SAND2009-5661C

# Operational Considerations of PV and Wind Generation

**Jordan Energy Planning Workshop**
**6-10 September, 2009**
**Amman, Jordan**

**Abbas Akhil**
**Energy Storage and Distributed Generation**
**Sandia National Laboratories**
**(505) 844-7308**
**aaakhil@sandia.gov**

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company,
for the United States Department of Energy's National Nuclear Security Administration
under contract DE-AC04-94AL85000.

# Outline of Presentation

- My background and experience
- How PV and wind generation work in the electric system
- The effects of their intermittency
- Experience in other electric systems
- How they might be applied in Jordan

Sandia National Laboratories

# My Background and Experience

- Born and grew up in Hyderabad, India
- Moved to USA for higher education
- Lived in Albuquerque, New Mexico for 37 years

- 13 years experience in electric company
  - System Expansion Planning, Coal Power Plants, Cogeneration, Solar and Wind Generation

- 20 years experience Sandia National Laboratories
  - Battery Energy Storage, Distributed Generation, Microgrids, Integration of PV, Wind and Energy Storage in Electric Systems
  - Projects in Alaska, Mexico, mainland USA and Hawaii

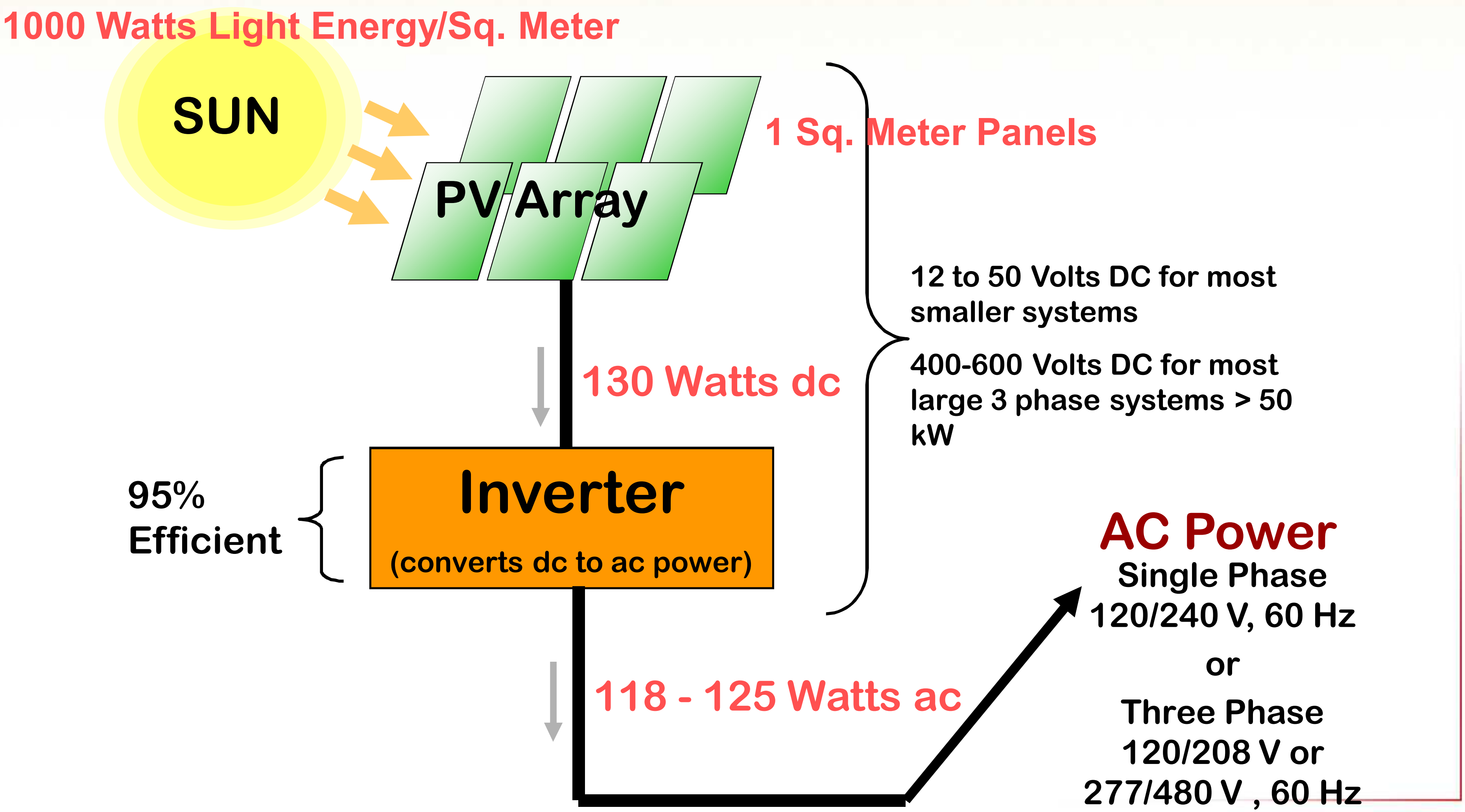
# How PV, Wind Generation and Energy Storage Work in the Electric System

Sandia National Laboratories

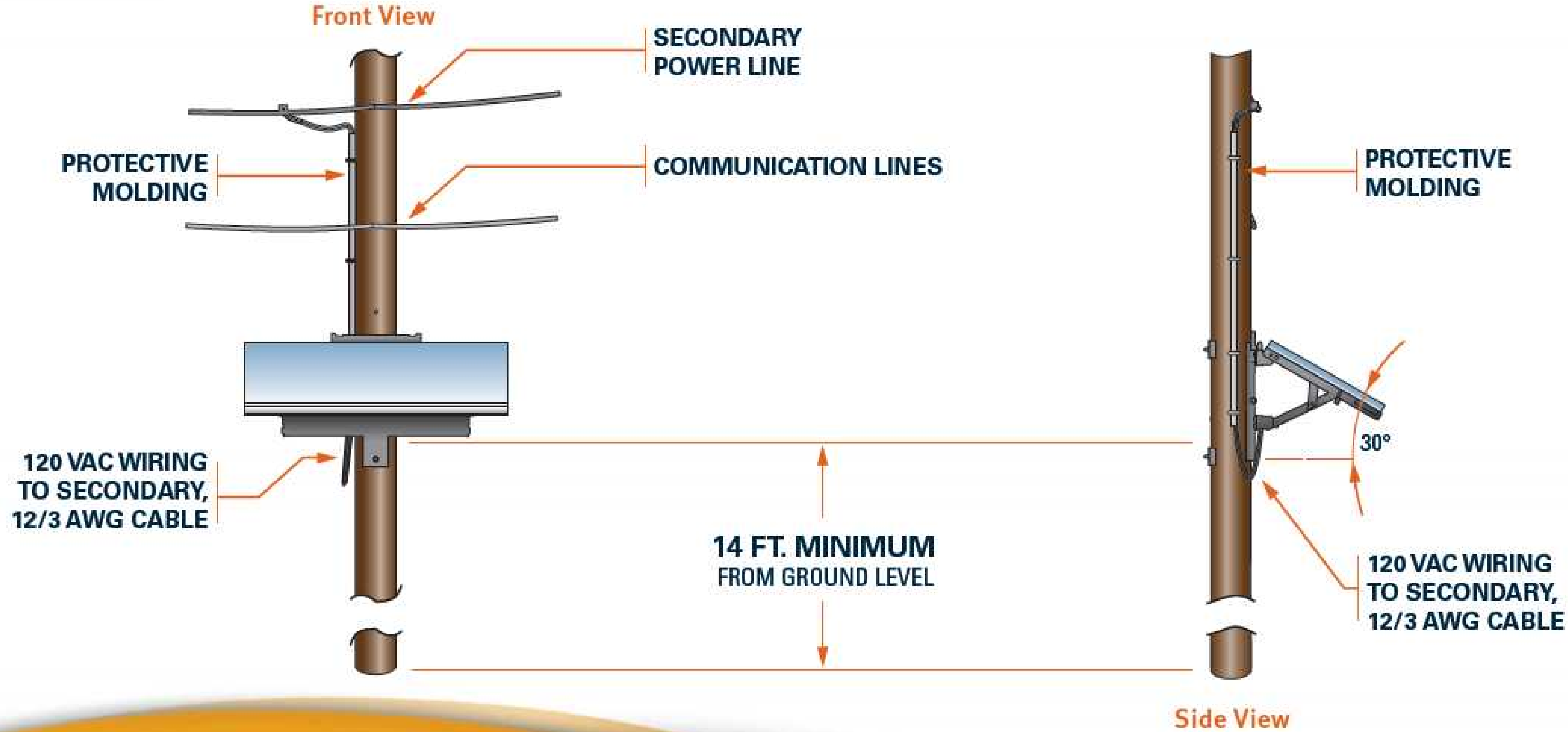
- **PV and Wind depend on intermittent availability of sun and wind**

