ESMAP-SAR-EAP Renewable Energy Training Program 2014

Energy Storage for Renewable Integration

24th Apr 2014

Jerry Randall

DNV GL – Renewables Advisory , Bangkok

DNV GL Personnel

- ***Jerry Randall (Speaker)***

  DNV GL Project Development Engineer, Bangkok

  – Experience of wind project feasibility & development across Asia

  – Previously worked for large Chinese WTG manufacturer

  – Graduate of the University of Cambridge

DNV GL Personnel

- ***Jerry Randall (Speaker)***

  DNV GL Project Development Engineer, Bangkok
  - Experience of wind project feasibility & development across Asia
  - Previously worked for large Chinese WTG manufacturer
  - Graduate of the University of Cambridge

- ***Richard Fioravanti (Global Expert)***

  DNV GL Service Line Leader, Distributed Energy Resources
  - On the Board of the NY-BEST organization (www.ny-best.org)
  - Previously work in advanced aerospace and distributed generation applications
  - Graduate of the University of Southern California

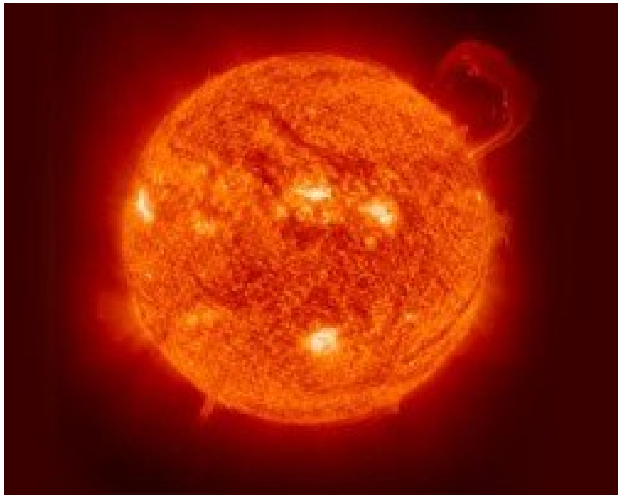
Contents

Private and confidential

Variability of Renewable Resources

Solar Energy

1. Sunrise and sunset – highly predictable

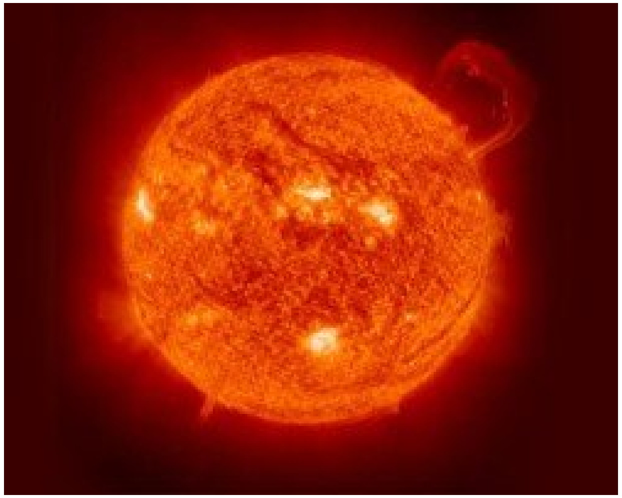


Variability of Renewable Resources

Solar Energy

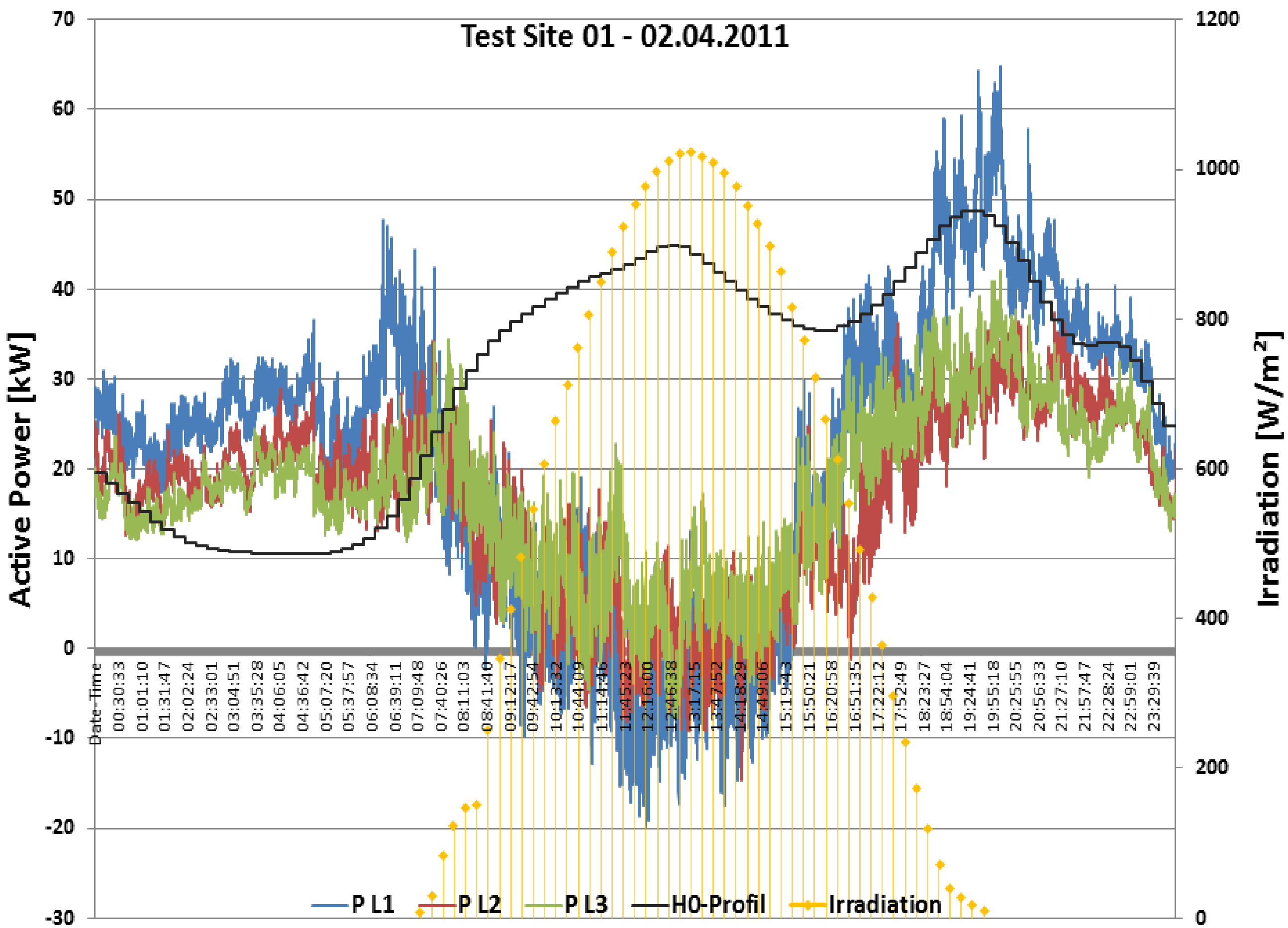
1. Sunrise and sunset – highly predictable

2. Seasonal variations – highly predictable



Private and confidential

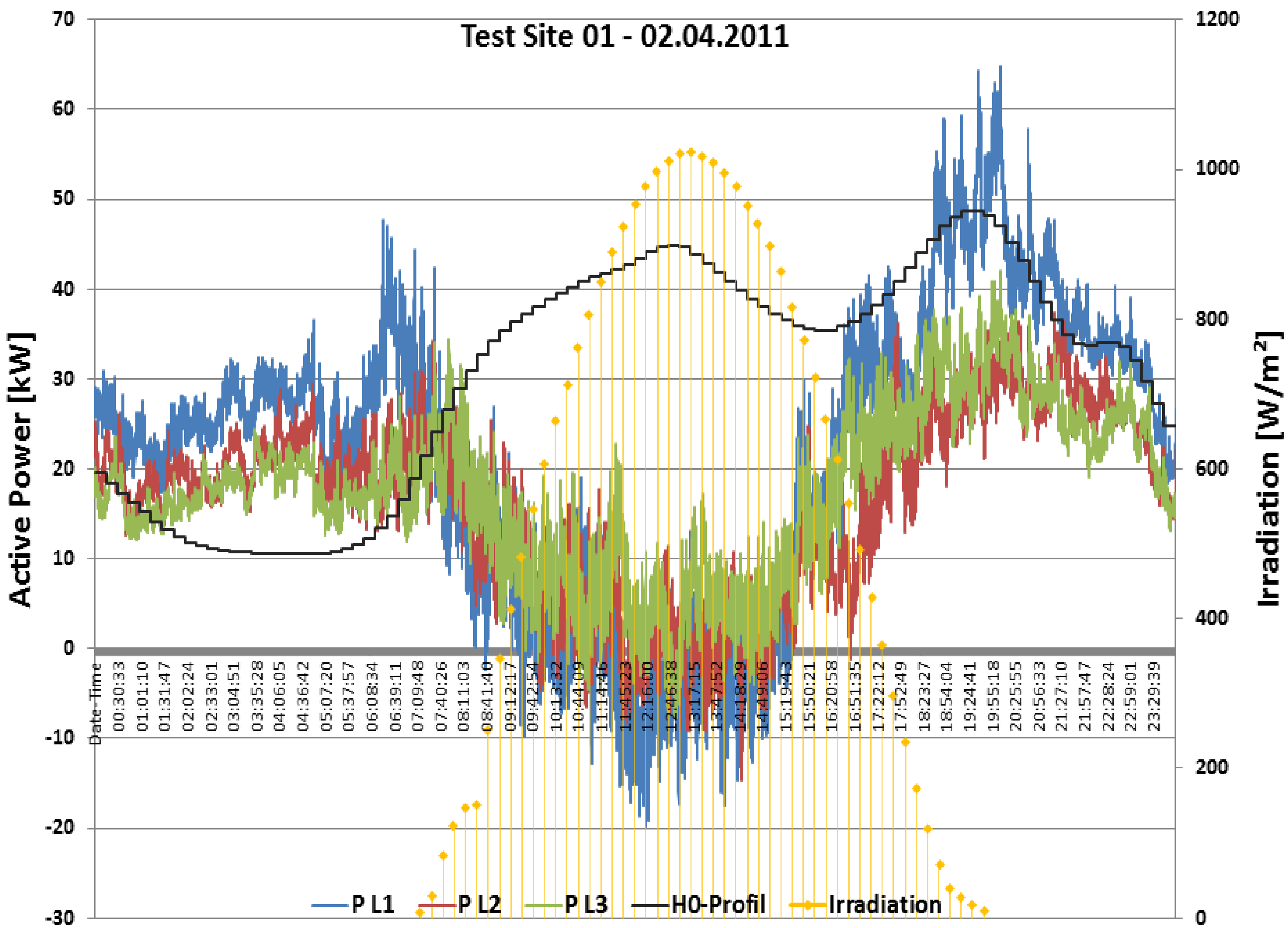
Impact of Solar on Distribution System Load



- **Black line** indicates the average load curve of the 134 households
- **Yellow background** quarter hourly solar radiation at the test site

