Issues in Integration of Renewables in Island and Regional Electric Grids

March 23, 2010

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Distributed Generation and Energy Storage
Sandia National Laboratories
Phone: 505-280-0997
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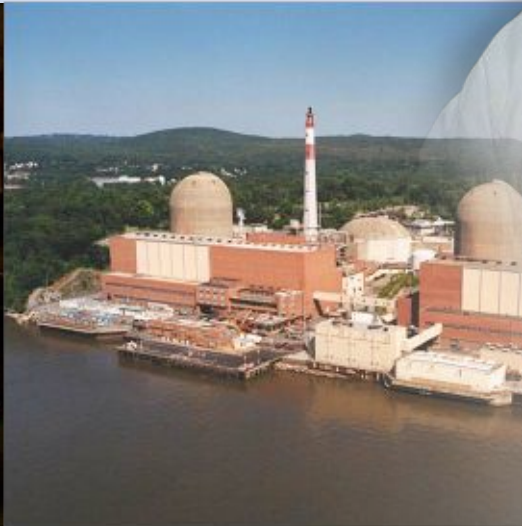
Sandia
National
Laboratories

Our Business: National Security

- **Core purpose**
  - to help our nation secure a peaceful and free world through technology

- **Highest goal**
  - to become the laboratory that the United States turns to first for technology solutions to the most challenging problems that threaten peace and freedom for our nation and the globe

Four Mission Areas

- **Nuclear Weapons**
- **Defense Systems and Assessments**
- **Energy, Resources and Nonproliferation**
- **Homeland Security and Defense**

Sandia National Laboratories

Sandia's Sites

**Albuquerque,
New Mexico**

**Livermore,
California**

**Kauai,
Hawaii**

**Yucca Mountain,
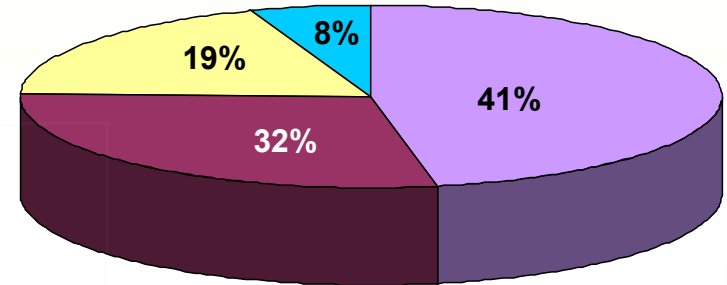Nevada**

**WIPP,
New Mexico**

Pantex, Texas

Tonopah, Nevada

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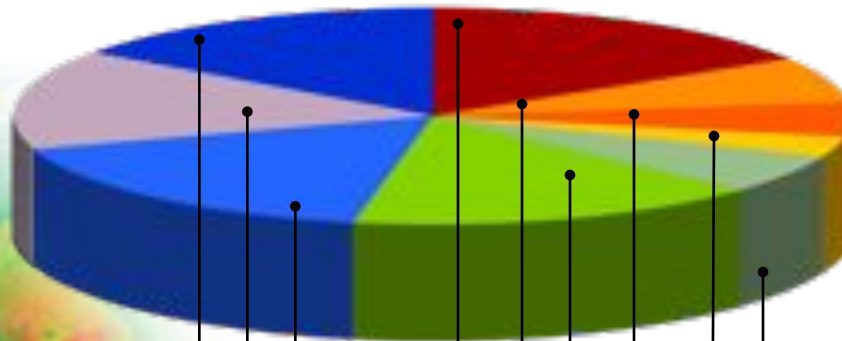
Sandia's People and Budget

- **On-site workforce: 11,415**
- **Regular employees: 8225**
- **Gross payroll: ~$900 million**

FY09 Operating Revenue
$2.2 billion

8%
19%
41%
32%

■ Nuclear Weapons
■ Defense Systems and Assessments
■ Energy, Resources and Non-proliferation
■ Homeland Security and Defense

Technical staff (3,850) by discipline:

Physics 6%
Math 2%
Chemistry 4%
Computing 16%
Other Science 4%
Other Fields 17%

Electrical Engineering 19%
Mechanical Engineering 16%
Other Engineering 15%

Sandia National Laboratories

Solar Technology

Technologies:

Photovoltaics

- Modules/arrays
- Inverters
- Systems

Concentrating Solar Power

- National Solar Thermal Test Facility (Tower)
- Troughs
- Dishes

Solar Hot Water

Activities:

Advanced R&D

- New systems integrations
- Hydrogen production
- New "smarts": controls, communications, power conversion

Modeling – performance prediction

Reliability engineering

Evaluations/characterizations of new components/products

Barrier removal: codes, standards, certification, design assistance, technical support

Customers:

DOE/Solar

Industry

NASA

Working to expand with Military

Wind Energy Technology

Blade Technology

- **Materials and Manufacturing**
- **Structural, Aerodynamic, and Full System Modeling**
- **Lab - Field Testing and Data Acquisition**
- **Sensors and Structural Health Monitoring**
- **Advanced Blade Concepts**

System Reliability

- **Industry Data Collection**
- **Modeling and Testing of System-Critical Components**
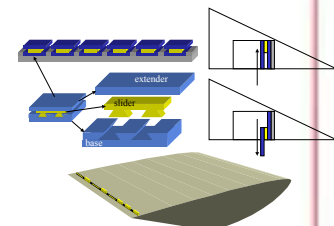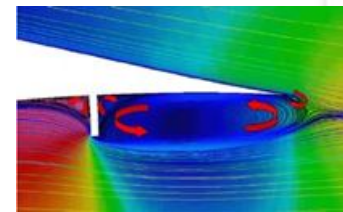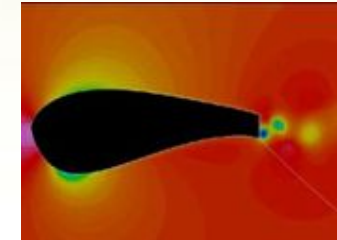
Geothermal Research
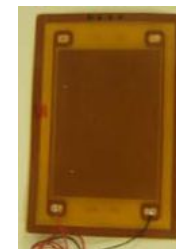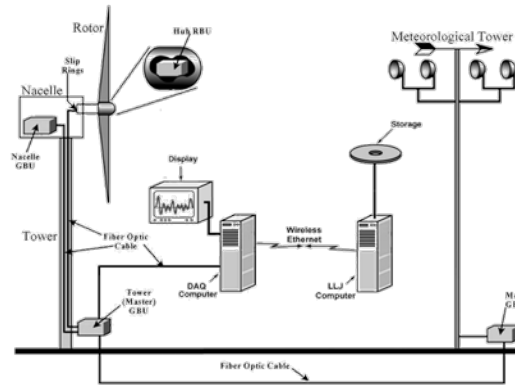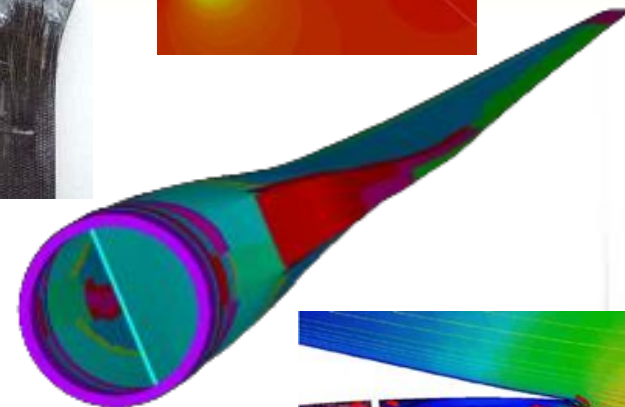## Drilling and Monitoring in Harsh Environments