- **PV and Battery Storage systems have no mechanical inertia**
  - **There is no rotating "mass" as in a conventional generator**
  - **Both depend on power electronics to "imitate" a conventional generator**
    - Short circuit current limitation
    - Very fast response and ramp rates

# Schematic of a Simple PV System




Sandia National Laboratories




Sandia National Laboratories

Sandia
National
Laboratories

1.5MW Hawaii's largest Solar Farm in service December 2008

10 acres, 12 separate arrays, 7,000+ panels, tracker system

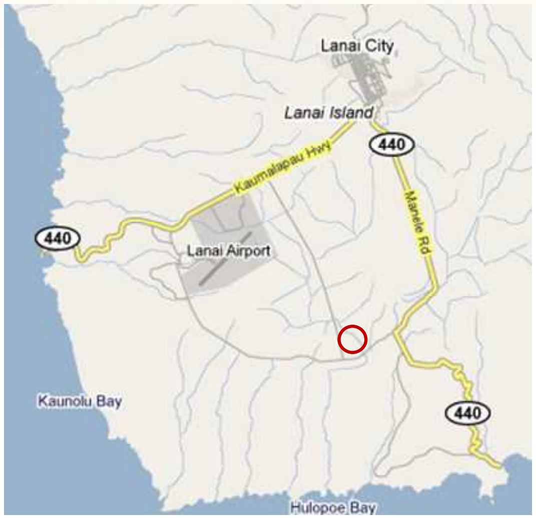
3,000MWhour production = 30% of Lanai's daytime peak demand, 10% of Lanai's annual demand

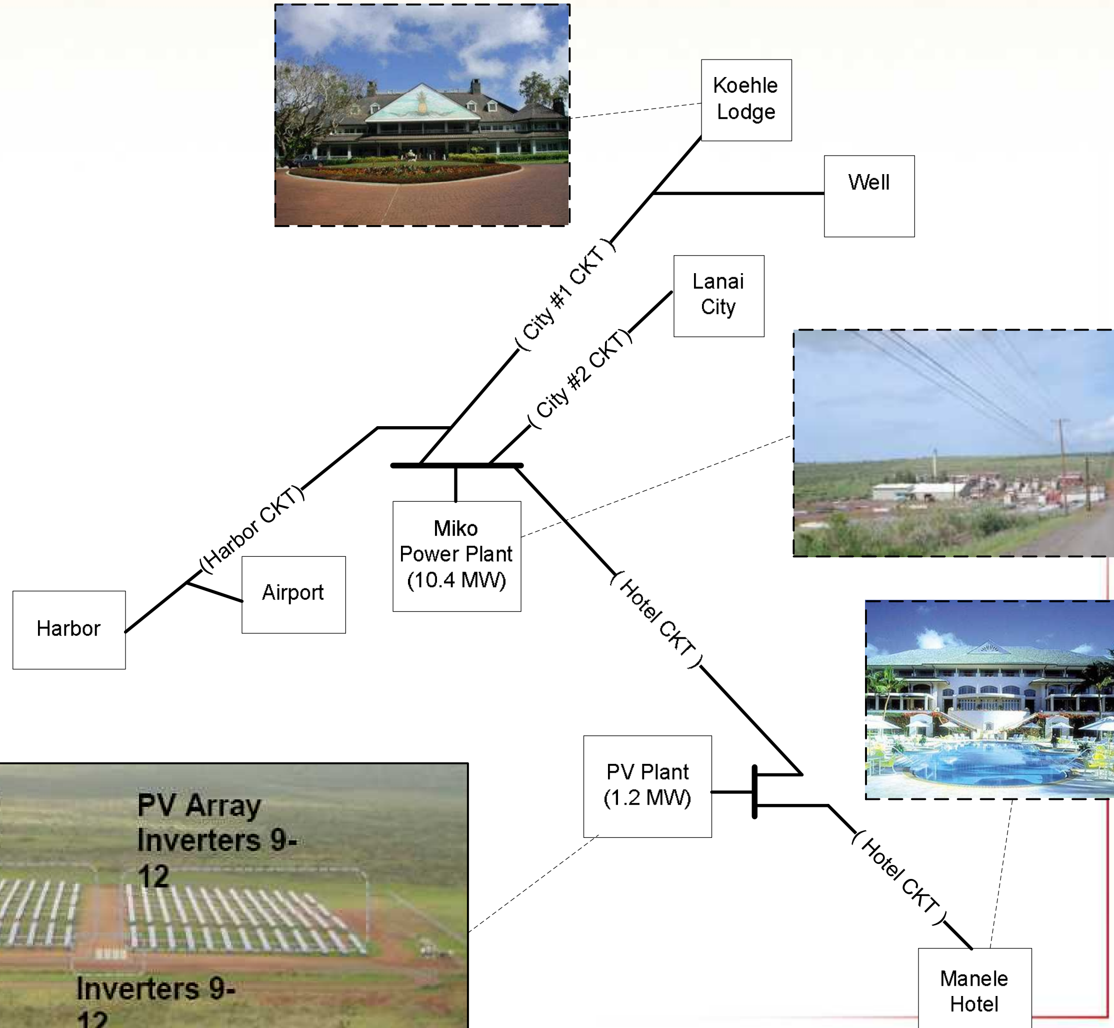
2,300 tons of carbon dioxide emissions eliminated annually = 5,000 barrels of oil or 237,000 gallons of gasoline