Source: G. Heilscher, H. Ruf: Ulm University of Applied Sciences, 2011

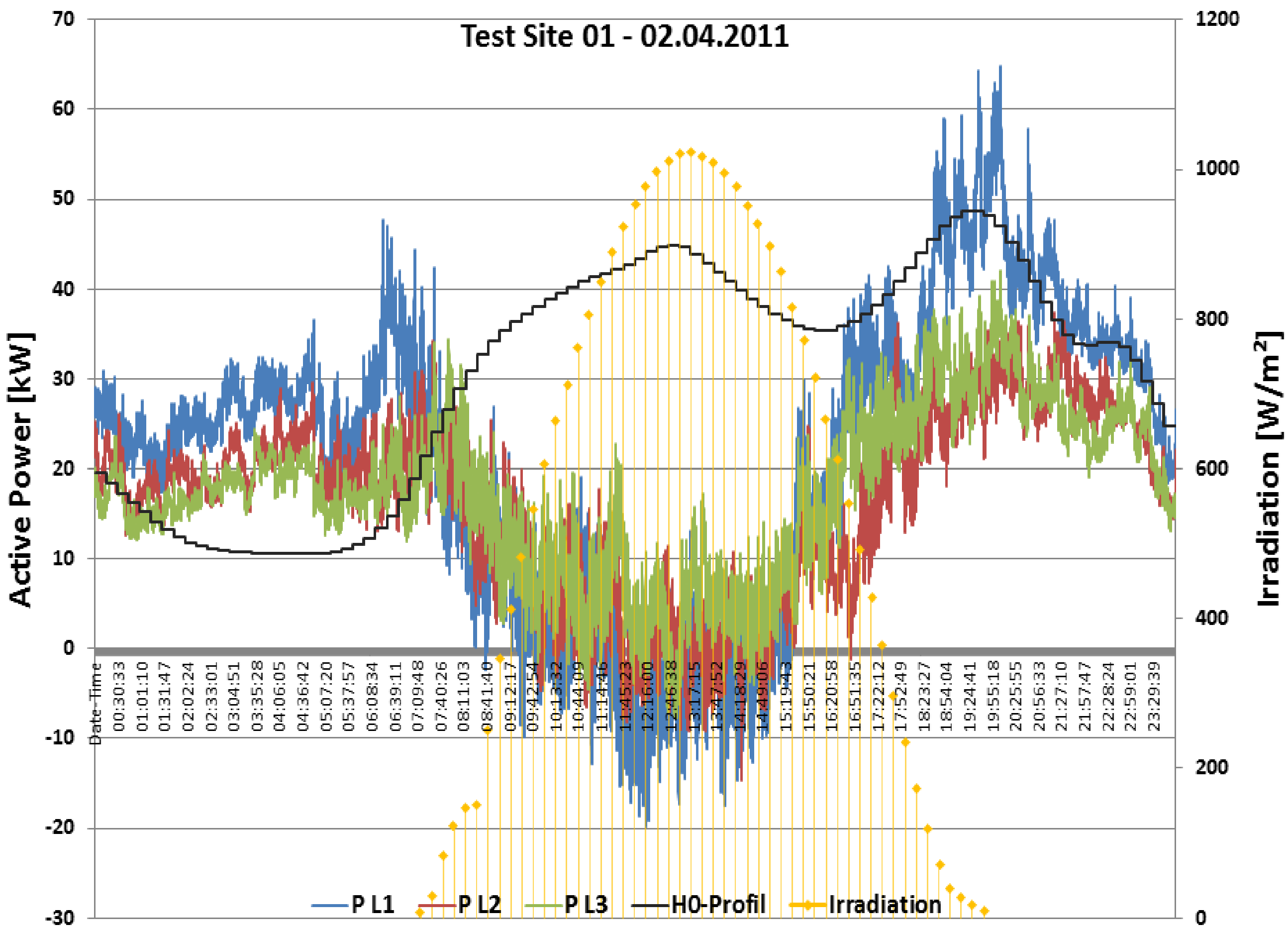
Impact of Solar on Distribution System Load



- **Black line** indicates the average load curve of the 134 households
- **Yellow background** quarter hourly solar radiation at the test site
- The **load measured** at the low voltage transformer drops during daytime due to feed in of solar power

Source: G. Heilscher, H. Ruf: Ulm University of Applied Sciences, 2011

Impact of Solar on Distribution System Load



- **Black line** indicates the average load curve of the 134 households
- **Yellow background** quarter hourly solar radiation at the test site
- The **load measured** at the low voltage transformer drops during daytime due to feed in of solar power
- Time of **maximum solar generation** does not match typical load profile
- Between 9 AM and 2 PM **load flow is reverse** at the transformer

Source: G. Heilscher, H. Ruf: Ulm University of Applied Sciences, 2011

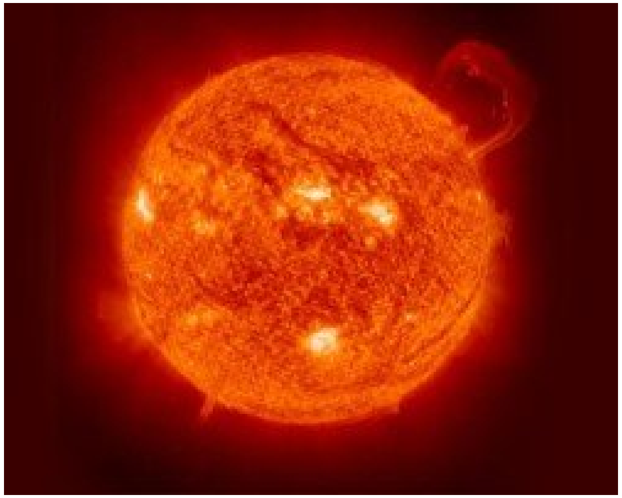
Variability of Renewable Resources

Solar Energy

1. **Sunrise and sunset** – highly predictable

2. **Seasonal variations** – highly predictable

3. **Weather variations** – unpredictable & volatile



Variability of Renewable Resources

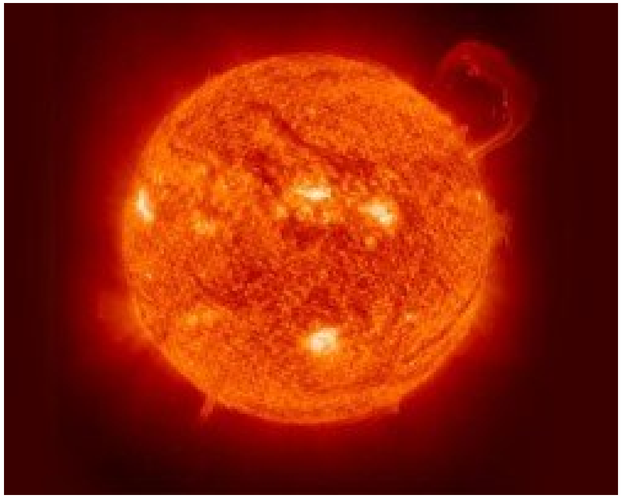
Solar Energy

1. Sunrise and sunset – highly predictable

2. Seasonal variations – highly predictable

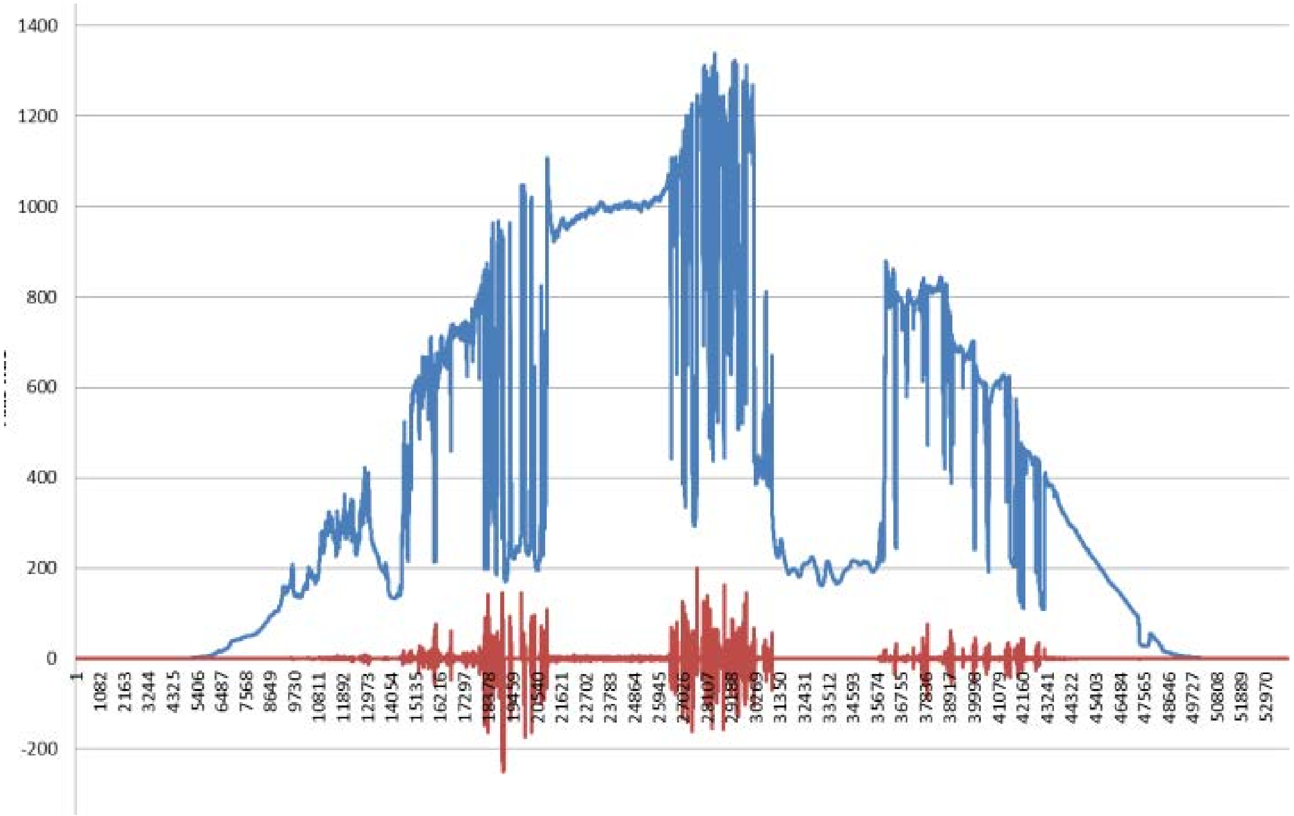
3. Weather variations – unpredictable & volatile

- A cloud covers the sun within 1 sec → 80% power reduction
- A fast cloud crosses a 10 MW system in about 1 minute
- *Volatility* must be considered when the penetration level is high to ensure grid resiliency



