



# Value of Energy Storage

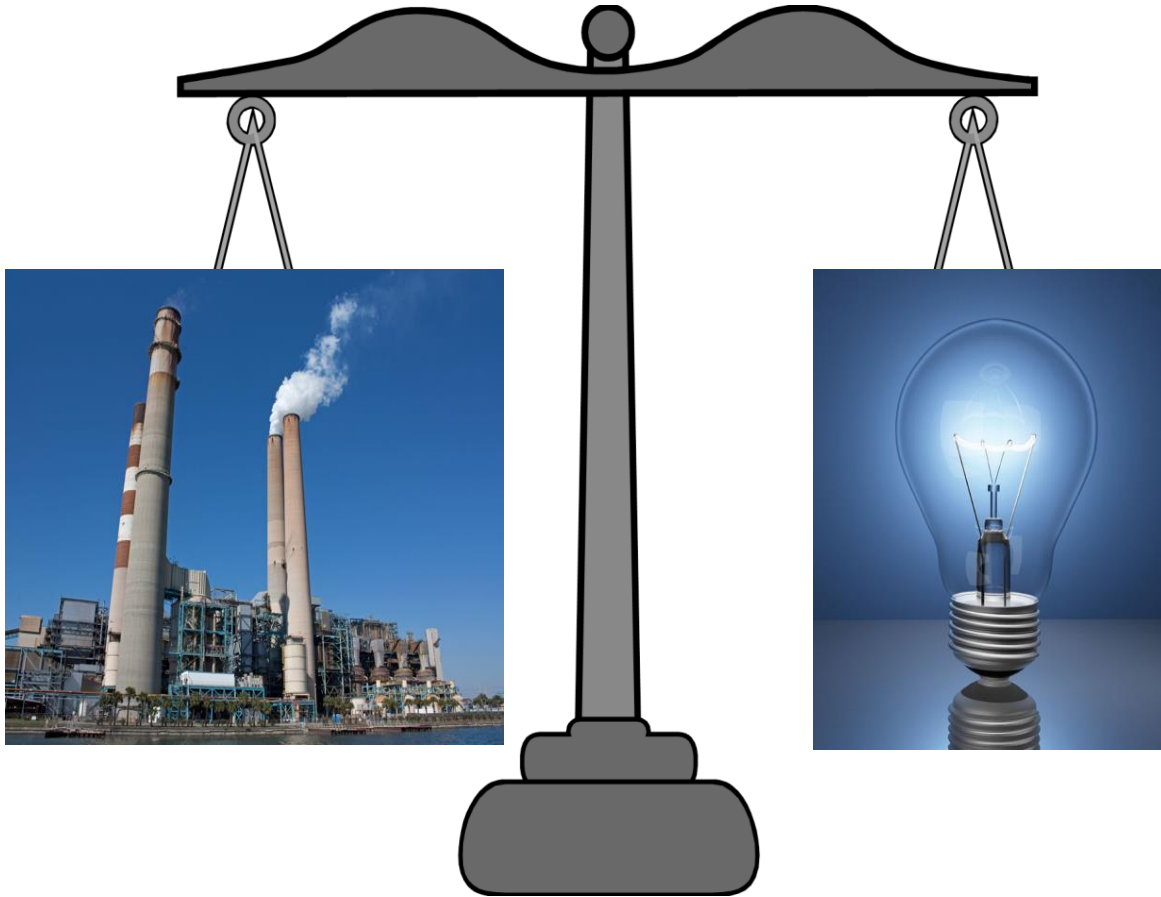
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# Power system operation

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Power produced = Power consumed