LĀ OLA

Lānaʻi's Solar Farm

# Lanai Grid

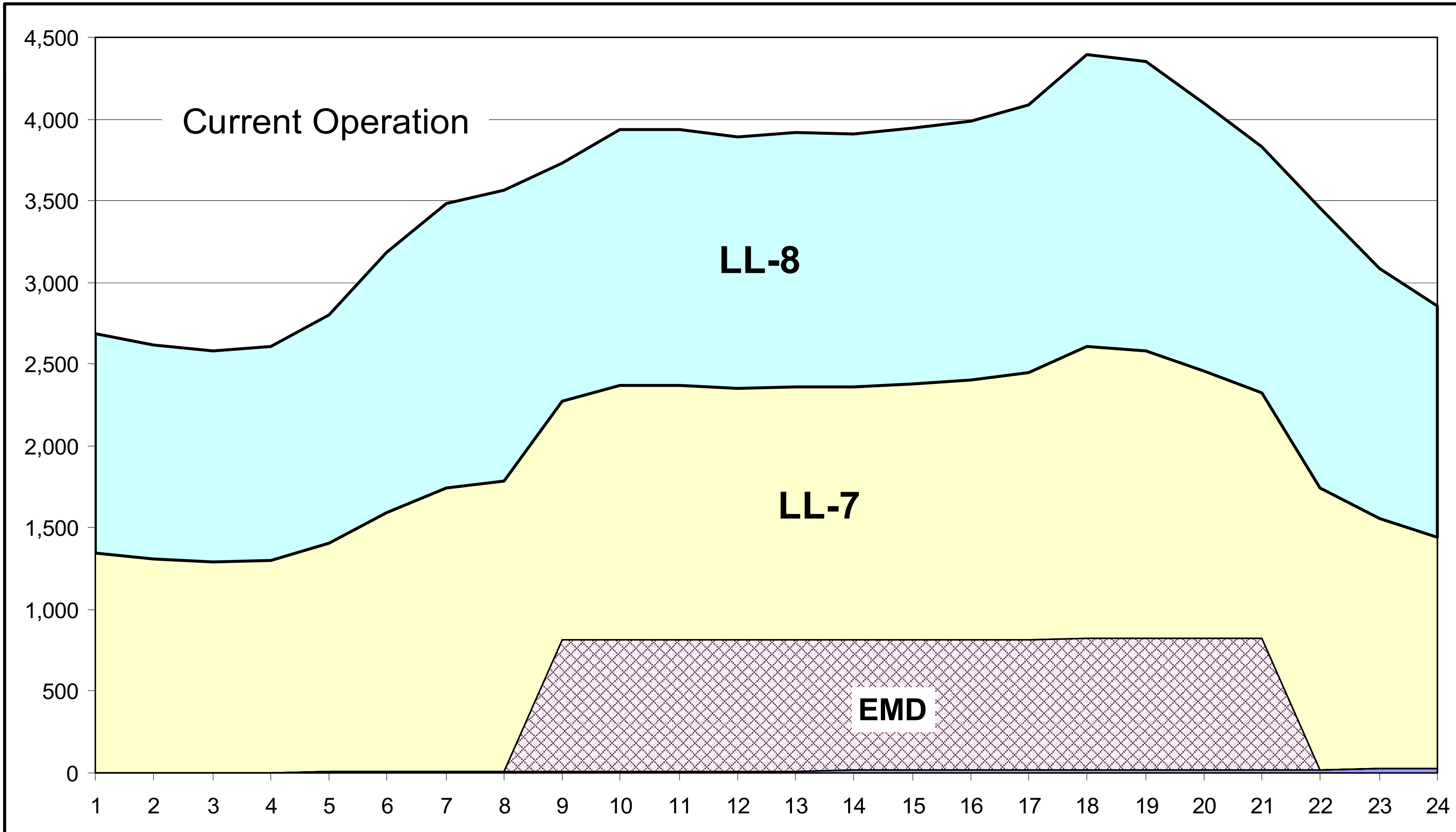


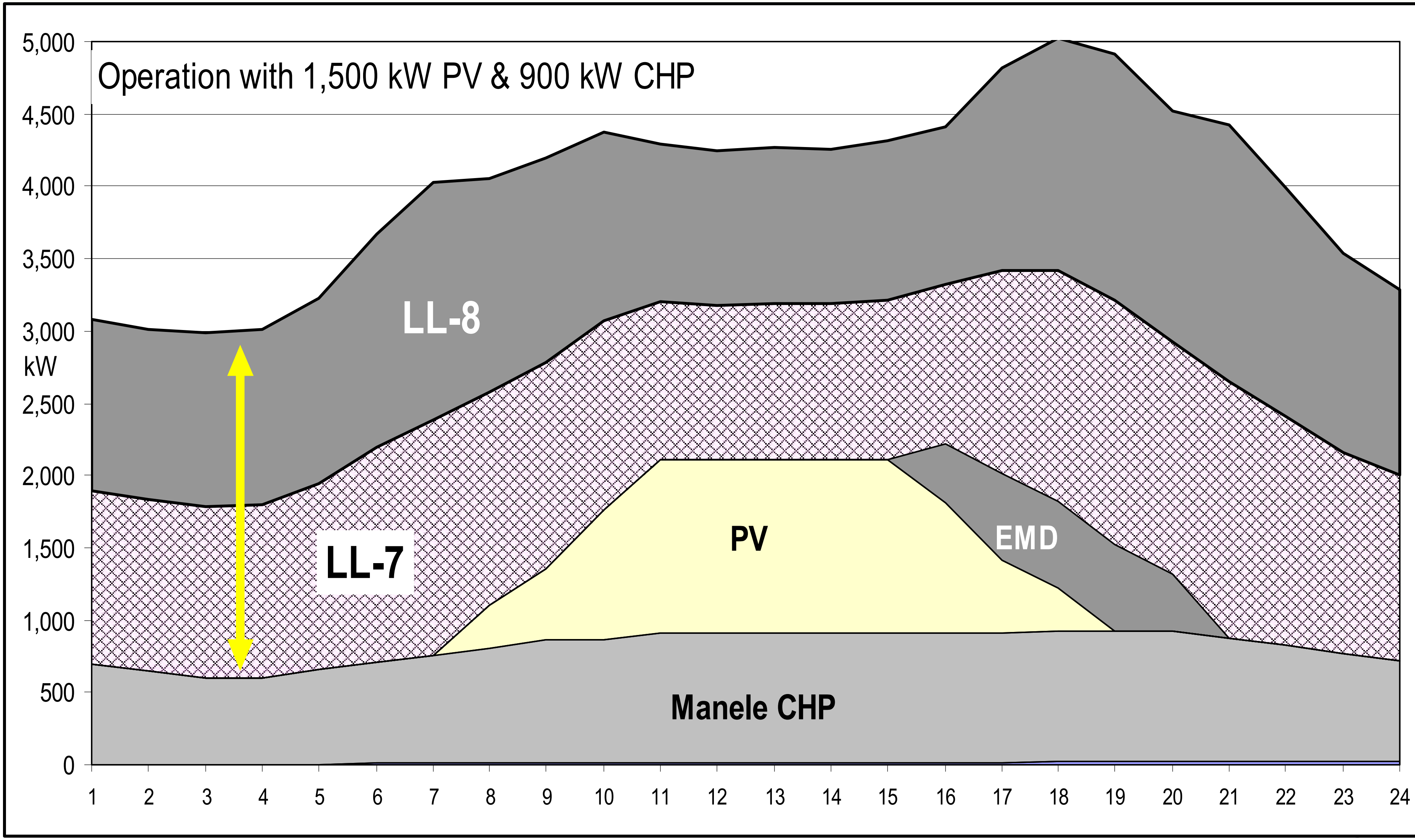


Sandia National Laboratories