Private and confidential

Variability of Renewable Resources

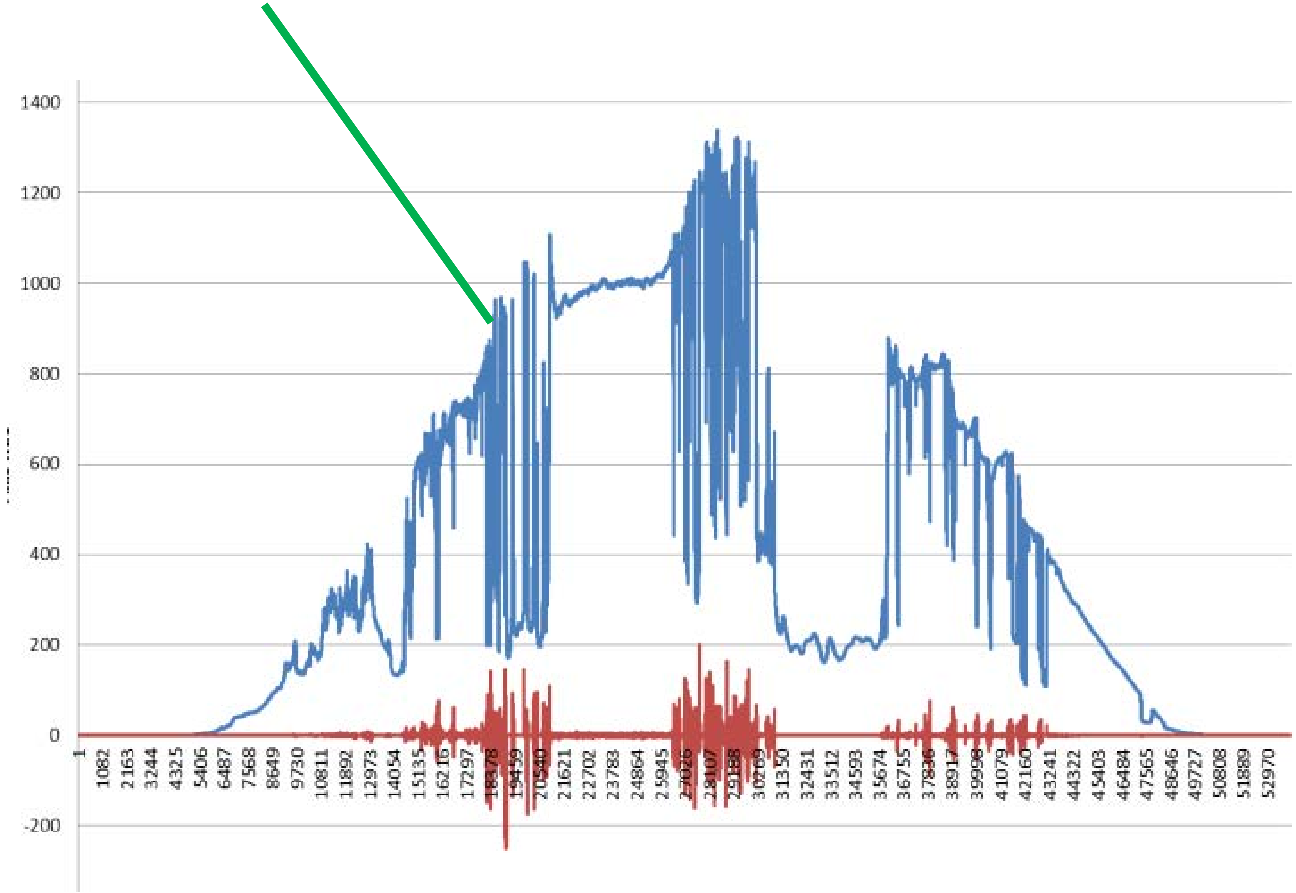


Private and confidential

Data source: NREL, Airportdata, 2010, Evaluation BEW, DNV KEMA

Variability of Renewable Resources

Rapid fluctuation due to cloud movement



Private and confidential

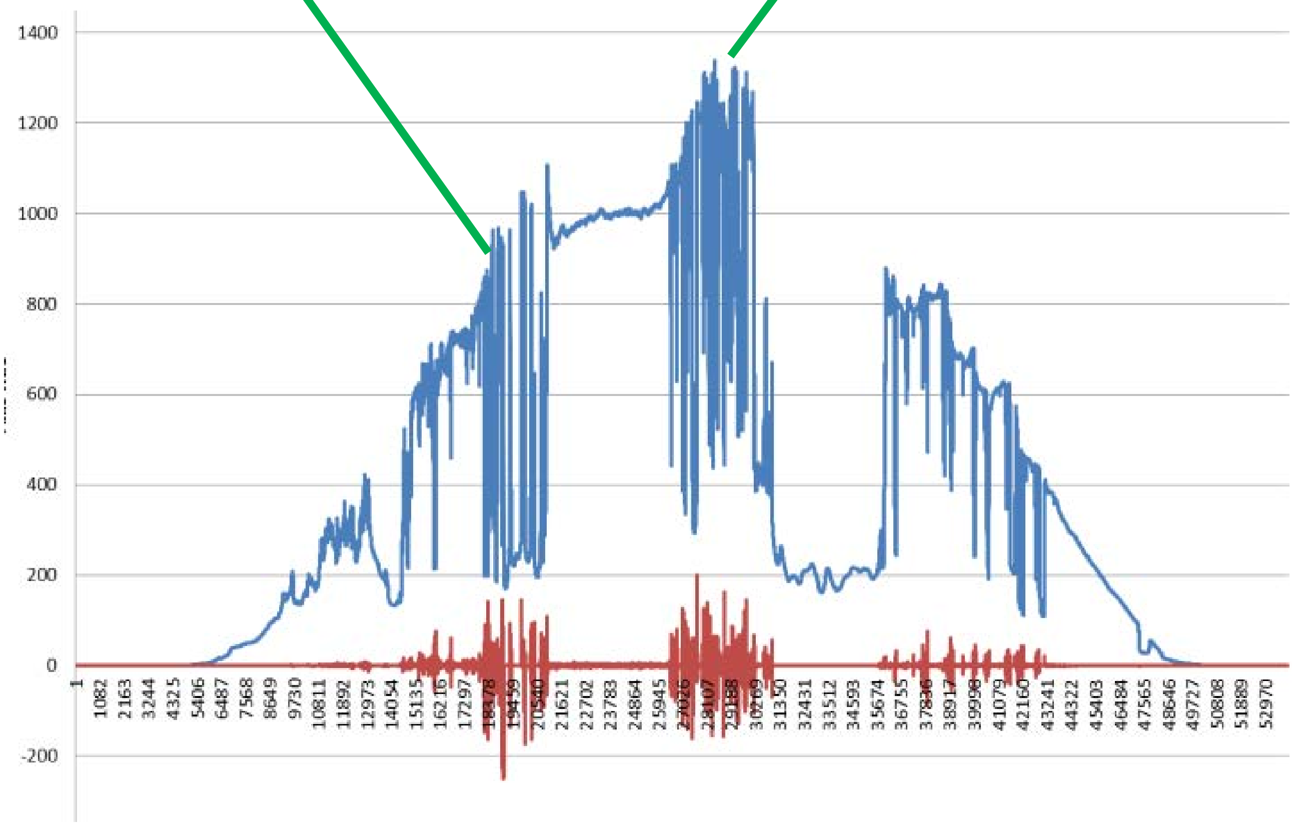
Data source: NREL, Airportdata, 2010, Evaluation BEW, DNV KEMA

DNV·GL

Variability of Renewable Resources

Rapid fluctuation due to cloud movement

Peaks occur when direct and reflected sunlight combine



Private and confidential

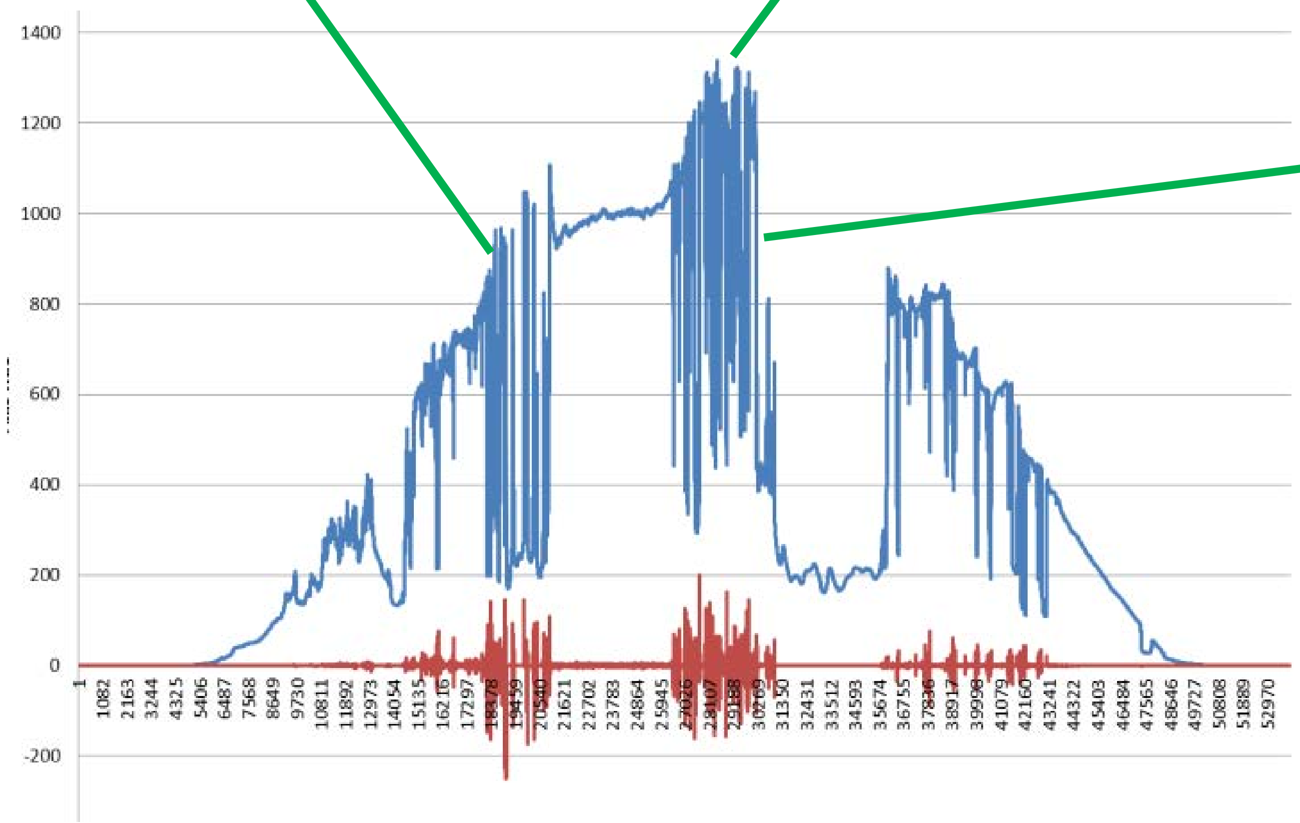
Data source: NREL, Airportdata, 2010, Evaluation BEW, DNV KEMA

Variability of Renewable Resources

Rapid fluctuation due to cloud movement

Peaks occur when direct and reflected sunlight combine

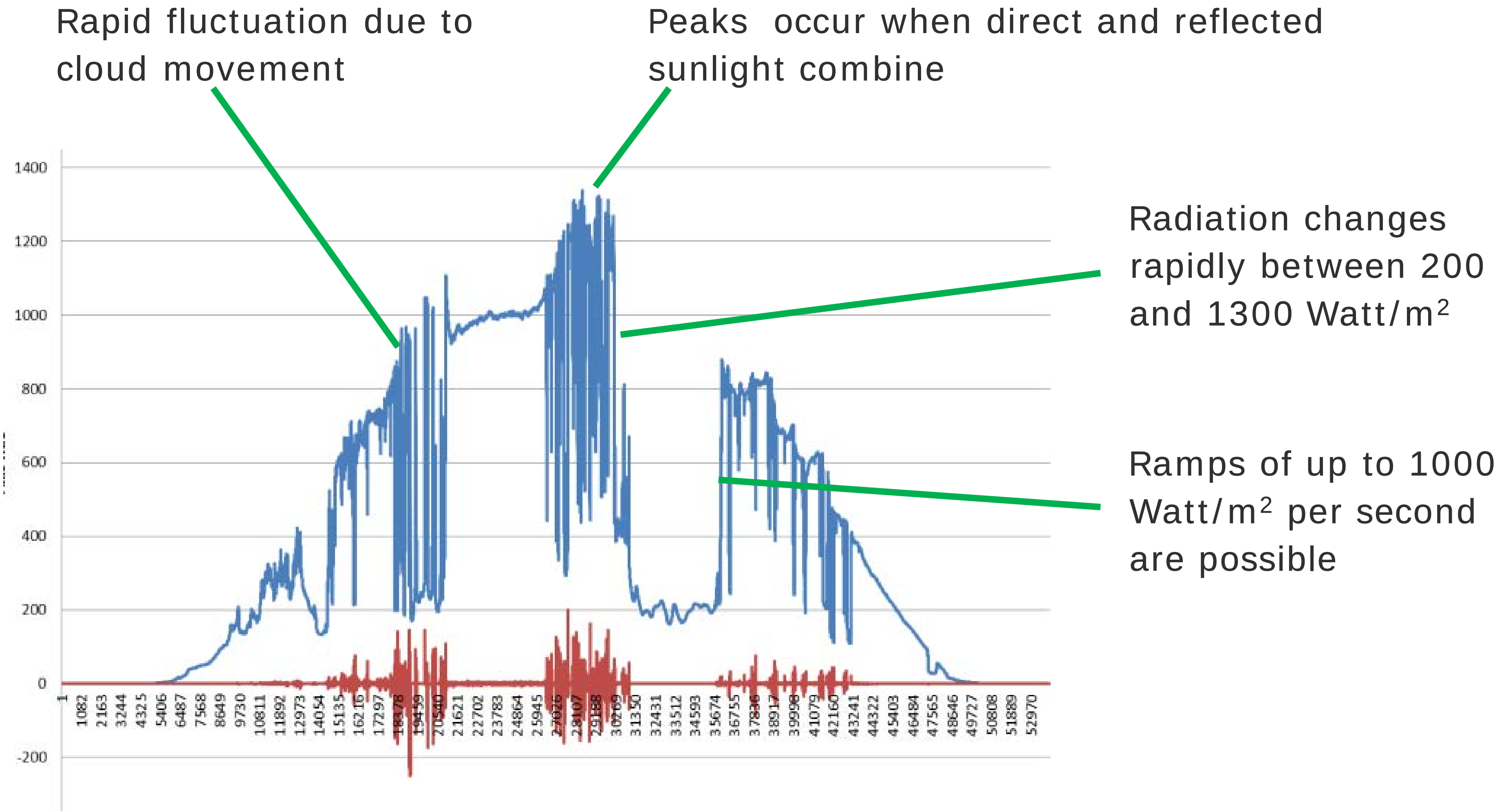
Radiation changes rapidly between 200 and 1300 Watt/m^2



