demand Growth, 1950-2035 (percent, 3-year moving average)



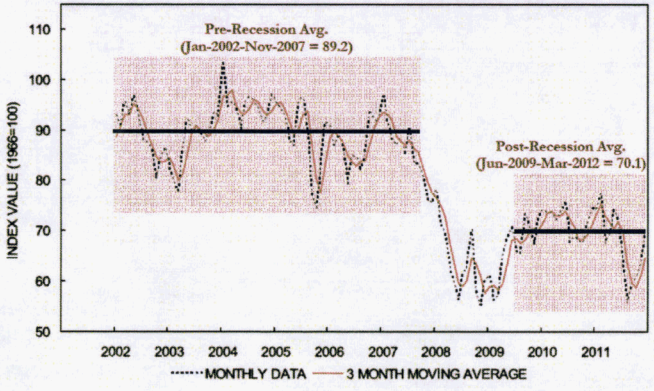
Source: EIA, 2012 Annual Energy Outlook

Three new forces have shaped the recent drop in growth

- **First, consumer psychology has shifted as a new generation of consumers has arrived with new values and norms; new technologies are pushing them to explore the frontiers of energy efficiency on their own; and they are into belt-tightening, faced with continued economic uncertainty**
- **Second, utilities are stepping up their spending on energy efficiency programs, often prompted by energy efficiency standards and new legislation**
- **Third, states and federal governments are continuing to push ahead with aggressive enhancements to codes and standards**

Consumer confidence continues to be a drag on consumer spending

Index of Consumer Sentiment – Recent Changes

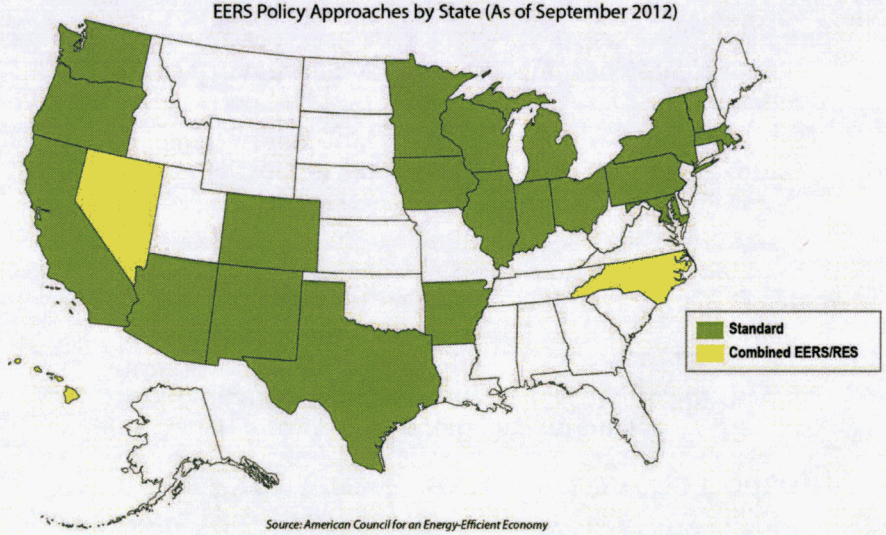


Source: University of Michigan Survey of Consumers

Note: Sentiment index for March 2013 increased to 78.6 from 77.6 a month earlier but fell again in April 2013 by several points

Several states have passed laws either requiring or promoting energy efficiency

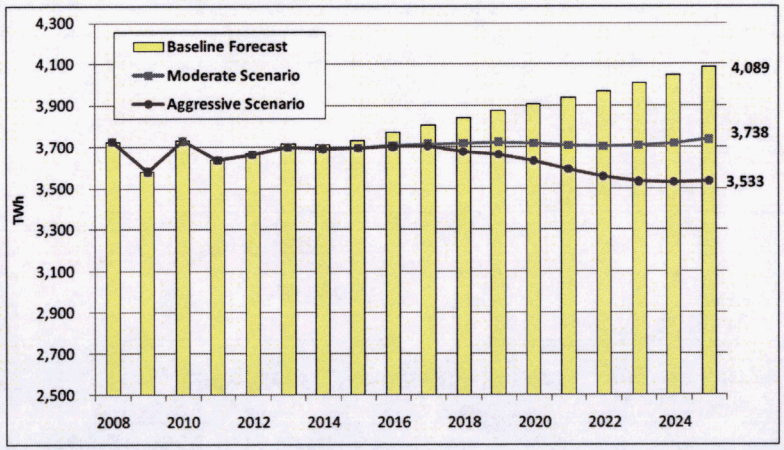
EERS Policy Approaches by State (As of September 2012)



Source: American Council for an Energy-Efficient Economy

New codes and standards could dramatically decrease baseline energy consumption

Impact of Codes and Standards on Total U.S. Electricity Consumption (TWh)



Source: IEE, Assessment of Electricity Savings Achievable through New Appliance/Equipment Efficiency Standards and Building Efficiency Codes (2010-2025)

Two more forces have appeared on the horizon

- The fourth force is distributed generation, led by the revolution in roof-top solar and supplemented by micro turbines
- Roof-top solar is approaching grid parity, capitalizing on heavy upfront cash subsidies and spurred on by net metering tariffs that over-compensate solar customers
- The leasing model pioneered by SolarCity is being copied rapidly by others
- The fourth force alone can eliminate load growth

Net metering enables distributed generation to expand

- In 2003, there were less than 7,000 U.S. customers on net metering
- By 2010, there were 156,000 (roughly half in California)
- In 2010, that amounts to 0.1% of total U.S. electricity sales
- In California, the 5% cap is predicted to be reached by 2015

Source: Net Metering: A Worrisome Trend, The International Energy Newsletter, July 2012.

With distributed generation, net-zero energy homes become a reality

- In Austin, Texas, the Zero Energy Capable Homes program requires that new single-family homes be net-zero energy capable by 2015
- The largest community of net-zero homes in the U.S. is rising in West Village at UC Davis in California
- The California Energy Commission has called for all new residential construction to be zero net energy by 2020 and for all new commercial construction to be zero net energy by 2030

The fifth force is fuel switching

- The revolution in shale oil and gas is pushing fuel prices downwards
- The use of gas for commercial air conditioning and in industrial process is going to become economic, leading to significant inter-fuel substitution away from electricity in the commercial and industrial sector
- Gas-fired residential heat pumps may also begin making inroad into the home HVAC market

What are the options for electric utilities?

- To deal with the five forces, we discuss four strategies and three tactics
- While strategies are important, it is equally important not to overlook tactics
- Recall the adage – "Amateurs discuss strategy; experts discuss tactics."

First strategy – stay the course

- The assumption is that growth will resume by itself; declining energy prices will herald an industrial revival and boost electricity sales
- CERA's Larry Makovitch has put forward a provocative argument along these lines
  - http://www.powermag.com/issues/features/Expect-U-S-Electricity-Consumption-to-Increase_5634.html
- This is a very high risk strategy, as noted on the next slide

All industries ignore the changing world at their own peril

"The car as we know it, and how it's used in people's lives, is going to change really dramatically and it's going to change fast. If we don't start imagining this future, and then start trying to help shape this future, we're going to be left behind, because this future is going to happen with or without us."

Bill Ford, Executive Chairman, Ford Motor Company

http://www.chicagotribune.com/business/la-fi-hy-autos-bill-ford-milken-talk-20130501,0,3825298.story

Second strategy – electrification

- Push on plug-in electric vehicles and other plug loads
  - http://www.economist.com/news/leaders/21578679-electric-car-stalls-race-be-green-wheels-future-not
- Conduct research, development and demonstration of new industrial processes that are electricity-intensive
- The results of this strategy will only payoff in the long run; they will provide very limited benefits in the near-term
- Efforts to boost electricity sales in the 1980s and 1990s have borne little fruit

Third strategy – the safe haven

- Become a wires company
- But many are already wires companies
- All wires companies face the risk of collecting insufficient revenue since the bulk of distribution charges are tied to sales and as sales growth slows down, they will not be able to cover their fixed costs

The fourth strategy – go on the offensive

- This strategy is premised on being able to out-sun SolarCity by creating a non-regulated affiliate that operates in other service areas
- It requires the creation of a new enterprise culture that will compete with mainstream solar companies
- This strategy does not fit with the core competency of the industry and is high risk
- Additional risk arises if net metering disappears

The first tactic – rethink rate design

- Shift from one-part volumetric rates to three-part rates that reflect costs more accurately and improve equity and efficiency
- The first part should be a fixed charge to cover metering and customer care services
- The second part should be a demand charge that covers the cost of being connected to the grid
- The third part should be a time-varying energy charge

The second tactic – rethink forecasting

- Sales models have been over-forecasting sales for the past five years because a key element is missing in the math – changing customer tastes and behavior
- The new models need to learn from how firms in competitive industries do their sales forecasts
- Besides relying on trend lines, they include insights from observational market research which involves frequent and ongoing interactions with consumers
- New data needs to be collected and added to the equations
- Consider forecasting peak demand through Quantile Regression rather the Ordinary Least Squares

The third tactic – rethink load and market research

- They need to be integrated and carried out on the same groups of customers, consistently over time
- Additionally, competitor offerings need to be studied and customer perceptions about those offerings need to be gleaned
- The objective should be to yield insights not just about the past and current patterns of use but about likely future changes

In closing

- The slowdown in sales growth is not an aberration but very much in line with the trend we have seen over the past six decades
- However, it is being driven by forces that are unique to the present circumstances, three of which have already manifested themselves and two of which loom on the horizon
- This is the time for strategic introspection and the deployment of new tactics

Continuing the conversation

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Dr. Ahmad Faruqui is a Principal with The Brattle Group whose work is focused on the full spectrum of customer-side issues involving demand forecasting, rate design, energy efficiency, demand response, and the smart grid broadly speaking. He has worked for more than three dozen utilities around the globe and testified before a dozen state and provincial commissions and legislative bodies. His work has been cited in *The Economist*, *The New York Times*, the *Washington Post* and *USA Today*. He has appeared on Fox Business News and National Public Radio. The author, co-author or editor of four books and more than 150 articles, he holds a Ph.D. in economics from The University of California at Davis and B.A. and M.A. degrees in economics from The University of Karachi, Pakistan.

The views expressed in this presentation are strictly those of the presenter and do not necessarily state or reflect the views of The Brattle Group, Inc.

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- Commercial Damages
- Environmental Litigation and Regulation
- Intellectual Property
- International Arbitration
- International Trade
- Product Liability
- Regulatory Finance and Accounting
- Risk Management
- Securities
- Tax
- Utility Regulatory Policy and Ratemaking
- Valuation

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- Electric Power
- Financial Institutions
- Health Care Products and Services
- Natural Gas and Petroleum
- Telecommunications and Media
- Transportation

Offices

NORTH AMERICA

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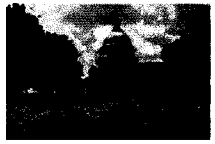
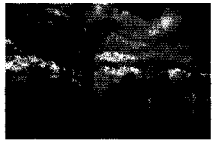
New York

San Francisco



Washington, DC

EUROPE



London

Madrid

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Bloomenergy

Introducing Bloom Energy

March 20, 2014

The Bloom Energy Server

Fuel Cell
25 W

System
200 kW

Solution
200 kW to MW's

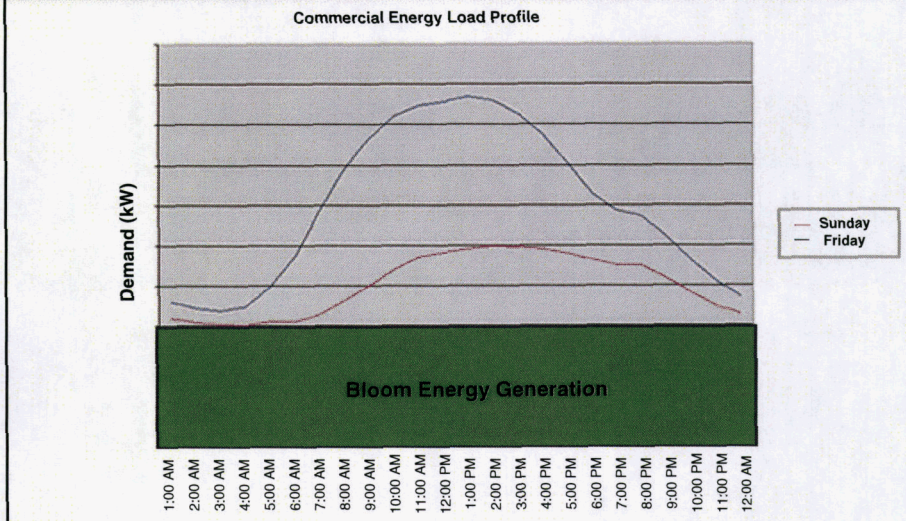
Runs on natural gas or biogas

Converts fuel to electricity
- Without combustion
- 60%+ electrical efficiency
- Modular and scalable
- Highly reliable

Outputs
- AC or DC power
- Low/No CO_2
- No NO_x or SO_x

Bloomenergy

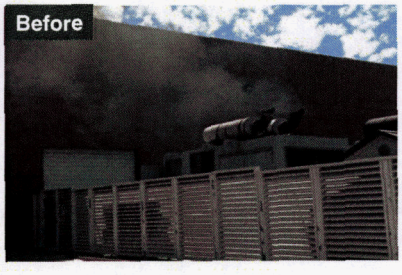
Bloom Generation Sized to Minimum Load



Bloomenergy

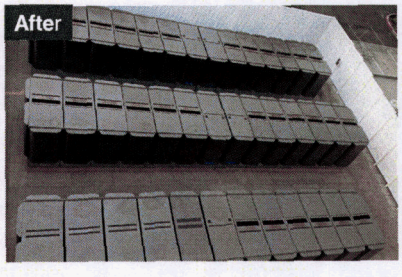
life technologies™

Before



- Millions of dollars of biotech inventory that must be refrigerated 24x7
- During utility grid outage, diesel generators could not get fuel, as supplies were rationed to hospitals

After



- 24x7 onsite power
- Avoids need for diesel generators; no transfer switch complexity risk
- Personalized Energy - scales with their needs

Bloomenergy

Walmart

Industry
Retail

Bloom Installations
Powering Stores in California and in the Northeast USA

Walmart needed a sustainable energy solution that would contribute to lower costs and provide the potential to supply continuous power to stores, even during critical grid outages.

Bloomenergy

macy's

Industry
Retail

Bloom Installation
600 kW – Cheshire, CT

Macy's fulfillment center in Connecticut was facing increasingly unreliable power and rising costs.

The Bloom Energy system helps Macy's stay cost competitive and keep the Connecticut distribution center open.

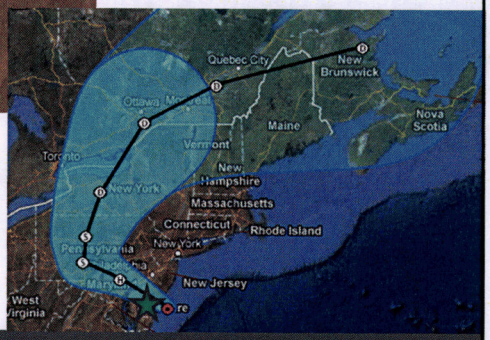
Bloomenergy

Bloom Works Reliably for Delmarva

"Bloom Energy electrical project in New Castle was unaffected by Hurricane Sandy."

- Delmarva Regional President

- **Hurricane passed directly over installation**
- **Gas supply and power generation uninterrupted**



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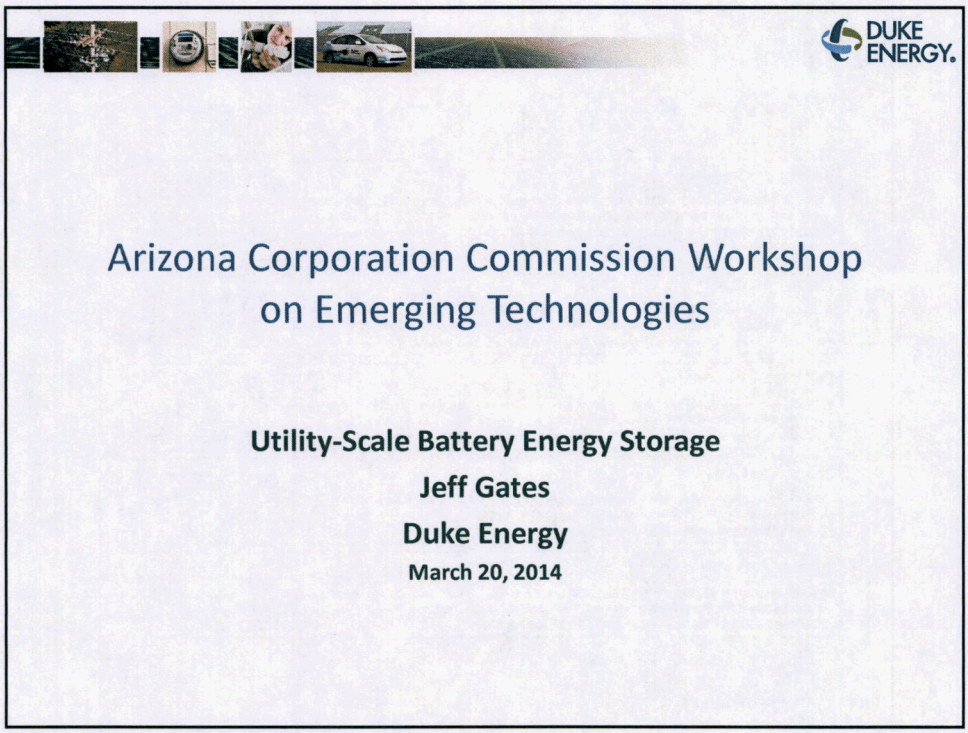
Bloomenergy®

Be the solution

Thank You!
Josh Richman
VP, Business Development
Josh.Richman@BloomEnergy.com



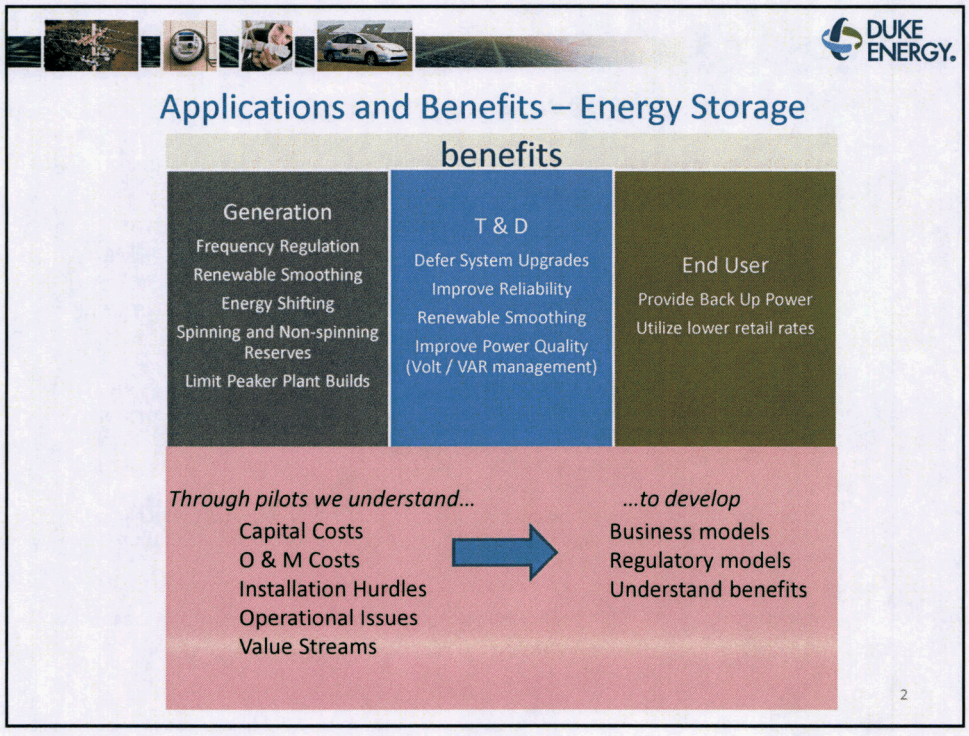
Arizona Corporation Commission Workshop on Emerging Technologies