# Lanai Unit Dispatch w/o PV Plant

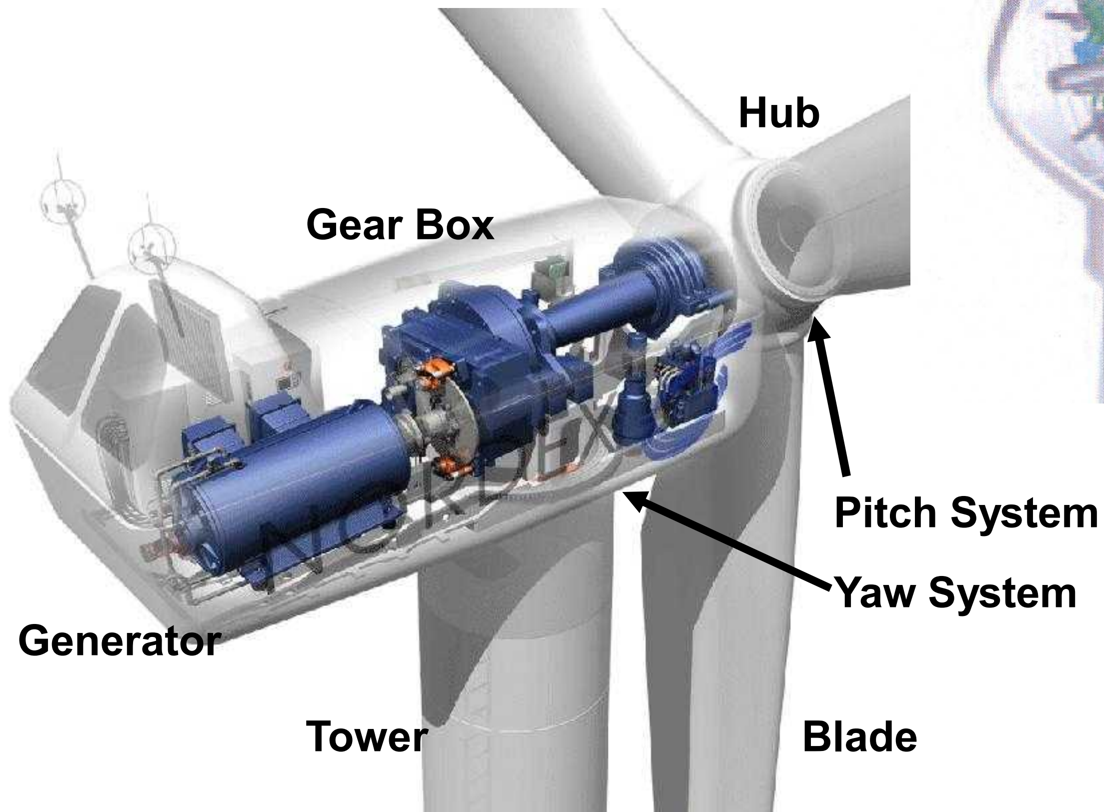


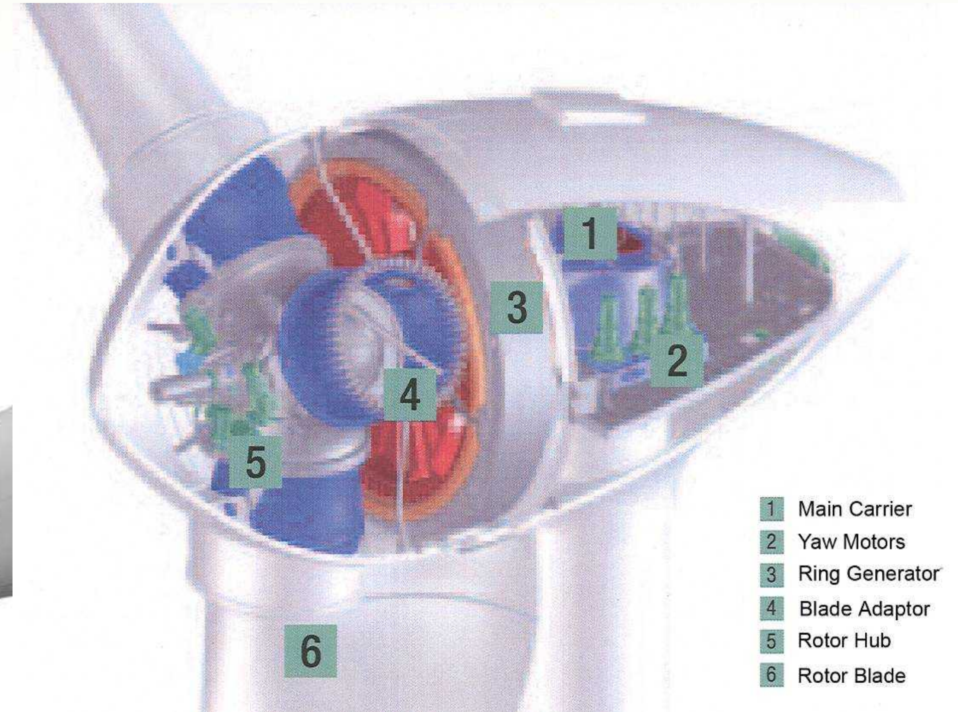
# Lanai Unit Dispatch with PV Plant and CHP at Hotel