Private and confidential

Data source: NREL, Airportdata, 2010, Evaluation BEW, DNV KEMA

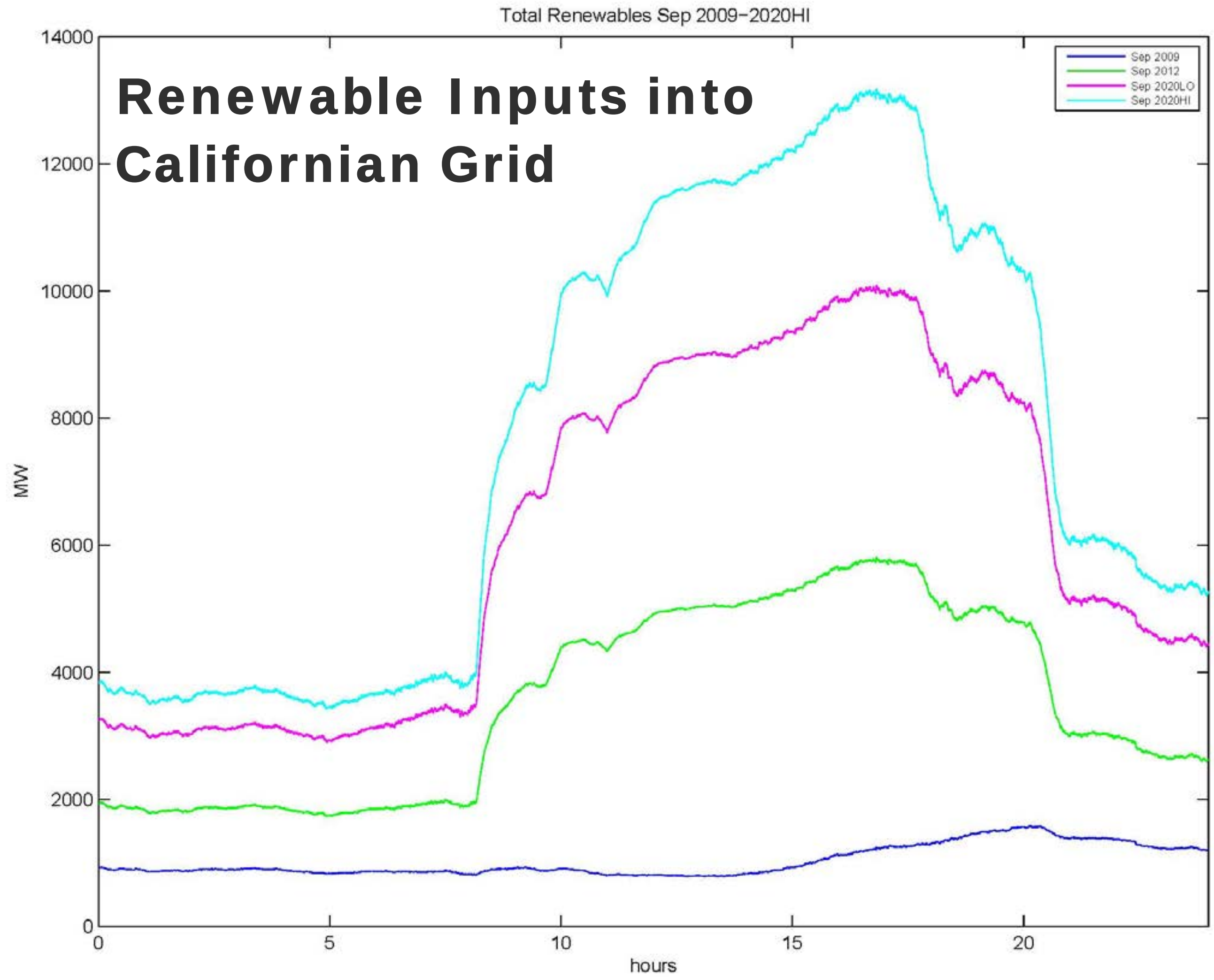
Variability of Renewable Resources



Private and confidential

Data source: NREL, Airportdata, 2010, Evaluation BEW, DNV KEMA

Investigating Renewable Scenarios



Legend:

2020HI Renewables
2020LO Renewables
2012 Renewables
2009 Renewables

Variability: Two Different Problems

1) Renewable Variability

- Diurnal and Seasonal
- At night mostly wind production
- Mid-day mostly solar (Concentrated & PV)
- Variation can be addressed with regulation or slow storage

Variability: Two Different Problems

1) Renewable Variability

- Diurnal and Seasonal
- At night mostly wind production
- Mid-day mostly solar (Concentrated & PV)
- Variation can be addressed with regulation or slow storage

2) Ramping

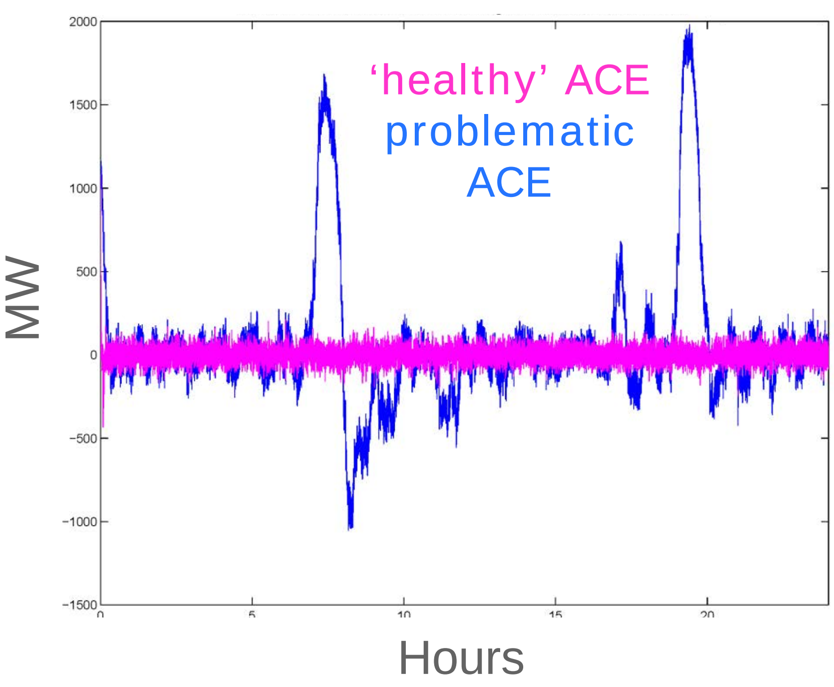
- Diurnal and Short-term
- Wind down in morning and up in evening
- Solar up in morning and down late afternoon
- Ramping severity varies seasonally
- Ramping is much more of a problem than the calmer period variability
- Ramping requires coordination of fast storage with less fast conventional generation

Effect of Variability on Grid

Common metrics have been defined for assessing grid performance

- Area Control Error (ACE)
  - Measures difference between scheduled and actual load and supply.
  - MW Signal that fluctuates around zero.
  - Performance criteria stipulates allowable magnitude and variability