- **Geothermal Well Construction**
  - High-Temperature Electronics
  - Diagnostics-While-Drilling
  - Rock Reduction Technologies
  - Wellbore Integrity and Lost Circulation
  - Drilling Dynamics Modeling and Simulation
  - Vibration Mitigation

DRILLER
Optimizes drilling process using real-time data

DRILLING ADVISORY SOFTWARE combines surface conditions with downhole information

CONTROL SIGNALS

HIGH-SPEED DATA LINK

DOWNHOLE SENSORS

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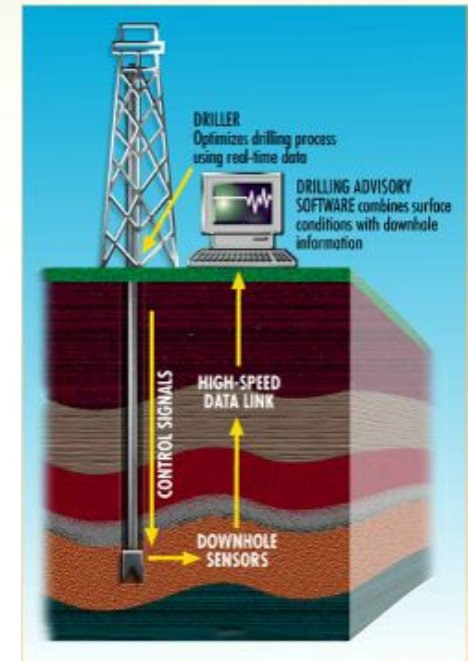
Energy Infrastructure and Distributed Energy Resources

- **Distributed energy resources**
- **Power electronics**
- **Energy storage**
- **Energy Surety Microgrids**

1.2 MW, 7.2 MWh Distributed Energy Storage System in Chemical Station, North Charleston

12kV / 480V Transformer   PCS   NAS Battery

Started Operation on June 26ᵗʰ , 2006

AEP **APPALACHIAN POWER**
A unit of American Electric Power

NGK Insulators Ltd
S&C Electric Co.
DOE / SANDIA

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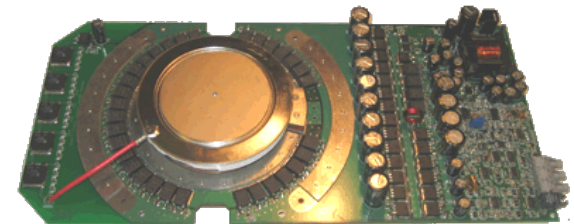
Energy Systems Analysis

- **Competencies:**
  - Power grid (generation, transmission, distribution) operations, modeling
  - Renewables integration
  - Energy transport security (pipelines, power grid, marine, railways)
  - SCADA and control systems analysis and security
  - Energy system vulnerability, safety, and risk assessment
  - Energy system modeling and simulation
  - Energy systems analysis

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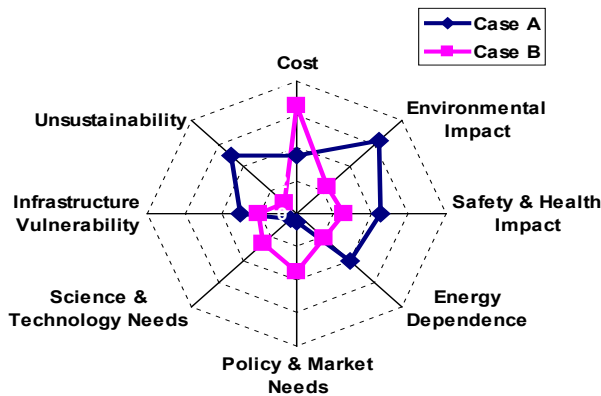
Personal Background

- **20 years @ Sandia**
- **12 years @ Public Service Company of New Mexico**
- **Energy Storage for electric utility applications**
- **Distributed Generation**
- **Energy Surety Microgrids**
- **Projects in:**
  - **Alaska**
  - **Hawaii**

- **Proud owner of 4th Prius**
  - **2000 – 1st Gen**
  - **2001**
  - **2005 – 2nd Gen**
  - **2010 – 3rd Gen**