# Wind Turbine Components

Conventional Drive Train



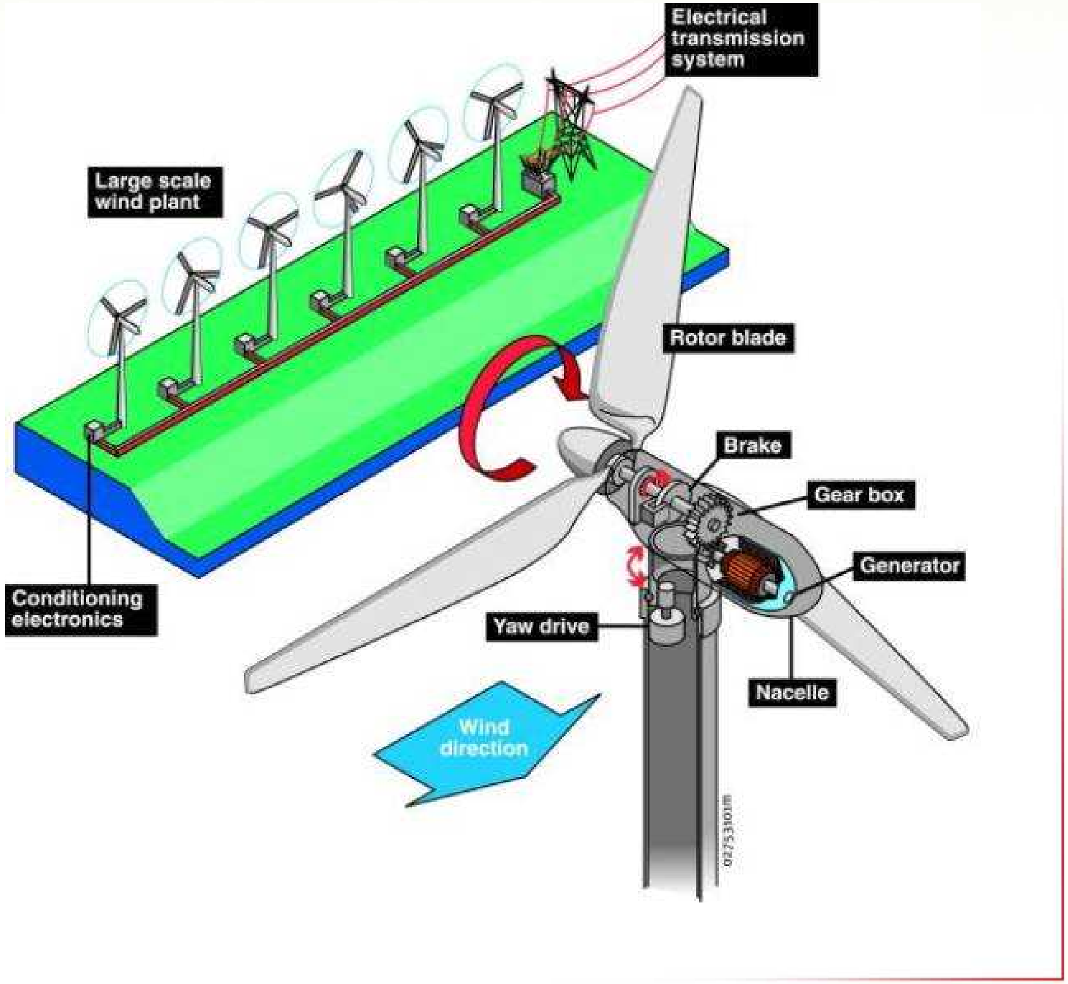




Direct Drive System

Sandia National Laboratories

# Typical Wind Farm Components

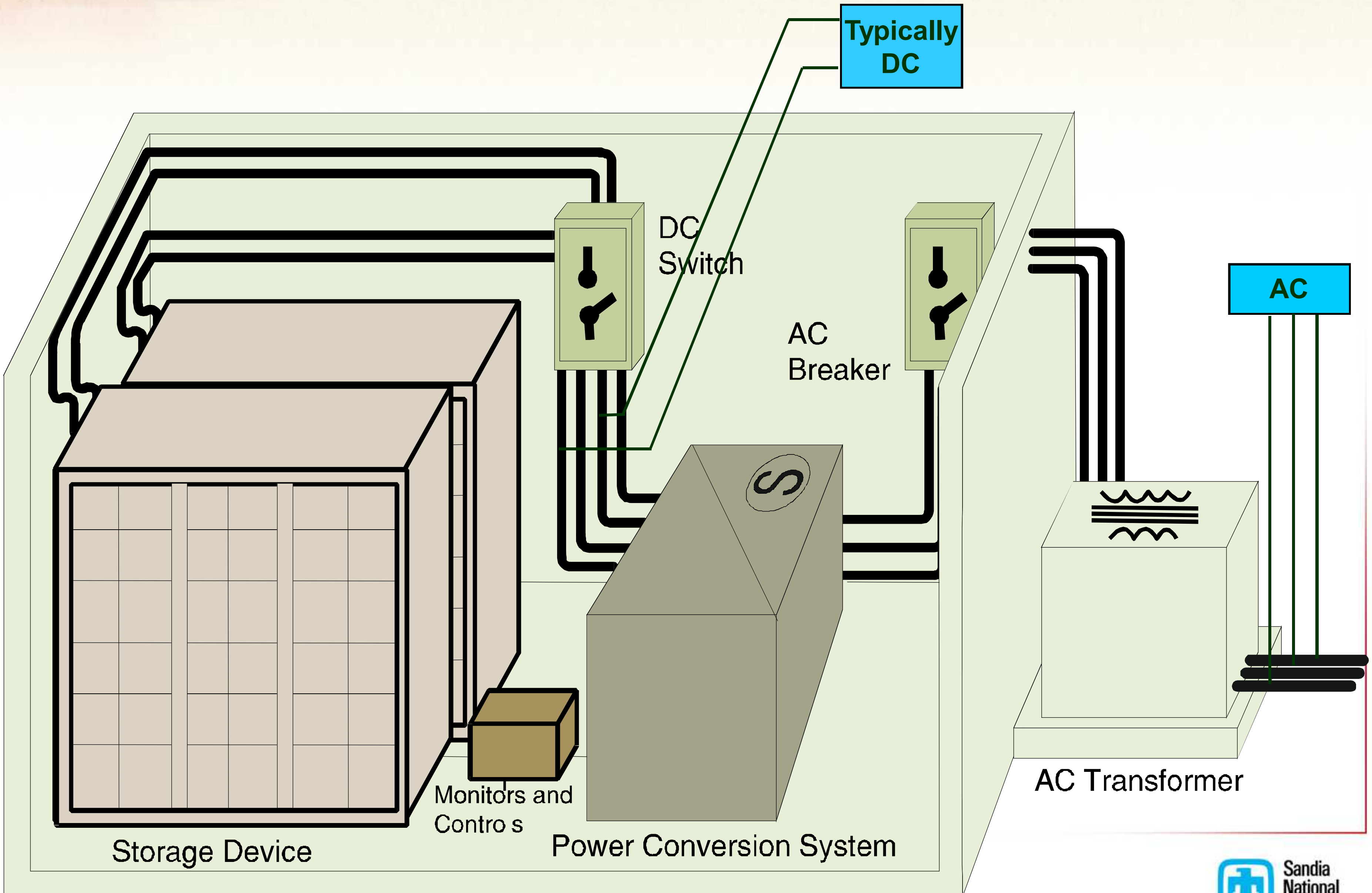
- Turbine
- Foundations
- Electrical collection
- Power conditioning
- Substation
- SCADA
- Roads
- Maintenance facilities





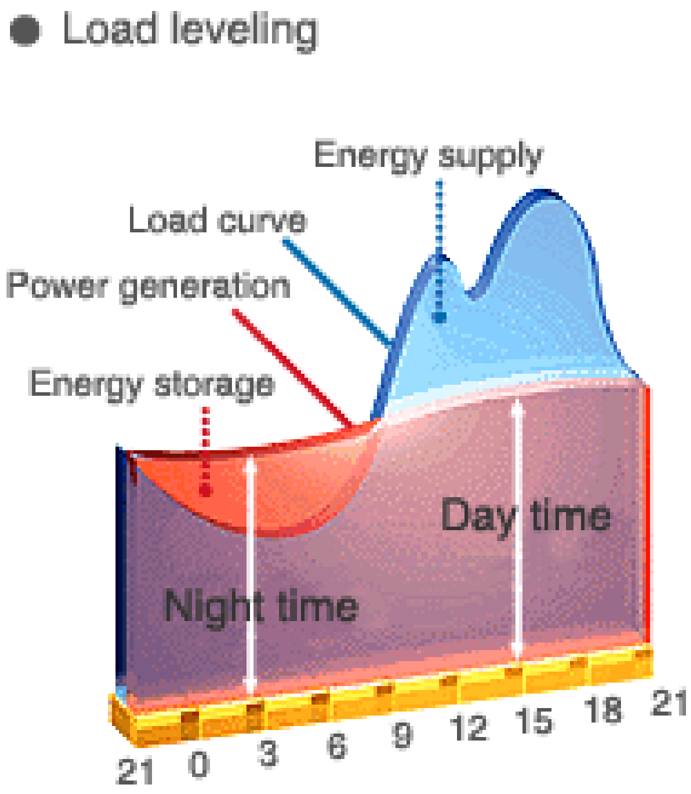

Sandia National Laboratories

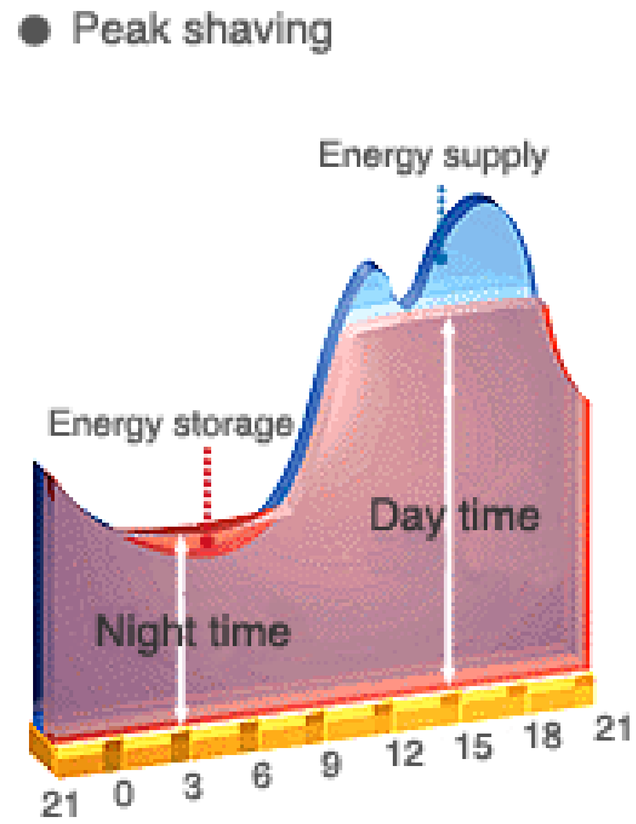
# Schematic of an Energy Storage System




Sandia National Laboratories

# How Energy Storage Works




*Source: NGK*

Sandia National Laboratories

# Applications and Energy Requirements

| Application | Storage Support Time |
|---|---|
| Frequency Regulation | 1 – 5 minutes |
| Spinning Reserve | 15 – 20 minutes |
| Distribution Upgrade Deferral | 1 – 4 hours |
| Time-of-Use Cost Management | 15 minutes – 1 hour |
| Demand Management | 15 minutes – 1 hour |
| Power Quality | Seconds to 5 minutes |