# Potential imbalances

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Seconds

Outages

Random fluctuations

Minutes

Ramps

Hours

Diurnal cycles

Days

Weekly cycles

Unavailability, scarcity



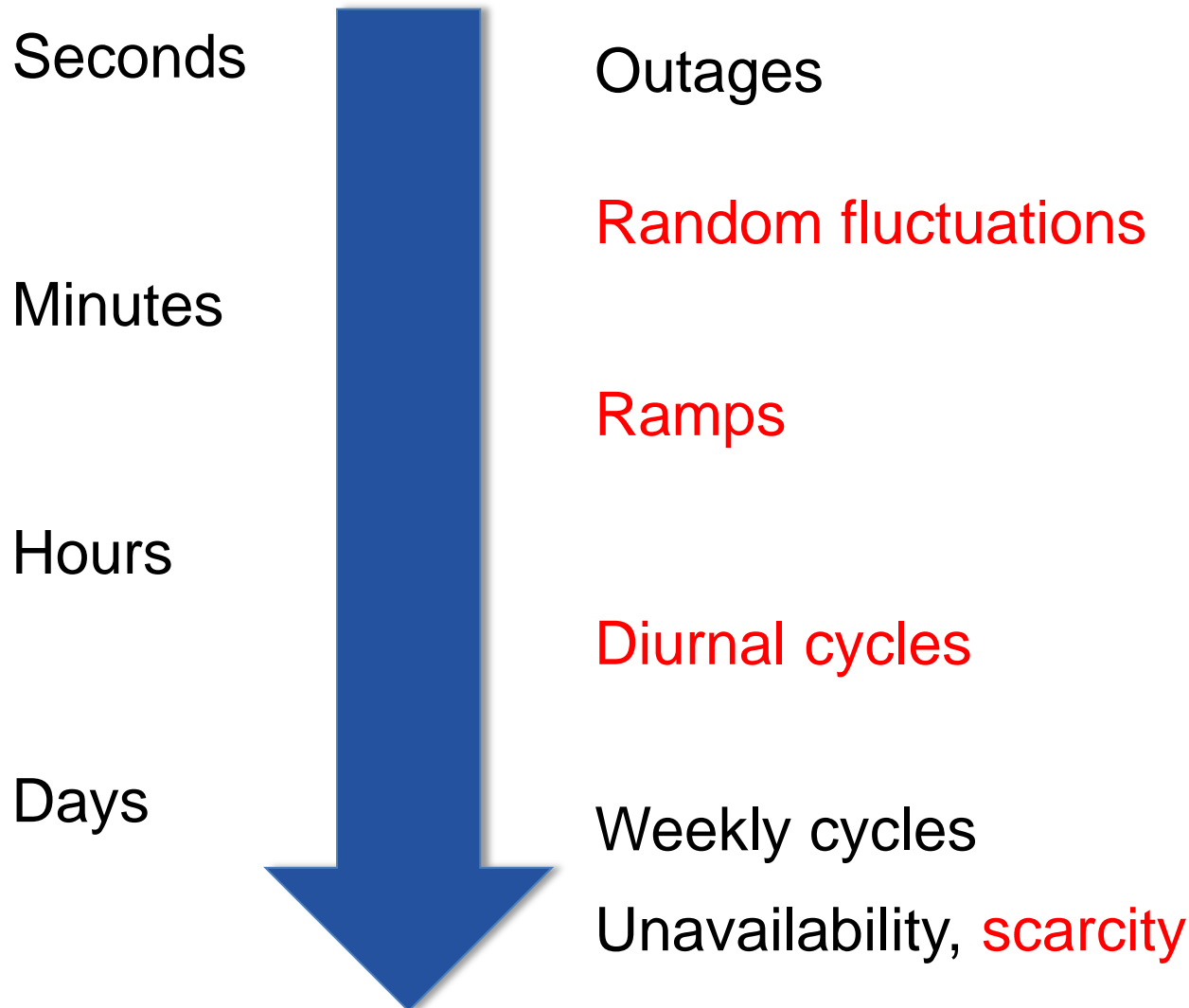
# Traditional way of dealing with imbalances

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- Generation follows load
- Need flexible generation:
  - Increase or decrease output rapidly
  - Start quickly
  - Cycle on/off daily
- Need reserve capacity