Issues for Renewable Penetration

- **Policy and Regulatory**
  - Renewable Portfolio Standards
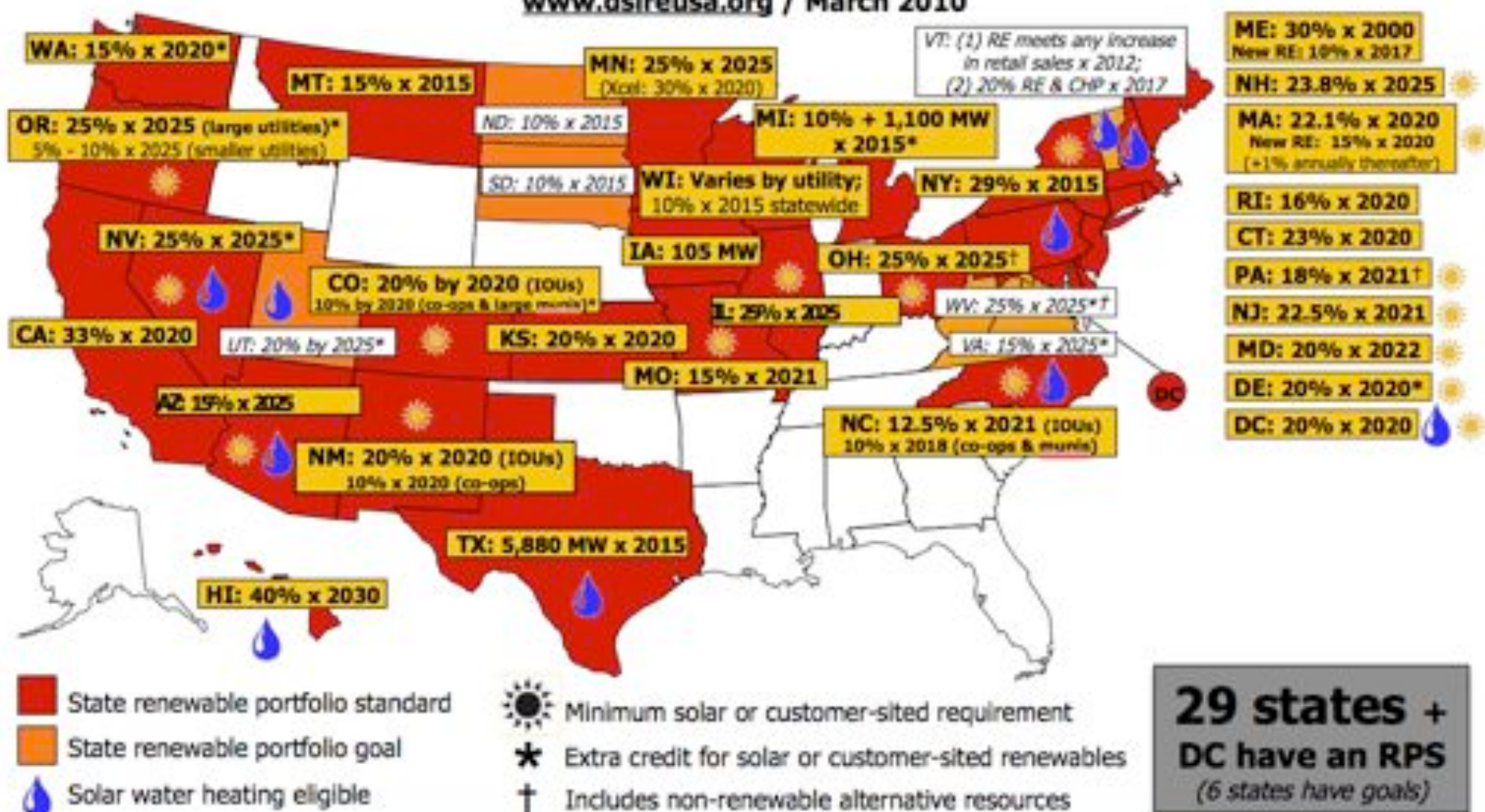 - Rates: Feed-in-Tariff, Net Metering
  - Subsidies and incentives
- **Financial**
  - Cost of renewable technologies
  - Displacement of legacy infrastructure
- **Technical**
  - Intermittency: PV and wind
  - High penetration levels
  - Centralized and dispersed penetration
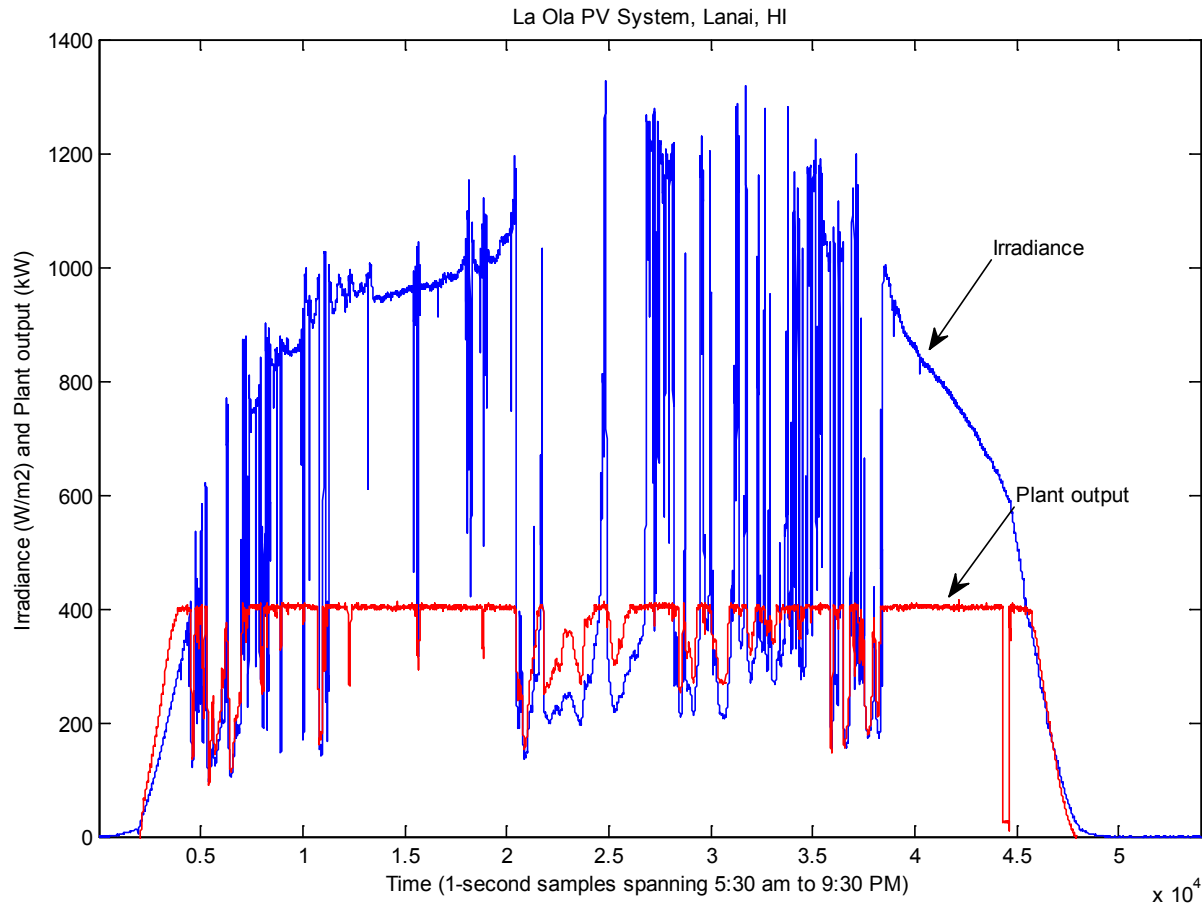 - Control and dispatchability

Renewable Portfolio Standards

www.dsireusa.org / March 2010

WA: 15% x 2020*

MT: 15% x 2015

MN: 25% x 2025 (Xcel: 30% x 2020)

VT: (1) RE meets any increase in retail sales x 2012; (2) 20% RE & CHP x 2017

ME: 30% x 2000 New RE: 10% x 2017

ND: 10% x 2015

MI: 10% + 1,100 MW x 2015*

NH: 23.8% x 2025

OR: 25% x 2025 (large utilities)* 5% - 10% x 2025 (smaller utilities)

SD: 10% x 2015

WI: Varies by utility; 10% x 2015 statewide

NY: 29% x 2015

MA: 22.1% x 2020 New RE: 15% x 2020 (+1% annually thereafter)

NV: 25% x 2025*

IA: 105 MW

RI: 16% x 2020

CO: 20% by 2020 (IOUs) 10% by 2020 (co-ops & large munis)*

OH: 25% x 2025†

CT: 23% x 2020

CA: 33% x 2020

UT: 20% by 2025*

IL: 25% x 2025

WV: 25% x 2025*†

PA: 18% x 2021†

KS: 20% x 2020

NJ: 22.5% x 2021

AZ: 15% x 2025

MO: 15% x 2021

VA: 15% x 2025*

MD: 20% x 2022

DE: 20% x 2020*

NC: 12.5% x 2021 (IOUs) 10% x 2018 (co-ops & munis)

DC: 20% x 2020

NM: 20% x 2020 (IOUs) 10% x 2020 (co-ops)

TX: 5,880 MW x 2015

HI: 40% x 2030

Legend:
- State renewable portfolio standard
- State renewable portfolio goal
- ☀ Minimum solar or customer-sited requirement
- ✱ Extra credit for solar or customer-sited renewables
- 💧 Solar water heating eligible
- † Includes non-renewable alternative resources