# 100kW NaS Battery

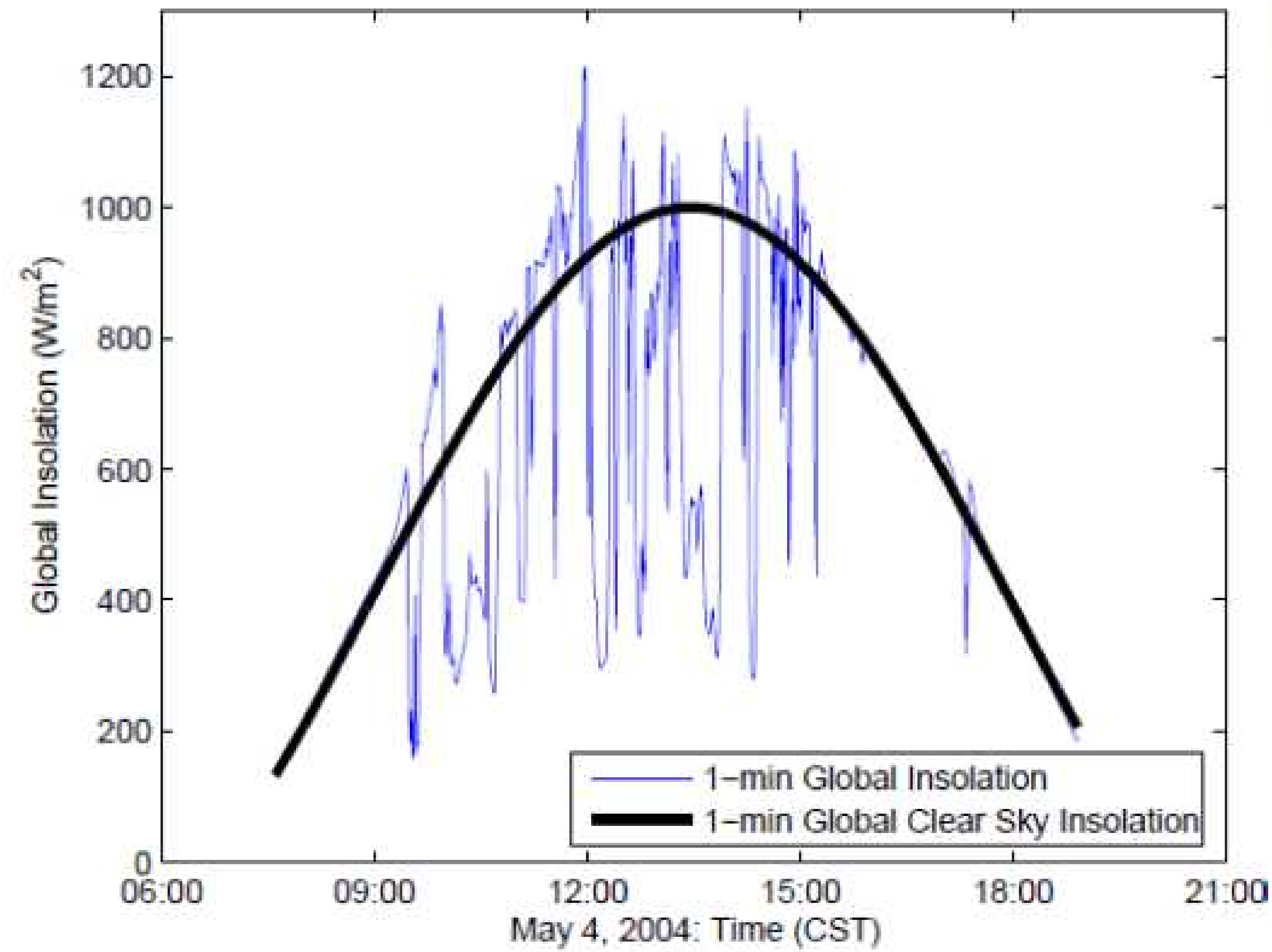




***Source: NGK***

# Effects of Intermittency of PV and Wind Generation

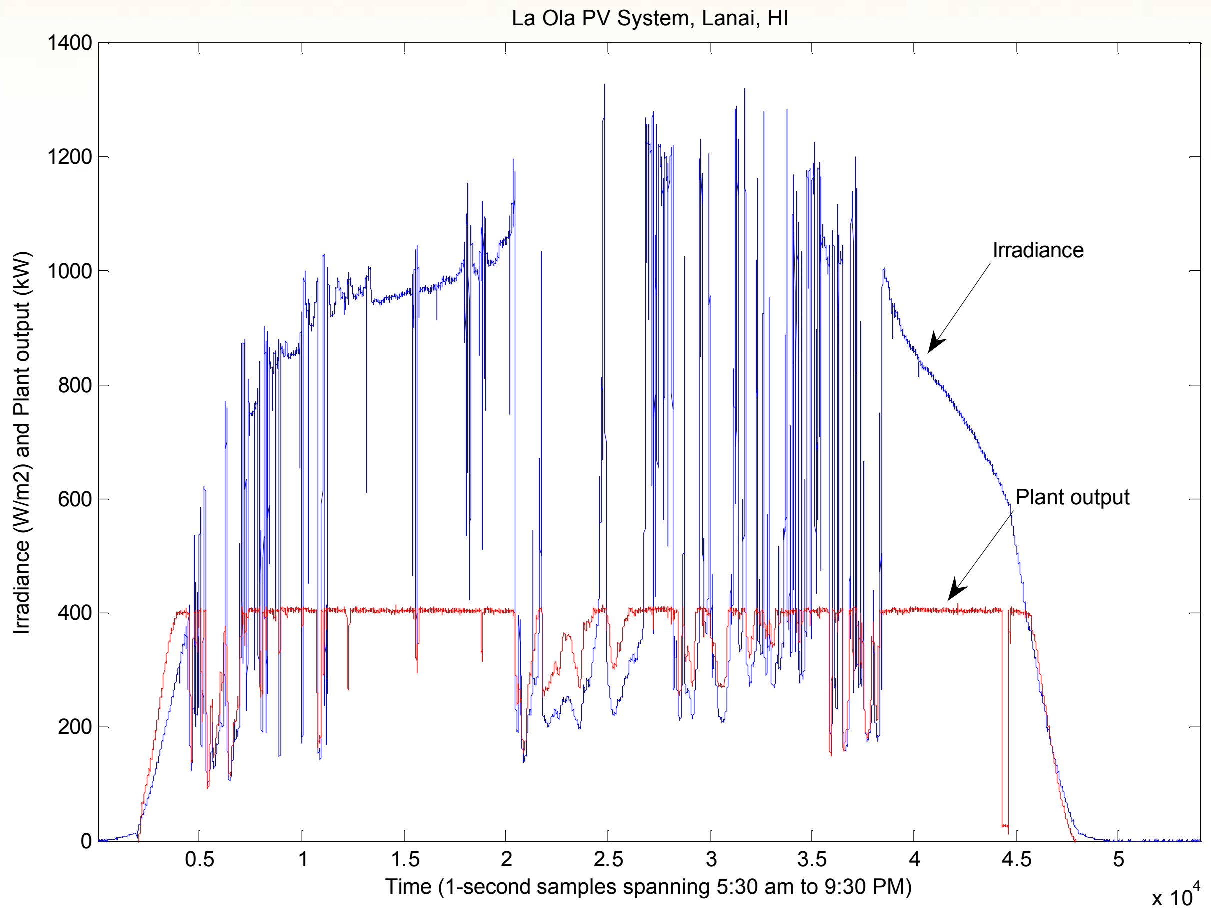
# Clouds can produce rapid ramps in solar insolation