Utility-Scale Battery Energy Storage

Jeff Gates

Duke Energy

March 20, 2014



Applications and Benefits – Energy Storage benefits

Generation	T & D	End User
Frequency Regulation	Defer System Upgrades	Provide Back Up Power
Renewable Smoothing	Improve Reliability	Utilize lower retail rates
Energy Shifting	Renewable Smoothing	
Spinning and Non-spinning Reserves	Improve Power Quality (Volt / VAR management)	
Limit Peaker Plant Builds		

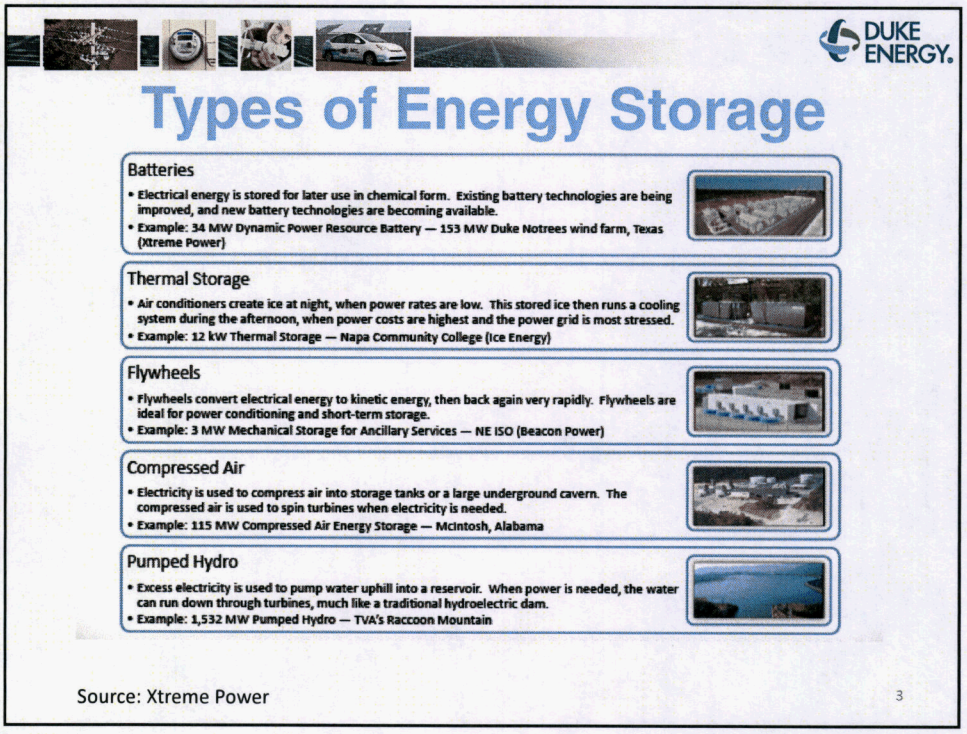
Through pilots we understand…

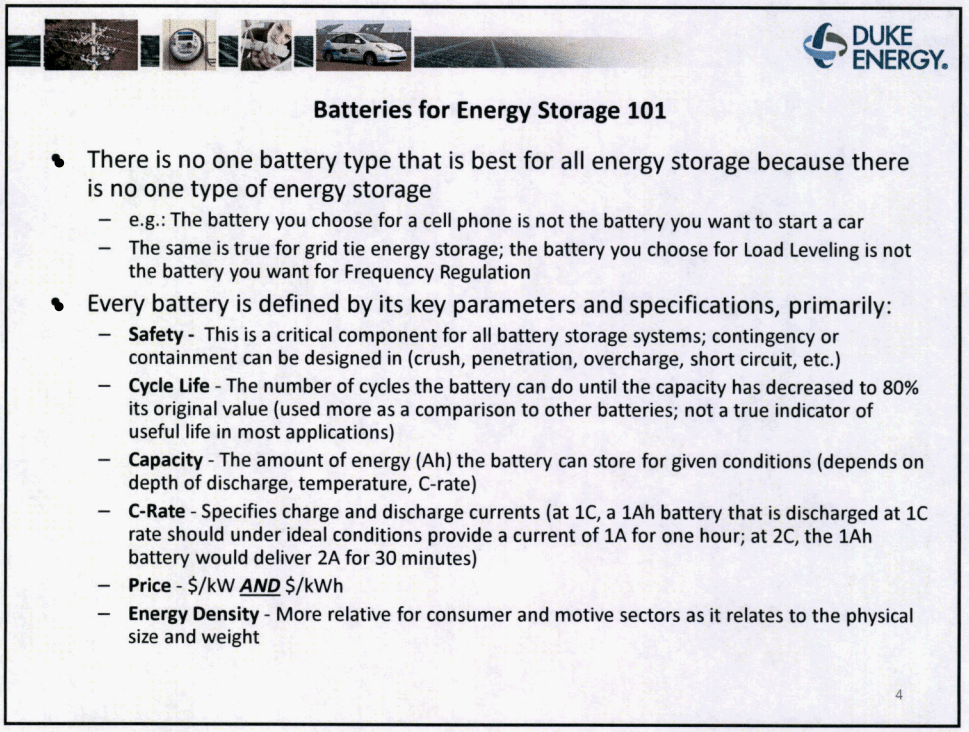
- Capital Costs
- O & M Costs
- Installation Hurdles
- Operational Issues
- Value Streams

…to develop

- Business models
- Regulatory models
- Understand benefits

2


DUKE ENERGY.
Types of Energy Storage
Batteries
• Electrical energy is stored for later use in chemical form. Existing battery technologies are being improved, and new battery technologies are becoming available.
• Example: 34 MW Dynamic Power Resource Battery — 153 MW Duke Notrees wind farm, Texas (Xtreme Power)
Thermal Storage
• Air conditioners create ice at night, when power rates are low. This stored ice then runs a cooling system during the afternoon, when power costs are highest and the power grid is most stressed.
• Example: 12 kW Thermal Storage — Napa Community College (Ice Energy)
Flywheels
• Flywheels convert electrical energy to kinetic energy, then back again very rapidly. Flywheels are ideal for power conditioning and short-term storage.
• Example: 3 MW Mechanical Storage for Ancillary Services — NE ISO (Beacon Power)
Compressed Air
• Electricity is used to compress air into storage tanks or a large underground cavern. The compressed air is used to spin turbines when electricity is needed.
• Example: 115 MW Compressed Air Energy Storage — McIntosh, Alabama
Pumped Hydro
• Excess electricity is used to pump water uphill into a reservoir. When power is needed, the water can run down through turbines, much like a traditional hydroelectric dam.
• Example: 1,532 MW Pumped Hydro — TVA's Raccoon Mountain
Source: Xtreme Power
3


DUKE ENERGY.
Batteries for Energy Storage 101
There is no one battery type that is best for all energy storage because there is no one type of energy storage
e.g.: The battery you choose for a cell phone is not the battery you want to start a car
The same is true for grid tie energy storage; the battery you choose for Load Leveling is not the battery you want for Frequency Regulation
Every battery is defined by its key parameters and specifications, primarily:
Safety - This is a critical component for all battery storage systems; contingency or containment can be designed in (crush, penetration, overcharge, short circuit, etc.)
Cycle Life - The number of cycles the battery can do until the capacity has decreased to 80% its original value (used more as a comparison to other batteries; not a true indicator of useful life in most applications)
Capacity - The amount of energy (Ah) the battery can store for given conditions (depends on depth of discharge, temperature, C-rate)
C-Rate - Specifies charge and discharge currents (at 1C, a 1Ah battery that is discharged at 1C rate should under ideal conditions provide a current of 1A for one hour; at 2C, the 1Ah battery would deliver 2A for 30 minutes)
Price - $/kW AND $/kWh
Energy Density - More relative for consumer and motive sectors as it relates to the physical size and weight
4

DUKE ENERGY.

Terminology

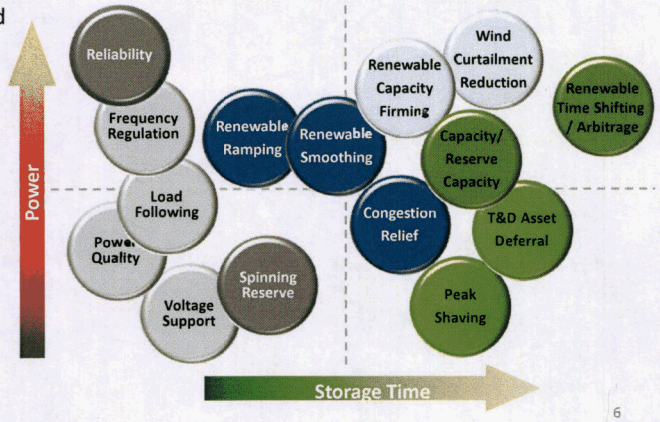
- **Cell** – The smallest form factor for energy storage
- **Battery** – A collection of cells
  - Cells are connected in series (S) to increase voltage (VDC)
  - Cells are connected in parallel (P) to increase capacity (Ah)
  - Generally expressed in terms of "S" and "P"
    - 12S2P – Toshiba
    - 8S3P – Samsung
    - 6S12P - Microvast
- **Module** – A battery with an integrated BMS (also called a smart battery)
  - Toshiba & GE are examples of Modules because they include the battery and BMS in a single unit
  - Samsung, Microvast are not modules since the BMS is only connected at the string or tray level
- **String** – A collection of Batteries/Modules connected in series to form the system main DC voltage
  - A.K.A. - Rack, Pack, Tower
- **DC Block** – A collection of packs/strings/racks connected in parallel to form the overall capacity and power needs of the system

5

DUKE ENERGY.

Select the Right Battery for the Application

- Any battery can charge and discharge energy
- Any battery can be used in ESS from a *functional* perspective
- But there can be a big difference with performance and price
- There are batteries designed for power and those more in line for energy
- The battery choice will depend on the end use application(s)



6

DUKE ENERGY.

Energy Storage Systems have 6 major parameters that are assessed

- **Price**
  - Upfront price of the DC Block ($/kWh), this is not total system cost
- **Safety**
  - The safety of the battery chemistry
  - It is a relative parameter
  - Contingencies can be designed in to mitigate certain hazards (i.e. a gas tank design)
- **Power**
  - How much current can be pushed into or out of the battery (C-Rate)
- **Energy**
  - How long can the battery sustain a particular current
- **Life**
  - Can be related to cycle life but should also consider calendar life as well
- **Performance**
  - The catch all, usually referencing those specs that affect system design
    - Charge/Discharge balance
    - Effective Capacity
    - Efficiency

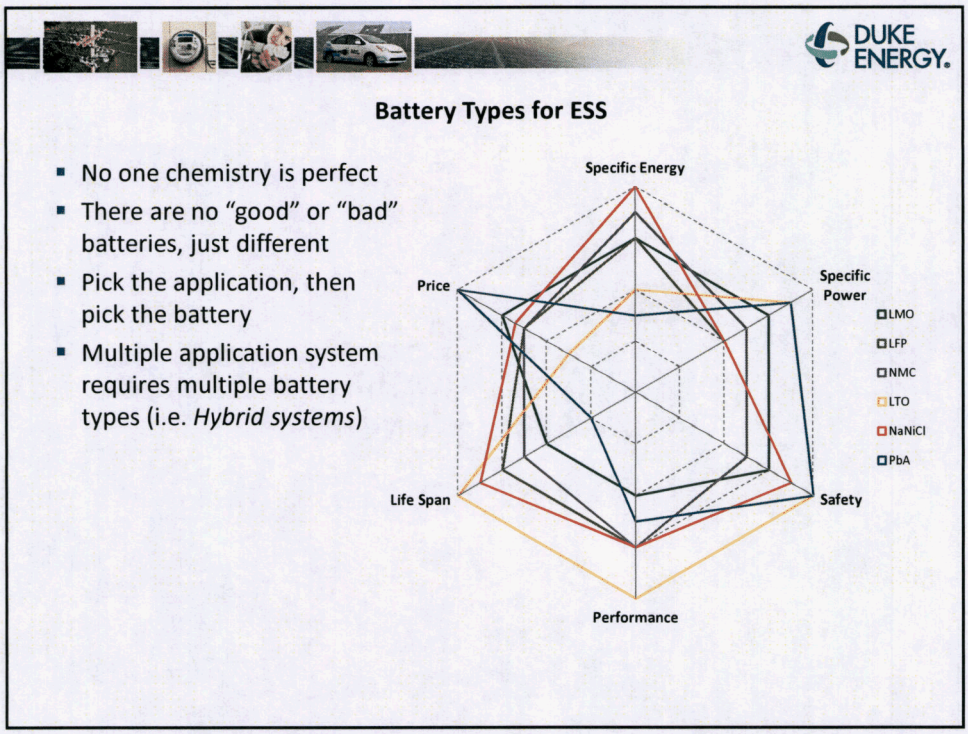
7

DUKE ENERGY.

Battery Types for ESS

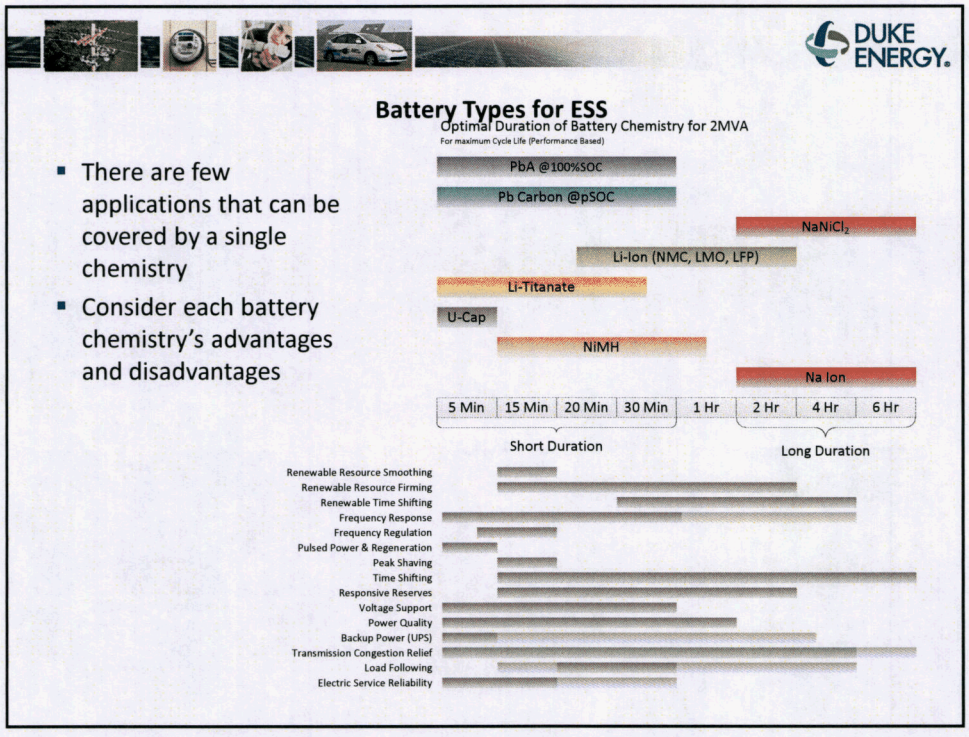
Chemical name	Material	Abbreviation	Short form	Company
Lithium Manganese Oxide[1] Also Lithium Manganate or lithium-ion-manganese	$LiMn_2O_4$	LMO	Li-manganese, or spinel	Samsung SDI, Sanyo, Hitachi, 4R, Actacell, Panasonic
Lithium Iron Phosphate[1]	$LiFePO_4$	LFP	Li-phosphate	CALB, A123, Valence, Saft, BYD Bren-tronics
Lithium Nickel Manganese Cobalt Oxide[1] Also lithium-manganese-cobalt-oxide	$LiNiMnCoO_2$ (10–20% Co)	NMC	Or NCM	Dow Kokam, EnerDel, LG Chem, Sanyo, SK
Lithium Titanate[2]	$Li_4Ti_5O_{12}$	LTO	Li-titanate	Toshiba, Microvast, Altar Nano
Lithium Nickel Cobalt Aluminum Oxide	$LiNiCoAlO_2$	NCA	NCA	Saft, Panasonic, JCI
Sodium Nickel Chloride	$NaNiCl_2$	NaX	Durathon™, SONICK™	GE, Fiamm
Sodium Sulfur	NaS	NAS		NGK
VRLA Lead Acid	$PbSO_4$	PbA	VRLA	EnerSys, BSB, Shin Kobe, Exide East Penn...
Redox - Flow	ZnBr, VO_2, FeCr		Flow	ZBB, Enervault, RedFlow, American Vanadium/ Gildemeister

