Supply-Following Loads: A Berkeley Perspective

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100% Renewable Energy Workshop

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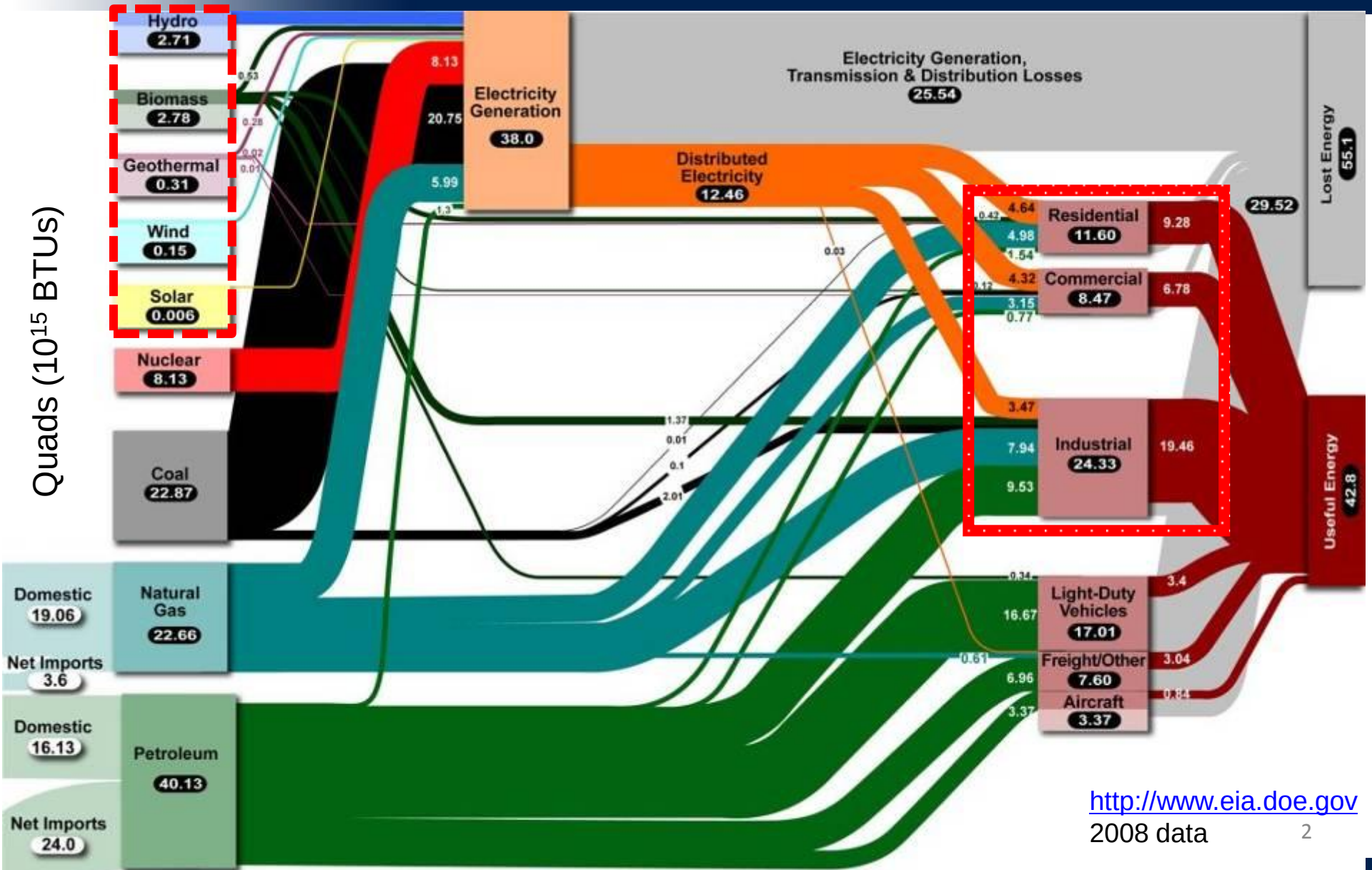
Energy "Spaghetti" Chart