29 states + DC have an RPS
(6 states have goals)

Net Metering

www.dsireusa.org / March 2010

WA: 100
MT: 50*
ND: 100*
ME: 660
co-ops & munis: 100
OR: 25/2,000*
MN: 40
VT: 250
NH: 100
WY: 25*
WI: 20*
MI: 150*
MA: 60/1,000/2,000*
RI: 1,650/2,250/3,500*
CT: 2,000*
NV: 1,000*
NE: 25
IA: 500*
OH: no limit*
NY: 10/ 25/500/2,000*
IL: 40*
PA: 50/3,000/5,000*
UT: 25/2,000*
IN: 10*
WV: 25
NJ: 2,000*
CA: 1,000*
KS: 25/200*
KY: 30*
VA: 20/500*
DC
DE: 25/500/2,000*
CO: no limit
co-ops & munis: 10/25
MO: 100
NC: 1,000*
MD: 2,000
AZ: no limit*
OK: 100*
DC: 1,000
NM: 80,000*
AR: 25/300
GA: 10/100
AK: 25*
LA: 25/300
FL: 2,000*
HI: 100
KIUC: 50

43 states +
DC & PR have
adopted a net
metering policy

■ State policy

■ Voluntary utility program(s) only

PR: 25/1,000

★ State policy applies to certain utility types only (e.g., investor-owned utilities)

Note: Numbers indicate individual system capacity limit in kW. Some limits vary by customer type, technology and/or application. Other limits might also apply.

PV Variability in Actual PV System

La Ola PV System, Lanai, HI

- Irradiance and PV system ac output A typical partly cloudy day in July
- PV system rating: 1,300 kW ac, presently limited to 400 kW ac (intentionally)
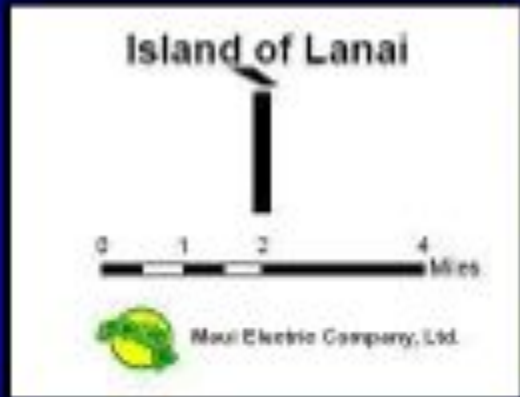
2008 Lanai 100% RE Study

- **Purpose is to define a pathway to help Lanai reach 100% Renewable Energy**

- **Study Partners: Castle & Cooke, MECO, NREL, Sandia, and Sentech**

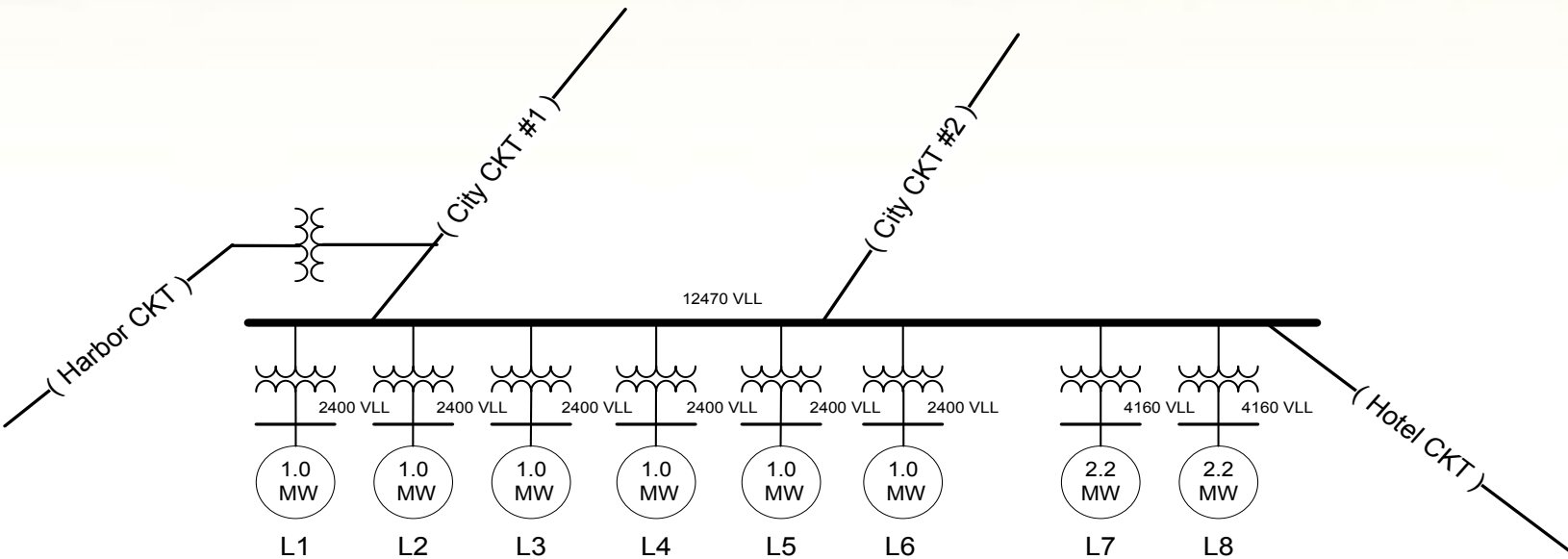- **Focused on how to develop a pathway to reach 100% renewable energy on Lanai**

Proposed Large Wind Farm area

Island of Lanai

0   1   2   4
Miles.

Maui Electric Company, Ltd.