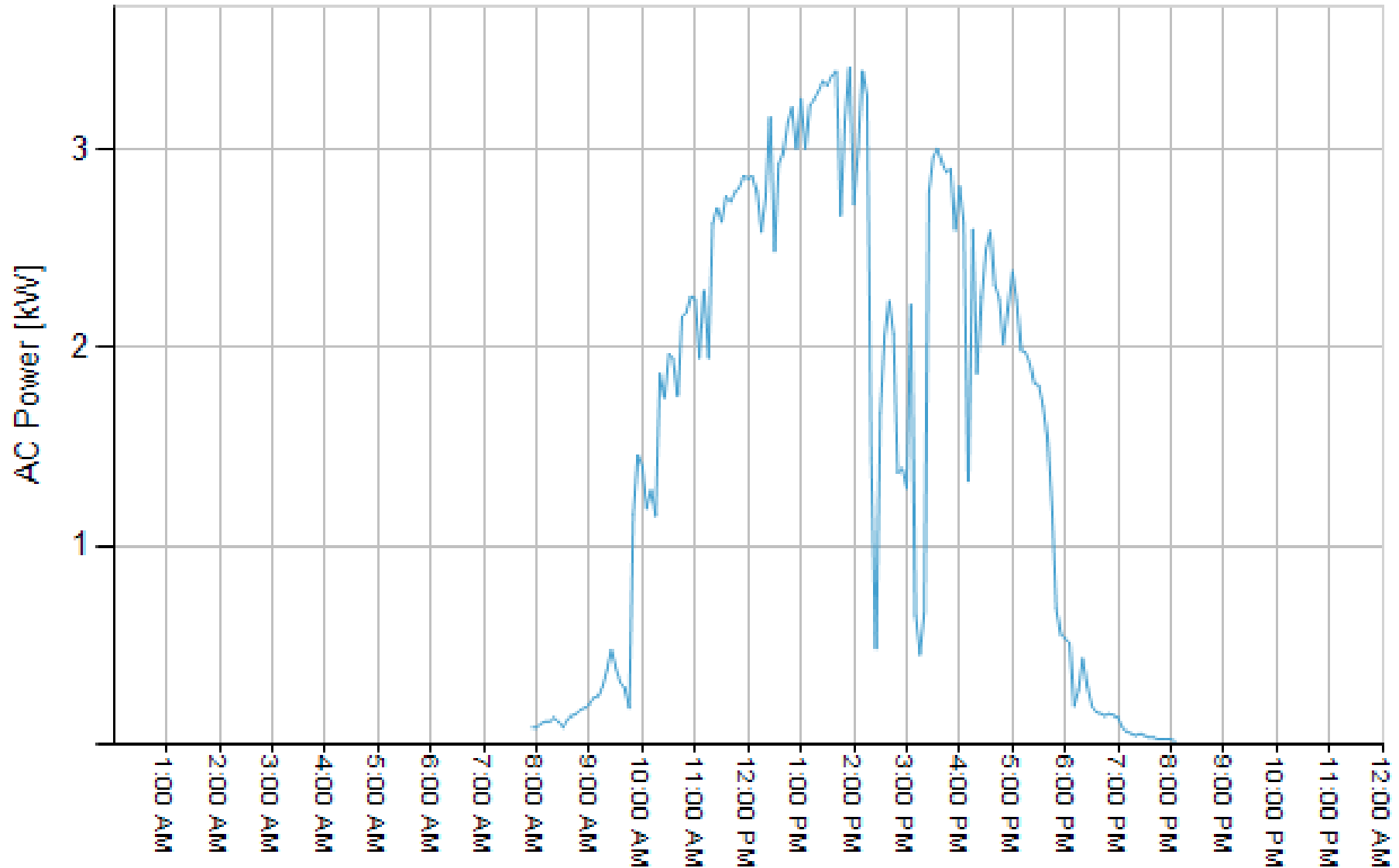
# Renewable generation makes things worse..