Example of ACE Performance



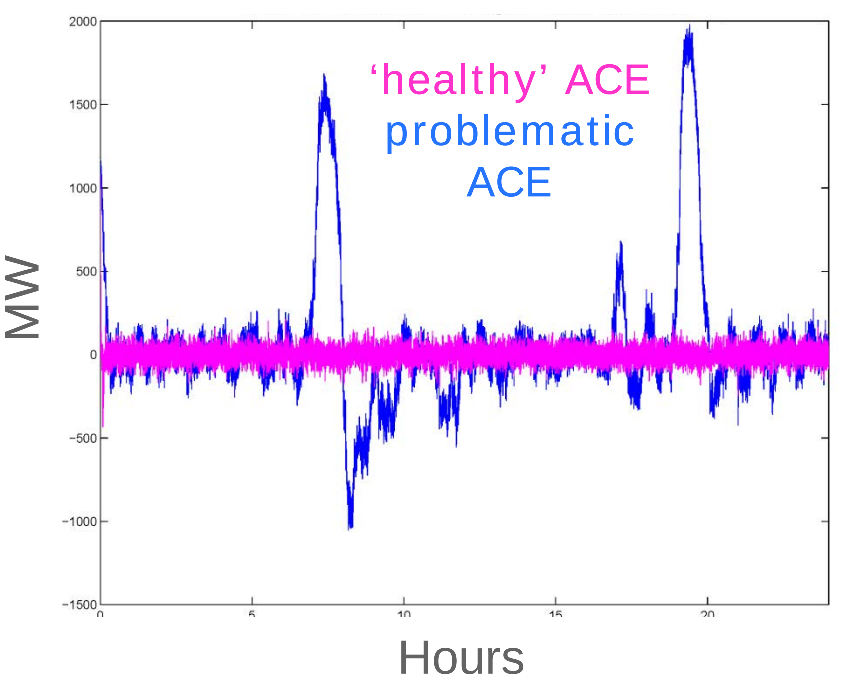
Effect of Variability on Grid

Common metrics have been defined for assessing grid performance

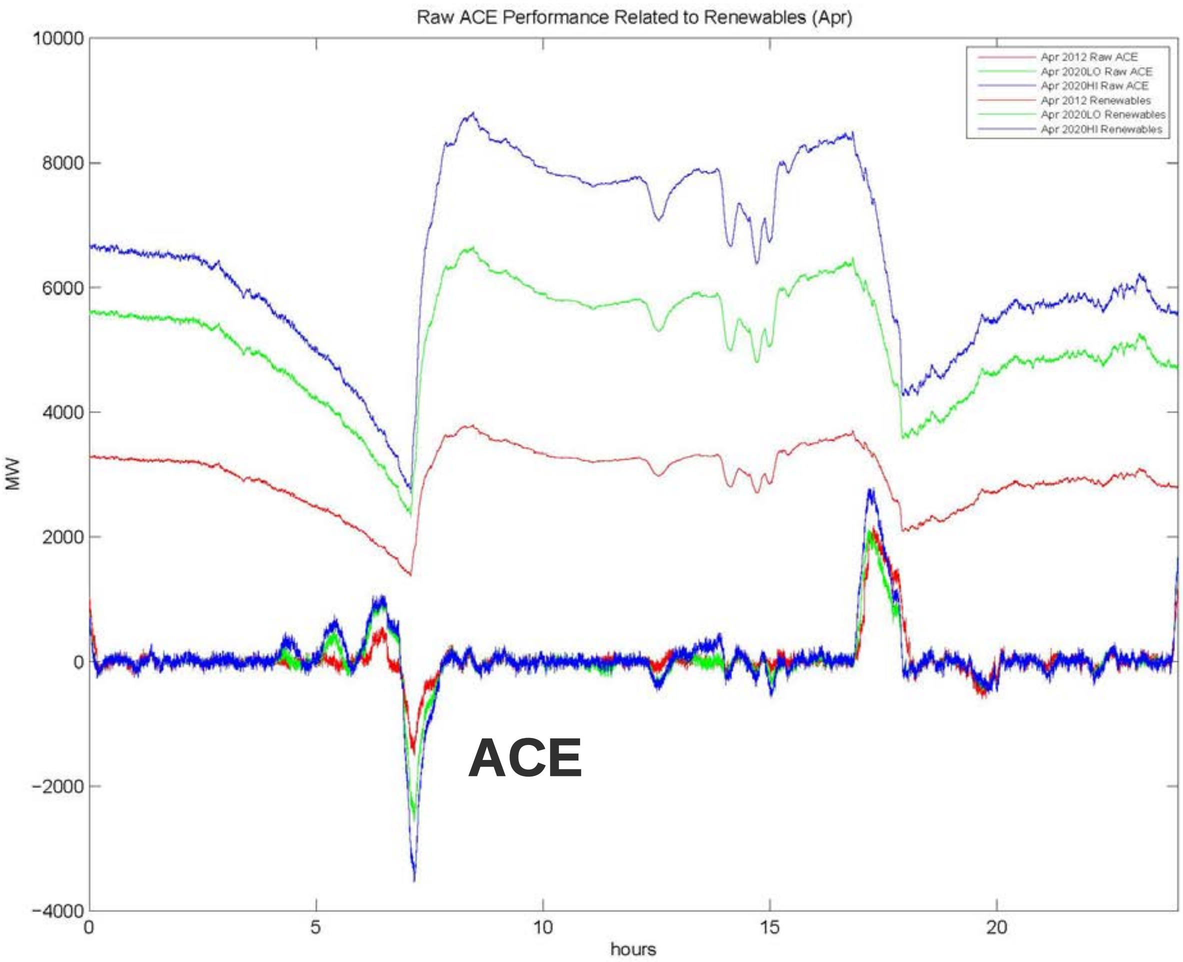
- Area Control Error (ACE)
  - Measures difference between scheduled and actual load and supply.
  - MW Signal that fluctuates around zero.
  - Performance criteria stipulates allowable magnitude and variability

- Frequency Deviation
  - Difference in load and supply results in frequency above or below nominal frequency (60Hz).

Example of ACE Performance

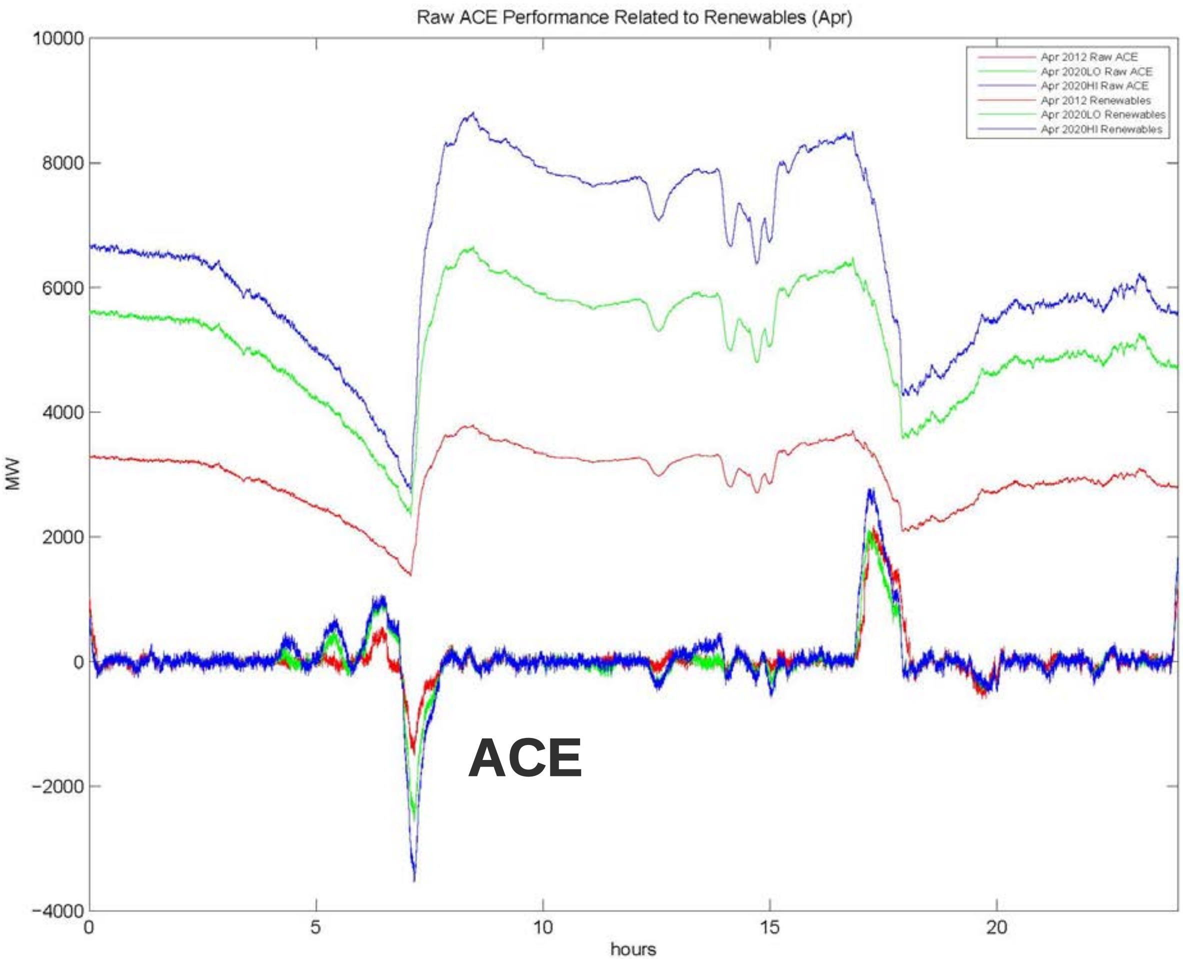


ACE Affected by Increasing Renewables



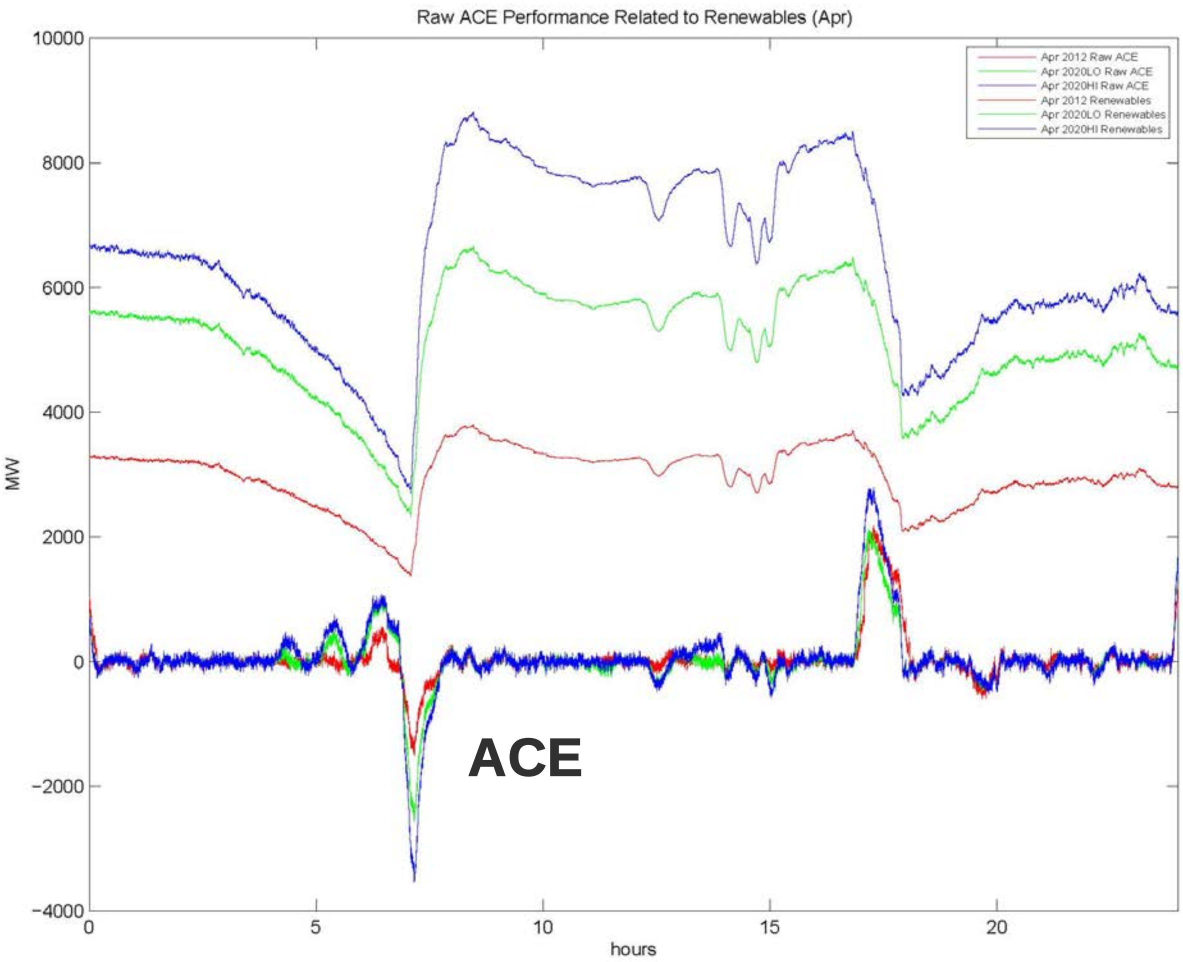
Private and confidential

ACE Affected by Increasing Renewables



- Costs for regulation and balancing go up
- Increase in spinning reserves needed
- Conventional units operated inefficiently
- High flexibility of the system needed