The Lodge at Koele Resort

Lanai City

Lanai Airport

Miki Basin Power Plant

Manele Bay Resort

Focus area of Lanai 100% RE Study

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Miki Basin Power Station

(6) 1.0 MW EMD Diesel Generators
(2) 2.2 MW Caterpillar Diesel

Lanai Current Electrical Power System

Mostly wells

City#2

City#1

PV

CHP

Manele Hotel

Miki Basin
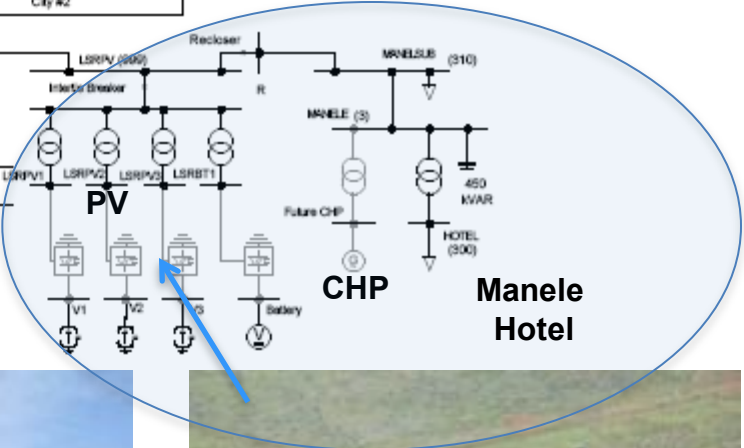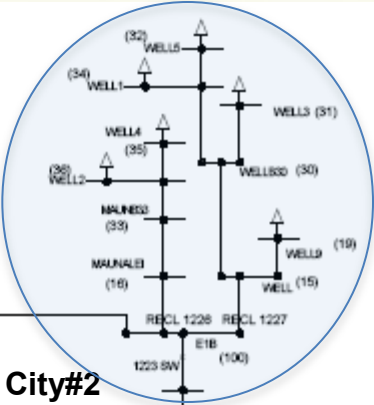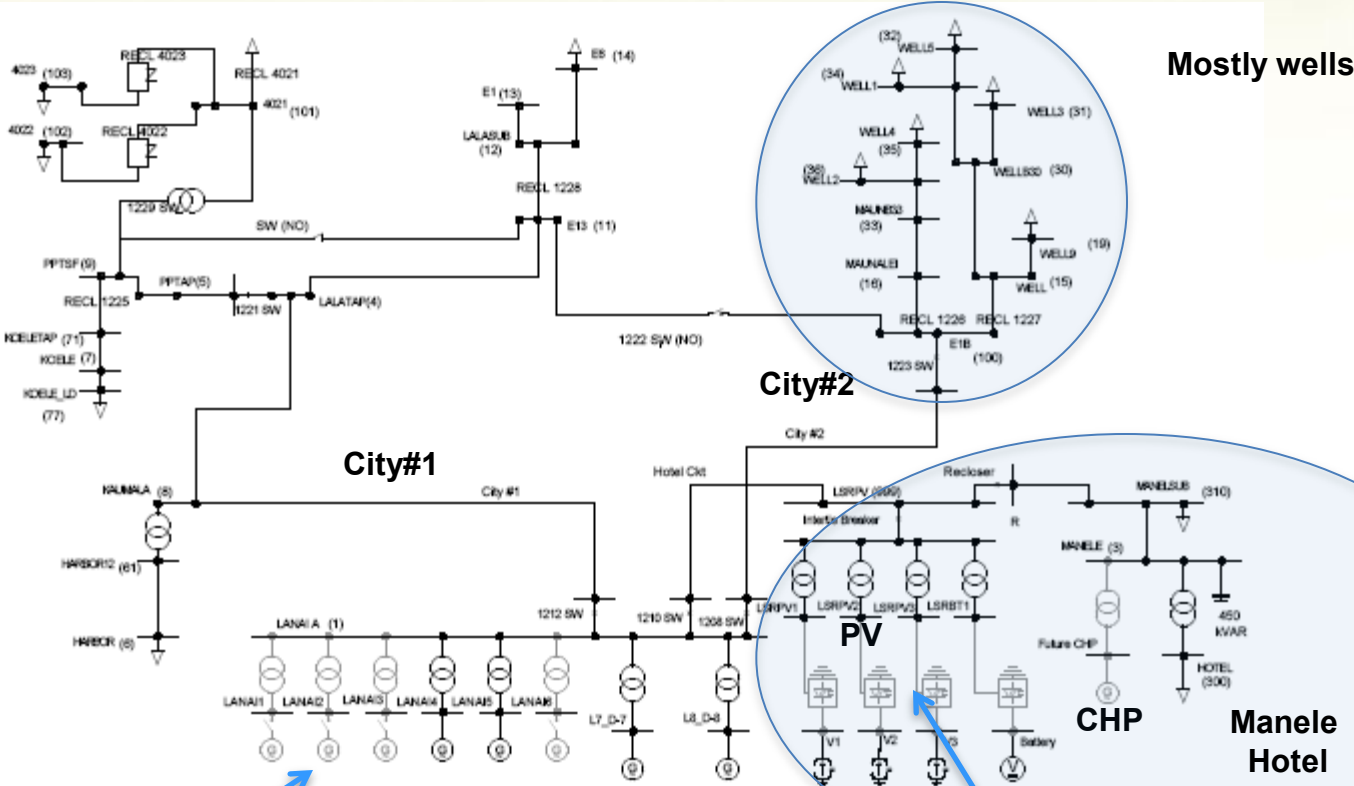
Sample 1 sec Data
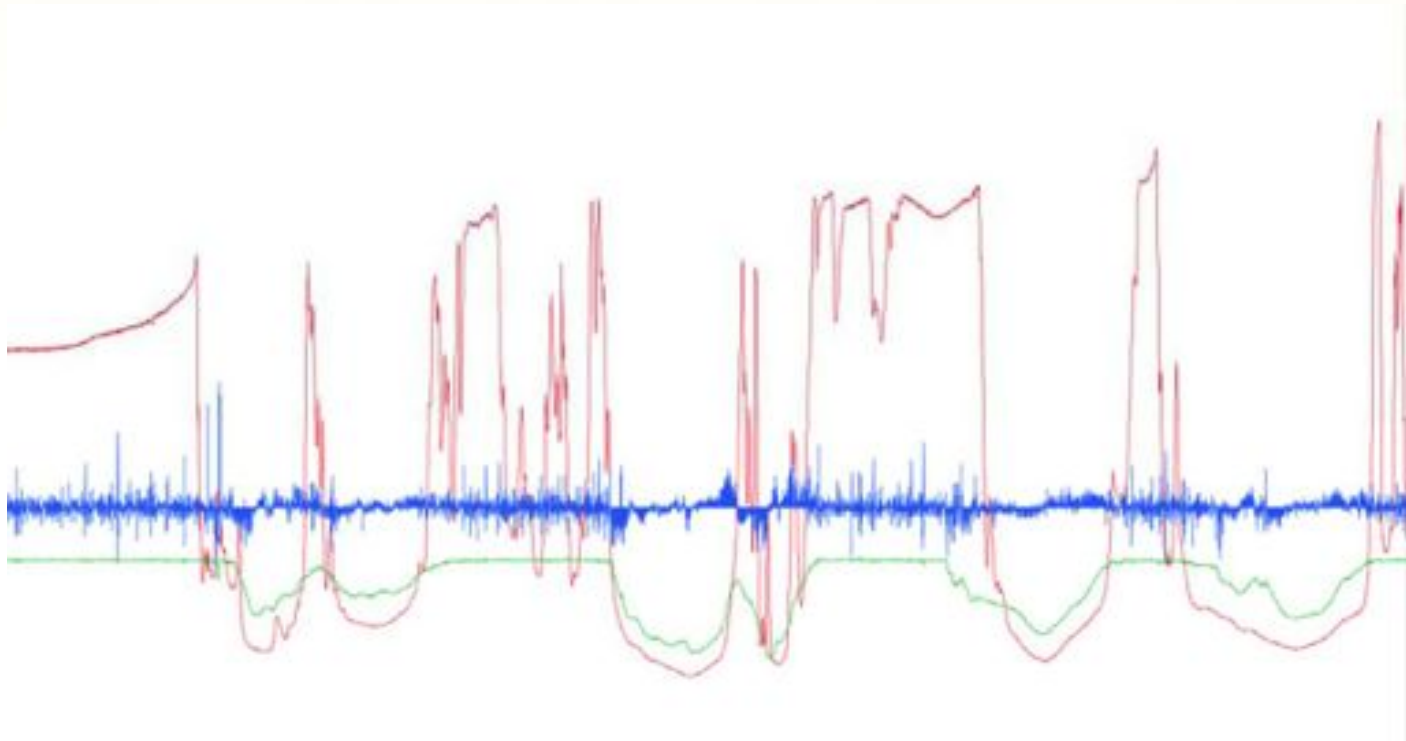
Ramp Rate Characteristics