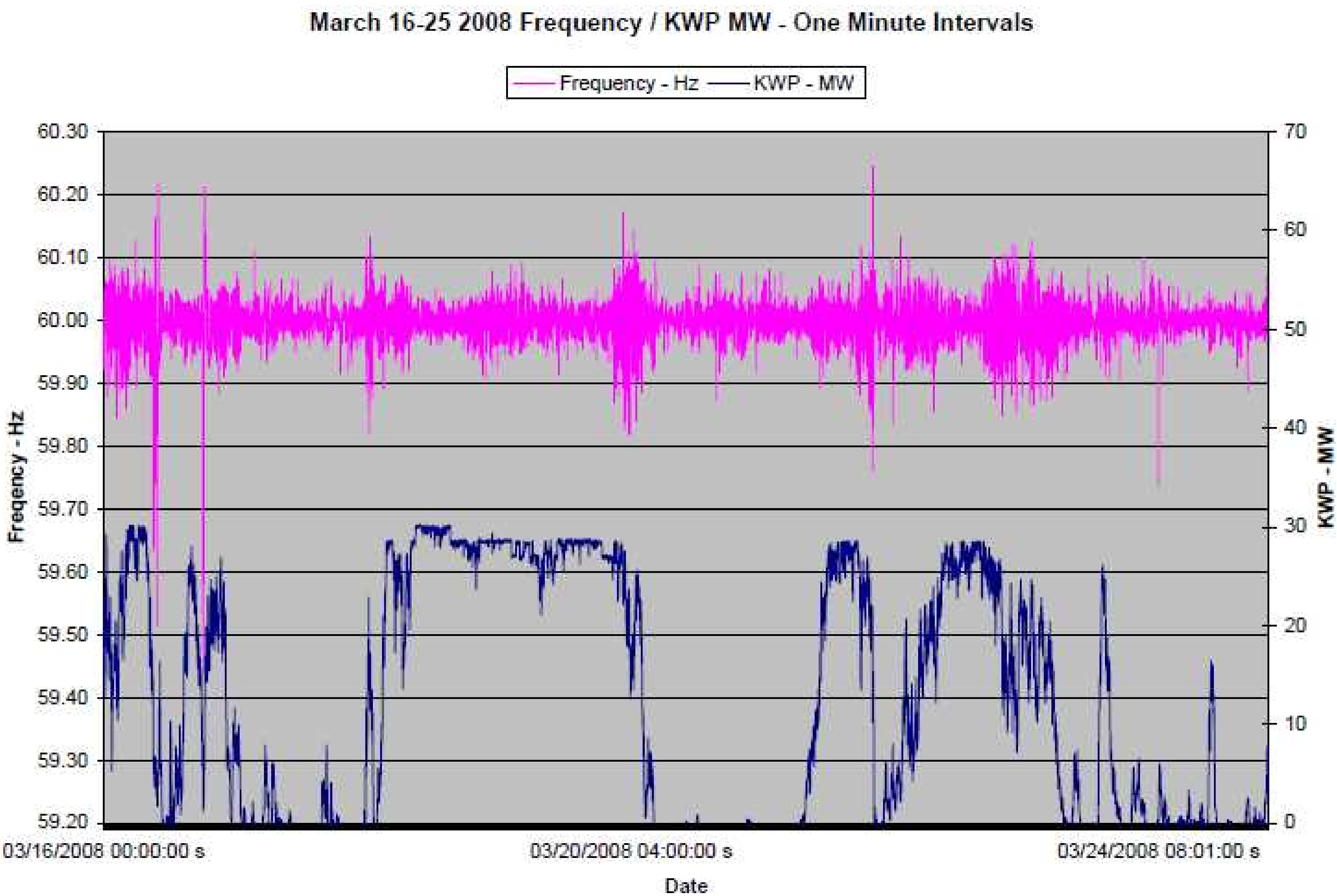

**Source:** LBNL analysis of Southern Great Plains data set

Sandia National Laboratories

# PV Variability in Actual PV System

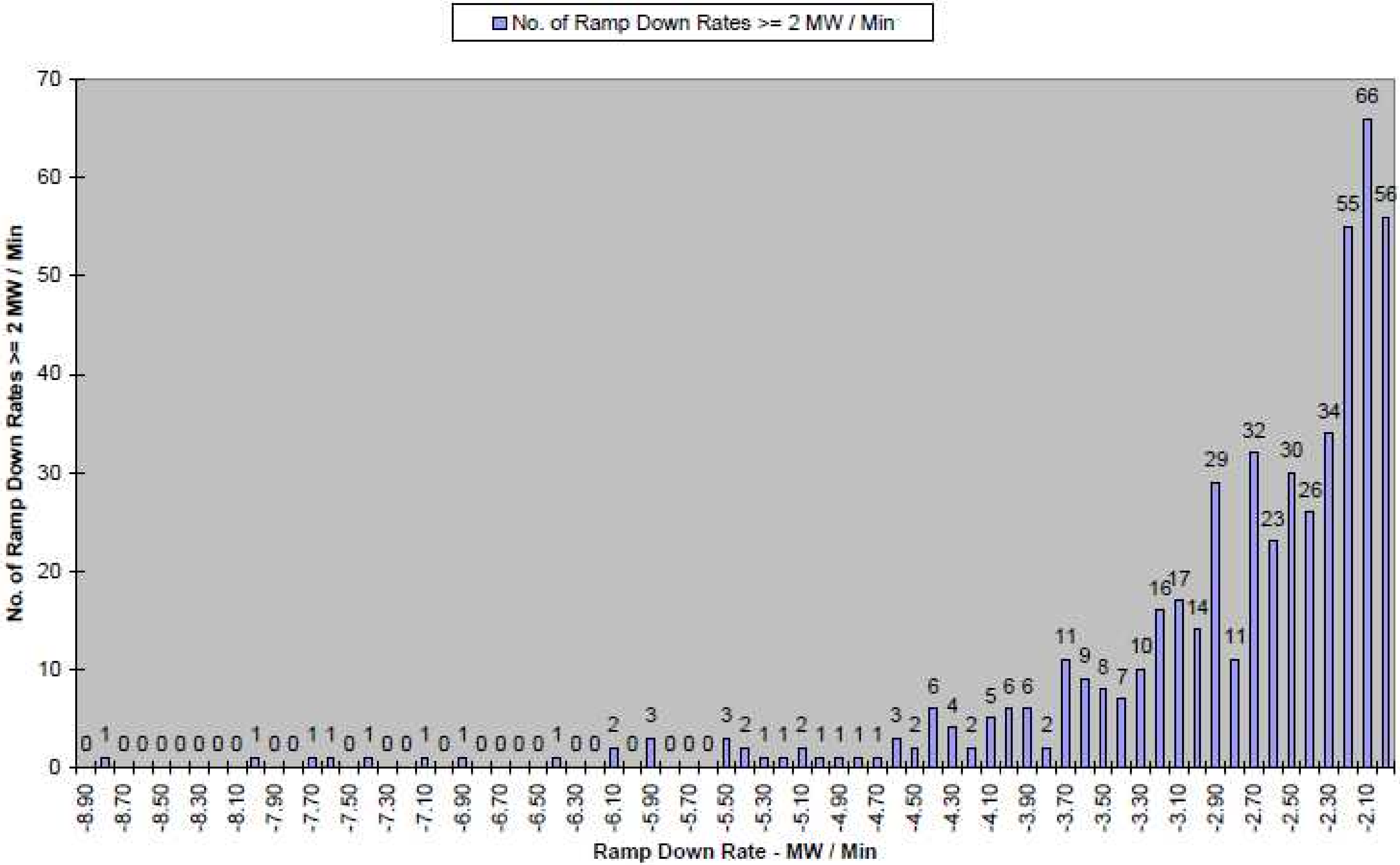



- **Irradiance and PV system ac output A typical partly cloudy day in July**
- **PV system rating: 1,300 kW ac, presently limited to 400 kW ac (intentionally)**