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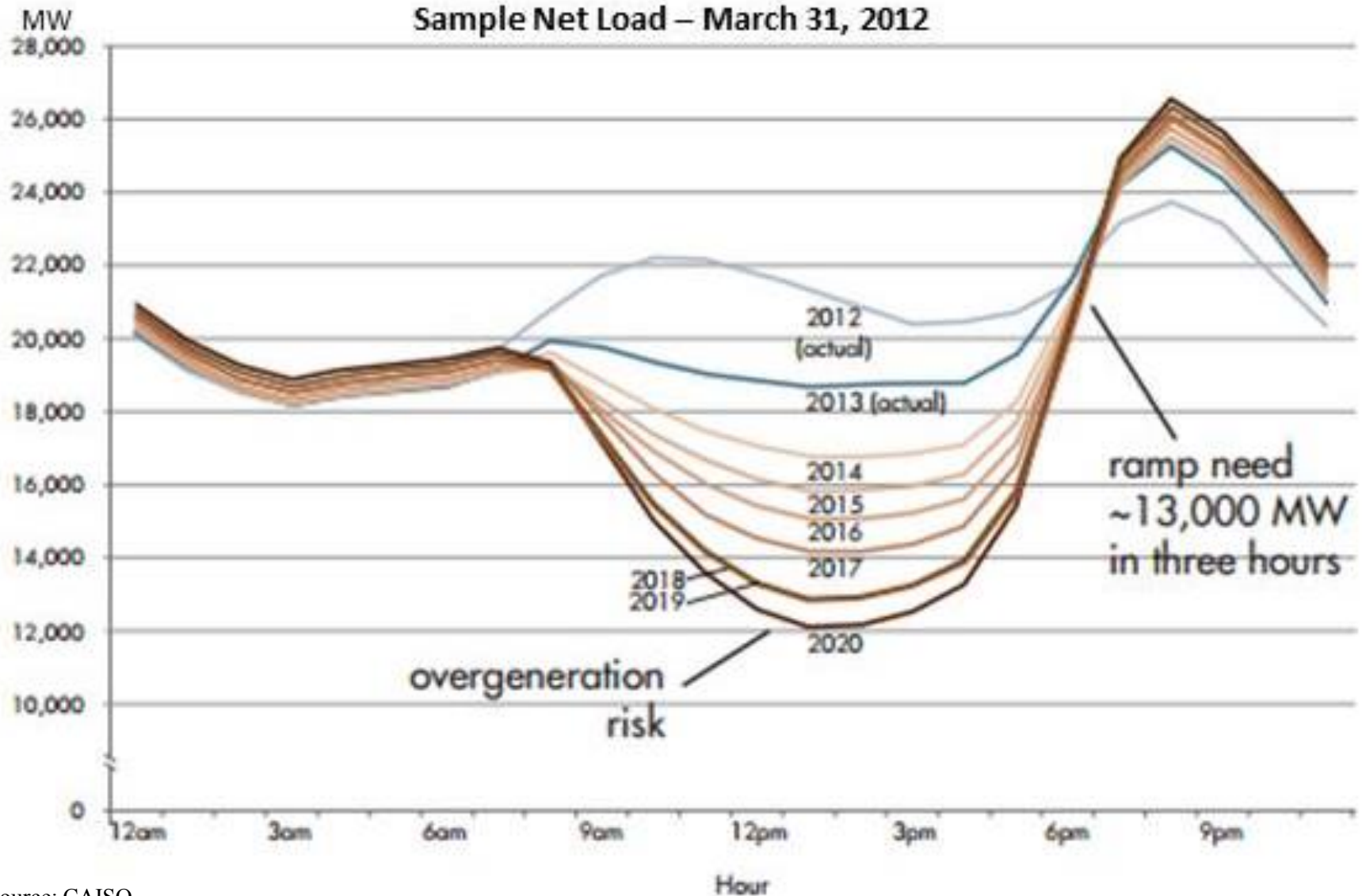