[1] Cathode material [2] Anode material



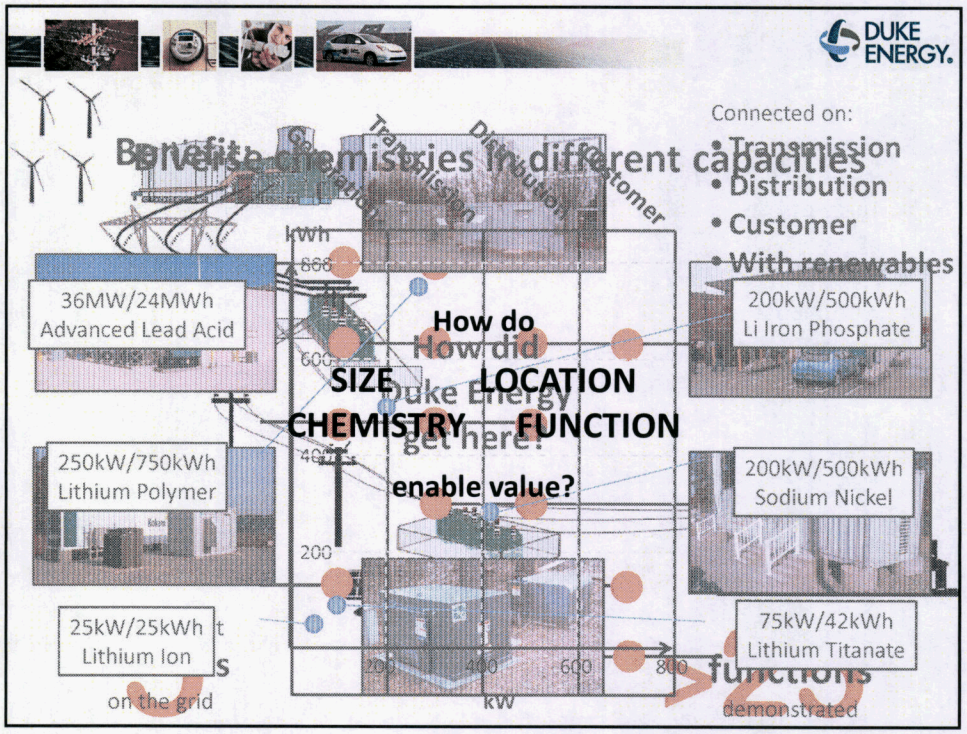
Battery Types for ESS

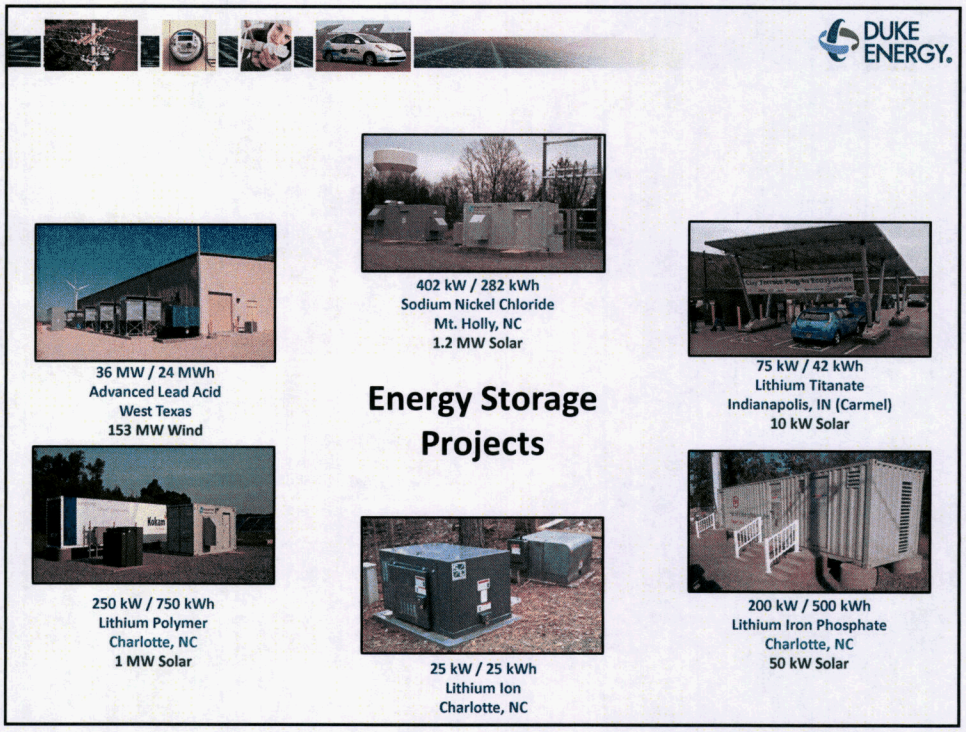
- No one chemistry is perfect
- There are no "good" or "bad" batteries, just different
- Pick the application, then pick the battery
- Multiple application system requires multiple battery types (i.e. *Hybrid systems*)



Battery Types for ESS

- There are few applications that can be covered by a single chemistry
- Consider each battery chemistry's advantages and disadvantages


DUKE ENERGY.
Benefits
Generation
Transmission
Distribution
Customer
Connected on:
• Transmission
• Distribution
• Customer
• With renewables
kWh
36MW/24MWh
Advanced Lead Acid
200kW/500kWh
Li Iron Phosphate
How do
SIZE LOCATION
CHEMISTRY FUNCTION
enable value?
250kW/750kWh
Lithium Polymer
200kW/500kWh
Sodium Nickel
25kW/25kWh
Lithium Ion
75kW/42kWh
Lithium Titanate
on the grid
demonstrated
kW


DUKE ENERGY.
36 MW / 24 MWh
Advanced Lead Acid
West Texas
153 MW Wind
402 kW / 282 kWh
Sodium Nickel Chloride
Mt. Holly, NC
1.2 MW Solar
75 kW / 42 kWh
Lithium Titanate
Indianapolis, IN (Carmel)
10 kW Solar
Energy Storage
Projects
250 kW / 750 kWh
Lithium Polymer
Charlotte, NC
1 MW Solar
200 kW / 500 kWh
Lithium Iron Phosphate
Charlotte, NC
50 kW Solar
25 kW / 25 kWh
Lithium Ion
Charlotte, NC

Notrees Wind Farm Project

Notrees, TX

Major system components:

- 36 MW / 24 MWh
- Xtreme Power Advanced Lead Acid Technology
- Co-located at site of 156 MW Wind Farm in Notrees, Texas
- Began commercial operation in December 2012
- 50:50 Cost share with DOE

Applications being tested

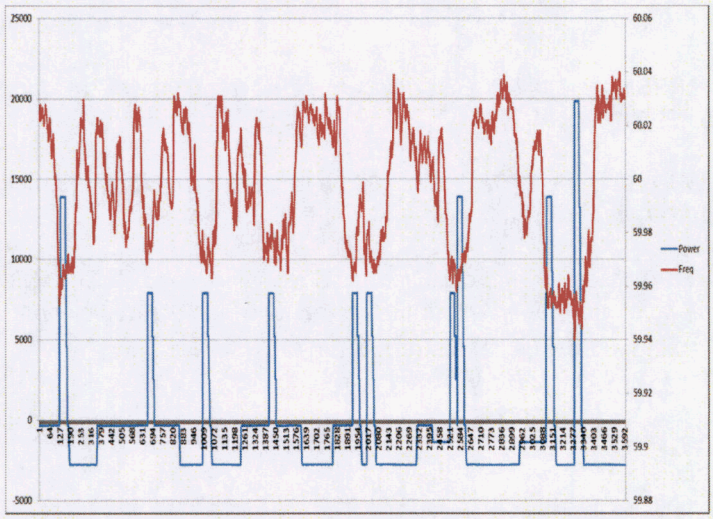
1 – Ancillary Services: participating in a series of ERCOT (Texas ISO) market tests to learn how to structure an efficient market that enables energy storage to provide ancillary services to the grid.

2 – Energy Shifting: Charging and discharging to maximize the value of energy delivered to the grid based on timing.

3-Avoiding Wind Curtailment : Using storage to store wind energy in order to avoid orders to cease providing power to the grid.

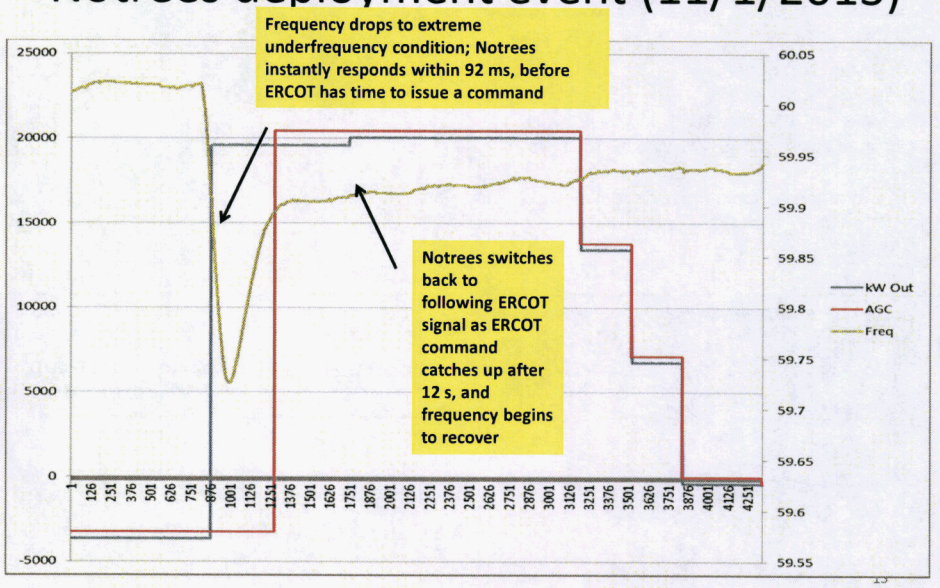
Typical duty cycle profile – 1 hour snapshot

Deployment for bid 20MW and frequency



14

Notrees deployment event (11/1/2013)

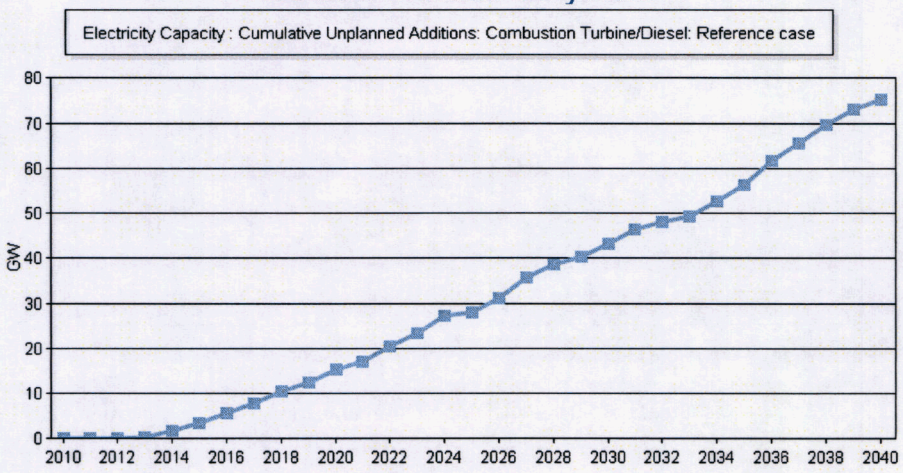


Grid Operator observations

- After first 3-months of Notrees operating in FRRS, ERCOT's observations:
  - *" FRRS improves ERCOT's ability to arrest frequency decay during unit trips "*
  - *" When deployed, FRRS reduces the rate of change of frequency and regulation deployed to conventional Resources"*
  - *" ERCOT believes that the pilot has already provided exceedingly valuable information about the degree to which the deployment of Regulation Service can be reduced by FRRS Resources "*
- FRRS Permanent Protocol language approved by ERCOT Board on Feb 11th 2014

16

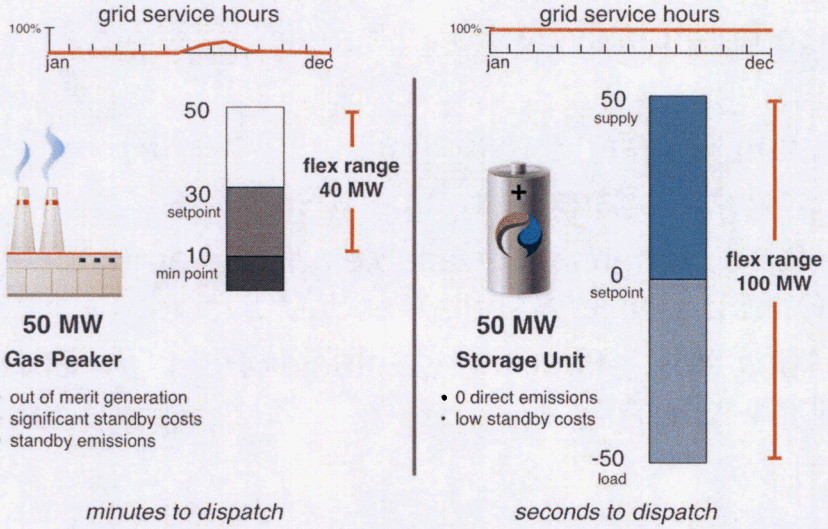
Problem: 40 GW peak generation needed in next 15 years



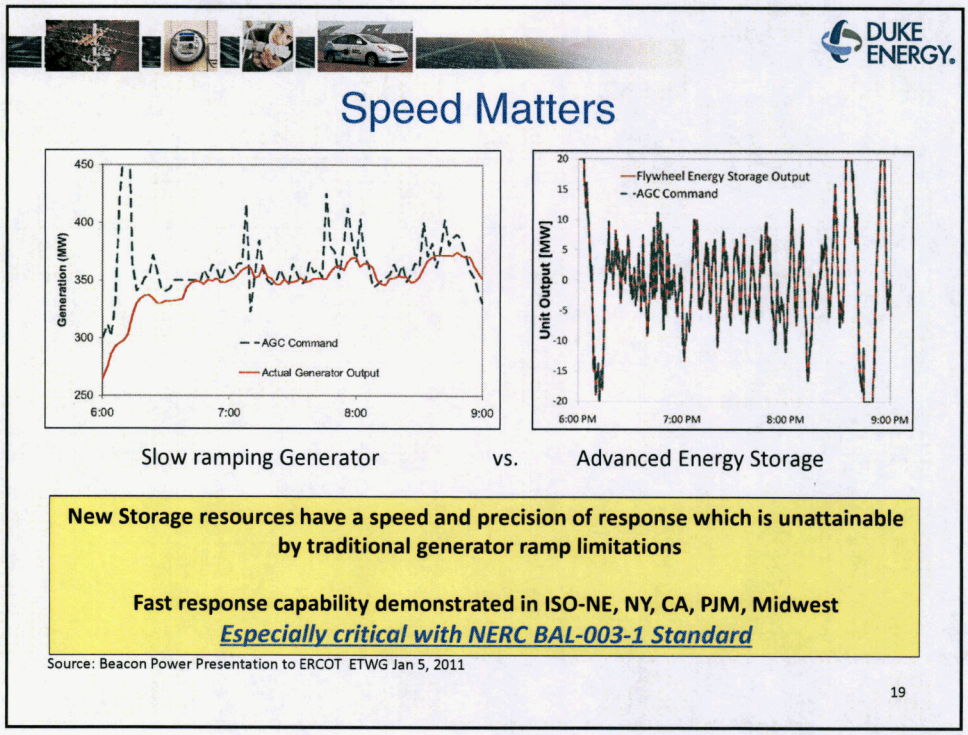
eia Independent Statistics & Analysis U.S. Energy Information Administration

ESA Energy Storage Association

Solution: Energy storage as flexible resource



ESA Energy Storage Association



Tools: Modeling

- ❑ Comprehensively model benefits of energy storage
- ❑ Analyze optimal resource portfolio (IRP)
- ❑ Evaluate offered resources (RFP)
- ❑ Use commercially available and government/lab (NREL, PNNL, Sandia) modeling tools
- ❑ Apply cost-effectiveness studies from CA (EPRI, DNV-KEMA)

ESA Energy Storage Association

Goals

- Optimize resources on the electric grid
- Increase grid resilience and efficiency
- Reduce cost to the consumer
- Decrease emissions
- Allow all stakeholders to benefit!

Energy Storage Association

Resources

- ESA: www.energystorage.org
- Projects: www.energystorageexchange.org
- NREL Study:http://www.nrel.gov/docs/fy13osti/58465.pdf
- PNNL Study:

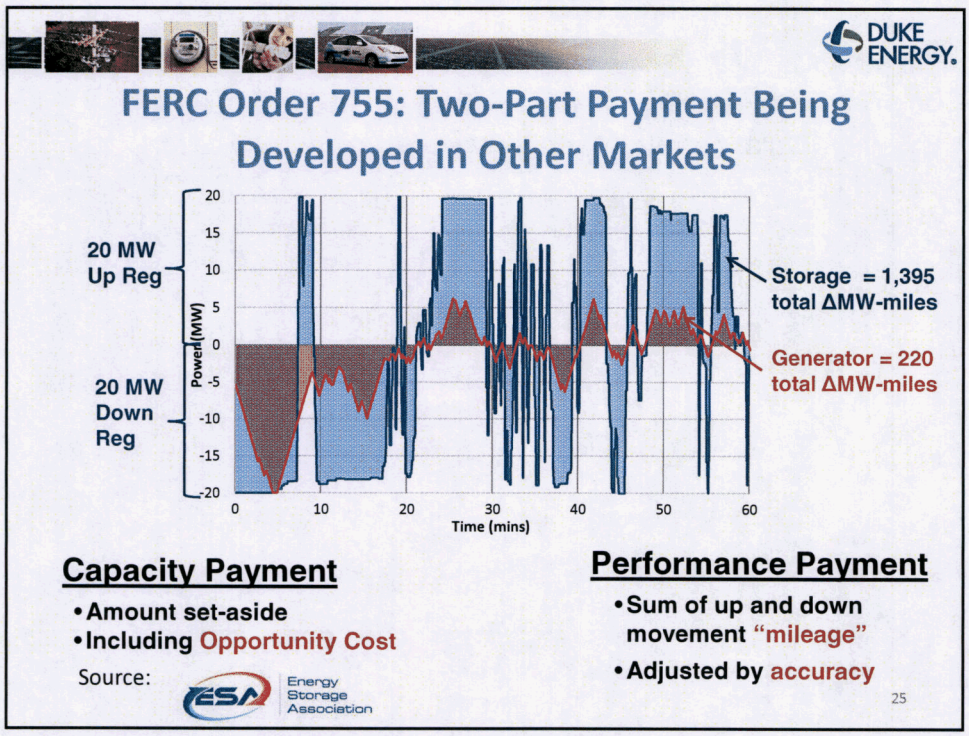
http://energyenvironment.pnnl.gov/pdf/PNNL-21388_National_Assessment_Storage_Phase_1_final.pdf