- **Large kW/sec ramps**
- **Duration of seconds to 3 minutes**

- **System effect depends on generating units on line**
  - Head room on generator

- **Mitigation approaches**
  - Cloud cover/movement prediction – 10 minutes
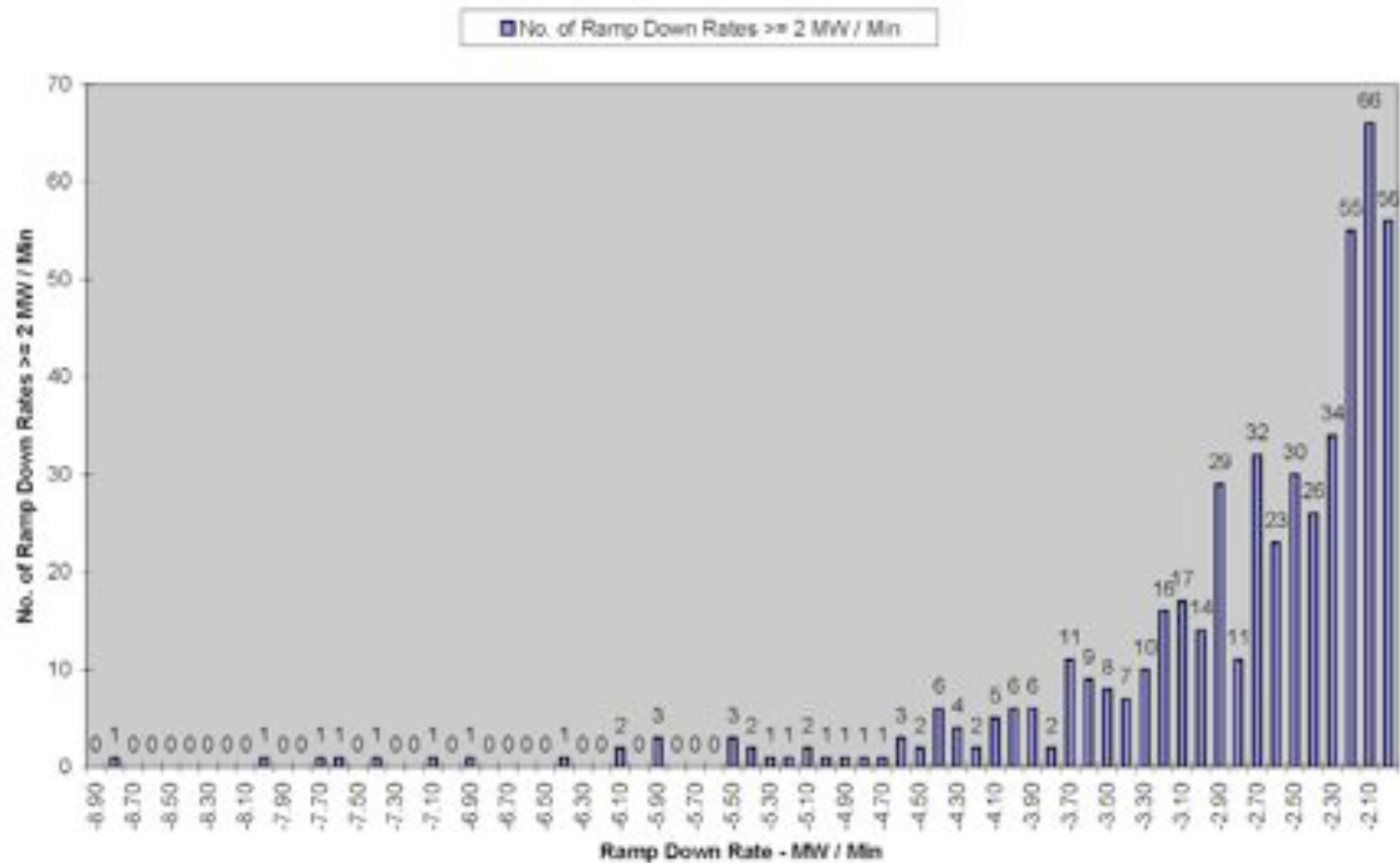 - Energy storage – Power, not energy

Wind Farm Characteristics

- **Similar ramp behavior in wind farm output**

- **Mitigation approaches**
  - Wind speed prediction – 10 minutes to 1 hour
  - Energy storage – Power, not energy