# Fluctuations in solar power

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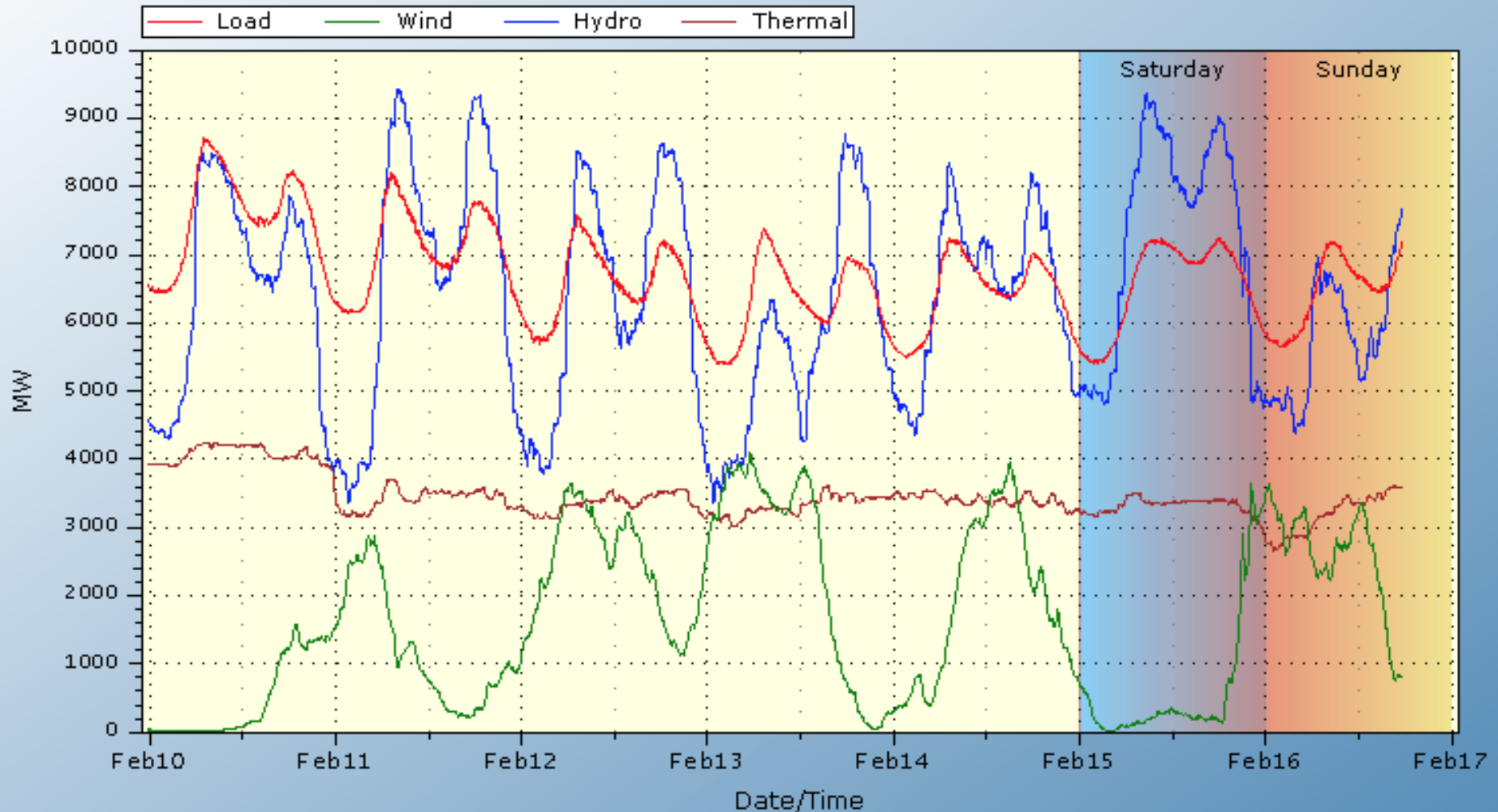
# The California “Duck Curve”



Source: CAISO

# Fluctuations in wind power

BPA Balancing Authority Load & Total Wind, Hydro, and Thermal Generation, Last 7 days  
10Feb2014 - 17Feb2014 (last updated 16Feb2014 17:46:51)