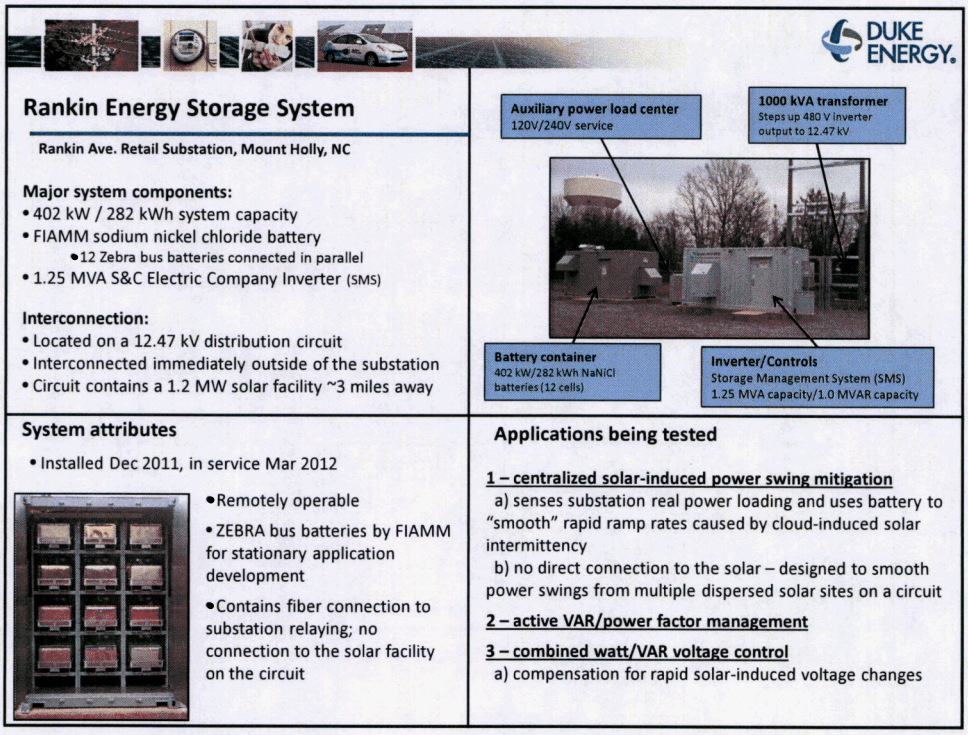
Energy Storage Association

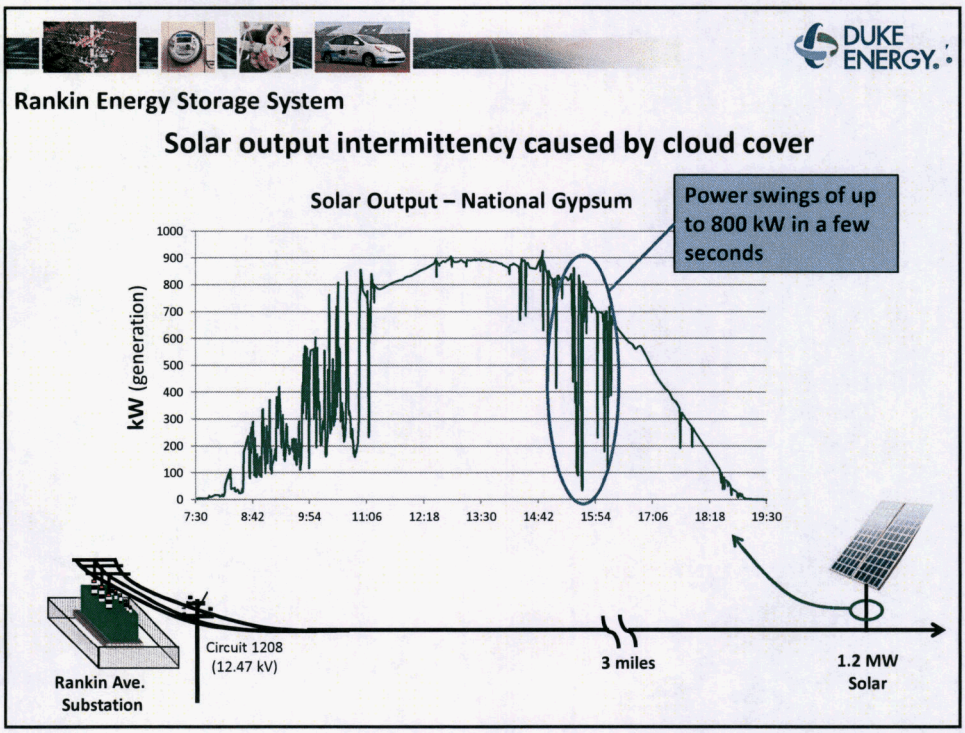
Summary

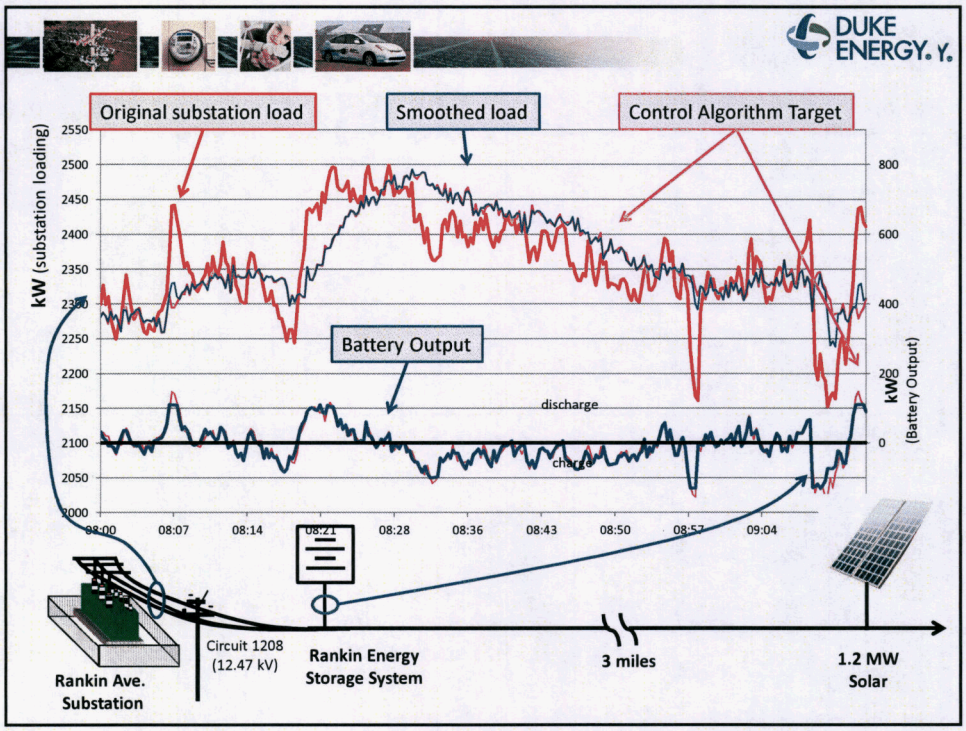
- Energy storage systems can offer many benefits to both the customer and the electric grid
  - Energy arbitrage
  - Frequency Regulation
  - Firming of renewable assets
  - System reliability
  - Back up power
- Capturing of multiple value streams enables wider range of cost-effective storage deployments
- Define the problem to be solved to determine the best technology to be used
- Creative business models attract diversity of capital and risk allocation to commercialize energy storage
  - Public/private partnerships
  - "Storage as a service" PPAs
  - Continued regulatory innovation

Appendix


DUKE ENERGY.
FERC Order 755: Two-Part Payment Being Developed in Other Markets
20 MW Up Reg
20 MW Down Reg
Power (MW)
Time (mins)
Storage = 1,395 total ΔMW-miles
Generator = 220 total ΔMW-miles
Capacity Payment
• Amount set-aside
• Including Opportunity Cost
Source:
ESA Energy Storage Association
Performance Payment
• Sum of up and down movement "mileage"
• Adjusted by accuracy
25


DUKE ENERGY.
Rankin Energy Storage System
Rankin Ave. Retail Substation, Mount Holly, NC
Major system components:
• 402 kW / 282 kWh system capacity
• FIAMM sodium nickel chloride battery
• 12 Zebra bus batteries connected in parallel
• 1.25 MVA S&C Electric Company Inverter (SMS)
Interconnection:
• Located on a 12.47 kV distribution circuit
• Interconnected immediately outside of the substation
• Circuit contains a 1.2 MW solar facility ~3 miles away
Auxiliary power load center 120V/240V service
1000 kVA transformer Steps up 480 V inverter output to 12.47 kV
Battery container 402 kW/282 kWh NaNiCl batteries (12 cells)
Inverter/Controls Storage Management System (SMS) 1.25 MVA capacity/1.0 MVAR capacity
System attributes
• Installed Dec 2011, in service Mar 2012
• Remotely operable
• ZEBRA bus batteries by FIAMM for stationary application development
• Contains fiber connection to substation relaying; no connection to the solar facility on the circuit
Applications being tested
1 – centralized solar-induced power swing mitigation
a) senses substation real power loading and uses battery to "smooth" rapid ramp rates caused by cloud-induced solar intermittency
b) no direct connection to the solar – designed to smooth power swings from multiple dispersed solar sites on a circuit
2 – active VAR/power factor management
3 – combined watt/VAR voltage control
a) compensation for rapid solar-induced voltage changes


DUKE ENERGY.
Rankin Energy Storage System
Solar output intermittency caused by cloud cover
Solar Output – National Gypsum
Power swings of up to 800 kW in a few seconds
kW (generation)
1000
900
800
700
600
500
400
300
200
100
0
7:30
8:42
9:54
11:06
12:18
13:30
14:42
15:54
17:06
18:18
19:30
Circuit 1208
(12.47 kV)
3 miles
1.2 MW
Solar
Rankin Ave.
Substation

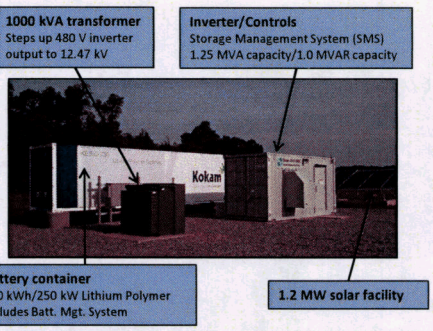

DUKE ENERGY.
Original substation load
Smoothed load
Control Algorithm Target
kW (substation loading)
2550
2500
2450
2400
2350
2300
2250
2200
2150
2100
2050
2000
800
600
400
200
0
kW (Battery Output)
Battery Output
discharge
charge
08:00
08:07
08:14
08:21
08:28
08:36
08:43
08:50
08:57
09:04
Circuit 1208
(12.47 kV)
Rankin Energy
Storage System
3 miles
1.2 MW
Solar
Rankin Ave.
Substation

Marshall Energy Storage System

Marshall Steam Station, Sherrills Ford, NC

Major system components:
- 750 kWh / 250 kW system capacity
- Kokam Superior Lithium Polymer Batteries
- 1.25 MVA S&C Electric Company Inverter (SMS)

Interconnection:
- Located on a 12.47 kV distribution circuit
- Separate but adjacent medium-voltage interconnection from 1.0 MW solar facility
- Located at the end of a distribution feeder



System attributes

- Installed May 2012, in service July 2012
- Remotely operable
- Battery and inverter independently sourced (both vendors to Duke)
- Located at the Marshall solar test site where multiple solar technologies are being field tested on a sealed coal-ash landfill

Applications being tested

1 – energy shifting
a) for system-level arbitrage
b) for local operational constraint management
c) based on forward-looking economic algorithm

2 – solar output smoothing and firming
a) for local feeder voltage management
b) solar-induced power swing mitigation

3 – active VAR/power factor management

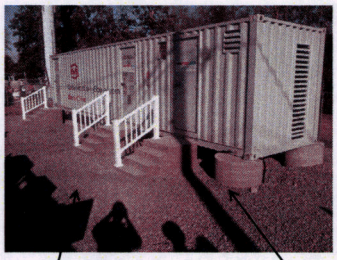
4 – combined algorithms / optimization
a) combined energy shifting and smoothing algorithm
b) use of distributed logic with economic, substation, and local input parameters

McAlpine Energy Storage System

McAlpine Creek Retail Substation, Charlotte, NC

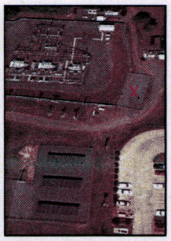
Major system components:
- 200 kW / 500 kWh system capacity
- BYD battery and inverter system
  - All components integrated within one container
- Lithium-iron-phosphate battery (BYD)

Interconnection:
- Located on a 24 kV distribution circuit
- Interconnected immediately outside of the substation
- Adjacent to 50 kW solar facility on McAlpine test circuit



System attributes

- Installation Sep - Oct 2012, in service 4Q 2012



- Interconnected next to a 50 kW solar facility in a planned islandable micro-grid scheme that will use the battery for grid frequency/voltage regulation.

Applications being tested

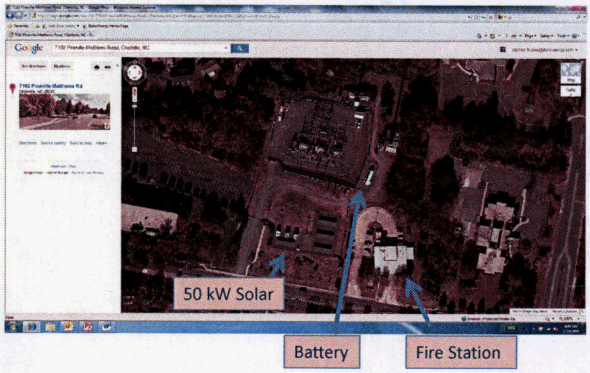
1 – consolidated inverter/battery construction

2 – energy shifting applications
a) dispatched based on schedule, local load peaks, etc

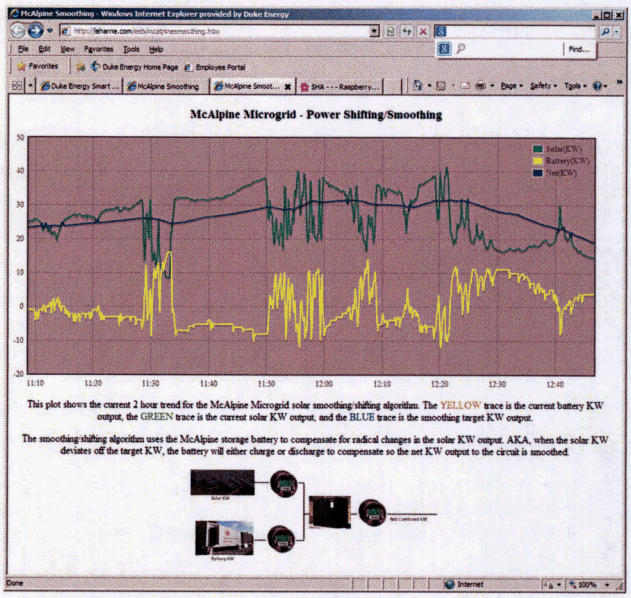
3 – integration with solar in a microgrid
a) will be configured with switches, solar, and load to create an autonomous microgrid that disconnects from the circuit

4 – solar output smoothing/firming

Using Energy Storage + Solar for a Customer and the Grid



- **Provide resiliency to a critical facility**
  - Fire station will be able to operate during periods of grid outages.
- **Utilize utility-owned, utility sited assets**
  - All equipment is owned and operated by Duke Energy.
- **Demonstrate ancillary and grid stability services:**
  - Energy shifting
  - Mitigating solar intermittency at the source

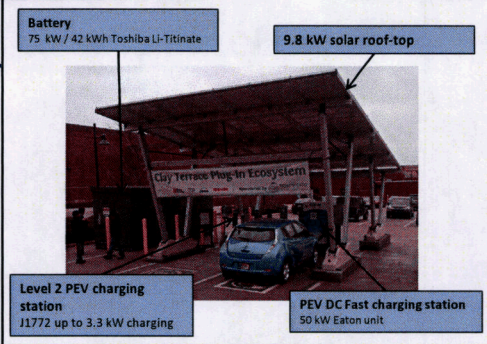


Clay Terrace Energy Storage System

Carmel, IN

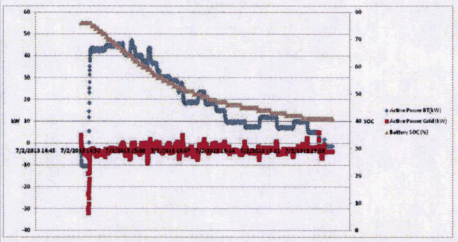
Major system components:
- 75 kW / 42 kWh system capacity
- Toshiba lithium titanate battery
- 9.8 kW roof-mounted solar
- Eaton 50 kW, Siemens 3.3 kW PEV charging stations

Interconnection:
- Behind a commercial meter (customer sited)
- Interconnected at 208 V, 3-phase transformer
- Located in the parking lot of a shopping mall



System attributes

- Installed 3Q 2012, in service 4Q 2012



Applications being tested

1 – Active management of combined solar, storage and PEV charging
a) testing energy management system and sizing of a behind-the-meter system

2 – Energy shifting

3 – Renewable smoothing at the source

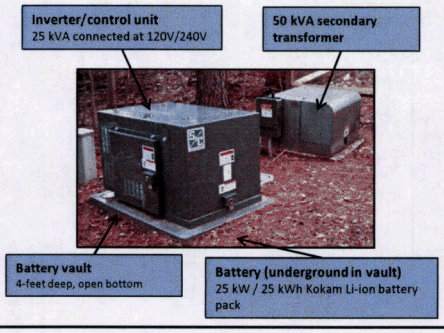
Community Energy Storage Systems

Two units installed

McAlpine 24 kV circuits, Charlotte, NC

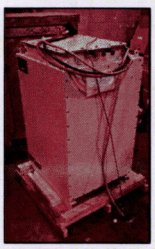
Major system components:
- 25 kVA inverter system – S&C Electric Company
- Kokam 25 kWh / 25 kW lithium ion battery
  - Battery located in underground vault

Interconnection:
- Interconnected at 120V/240V split single phase
- Configured to serve up to five customers on 50 – 75 kVA padmount transformers
  - Initially connected to one customer each for testing



System attributes

- Installation: unit 1 - Oct 2011; unit 2 - Dec 2011



- Remotely operable and monitored via DMS
- Demonstrating underground battery vault configuration

Applications being tested

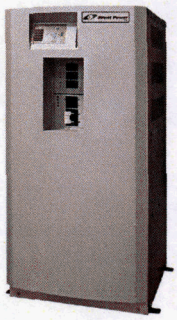
1 – automatic voltage managment
a) automatically injects/consumes VARs to maintain voltage within a specified setpoint

2 – islanding/back-up power
a) automatic islanding during a grid outage

3 – distributed energy shifting
a) various energy shifting applications using a network of distributed batteries

4 – control system for distributed storage
a) using distributed communications network to monitor and dispatch the battery

Home Energy Storage Pilot



9.2 kW
11.52 kWh
Samsung – Li Ion

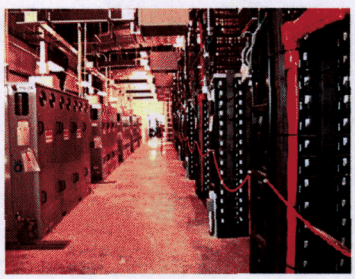
12 kW PV

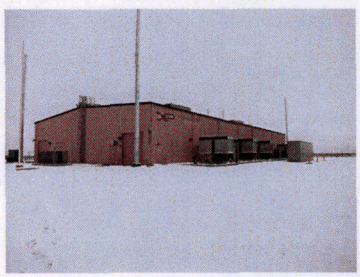
Applications To Be Tested

- Energy Shifting
- Islanding
- Renewable Smoothing at the Source

Overview

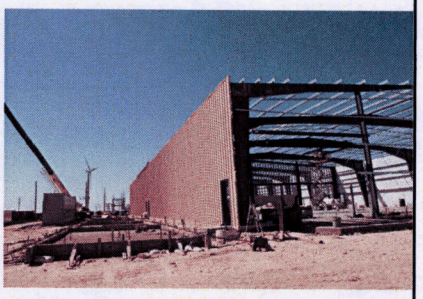
- Developed by Duke Energy and Xtreme Power (XP)
- 36 MW / 24 MWh output
- Advanced lead-acid battery technology
- 24 Dynamic Power Modules with 1.5 MW / 1.0 MWh
- Modules housed in ~ 20,000 sq. ft. building
- Construction Oct 2011 to full operations December 2012
- Primary Commercial Market - ERCOT
  - ERCOT Freq Regulation
  - FRRS Pilot
- Potential future markets:
  - Energy Arbitrage
  - Voltage Support
  - Wind Firming
  - Curtailment Mitigation





Timeline

- **Project**
  - Selected for DOE SGDP Award Nov 2009
  - Site construction began Oct 2011
  - Battery delivery to site starting June 2012
- **System Testing**
  - Commenced September 2012
  - COD December 2012
- **FRRS operations**
  - Began February 25, 2013 under ERCOT FRRS Pilot program
  - Ongoing operational changes as ERCOT evaluated impact of different parameter
- **Performance**
  - Market Participation a function of **Site Availability** & **FRRS performance parameters**



37

Public Utility Commission Texas

Specific Actions:

- ✓ Project 39764 explored general storage issues
- ✓ Project 39657 was the rulemaking to implement SB 943
- ✓ Project 40150 was the rulemaking for ERCOT pilot project authority
- ✓ Project 39917 was the rulemaking for settlement issues
  - ✓ Also exempted storage from retail load fees and 4CP cost allocation methods

✓ **"We need to remove as many impediments to storage as we can."** - Texas PUC, September 2011

38

Walmart

Walmart

Renewable Energy & Energy Efficiency

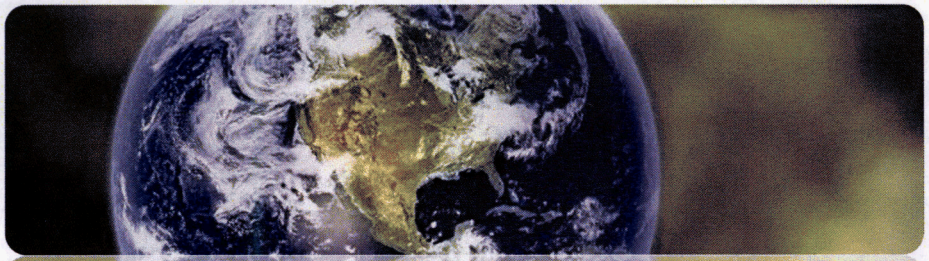
Ken Baker
Sr. Mgr. Sustainable Regulation and Regulation

Walmart in Arizona

- Facilities in Arizona
  - 119 Stores
  - 4 Distribution Centers

- 32,438 Associates
- Purchase over $681million/year from in state suppliers
- Support over 26,232 Arizona supplier jobs

Walmart's Sustainability Goals



Environmental sustainability has become an essential ingredient to doing business responsibly and successfully. As the world's largest retailer, our actions have the potential to save our customers money and help ensure a better world for generations to come. We've set three aspirational sustainability goals:

Be Supplied by 100% renewable energy

Create Zero Waste

Sell Sustainable Products

Walmart

Recently Announced Renewable Energy/Energy Efficiency Goals

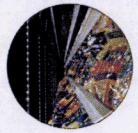
Walmart is on the path to being supplied by 100% renewable energy.