ACE Affected by Increasing Renewables



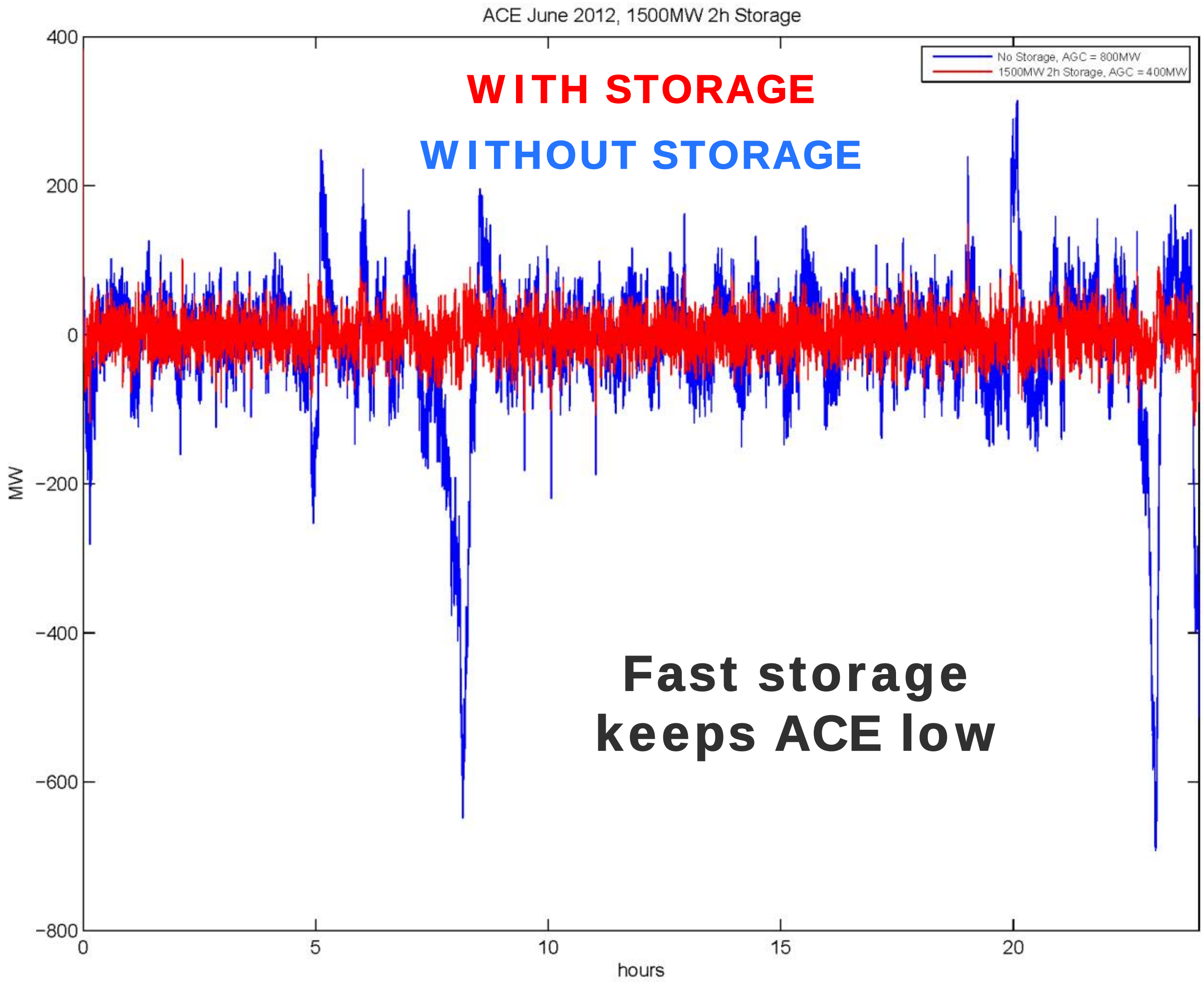
- Costs for regulation and balancing go up
- Increase in spinning reserves needed
- Conventional units operated inefficiently
- High flexibility of the system needed

A Need For Storage

Private and confidential

DNV·GL

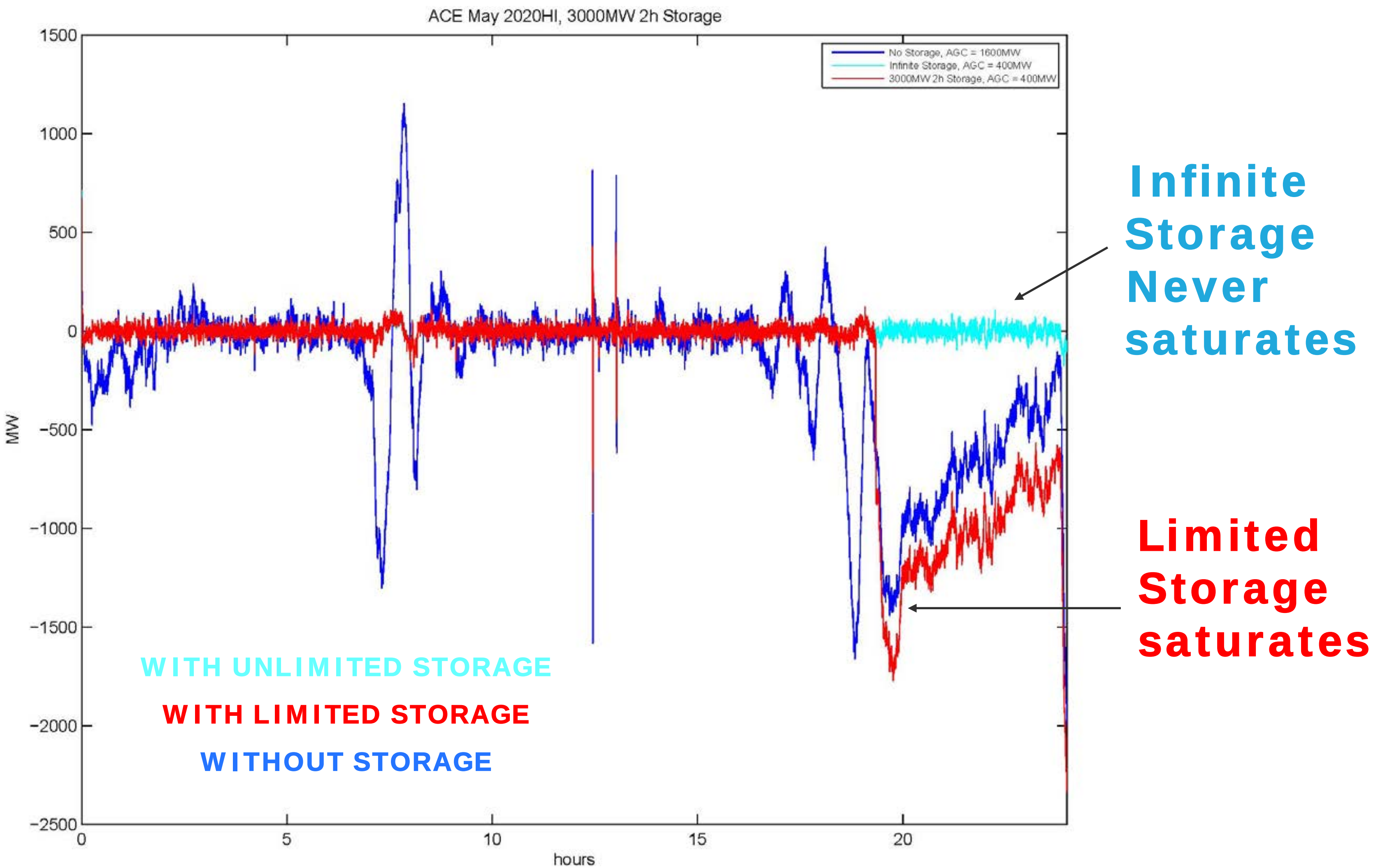
ACE with Storage



Private and confidential

DNV·GL

Sizing and Control of Storage



Private and confidential

DNV·GL

The Need for Storage

- Ramping problems are severe

The Need for Storage

- Ramping problems are severe
- Scheduling adjustments mitigate but will not cure the problem
  - 15 min instead of 1h Day-Ahead schedules

The Need for Storage

- Ramping problems are severe
- Scheduling adjustments mitigate but will not cure the problem
  - 15 min instead of 1h Day-Ahead schedules
- Fast storage must be correctly sized to mitigate large ramps

The Need for Storage

- Ramping problems are severe
- Scheduling adjustments mitigate but will not cure the problem
  - 15 min instead of 1h Day-Ahead schedules
- Fast storage must be correctly sized to mitigate large ramps
- Optimize storage control logic to improve use of storage capacity

The Need for Storage

- Ramping problems are severe
- Scheduling adjustments mitigate but will not cure the problem
  - 15 min instead of 1h Day-Ahead schedules
- Fast storage must be correctly sized to mitigate large ramps
- Optimize storage control logic to improve use of storage capacity
- Storage requires ramping capability of 0 – 100% in 5 min
  - May indicate limited effectiveness of Pumped Hydro and Compressed Air

The Need for Storage

- Ramping problems are severe
- Scheduling adjustments mitigate but will not cure the problem
  - 15 min instead of 1h Day-Ahead schedules
- Fast storage must be correctly sized to mitigate large ramps
- Optimize storage control logic to improve use of storage capacity
- Storage requires ramping capability of 0 – 100% in 5 min
  - May indicate limited effectiveness of Pumped Hydro and Compressed Air

Penetration levels

> 20% are where issues become problematic

> ~33% storage is essential

Recent Storage Activities

Technologies are already being tested and demonstrated with renewable systems

- Hawaii has set ramp rate requirements that are being met with electricity storage
- Onus on plant owner
- Lithium and Advanced Storage systems are commissioned and operating in the field today
- Next Generation storage devices are now in labs offering even greater potential



Recent Storage Activities

Technologies are already being tested and demonstrated with renewable systems

- Hawaii has set ramp rate requirements that are being met with electricity storage
- Onus on plant owner
- Lithium and Advanced Storage systems are commissioned and operating in the field today
- Next Generation storage devices are now in labs offering even greater potential

Not all solutions need to be Utility-Scale

- Distributed Bulk storage
- Use of Electric Vehicle Storage Capacity?
- Smart Grids?

Island Applications

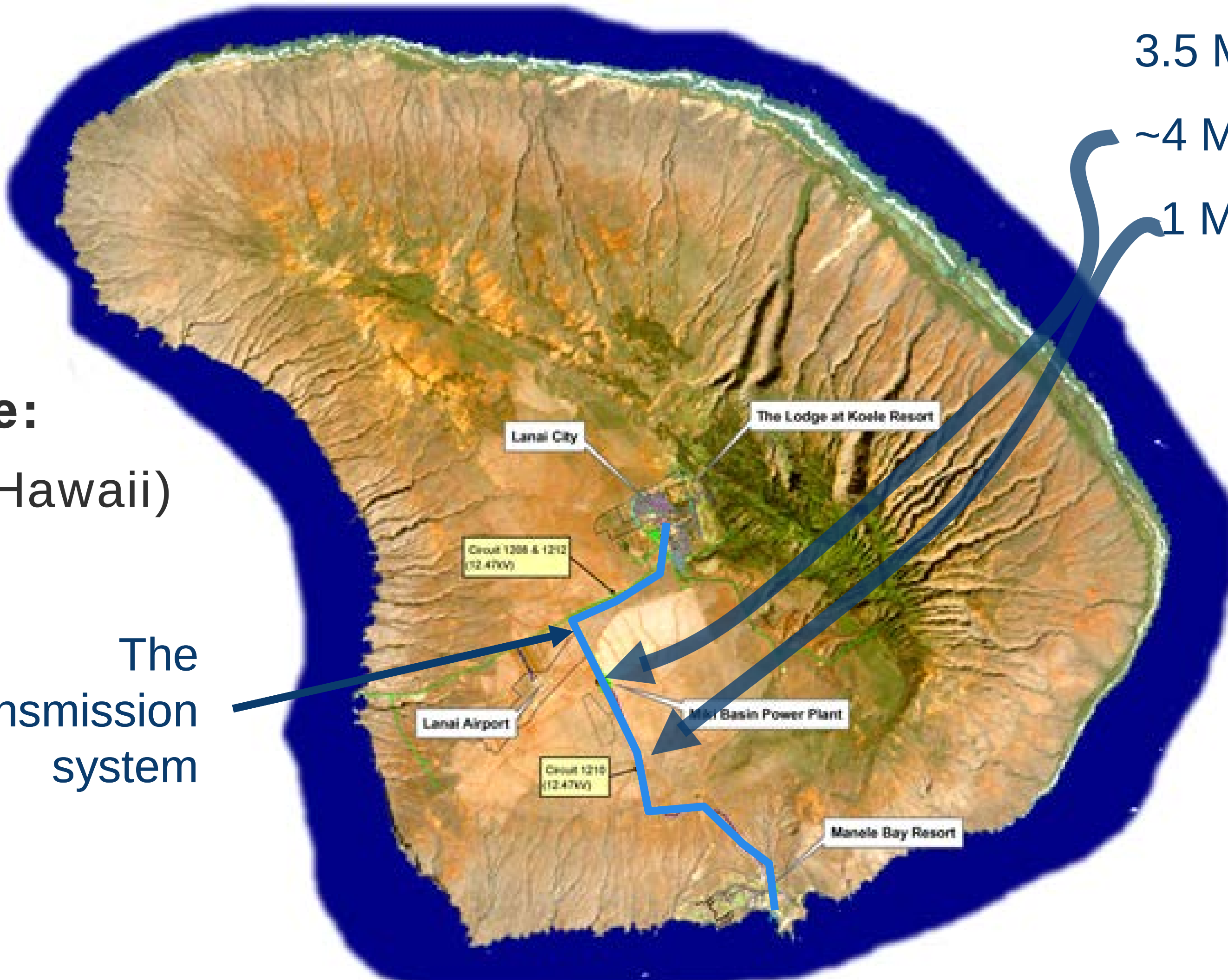
- Isolated grids magnify problems
- Islands rapidly exceed 20% renewable penetration (1 project)
- Cost of electricity is relatively high – helps economics