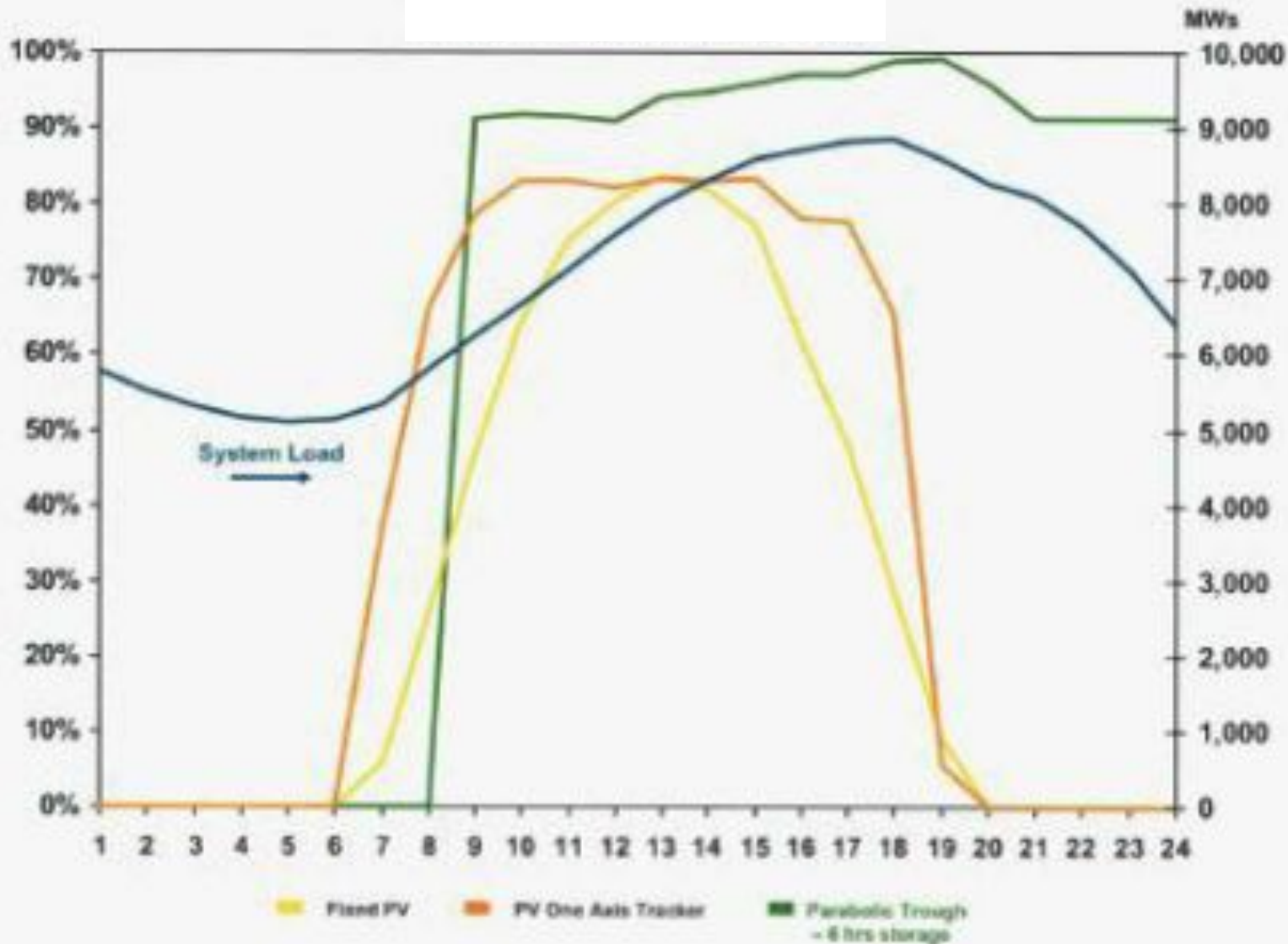March 16-25 2008 Frequency / KWP MW - One Minute Intervals
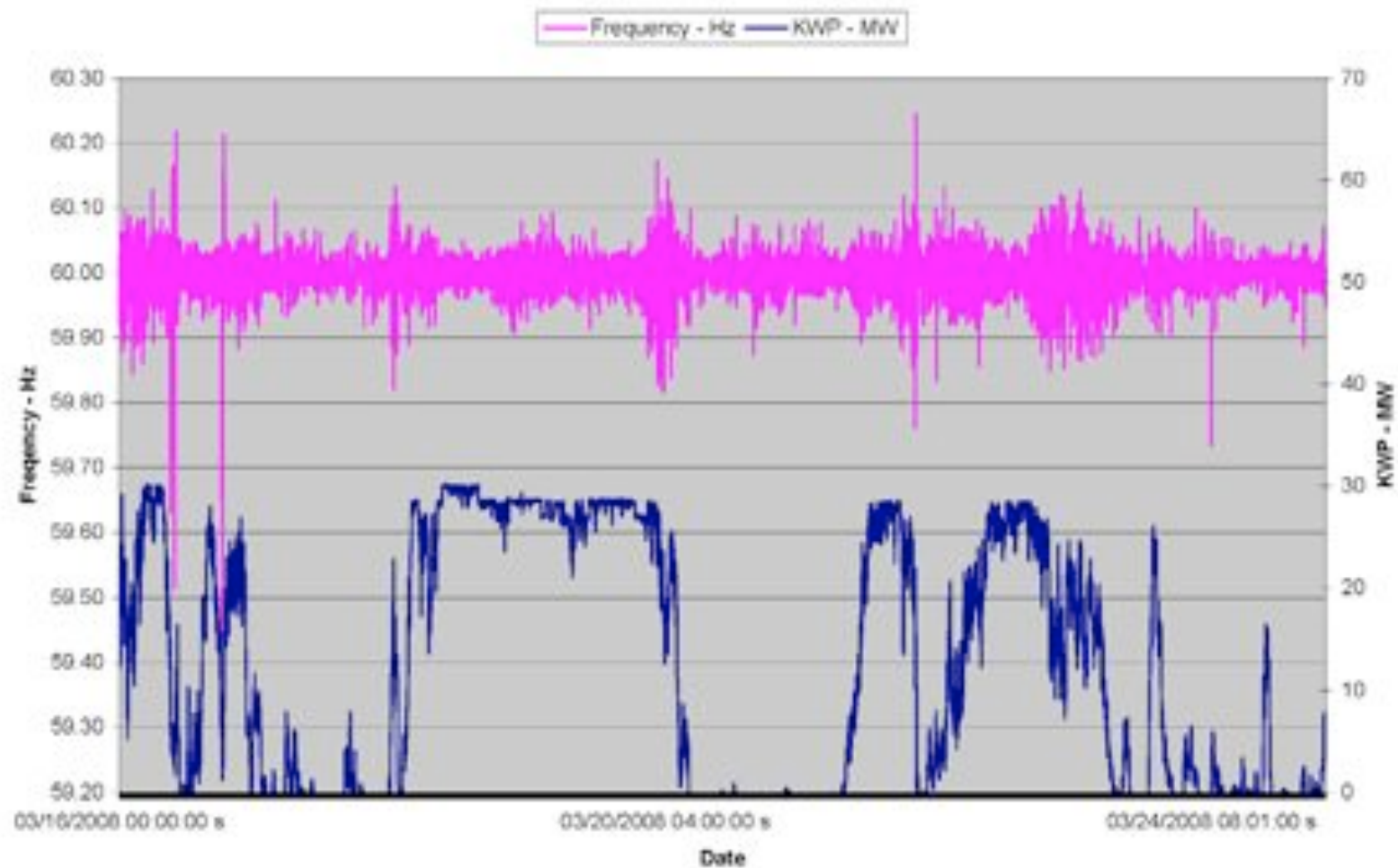
Ramp Down Rates >= 2 MW / Min Histogram for December 2007

Comparison of PV and CSP Outputs

Legend: Fixed PV | PV One Axis Tracker | Parabolic Trough – 6 hrs storage

CSP (Parabolic Trough) Systems

- **Large CSP systems are operational – 100's MW**
- **Smaller systems are emerging: 100 kW – 2 MW**
- **Energy storage is inherent in system**

- **Several turbine manufacturers, domestic and overseas**

Advantages of CSP Systems

- **Reduces intermittency by providing ride-through capability**

- **Energy storage is inherent in system: 1 to 6 hours**
  - Eliminates need for expensive battery energy storage