We will take a two tiered approach by both increasing renewable energy usage and increasing energy efficiency with the following commitments:

Commitment 1: scale renewables

Drive the production or procurement of 7 billion kWh of renewable energy globally by December 31, 2020—an increase of over 600% versus 2010

Commitment 2: accelerate efficiency



By December 31, 2020, reduce the kwh/sq.ft. energy intensity required to power our buildings around the world by 20% versus 2010

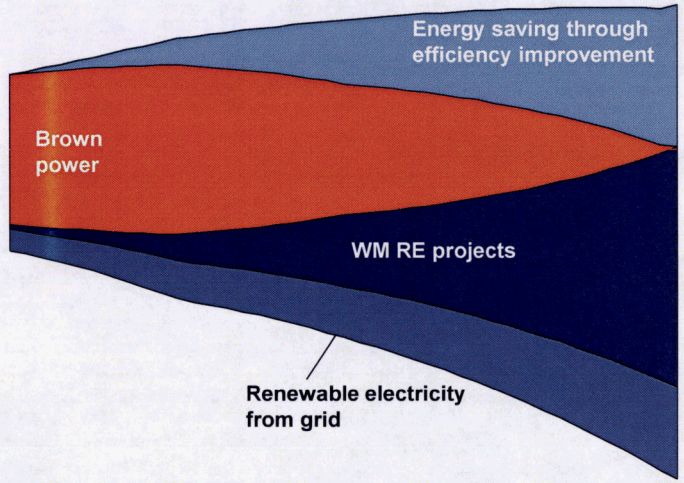
Walmart

Path to 100% Renewable Energy

Reduce through energy efficiency

Replace with renewable energy

Total energy consumption



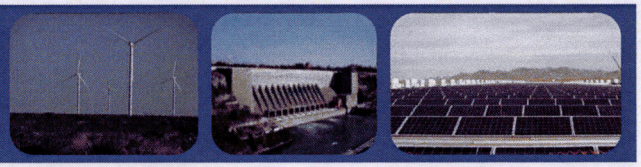
Walmart

Supporting and sourcing renewable energy

Definition of renewable energy

Renewable energy is generated from resources that replenish themselves in short periods of time.

1. **Purchasing**
   PPA for onsite or offsite RE generation



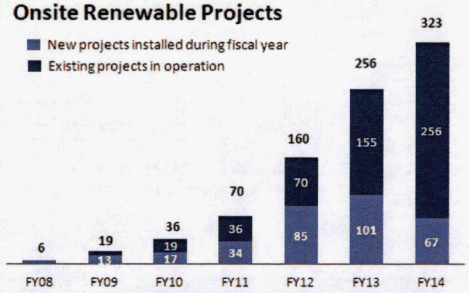
2. **Purchasing**
   Green power purchases, public policy engagement

3. **Producing**
   Onsite renewable energy, both owned and leased

Walmart

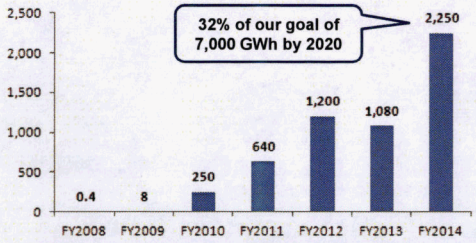
Renewable Energy Progress

Onsite Renewable Projects



Total Renewable Energy

(GWh)



Walmart

Solar Projects

Chino, CA Walmart & Sam's Club

Approximately 255 systems installed in the U.S. to date:

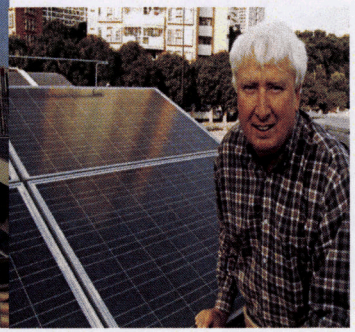
- Smaller systems provide 10%-20% of electricity needs
- Largest rooftop system provides roughly 35%

Current States or Territories with Solar: CA, HI, AZ, CO, NJ, LA, MA, MD, NY, CT, OR, Puerto Rico

Walmart

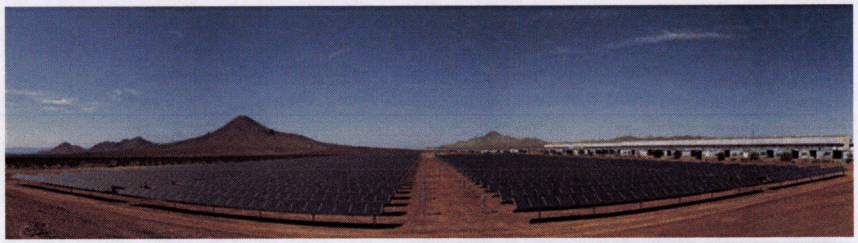
Walmart China 1st Large Solar Project

Mexico, UK, China
Japan, Puerto Rico
Also piloting Solar Projects



Walmart

Solar Systems - Ground Mounted / Roof Mounted



Apple Valley, CA DC

1MW Tracking System

Typical Roof Mounted System

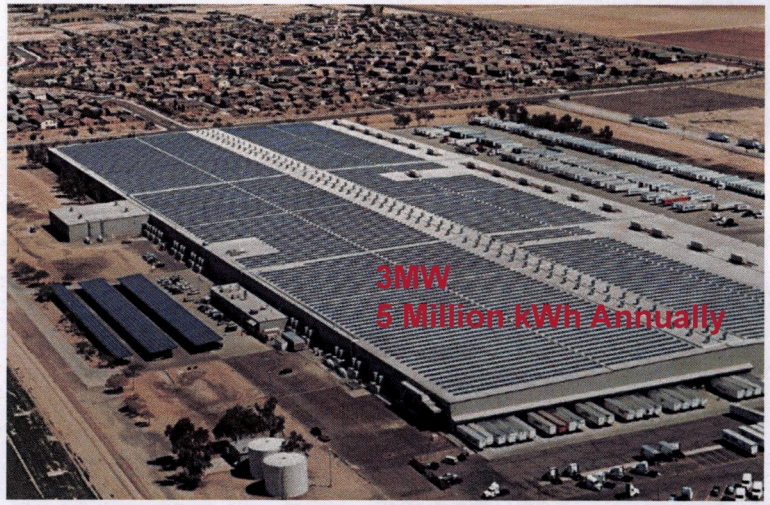
Walmart

ARIZONA

- 36 Solar facilities located in Arizona
- More solar installations than any other state with the exception of CA
- Total installed solar capacity is approximately 25 MW
- Solar energy production is approximately 32 million KWh annually

Walmart

Buckeye, AZ Distribution Center



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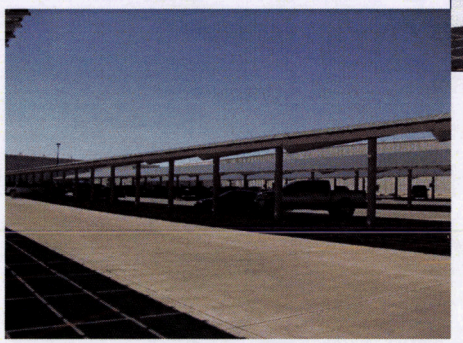
Casa Grande , AZ
Distribution Center

2.1 MW System
3 Million kwh/year

Walmart

Casa Grande , AZ
Distribution Center



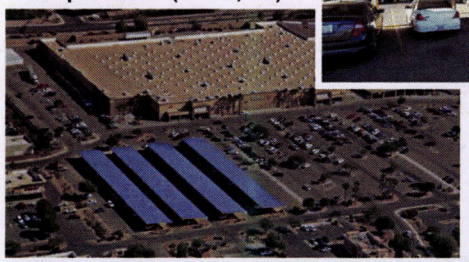
New Carport Concept

Walmart

Renewable Highlight: Solar Carports - 10 stores in Arizona completed in 2013

Supercenter (Glendale, AZ)

Supercenter (Yuma, AZ)



Sam's Club (Yuma, AZ)

Walmart

Wind

- Walmart's first onsite large wind project - 1 MW turbine at Red Bluff, CA DC was installed in 2012
- Turbine Height: 265 ft tower height, 250 ft blade diameter
- Electricity Production:
  - 2.2 million kWh each year
  - Approx. 15-20% of the DC's yearly electricity usage
  - 1500 metric tons of GHG emissions eliminated

Walmart

Renewable Energy: Wind

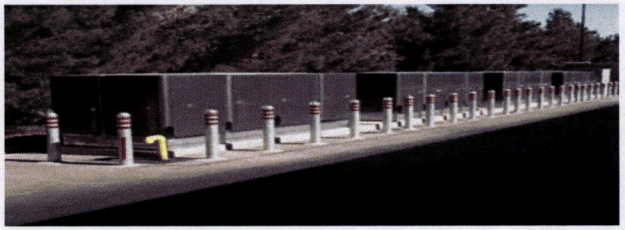
Walmart US & Mexico Wind Farm Energy Purchases

US and Mexico

- ✓ 348 stores in Mexico are supplied by wind power which provide roughly 17% of their electricity needs
- ✓ 350 Stores in Texas were supplied by wind power which provided roughly 15% of their electricity needs. This deal expired in March of 2013. We have made the decision to explore other projects. We are working on other wind deals and our appetite is strong for additional wind renewables.

Walmart

Renewable Energy: Fuel Cells



- 37 existing fuel cell locations in California
- Fuel cells supply 40% to 60% of the site's electricity
- Walmart purchases the renewable energy
- Renewable Energy as fueled by Biogas

Walmart

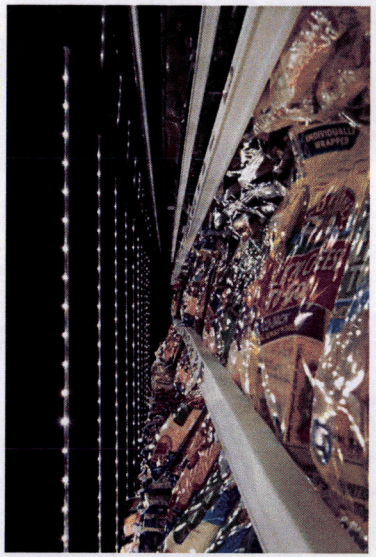
Energy Efficiency

- Daylighting
  - Skylights
  - Electronic Dimming Balasts
  - Computer Controlled Daylight System
  - Energy Management System

Walmart

Energy Efficiency

- T-8 fluorescent lamps
- New Construction and Remodels have LED lighting in refrigeration cases, parking lot signage, outdoor lighting, and occupancy sensors.
- Electronic Commutative Motor Retrofits.
- High efficiency HVAC
- White membrane roofs
- 70% of hot water needs met through heat reclaim system



Walmart

Capital Investment: Efficiency Projects

During 2013, we accelerated the program to **retrofit open refrigeration cases with doors**. This effort alone led to a decrease of more than 50 million kilowatt hours. We're working to increase the scope of closed refrigeration in the markets we serve.

Walmart continued to accelerate the deployment of **LED technology** in lighting applications in our stores. Nearly all lighting in new prototypical buildings is LED in the following markets: Brazil, Mexico and Central America, Chile, China, Japan and U.K.. All new Supercenters in the United States will have sales floor LED.

Walmart

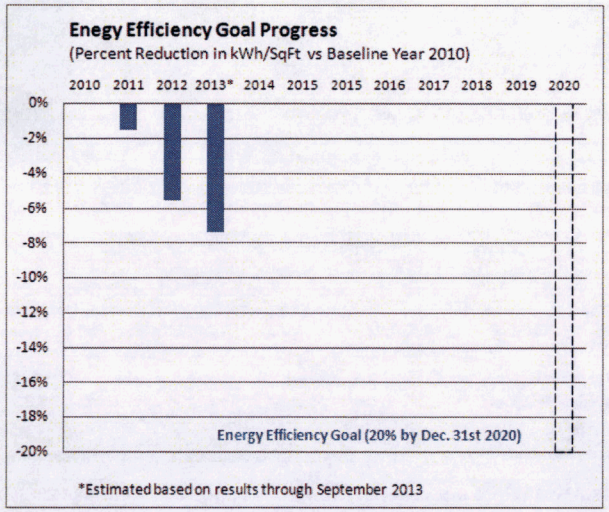
Efficiency Highlight – South Euclid, Ohio

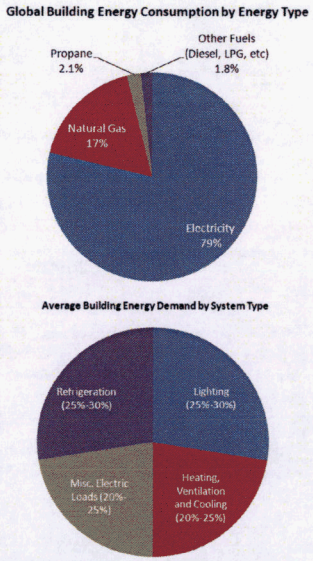
Walmart U.S. opened its **first 100 percent LED supercenter** in South Euclid, Ohio, which consumes 34 percent less energy than a conventional store. This marks a milestone for Walmart U.S. because it goes beyond sales floor LEDs to include all lighting throughout the building and parking lot.

LED are in every refrigerated case, parking lot and even in the vending machines. ⟶

Walmart

Energy Efficiency Goal Progress





Walmart

Renewable Energy: Adding it All Up

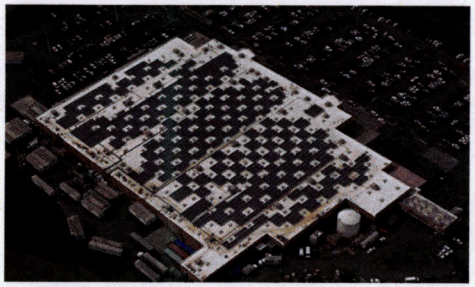
- **We're producing/procuring over 1 Billion renewable kwh/year globally**
  - Would serve over 78,000 American homes
- **In the US, we're an EPA Green Partners Leader**
  - 2nd largest purchaser among US retailers
  - Largest onsite generator among retailers; 2nd overall
  - 3rd largest purchaser in the Fortune 500

Walmart

What's Next?

Developing 2020 Vision for Energy Efficiency & Renewable Energy

- Drive innovation, scale, lower cost
- Think global
- Two pronged attack
  - Reduce through energy efficiency and load management
  - Provide the rest with renewable energy



Walmart

Thank you!