Island Applications

3.5 MW peak

~4 MW generation

1 MV PV



Example:

- Lanai (Hawaii)

The transmission system

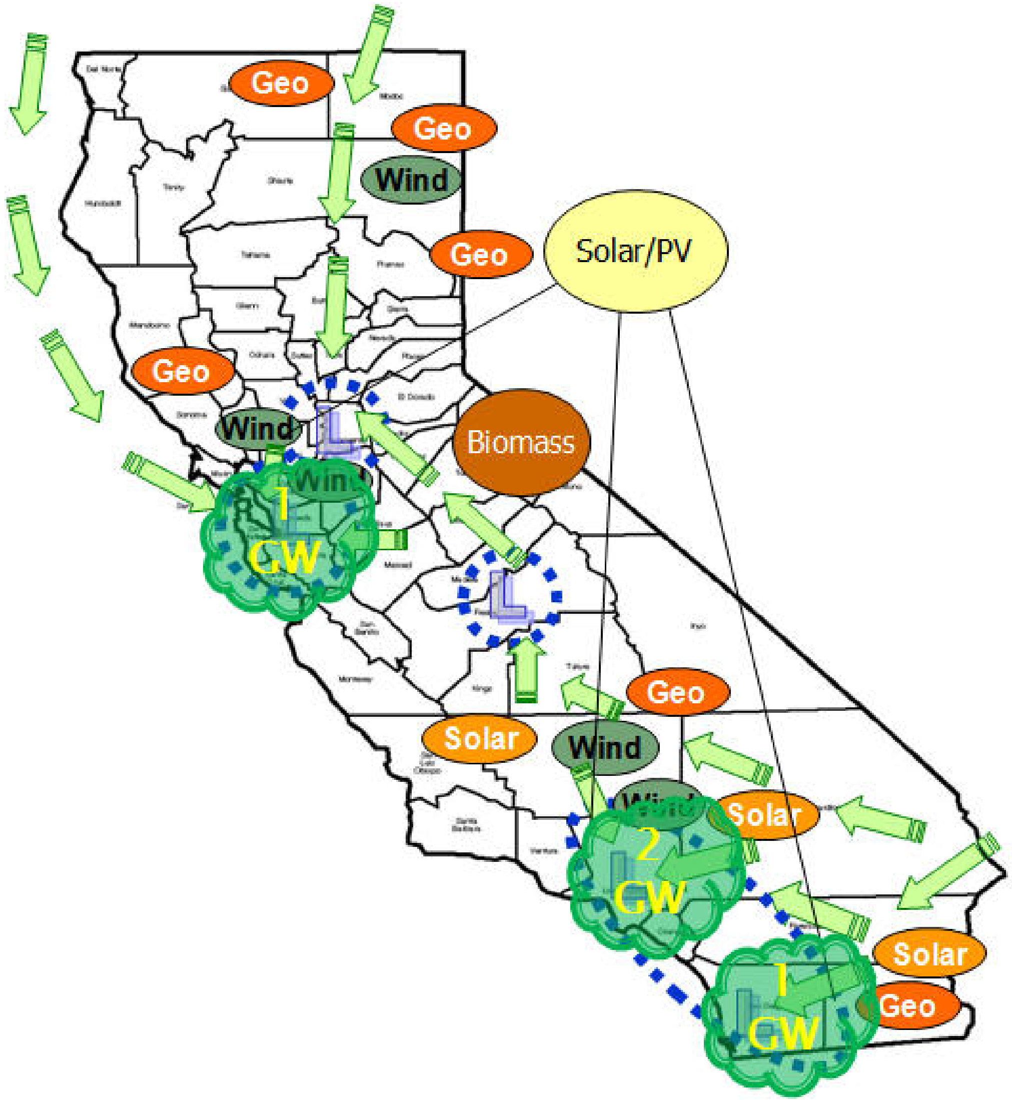
Benefits for Plant Owners

- Leveling the daily output of the solar system – essentially "locking" in demand savings that can be created by solar and lost by its intermittency
- Energy time shifting – from off-peak to peak periods
- Emergency Back-up

Overview

- Increased **renewables penetration** will demand storage
- Short-term **ramping volatility**, especially solar, is a big issue – demands fast acting storage solutions
- Eases **variability** and shift supply to peak demand
- Storage applications already in **existence**, especially in isolated grids
- How to **implement**?
  Centrally vs. Distributed.
  How to mandate without killing renewable projects?

CASE STUDY: CALIFORNIA



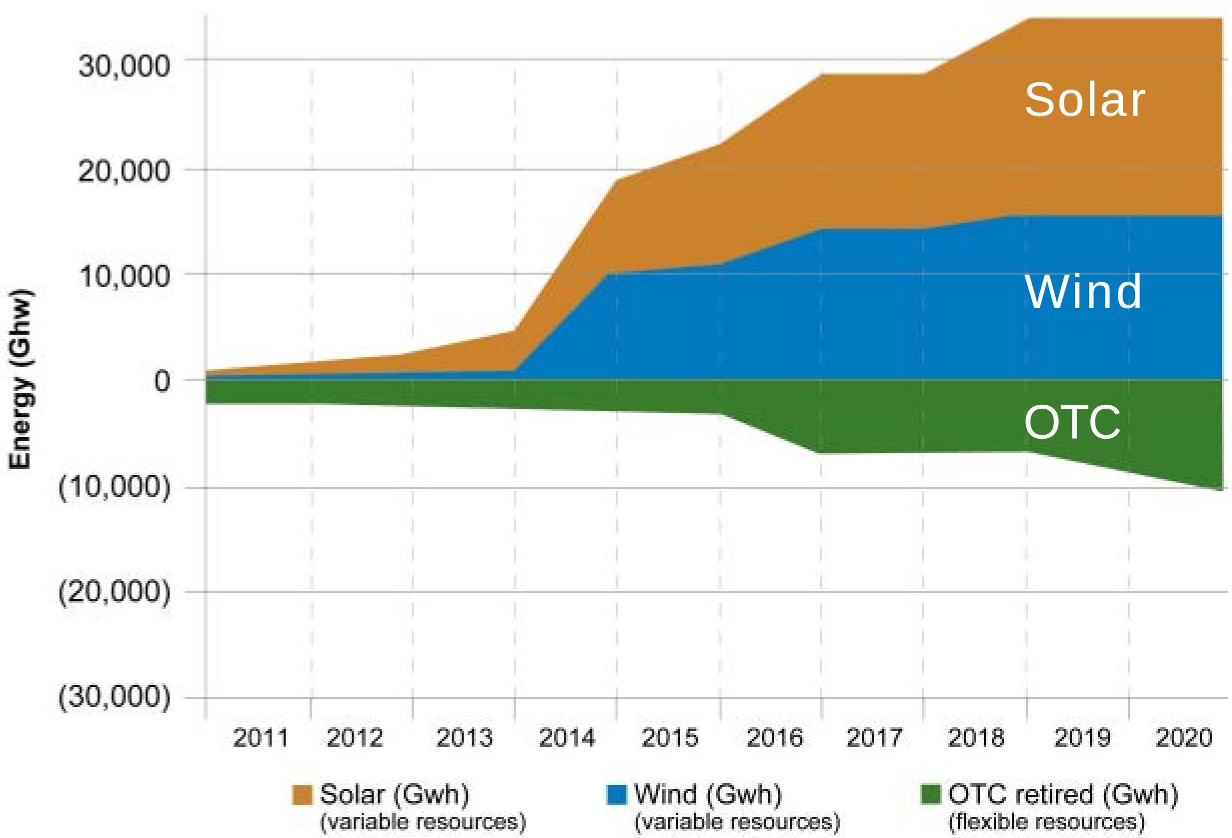
Courtesy: MegaWattsSF

Private and confidential

Flexible Capacity is Decreasing

The mix of generation resources will evolve

Figure 1: Energy changes



- The share of renewables will grow
- Retiring of flexible capacity from once-through cooling (OTC)
- Load growth expected and approximately 1,000 MW of combined heat and power