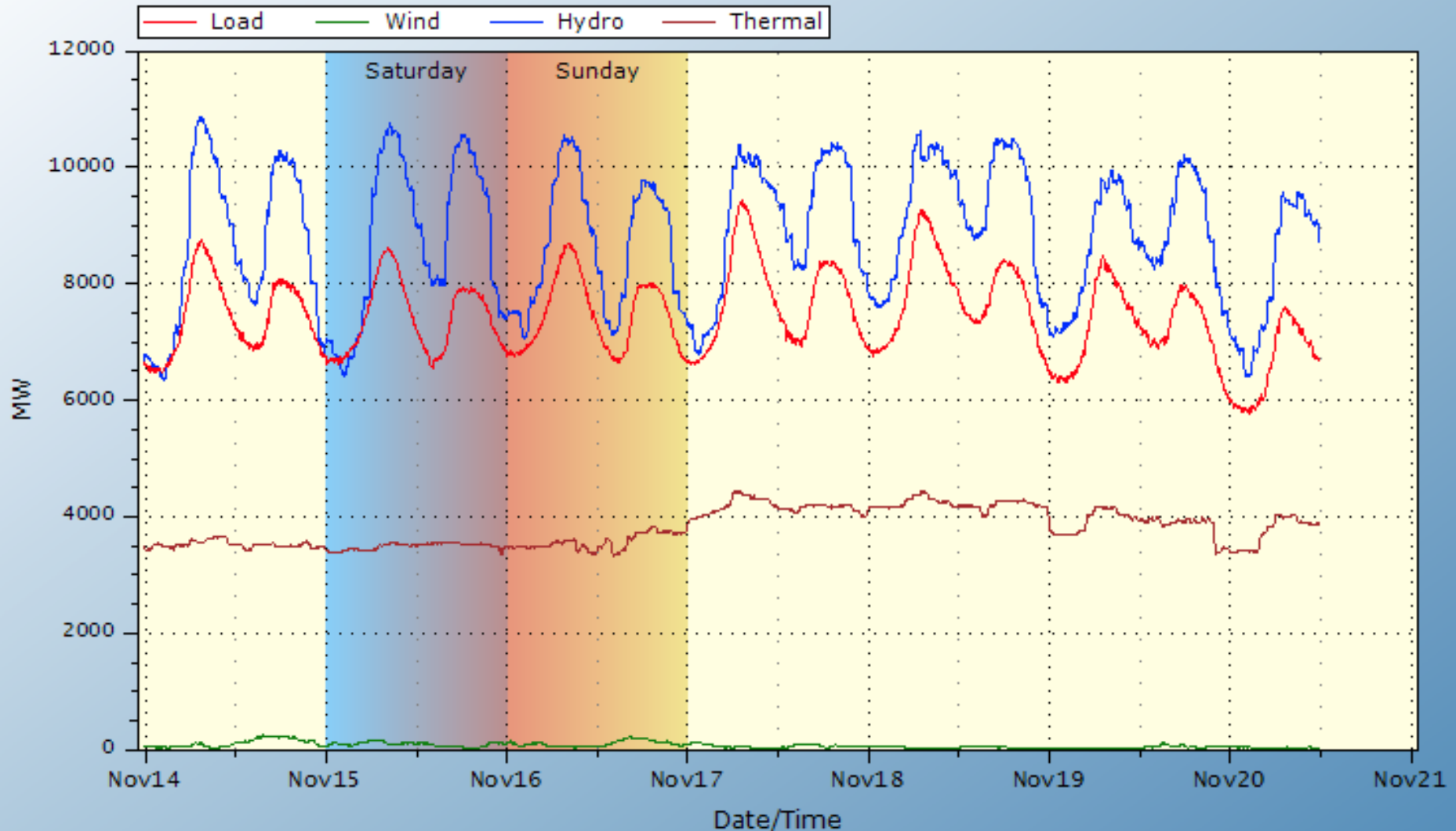


Based on 5-min readings from the BPA SCADA system for points 45583, 79687, 79682, and 79685



# Fluctuations in wind power

BPA Balancing Authority Load & Total Wind, Hydro, and Thermal Generation, Last 7 days  
14Nov2014 - 21Nov2014 (last updated 20Nov2014 12:03:00)



# Renewable generation makes things worse..

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Seconds

Outages

Random fluctuations

Minutes

Ramps

Hours

Diurnal cycles

Days

Weekly cycles

Unavailability, scarcity

And renewable generation is displacing flexible conventional generation..