- **Disadvantages:**
  - Higher maintenance - ??
  - Larger land area - ??
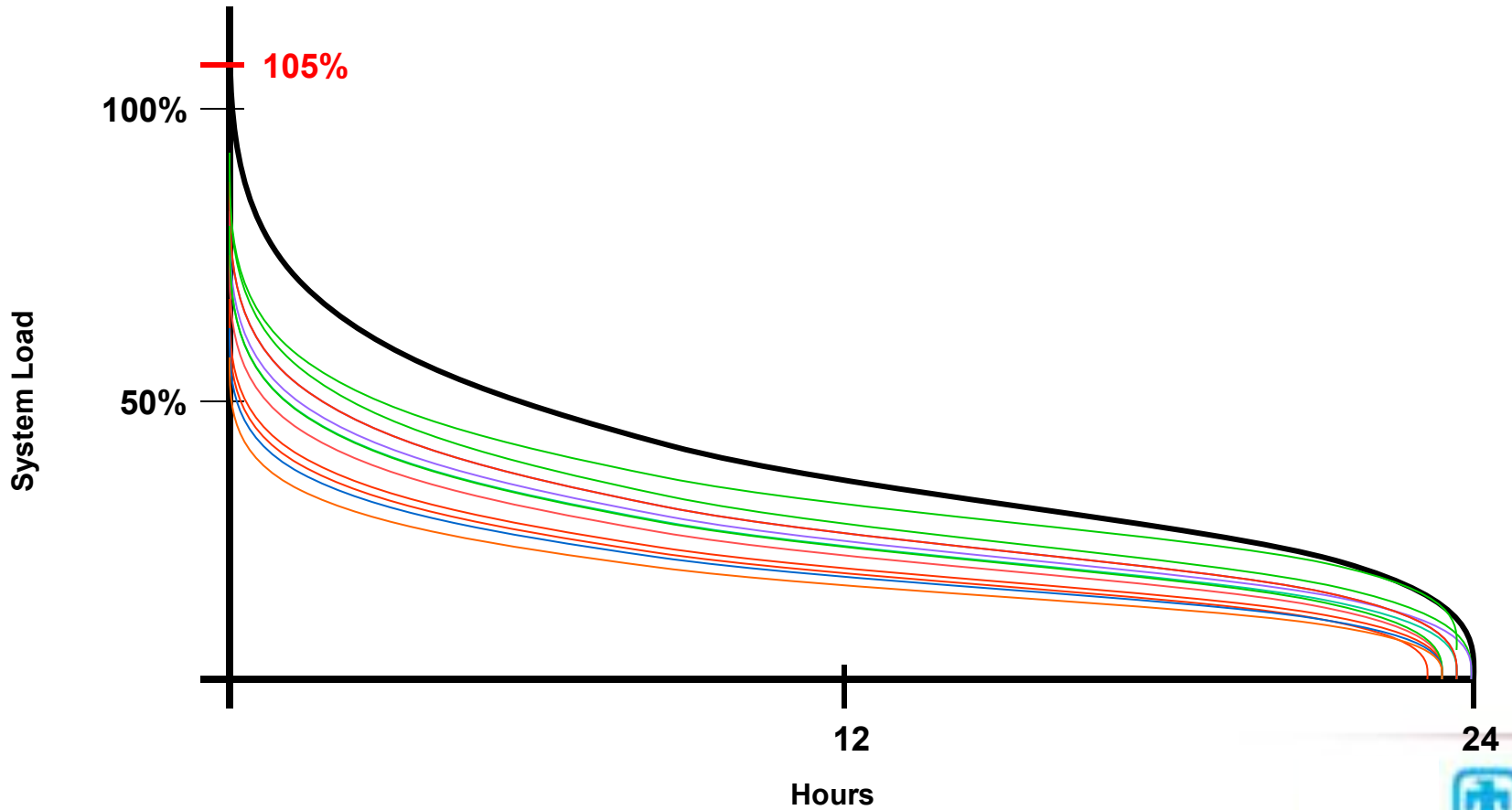 - Higher cost - ??

Central vs. Distributed Generation

- **Increases efficiency**
  - Utilizes both electricity and heat
  - Reliability of electric grid: generation closer to load; reduces T&D losses, etc.

- **Asset Utilization**

Typical Load Profile
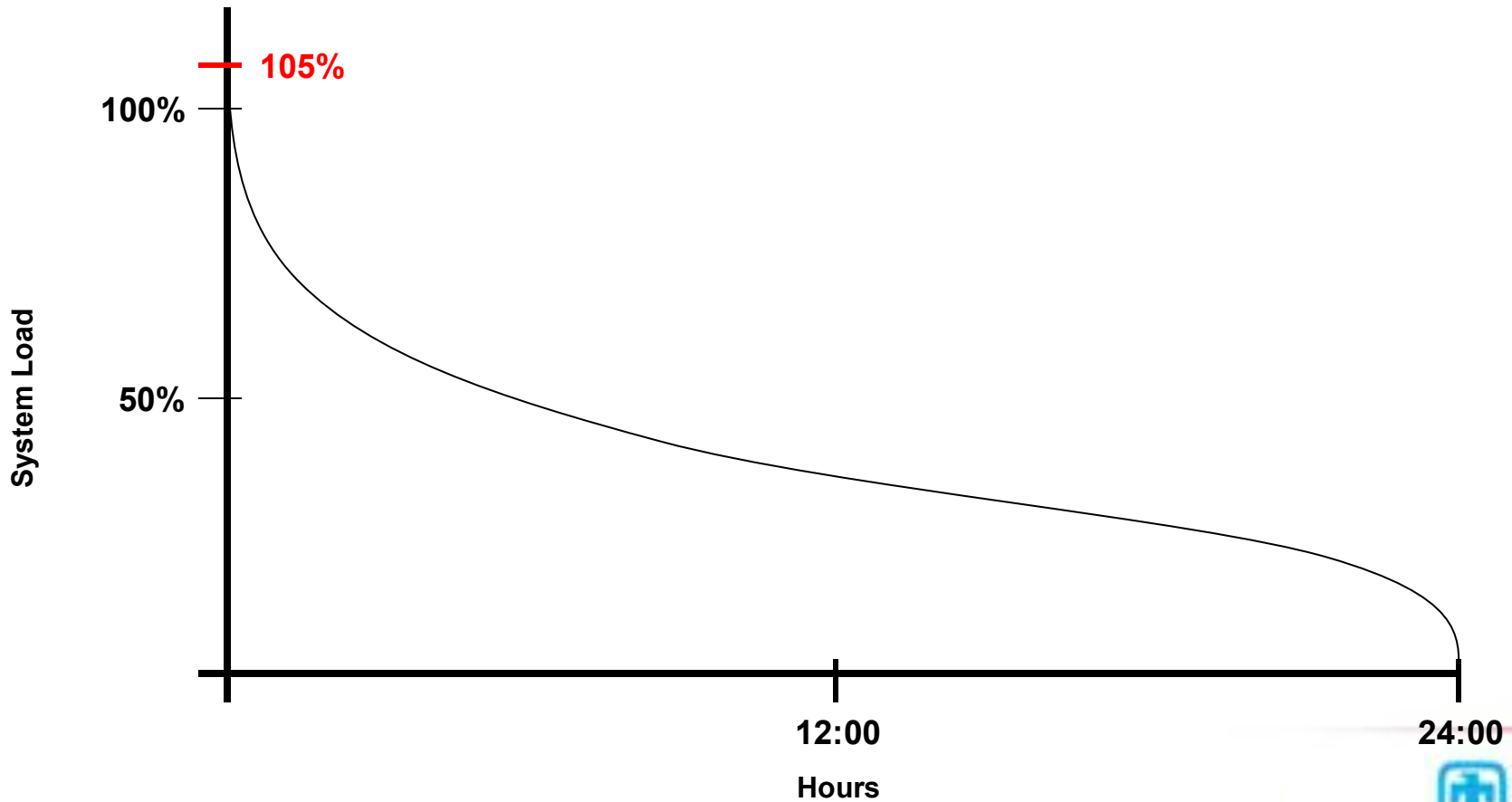
Load Shape Components

Recommended Reading

- **Technology and Transformation in the American Electric Utility Industry by Richard Hirsh**

- **Small is Profitable by Amory Lovins**