Walmart

SolarCity

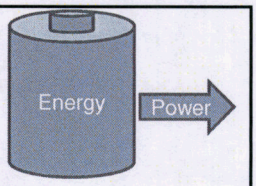
Combining PV and Grid-Interactive Storage

Meghan Nutting – Director of Policy and Electricity Markets

Why PV+Storage

1. **Reduced Cost to Deliver Clean Energy** – Site acquisition, financing, permitting, installation, interconnection, and communication costs are all significantly reduced when storage is jointly located with PV.
2. **Co-located Value** - The potential value of energy storage is greatest when located adjacent to the generator or the load, and ideally adjacent to both.
3. **Enables Widespread PV** - At extremely high PV penetration, storage can levelize production and enable further PV deployment without impacting the grid
4. **Decentralized Stability** – Local, dispatchable generation means critical systems means less grid variability, and backup power when needed

Energy Storage Attributes



Two Key Attributes

- Power – kilowatts (kW) or megawatts (MW)
- Energy – kilowatt-hours (kWh) or megawatt-hours (MWh)

Energy is often quantified as *duration* or *run-time*

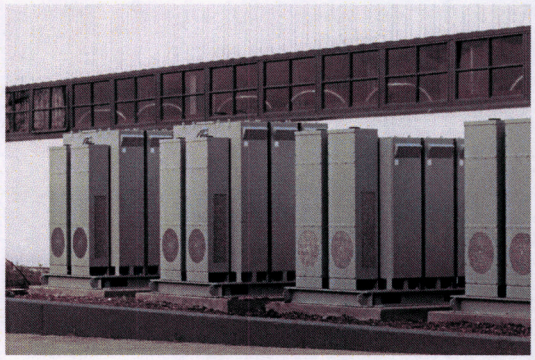
Example: A 5 kW, 3 hour duration battery holds 5 kW x 3 hours = 15 kWh

- **Cycle life** – Number of charge/discharge cycles until battery is considered dead
- **Calendar life** – Time until battery is considered dead
  - 8-15 years for most technologies
- **Energy Density / Physical Footprint / Weight**
- **Operating Temperature –** typically 30 – 110 F

SolarCity Slide 3

Commercial Installations

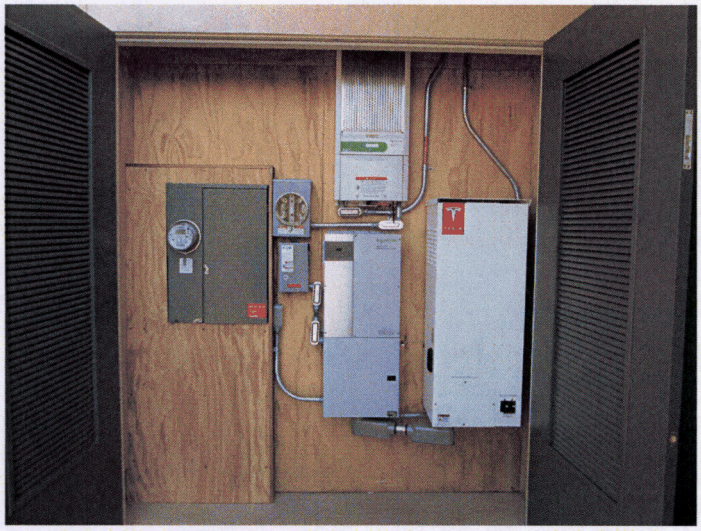
30 kW / 60 kWh



200 kW / 400 kWh

SolarCity Slide 4

Residential Installations



5 kW / 10 kWh – Lithium Ion

Operating Experience – Demand Management

SolarCity MySolarCity

HOME MONITORING SUPPORT SHARING

Commercial Demonstration Site
Northern California

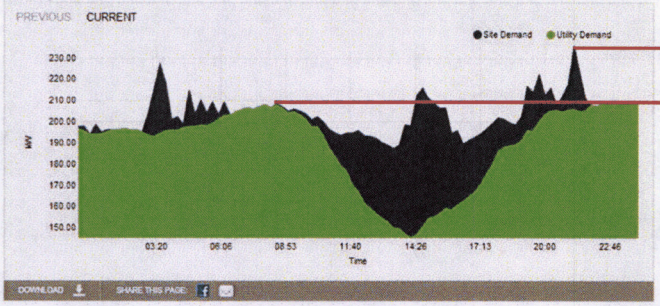
MY ACCOUNT | LOG OUT

DemandLogic Peak Reduction
February 02, 2014 10.3 hrs 100%

Solar: 354.2 kW Battery: 30 kW

DAY MONTH YEAR

PREVIOUS CURRENT



Old Max Demand

New Max Demand

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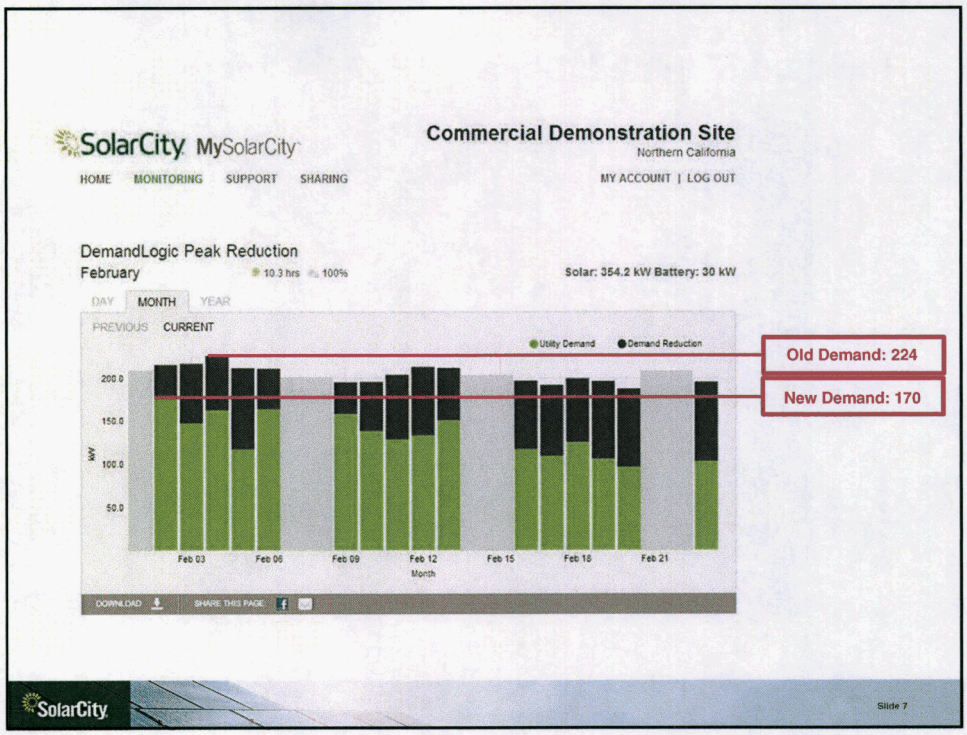
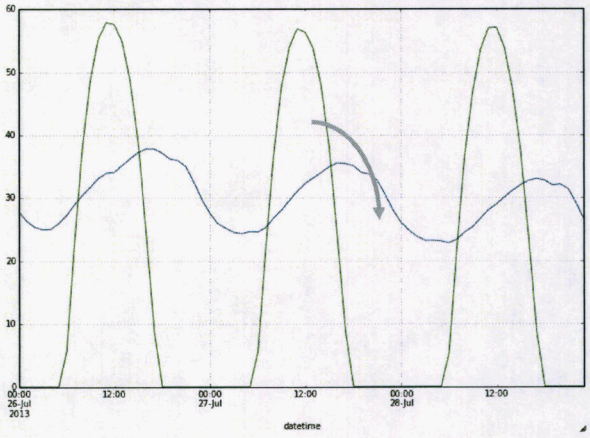


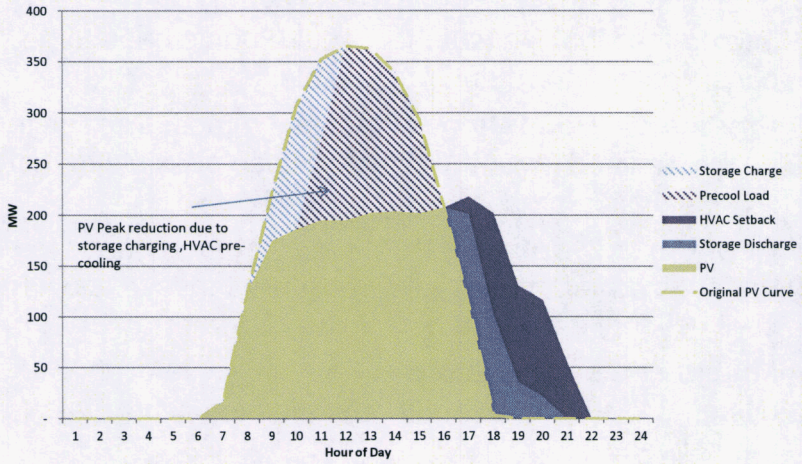
Bulk Storage/Time Shifting/Self Consumption

Concept – Charge during the day, discharge at night



This is the end game

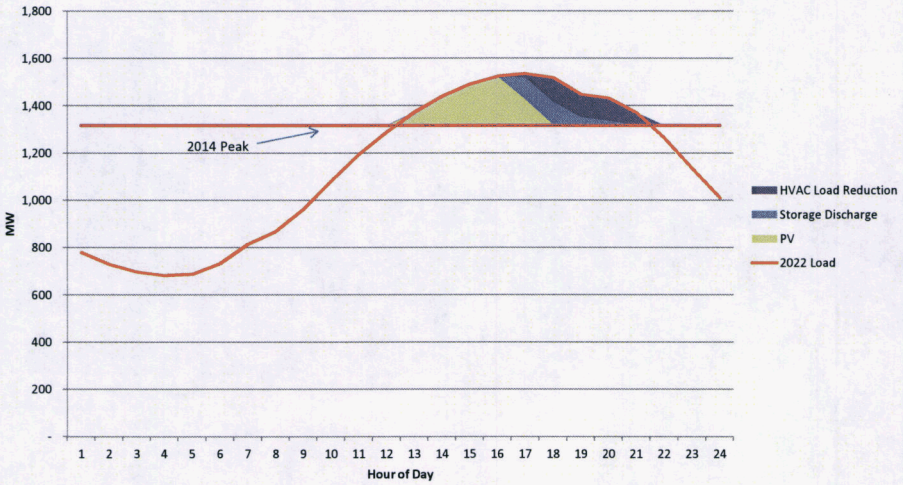
Combined Customer Side Solutions Provide a Path to Integrating Renewables…



SolarCity

Slide 9

…and Addressing Capacity Needs



Source: SolarCity Proposal for SCE Living Pilot Symposium

SolarCity

Slide 10

Solutions to Deployment Barriers

- **Interconnection Costs and Requirements –** Interconnection costs need to reflect true cost interconnection evaluation. Requirements need to be consistent, codified and predictable.
- **Predictable Permitting** – Permitting process needs to be streamlined, over-the-counter when possible to match PV installation process.
- **Harmonized Tariffs** – Treatment of storage needs to be harmonized with renewable generator tariffs to allow for bi-directional energy flows.
- **Multiple Income Streams** – Need policy to align customer benefits with grid operation and wholesale market value.

SolarCity Slide 11

SolarCity mnutting@solarcity.com

ABENGOA SOLAR

Innovative Technology Solutions for Sustainability

ABENGOA

Grid Integration Challenges and the Role of CSP with Thermal Energy Storage

March 20, 2014

Confidential

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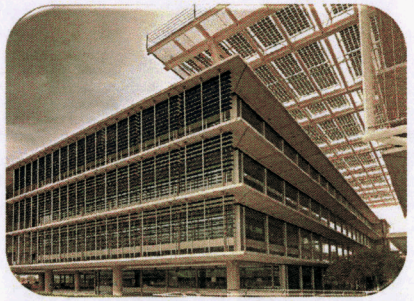
ABENGOA

Abengoa

Innovative solutions for a sustainable world

"Abengoa is a technology company that applies innovative solutions for sustainable development in the infrastructure, environmental and energy sectors, creating long-term value for our shareholders with a management model based on fostering entrepreneurial spirit, social responsibility, transparency and rigor"

- **Abengoa:** **26,402 employed globally**
- **2013 Revenues:** **$10.198 billion (7.356 B€)***
- **Listed:** **Madrid Stock Exchange NASDAQ**
- **U.S.:** **Strategic part of Abengoa's growth plans:**
  - Abengoa's second largest market
  - In 2013, the U.S. accounted for 28% of revenues



Abengoa's headquarters in Palmas Altas (Seville)

*Considering a current exchange rate of 1.39 USD / EUR.

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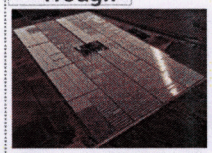
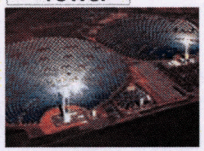
Abengoa Solar's CSP Technologies

	CSP with/without storage			Hybrids
	Trough	Tower	Storage	ISCC
				
Proprietary Technology	▪ Trough collectors ▪ Assembly methodology ▪ Solar field layout ▪ Molten salt storage ▪ Mirror technology	▪ Heliostats ▪ Mirror technology ▪ Receiver ▪ Solar field layout	▪ Molten salt storage ▪ Steam storage	▪ Collectors or heliostats ▪ Receivers ▪ Mirror technology ▪ Assembly methodology ▪ Solar field layout

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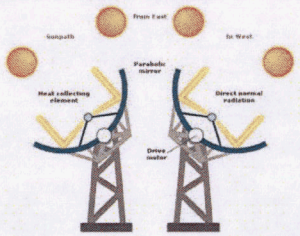
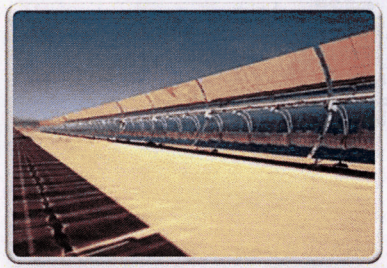
Parabolic Trough

Operating principle

- Parabolic mirrors are used to track the sun and concentrate sunlight onto receiver tubes placed along the focal line
- A heat transfer fluid is circulated through the tubes, which is then pumped through heat exchangers to generate steam
- The steam is used to generate electrical energy in a conventional steam turbine





Features

Track record	30 years in operation
Key features	Modular, TES, hybrids
Abengoa experience	690 MW in operation; 760 MW under construction; 100 MW under development

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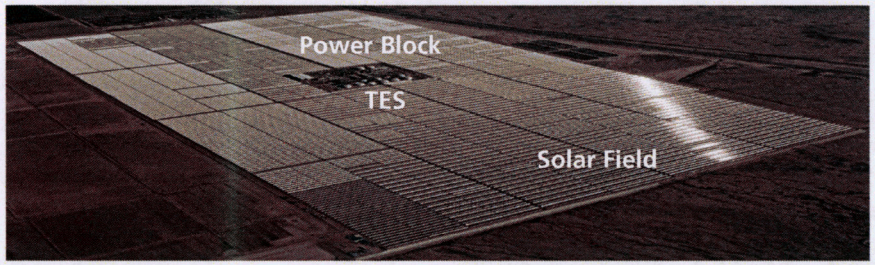
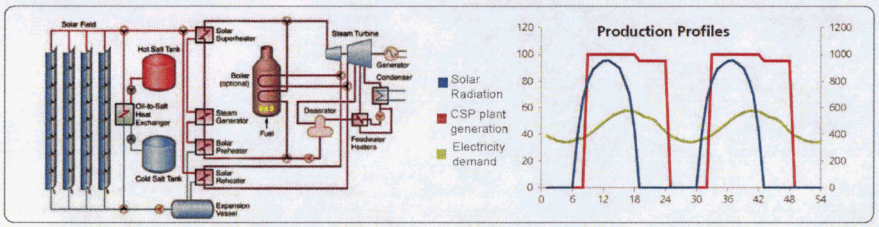
Solana 280 MW CSP Plant

Parabolic Trough w/TES





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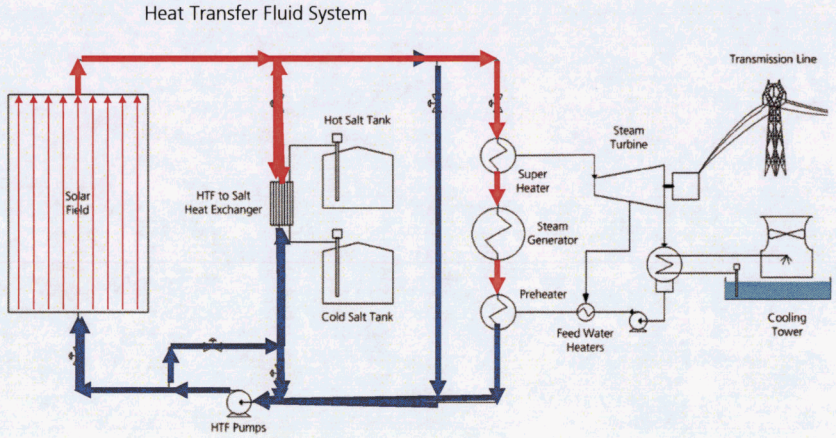
Parabolic Trough Process flow Diagram
with Indirect Thermal Energy Storage



Power Generation from TES ıtion

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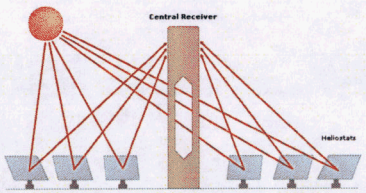
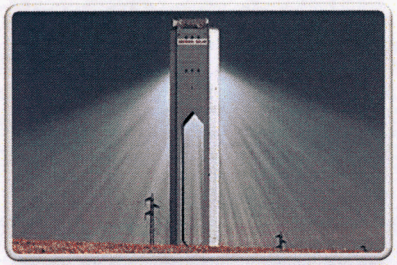
Power Tower

Operating principle

- A circular array of heliostats (2-axis tracking mirrors) is used to concentrate sunlight to a central receiver system mounted on the top of a tower
- The concentrated solar energy is used to generate steam that feeds a conventional turbine to generate electricity





Key features

Track record	Five years in operation
Key features	High temperatures / efficiency,
Abengoa experience	31 MW in operation, 50 MW under construction, 500 MW under development

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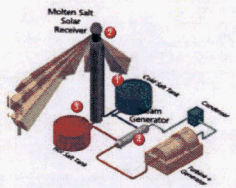
Molten Salt Tower

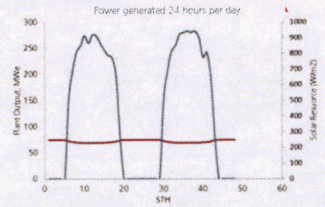
Operating Principle



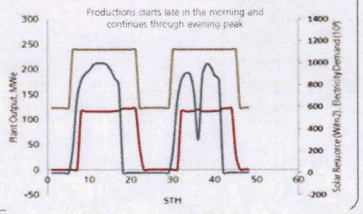
1. Cold molten salt (at approx. 260º C) is pumped from the cold salt tank to the solar receiver
2. The solar field heats the molten salt up to 560º C in the solar receiver
3. The hot molten salt is stored in the hot salt tank
4. When electricity is needed, hot molten salt exchanges heat with the water in the steam generator:
   - Molten salt is cooled and stored in the cold tank
   - Water is transformed into high pressure temperature steam
5. The superheated steam runs through a turbine that generates electricity

Production Profiles

a Base Load Solution



b Energy Shifter Solution



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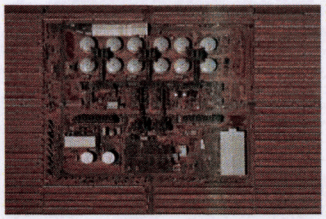
What is thermal energy storage?



- Thermal energy storage is simple and efficient.
- Hot fluid is kept in insulated tanks that can retain that heat for days with minimal losses.
- Stored heat can easily be converted to steam and create electricity at any time, providing tremendous value to utilities and grid operators.
- It can respond quickly to variable wind or solar, as well as to mitigate rapid changes in energy demand that would otherwise require expensive, fast-acting fossil plants.
- Dispatch capability provided by storage combined with a CSP plant's ability to quickly increase or decrease power output makes CSP an excellent complement to variable energy resources such as wind and PV.