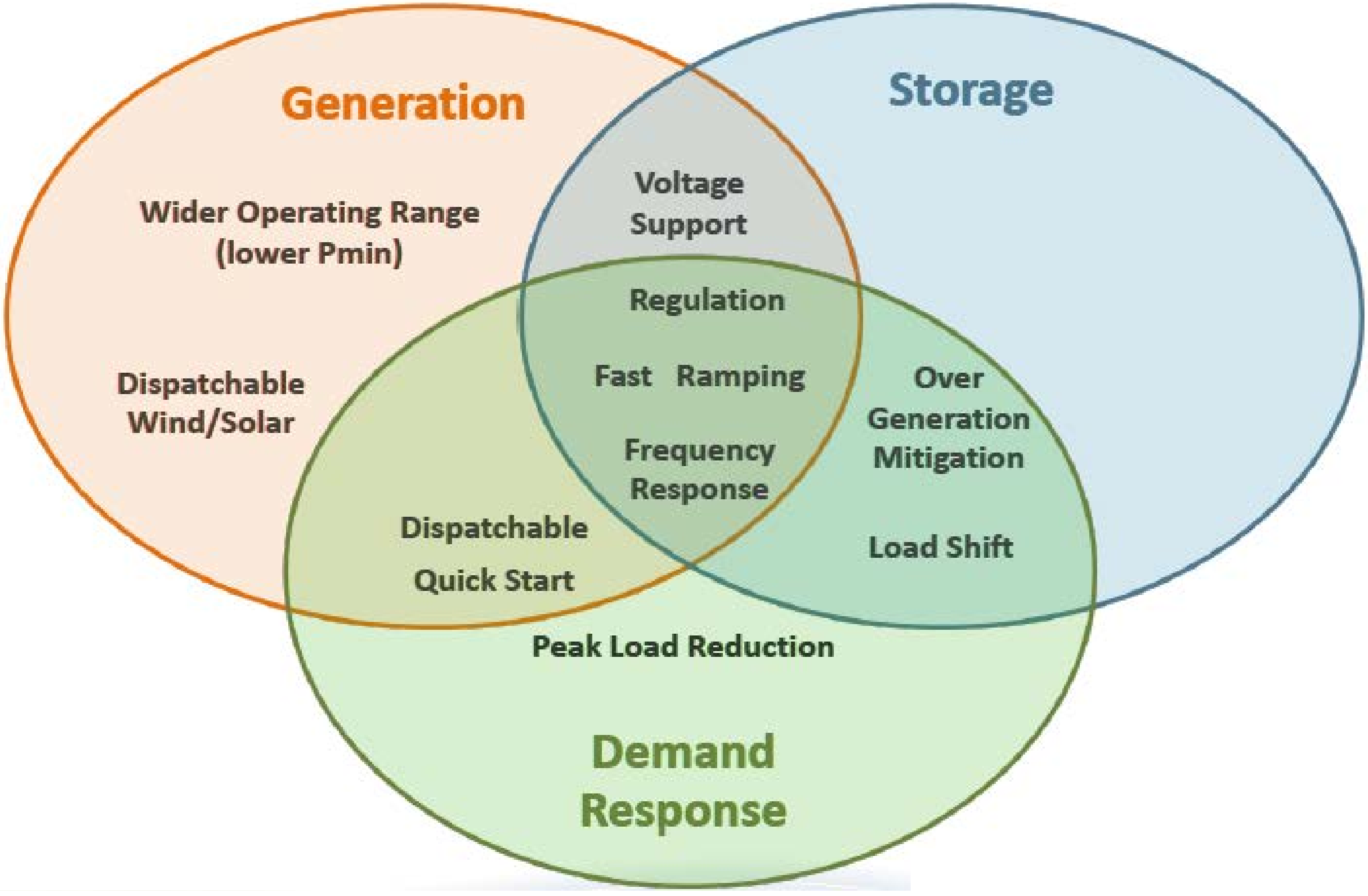
Operational Challenges

Over the next 10 years in California…

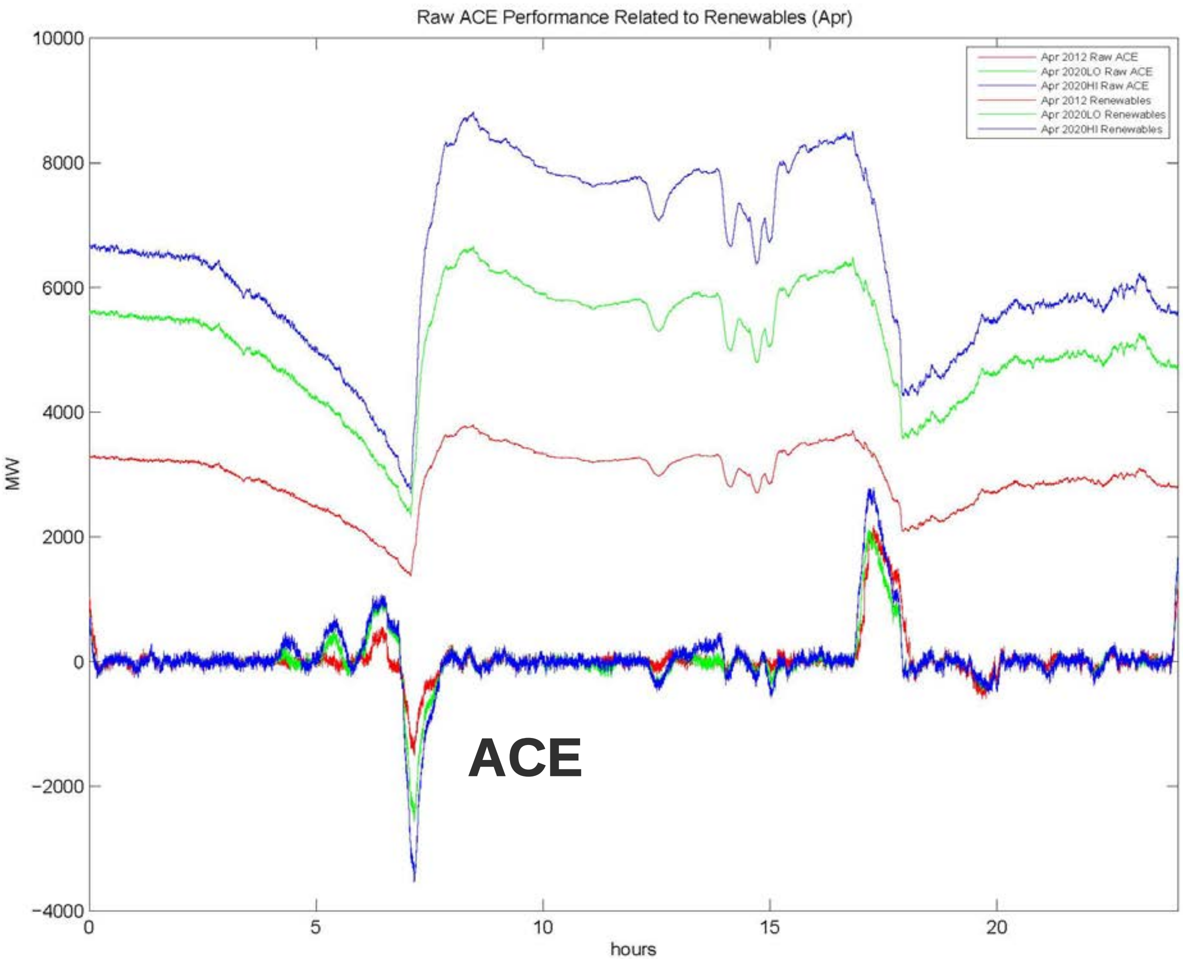
- Greater supply volatility
  - Over 20,000 MW of wind and solar capacity will be added
- Uncertainty surrounding thermal generation resources
  - ~12,000 MW of OTC thermal generation will be repowered or retired
- Less predictable load patterns
  - Changes in load patterns due to distributed energy resources and electric vehicles
- Changing revenue patterns
  - Decreasing marginal prices

* OTC – Once Through Cooling

Meeting Operational Challenges



ACE Affected by Increasing Renewables



Private and confidential

California Grid Study

- Undertaken using **KERMIT** tool, simulate grid now and for future scenarios.
- Energy **Ramps** <1 hour are going to be major issues
- Increased renewable capacity will increase **regulation needs** significantly
- Large amounts of regulation alone will **not solve** the problem
- **Fast energy storage** with 2 hours of capacity or more is an (expensive) solution

Required Storage Capacity and Control

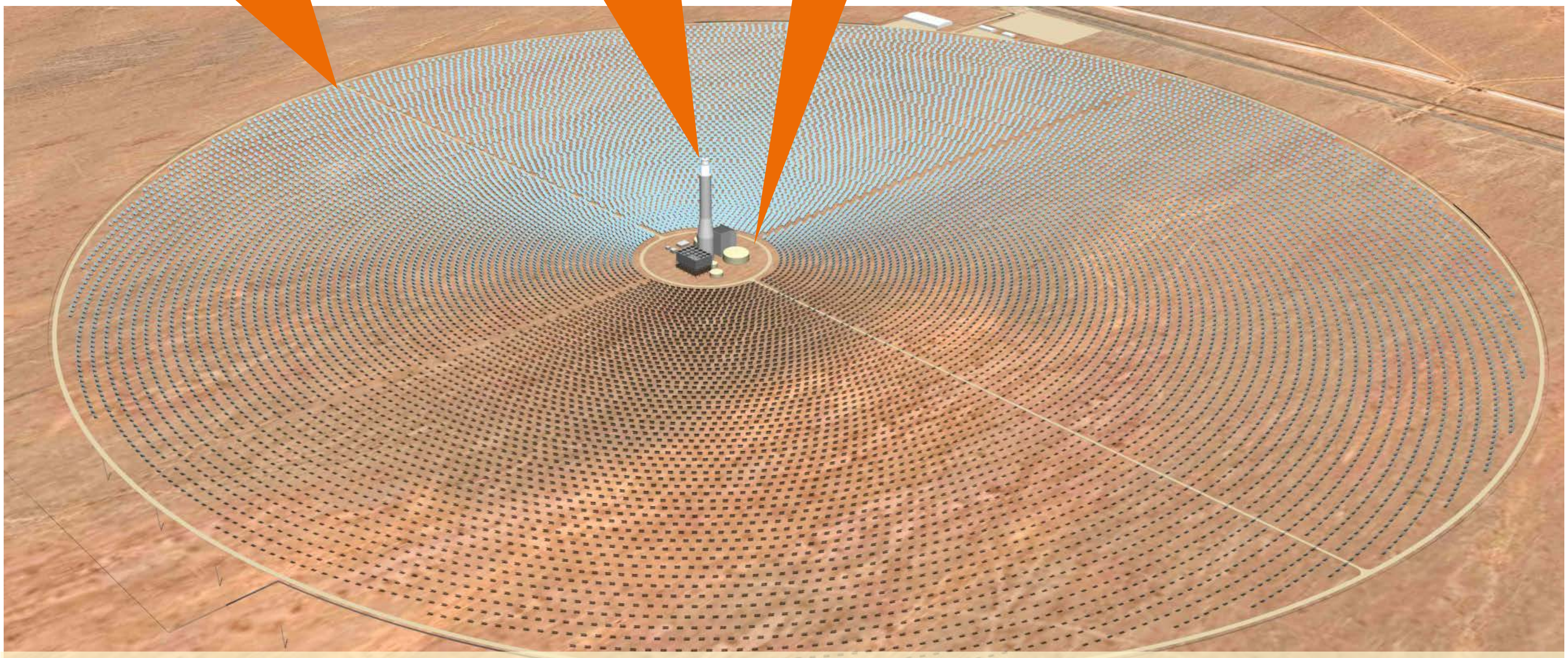
- **Storage capacity** needed
  - 2012 scenario, 1500MW 2h storage enough in most cases
  - In 2020HI scenario, 3000MW 2h storage enough in most cases
  - Even so performance will not be acceptable by today's standards
  - Requires further investigation of renewable scheduling for certainty
  - Performance will be sensitive to 15 – 30 minute errors in renewable forecasting
- 30 – 50 MW storage **equivalent** to 110 MW Conventional Thermal
  - Varies with other system conditions, especially how much regulation is present
- System regulation requirements for non-ramping periods
  - More than 800 MW in 2012
  - Approximately 1600 MW in 2020

Concentrated Solar Storage Solution

Thousands of sun-tracking mirrors

Central tower over 200m tall

Molten salt energy storage and steam power plant generate electricity on demand

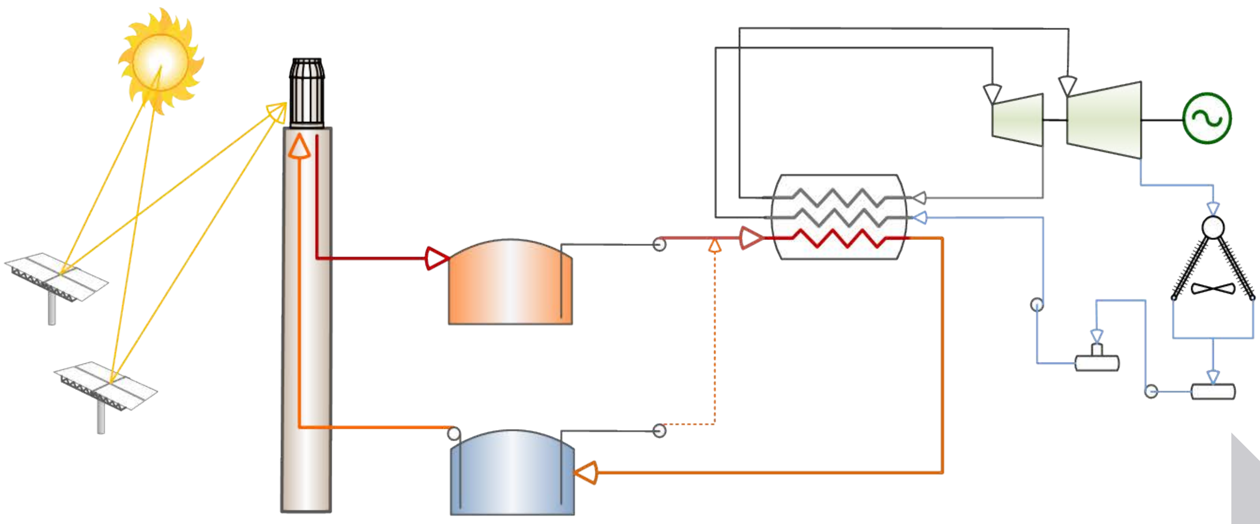


Solar Reserve's Crescent Dunes 110MW Project – with Storage

Courtesy: Solar Reserve

Private and confidential

Concentrated Solar Storage Solution



Sunlight heats the molten salts directly

Molten salt reserve used to power conventional steam turbine

Storage with greater flexibility at lower cost

Benefits of Concentrated Solar Storage

- Renewable resource that can function as a **load-following** plant
- **Dispatchable** renewable generation not tied to fuel prices
- Management of **large ramps**
  - Energy can be stored, not dumped
- **Zero emissions** ancillary services
- Lower **exposure** to fluctuating gas prices
- Will provide **additional value streams** for the plant owner
  - The storage component enables participation in ancillary and real-time markets
  - Power can be sold when prices are most favorable
  - Potential new market rules or products may favour flexible generation
- **Cost of Storage: ~ 15-20%** of project capital costs

Thank-you

Please Send any Questions to:

Jerry.randall@dnvgl.com & Richard.Fioravanti@dnvgl.com

www.dnvgl.com

SAFER, SMARTER, GREENER

Private and confidential