Sandia National Laboratories

# Ramp Down Rates >= 2 MW / Min Histogram for December 2007

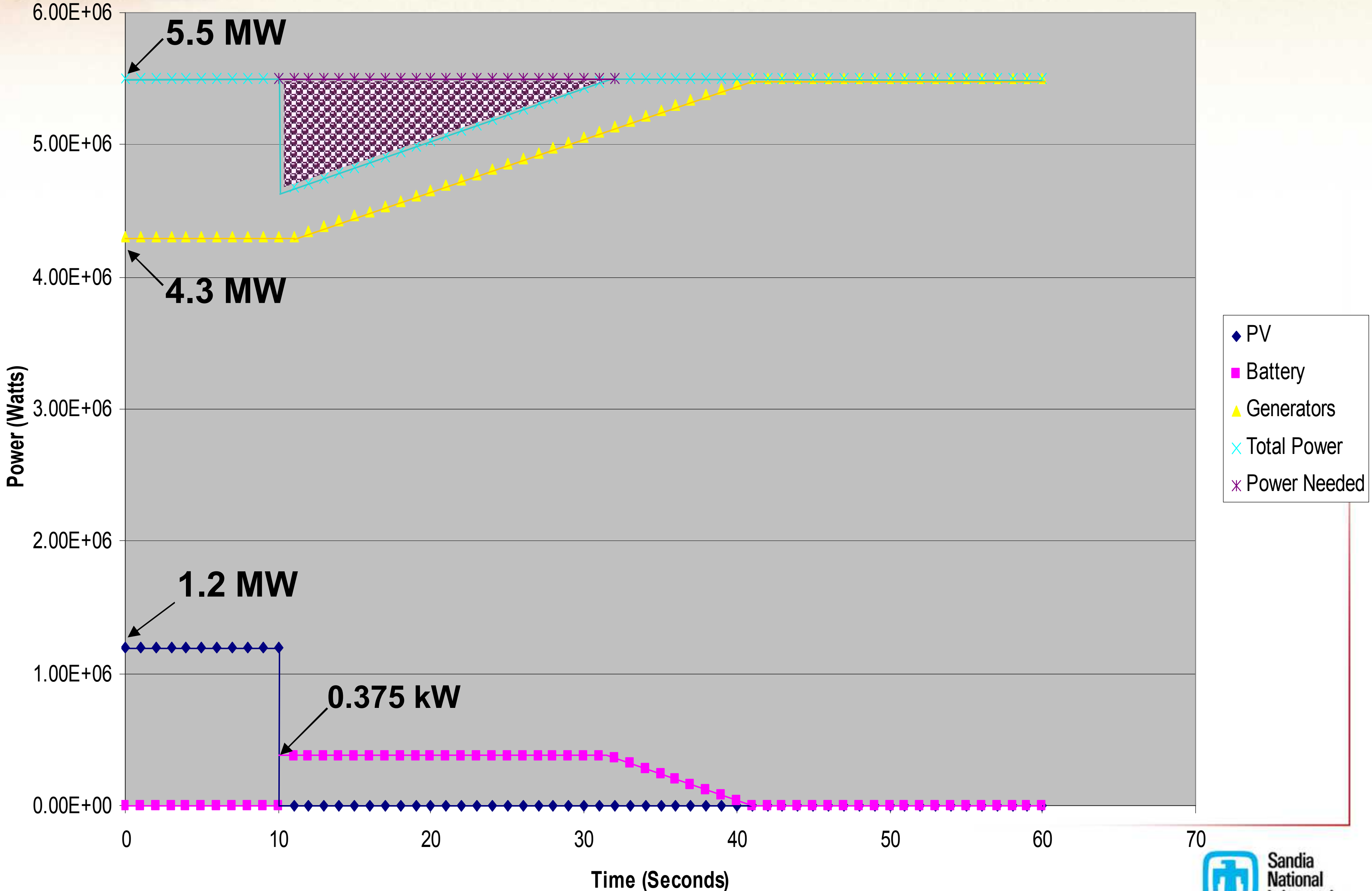



Sandia National Laboratories

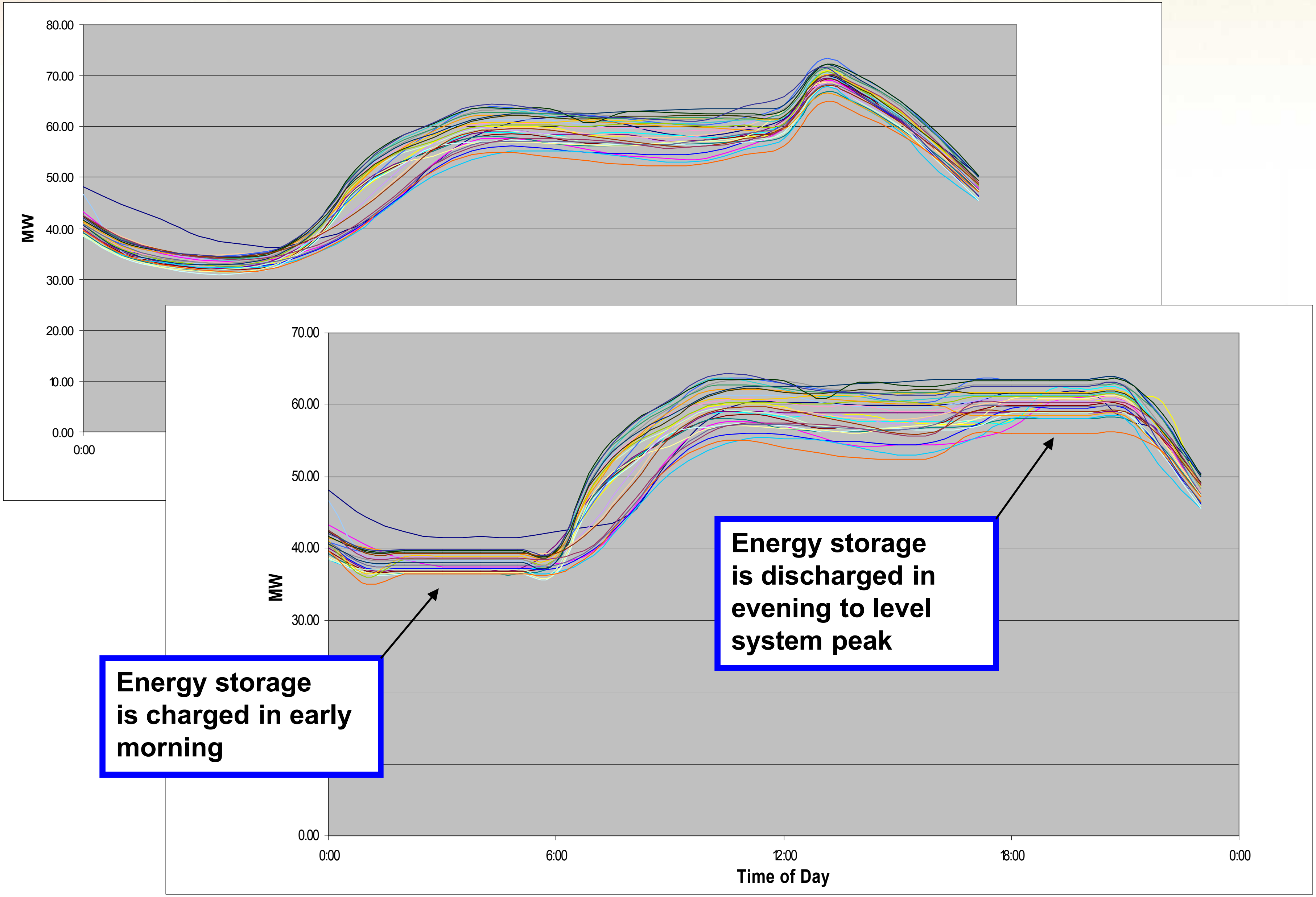
# Experience in Electric Systems

Sandia National Laboratories

# Lanai Power System



# Daily Load Profiles for January 2006
# 16 MWh Energy Storage – 85% Efficiency Storage



# Two Books Recommended for Reading

- "Technology and Transformation in the American Electric Utility Industry" by Richard Hirsh
- "Small is Profitable" by Amory Lovins

Sandia National Laboratories

# Thank You

# Questions and Discussion

Sandia National Laboratories