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Hybrids

Operating Principle

- A hybrid plant is a combination of a conventional plant and a solar field
- During the day, the solar field provides the steam cycle with a certain percentage of the energy it needs, substituting for fuel
- During the night, the conventional plant operates normally

Key Features

- Solar technology can be adapted to fit local infrastructure and demand profile or new plants
- Able to cover base-load electricity demand
- Large potential in emerging markets

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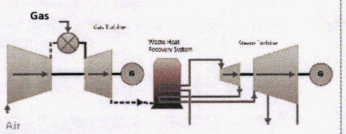
Abengoa Solar
Hybrid Products – The Concept

Hybrid Plant

Combined cycle

- ✓ High fossil fuel to electricity efficiency (50-60%)
- ✓ Base/Mid/Peak Load and quick answer to electricity needs
- ✓ Medium pollutant 0.45 ton CO2/MWh

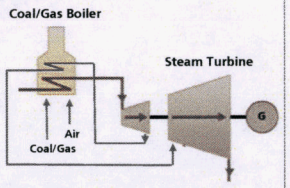


Coal Plant

- ✓ Cheap fuel source but medium efficiency (30-40%)
- ✓ Base Load Solution
- ✓ High pollutant 1 tonCO2/MWh

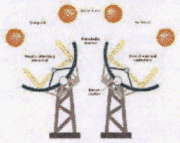
Gas Plant

- ✓ Medium efficiency (40%)
- ✓ Mid/Peak Load Solution
- ✓ Medium pollutant 0.8 ton CO2/MWh



+

Solar Field



Stage	T (-F)	P (psia)
HP	711	1450
IP	717	242

Or

Stage	T (-F)	P (psia)
HP	986	1700
IP	974	368

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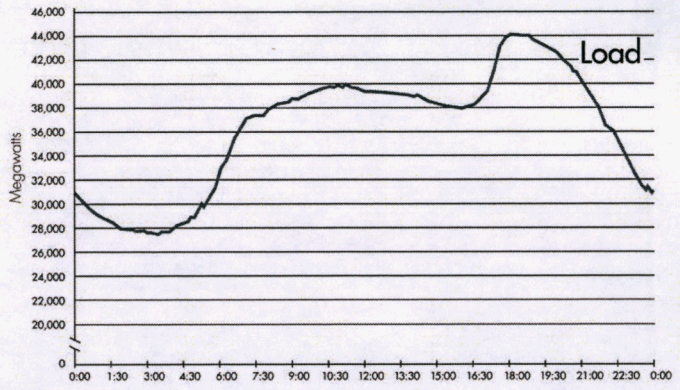
Load profile — sample winter day in 2020



California ISO

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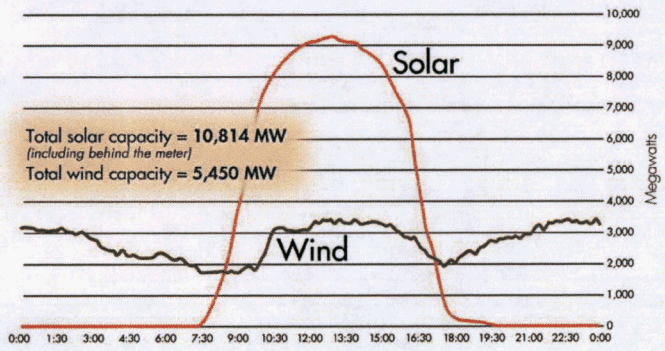
Wind & solar profiles — sample winter day in 2020



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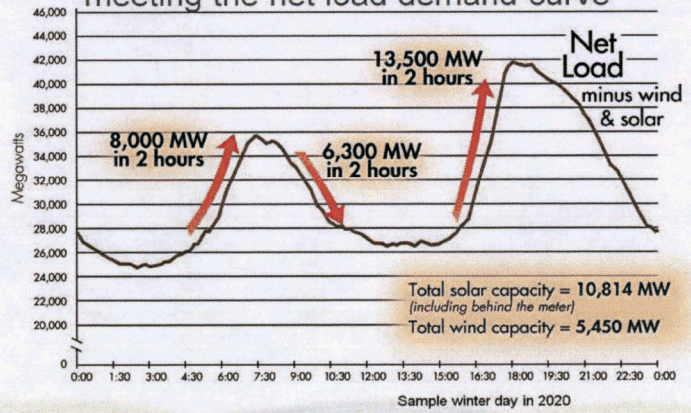
Flexible resources will be essential to meeting the net load demand curve



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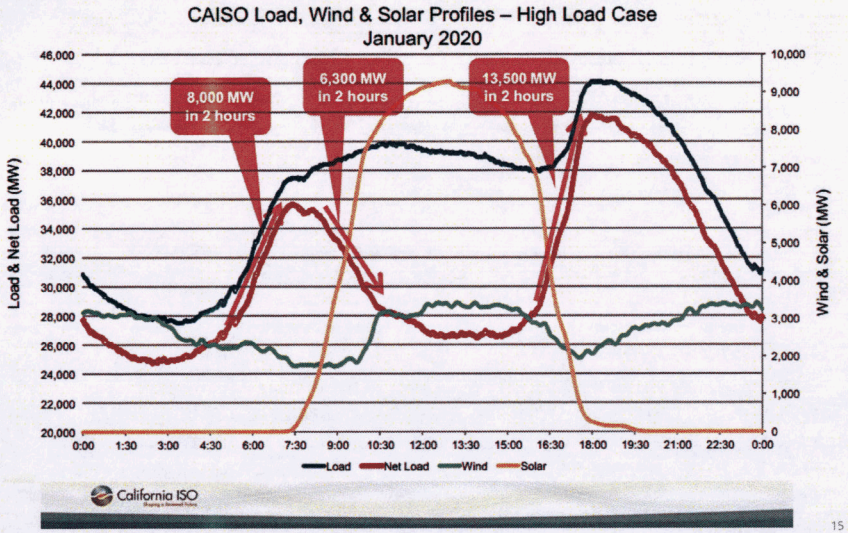
Ducks, camels, and bears



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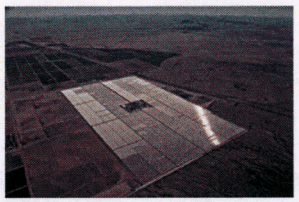
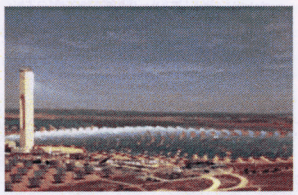
CSP – a conventional power plant fueled by the sun





- CSP converts solar energy into electricity while solving two growing problems associated with solar power: variability and grid integration.
- CSP can inexpensively and efficiently store solar energy in thermal form, enabling projects to operate day or night, cloudy or bright.
- CSP with integrated thermal energy storage also provides:
  - flexibility to grid operators and utilities by shifting electrical production to the times when it is most needed,
  - vital grid capabilities, called "ancillary services" (such as spinning and non-spinning reserves) essential for a reliable electric supply.
- Storage enables CSP plants to operate just like natural gas plants, but without the air emissions.

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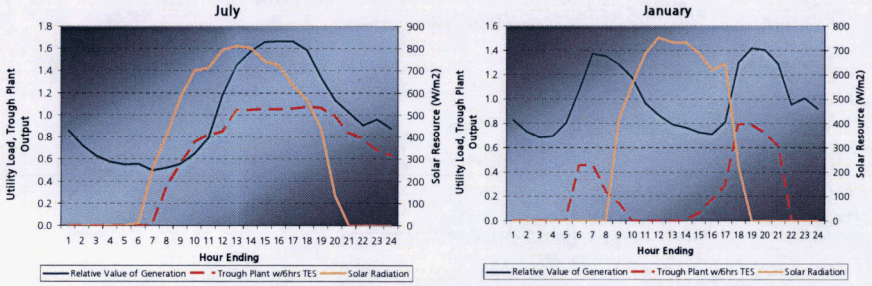
Firm Dispachable Power

Solana Solar Plant With Storage vs. APS Utility System Load



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CSP resources with TES can provide:

- Voltage Support
- Active Power Control
- Ancillary Services
  - Responsive Reserves
  - Spinning and Non-Spinning Reserves
  - Reg-Up and Reg-Down Ramping
- Inertia/Frequency Response
- Storage for over-generation conditions

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Geothermal / GeoExchange

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• GEOTHERMAL • SOLAR •

Glenn Meyers

www.VerdeSolAir.com

Geothermal / GeoExchange

- What Is It?
- How Does It Work?
- Why Do You Want It?

It's Not This...

What Is Geothermal/GeoExchange?

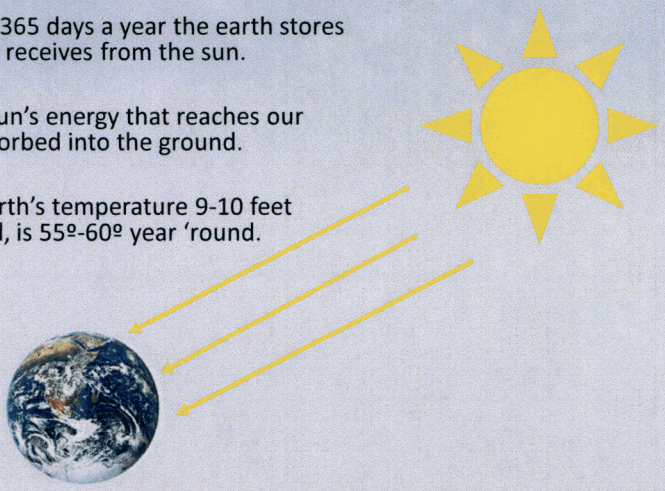
Geothermal comes from the Greek words *geo*, meaning earth, and *therme*, meaning heat. Geothermal heat, therefore, is literally "Earth heat."

In A Nutshell:

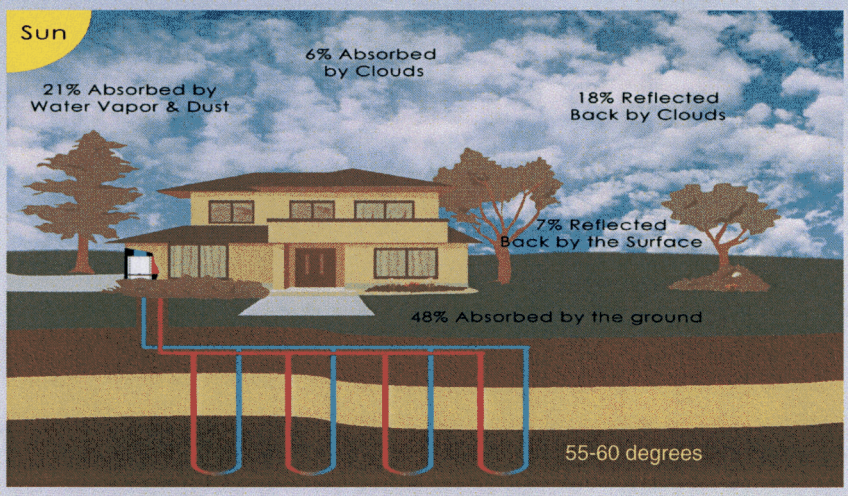
- GeoExchange systems take (or exchange) heat from one location and moves that heat to another location.

How Does It Work?

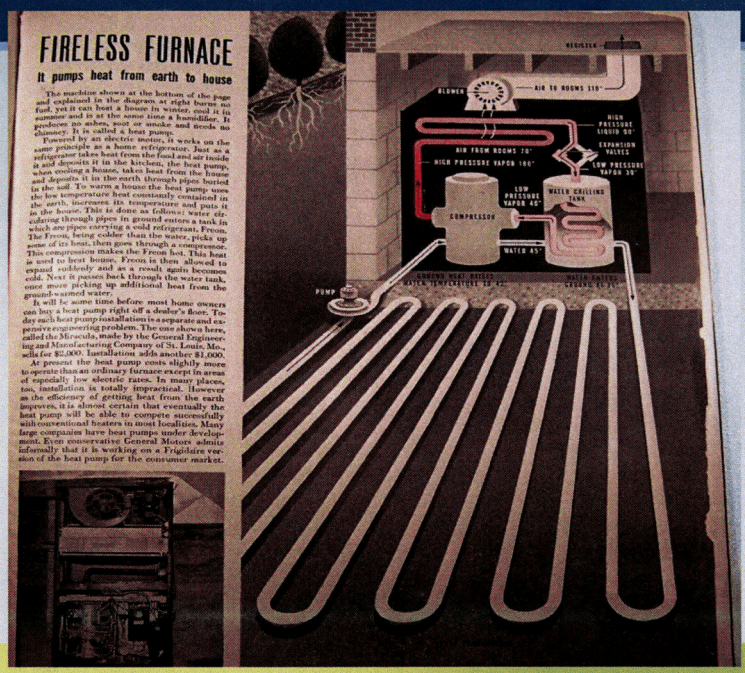
- All day long, 365 days a year the earth stores the energy it receives from the sun.
- 48% of our sun's energy that reaches our planet is absorbed into the ground.
- In AZ, the earth's temperature 9-10 feet underground, is 55º-60º year 'round.



How Does It Work?

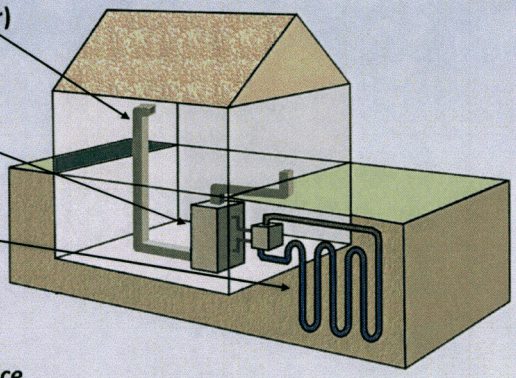


63 years ago… GEOTHERMAL was being installed in homes!



Three Important Parts

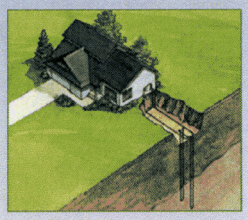
- **The Ductwork (or Radiant Floor)**
  - Air Return
  - Air Supply
- **The GeoExchange Unit**
  - Compressor
  - Pumps
- **The Ground Loop**
  - Filled with a heat transfer fluid



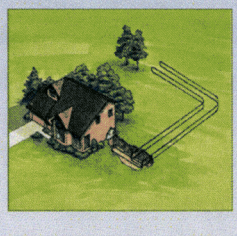
IF INSTALLED PROPERLY, GeoExchange systems can reduce maintenance costs by more than half.

The GeoExchange Ground Loop

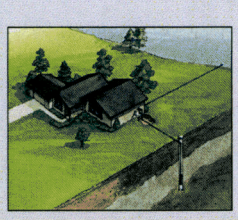
- Vertical Loop



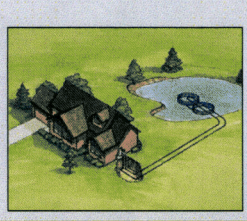
- Horizontal Loop



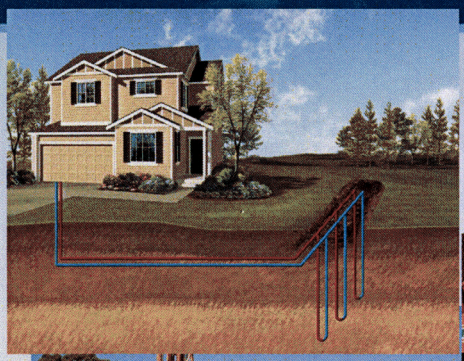
- Open Loop

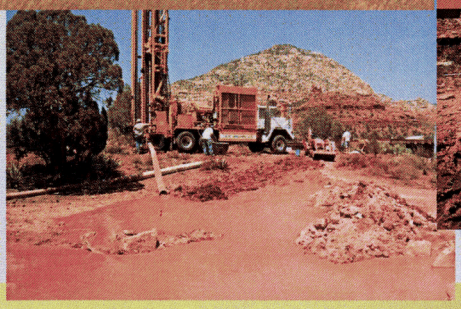


- Pond Loop

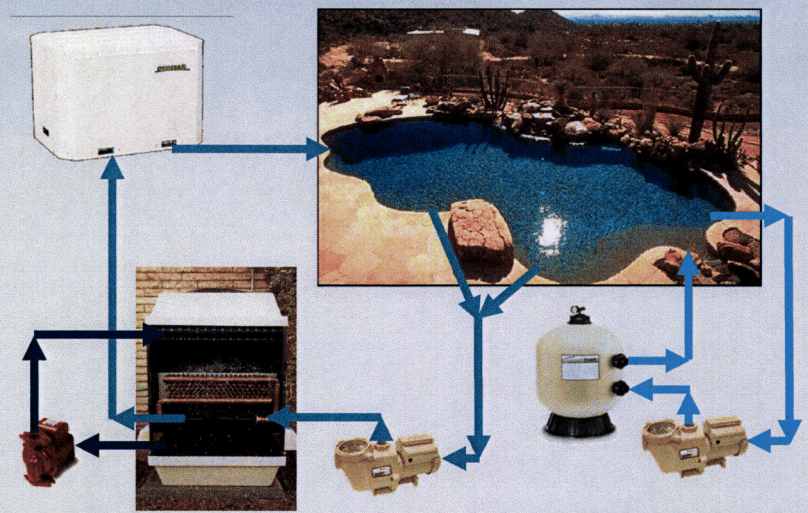


Vertical Drill





Pool Tied Hybrids



Why Do Homeowners Want It?

Save money.

- Cut energy cost's by **50%-70%** compared with conventional systems.
- Cut maintenance cost's by **50%** or more compared with conventional systems.
- Save **tens of thousands** of dollars over the life of the system, and save even more as energy costs increase.
- GeoExchange systems have the lowest life cycle cost of any type of HVAC system.

Why Would Utilities Want It?

Save money.

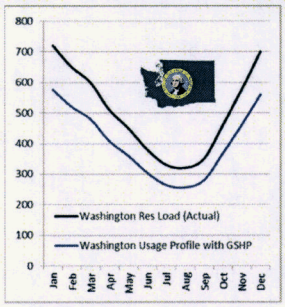
- Levels out the peaks in demand the more people install ground source heat pumps in their home

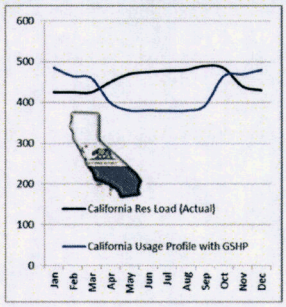
Utility impact

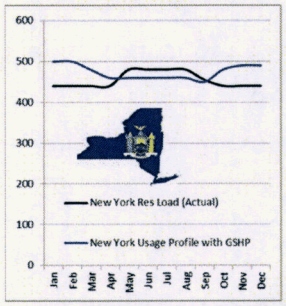
Typical Residential Load Profiles

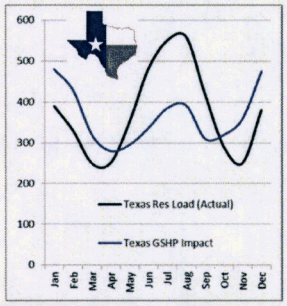
Before & After Installing GSHPs

Blue Lines are only representative samples based differences in typical equipment power usage and seasonal regional heating & cooling hours









Why Would Utilities Want It?

Save money.

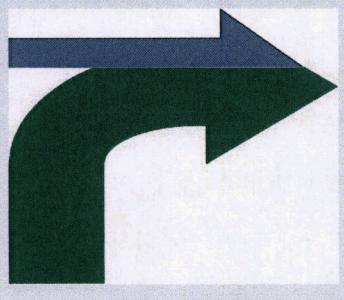
- Levels out the peaks in demand the more people install ground source heat pumps in their home.
- Each saved kilowatt also saves additional lost due to transmission.

The most efficient cooling, heating, & hot water system

- Heating efficiency: ***Up to 400%.***
- Cooling efficiency: ***Up to 38 SEER.***

One unit of energy (electricity) required to operate the unit.

Four units of free energy from the ground.