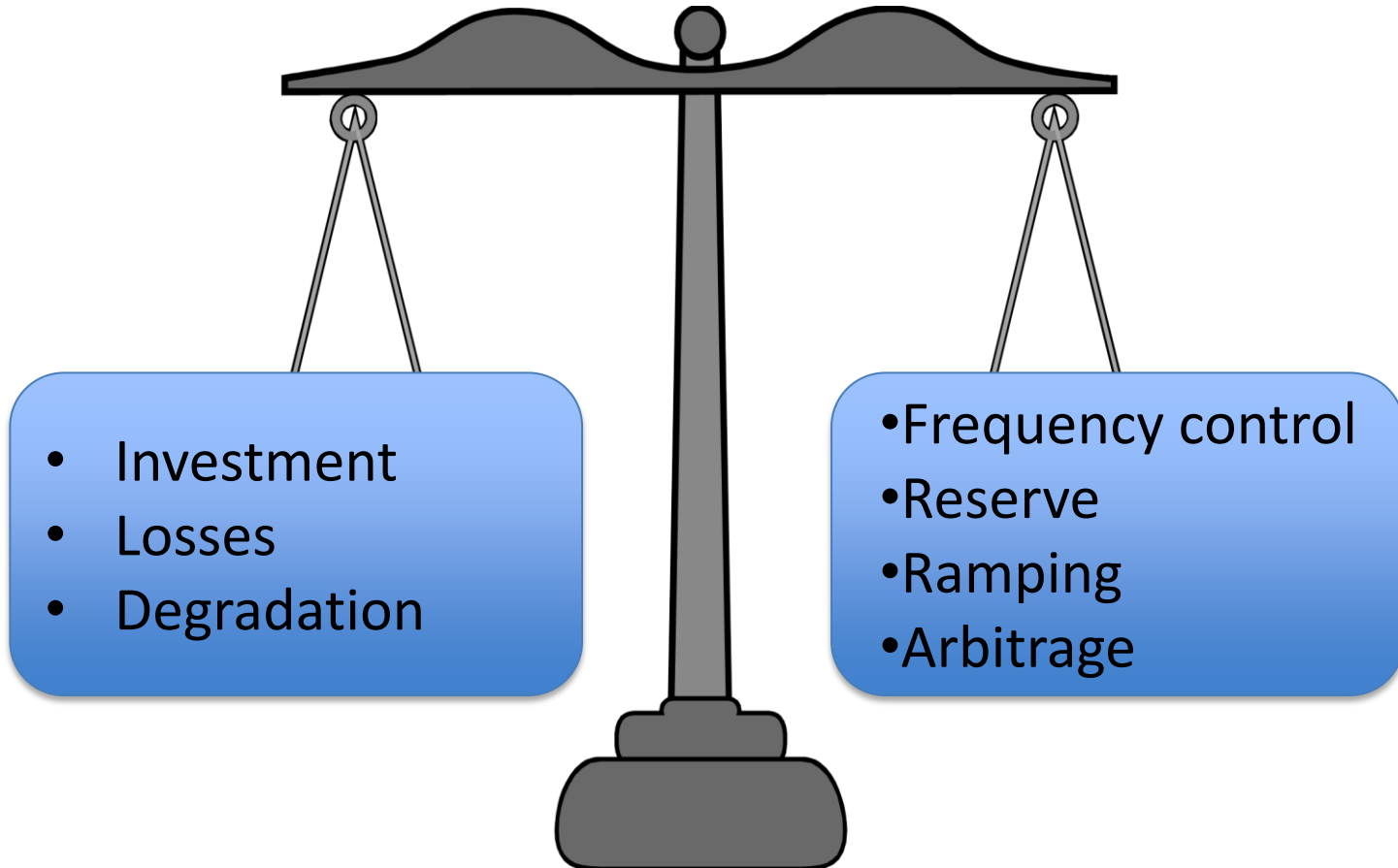
# Storage: the ultimate source of flexibility?

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- Storage can provide:
  - Reserve capacity
  - Frequency control
  - Ramping
  - Temporal arbitrage
  - Spatial arbitrage (virtual network capacity)

# But is it economically sustainable?

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Life cycle cost vs. value streams

# How should we proceed?

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- Quantify the various value streams
  - Some are easier than others
- Investigate compatibility
  - Physical compatibility
    - Can we use the same MW or MWh for two or more purposes at the same time?
  - Chemical compatibility
    - Degradation depends on application
    - Different types of batteries degrade differently
    - Is it worthwhile to combine applications in the same battery?