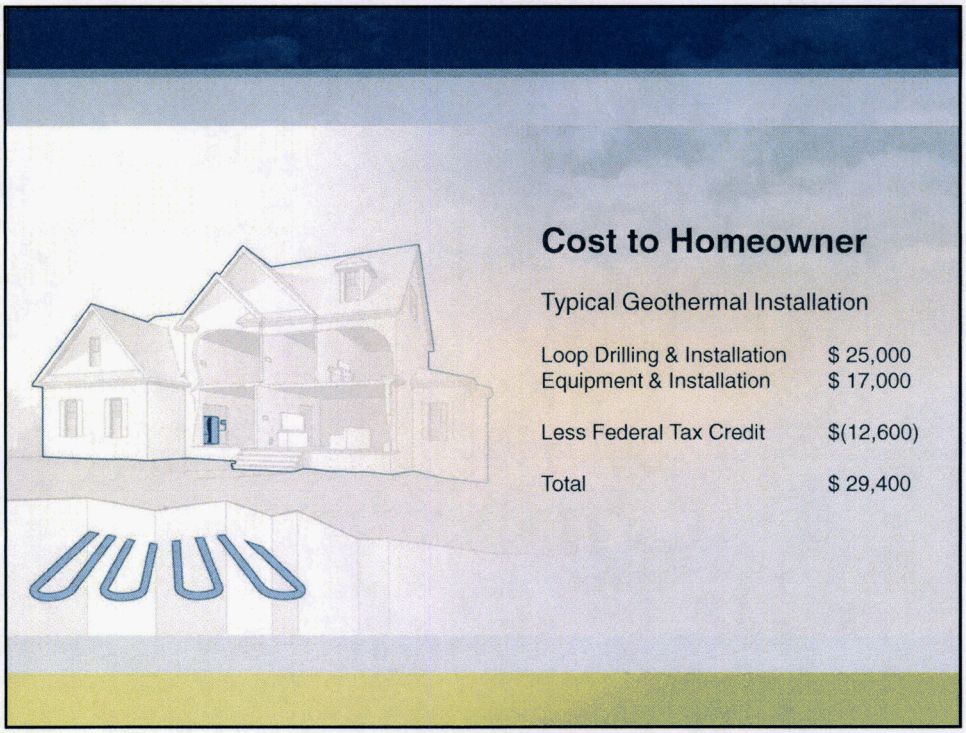
Five units of energy delivered to your home.

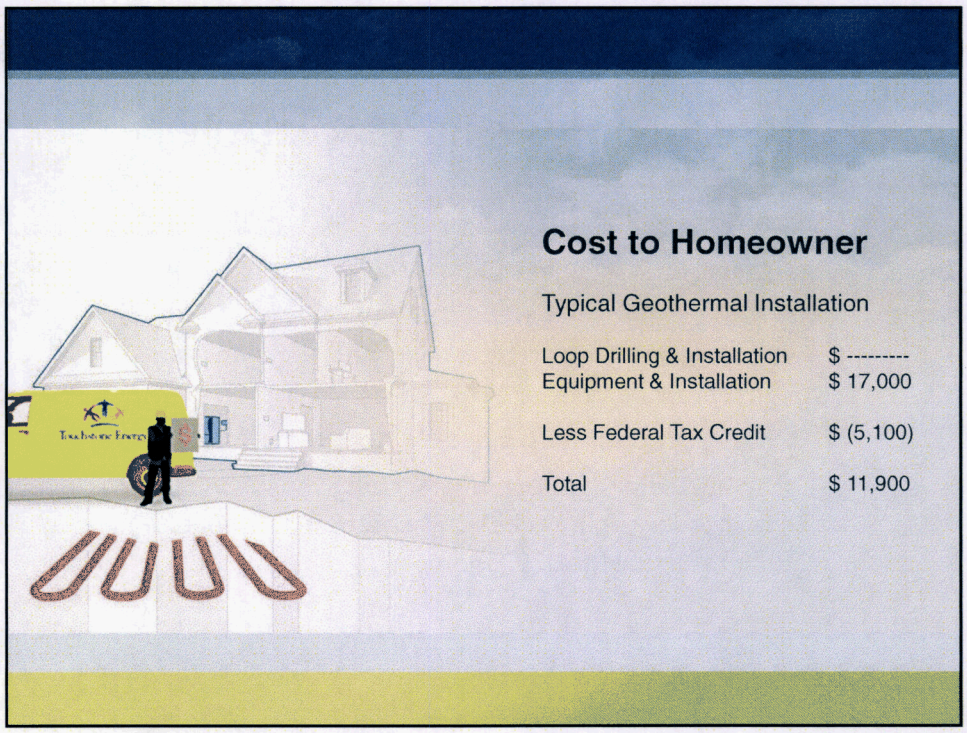
400% ***Efficient***

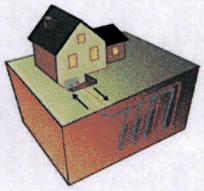
Why Would Utilities Want It?

Save money.

- Levels out the peaks in demand the more people install ground source heat pumps in their home.
- Each saved kilowatt also saves additional lost due to transmission.
- Many potential customers in Northern AZ.
- An additional opportunity for long term revenue as realized by many utilities in Oklahoma, Minnesota, Illinois, New Mexico, and others.


Cost to Homeowner
Typical Geothermal Installation
Loop Drilling & Installation $ 25,000
Equipment & Installation $ 17,000
Less Federal Tax Credit $(12,600)
Total $ 29,400

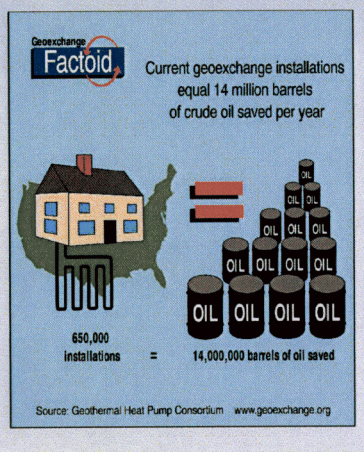

Cost to Homeowner
Typical Geothermal Installation
Loop Drilling & Installation $ ---------
Equipment & Installation $ 17,000
Less Federal Tax Credit $ (5,100)
Total $ 11,900

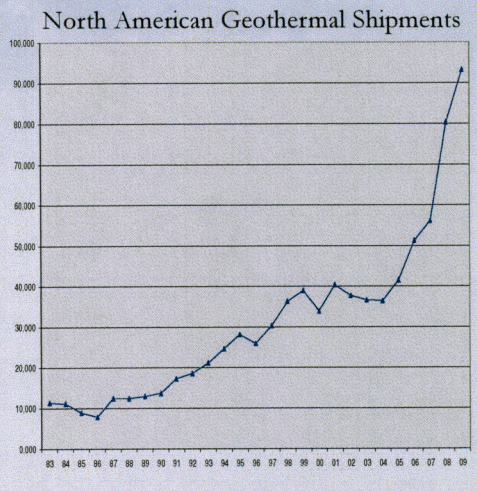
The Utility	The Homeowner	The Loop Contractor	HVAC Contractor
• Lower Cost-to-Serve by 20% to 40% • Diversified Asset Portfolio: Long Term, No Maintenance • 100+ Year Cash Flow • Improved Member Benefit • Real Peak Load Reductions • Off-Peak Load Growth • Renewable Energy Credits • Eliminate Costly Rebates	• 30% to 50% Lower Energy Costs • Improved Comfort with Multi-stage & Variable Speed Systems • Increased System Lifecycle from 12 Years to 30+	• Standardized Work Packages • Lower Overhead • Longer Range Work Scheduling • Increased Asset Utilization • Reliable Partnerships	• Increased Replacement Opportunities • High Quality Work Opportunities • Stable, 4-Season Work • Reliable Partnerships • Happy Customers
			
Win √	***Win √***	***Win √***	***Win √***

Utilities Who Develop and Own Geothermal Loop Fields:

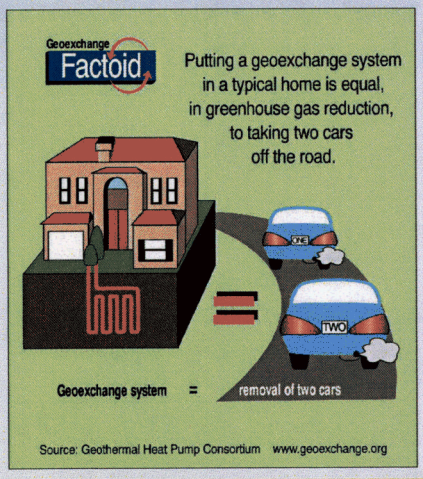
- **Create Cash Flow**
- **Grow Asset Portfolios**
- **Shave Peak Loads**
- **Grow Net Sales**
- **Improve Demand Response and Load Shedding**
- **Earn Renewable Energy Credits (1 per MWh)**
- **Improve Customer Experiences… Dramatically**

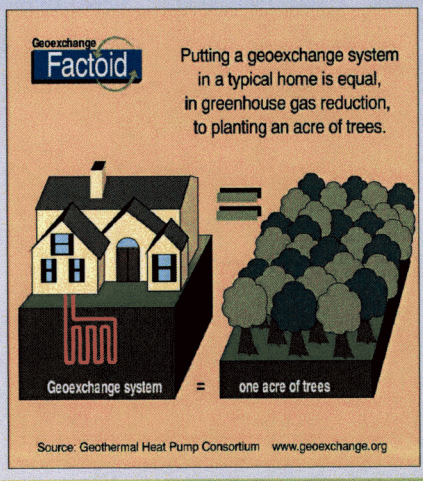
Energy Independence





Why Do You Want It?





In Summary

GeoExchange Technology is:

- Renewable
- Clean
- Combustion-free
- Safe
- Aesthetically pleasing
- Quiet
- Proven
- New construction or renovations
- Nearly any size lot

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Glenn Meyers

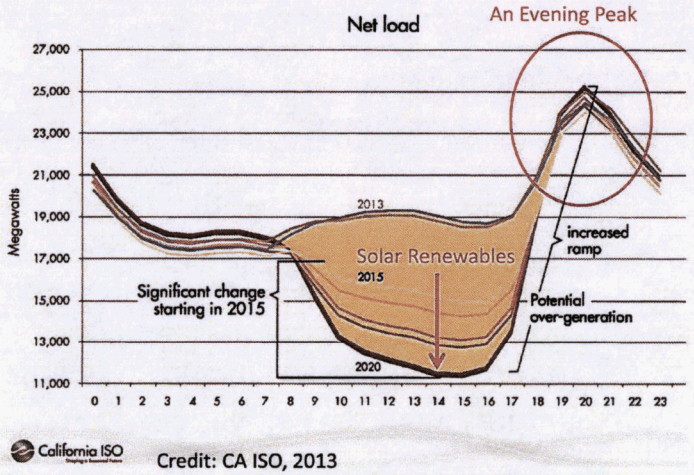
Electrical load shifting for residential and commercial buildings using thermal storage

Benjamin L. Ruddell, et al.
Arizona Corporation Commission
March 20th, 2014

SRP® ASU Arizona State University EPRI

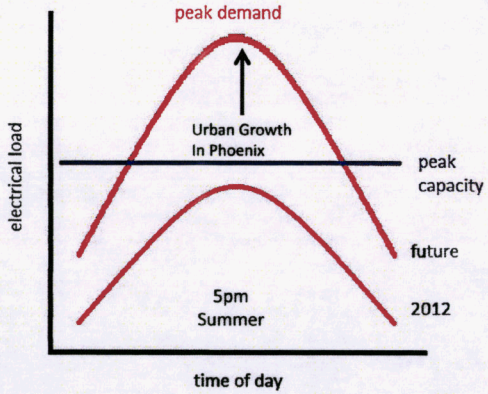
The "Duck" Curve (in California)

Growing need for flexibility starting 2015



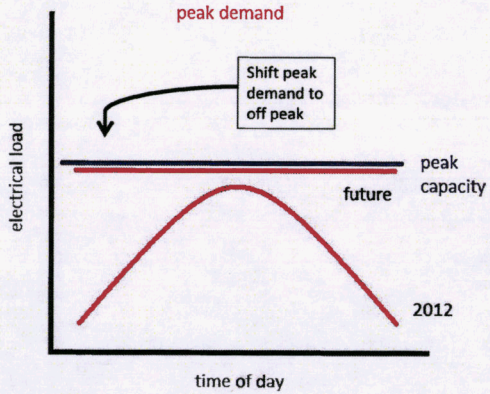
Credit: CA ISO, 2013

How to Solve Excess Peak Demand?
(in Arizona, especially summer 5pm A/C peaks)



- Add peak grid capacity?
- Suppress demand?
- Distributed generation?
- Import power?
- Shift demand?

How to Solve Excess Peak Demand?
(in Arizona, especially summer 5pm A/C peaks)



- Add peak grid capacity?
- Suppress demand?
- Distributed generation?
- Import power?
- Shift demand!

(Thermal Energy Storage, TES, for the primary driver, AC cooling load)

30 Ton-Hour, 5 Ton Commercial TES Testing in Phoenix, AZ Market

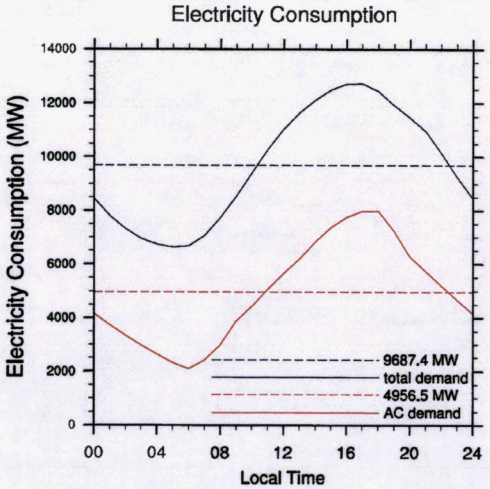
Credit: Ice Energy

Potential for Phoenix Arizona

"If small residential-scale units were installed with a 17.6 kWh (5 ton-hour) thermal storage capacity, 454,034 units would be required to create a 'partial' flattening of increased AC power demands during the 1pm to 8pm peak period. A mixture of small units with larger commercial scale units could accomplish the same objective. At current new-construction and HVAC renovation rates, if all new or renovated buildings were equipped with CTES systems, it would likely take between ten and twenty years to reach this level of market penetration."

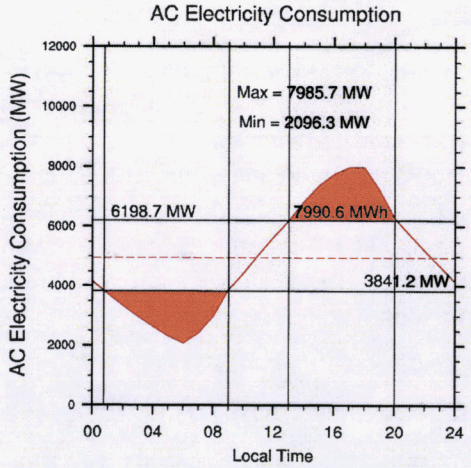
- Ruddell et al., *Applied Energy*, in review

During a July Heat Wave in Phoenix,
AC is 50% of demand…



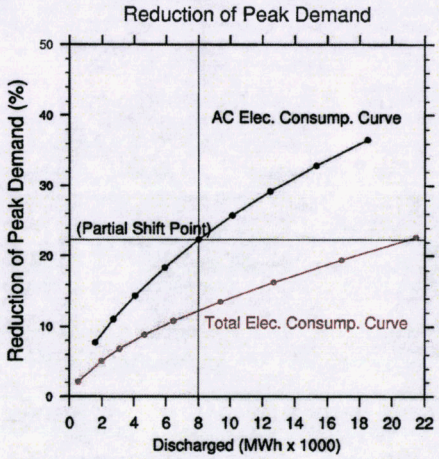
Ruddell et al., in review 2013

During a July Heat Wave in Phoenix,
1800 MW and 8000 MWh of AC Demand can be shifted to off peak hours from peak hours 1-8pm



Ruddell et al., in review 2013

During a July Heat Wave in Phoenix,
It takes 8000 MWh of TES to reduce peak loads by 11%,
and 22,000 MWh to reduce peak loads by 23%

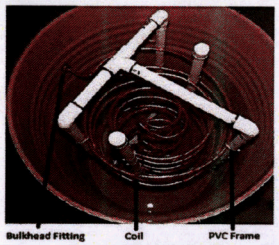


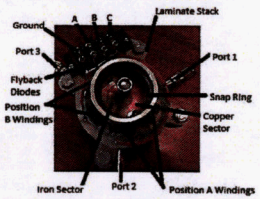
Ruddell et al., in review 2013

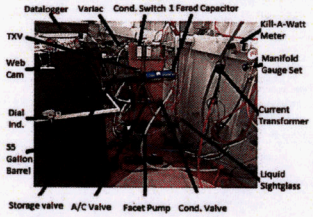
Multiple Benefits, Multiple Partners

- Utilities: can save on capital costs, especially if TES is used systematically in new cities.
- Utilities: save spot-market peak power costs.
- EPA Regulated Generators: save air pollution from daytime generation.
- Generators: can sell more base load and less peak generation.
- Consumers: save on power prices.
- Aggregators: do business on the margin between consumers and utilities.
- Developers: work with utilities to systematically implement TES in new developments.
- HVAC manufacturers and installers: new market and value for their equipment and services.

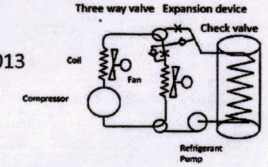
How to Build an Inexpensive 5 Ton-Hour, 1 Ton Residential TES





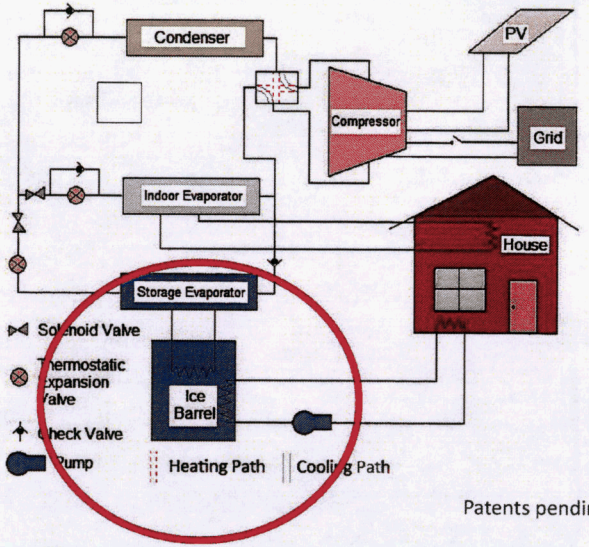


Patents pending 2013



Operation	Refrigerant flow
A/C	CW Left loop
Heating	CCW Left loop
Storage	CW Outside loop
Discharge	CW Right loop

Net Increase of On-Peak Electrical Energy Price vs. Off-Peak [$/kWh]	Estimated Net Savings per Summer Day (4 ton system) [$]	Net Estimated Annual Savings (4 ton system) [$]
$.10	-$.14	-$28.08
$.15	$.88	$170.82
$.20	$1.90	$369.72
$.22	$2.30	$449.28
$.25	$2.92	$568.62



Patents pending 2013