http://www.eia.doe.gov
2008 data

Sources and Loads

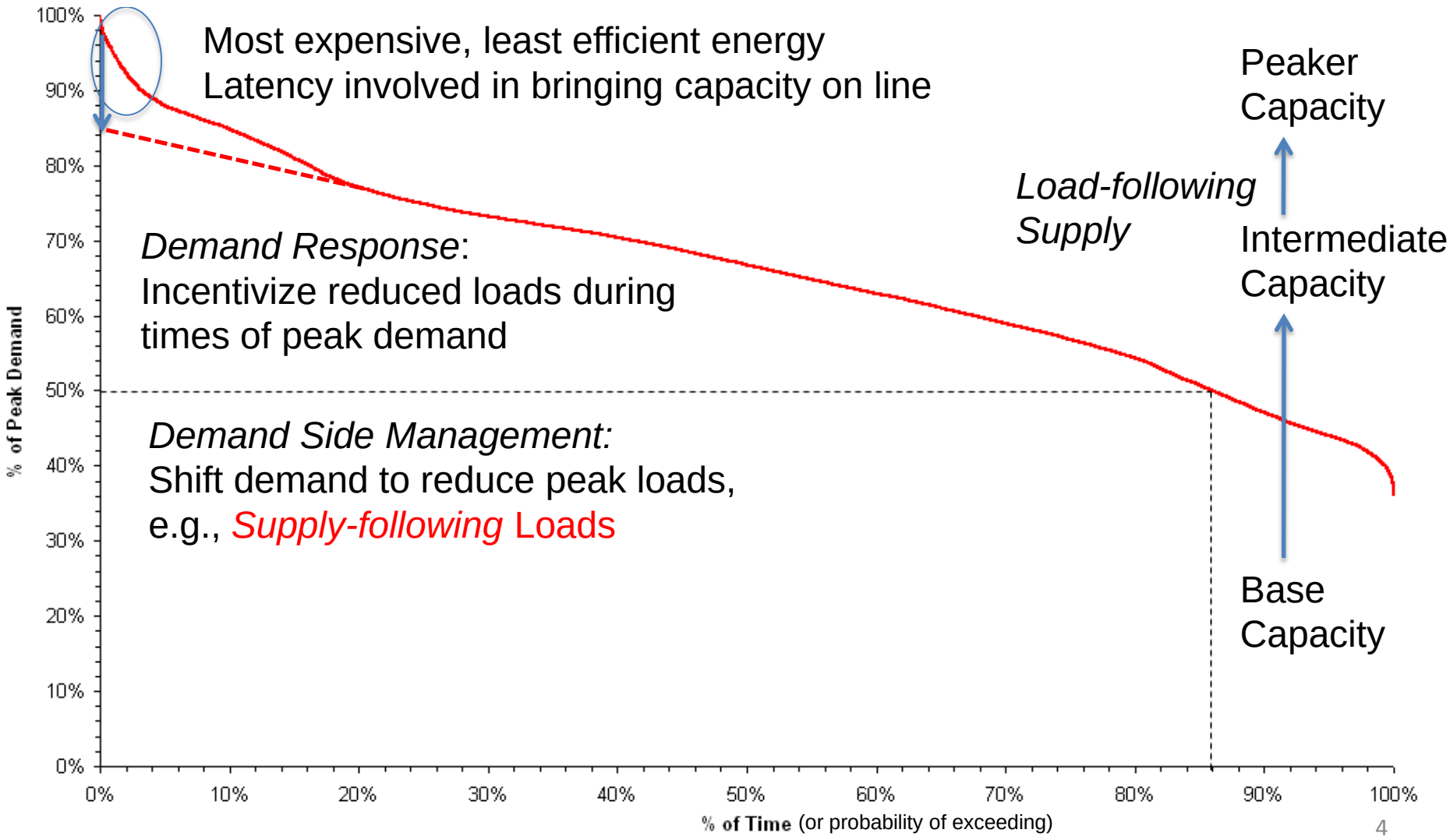
Dispatchable Sources

Non-Dispatchable Sources

Oblivious Loads

Aware Loads

Supply- versus Load-Following



E.g., Datacenter as a *Supply-Following* Load

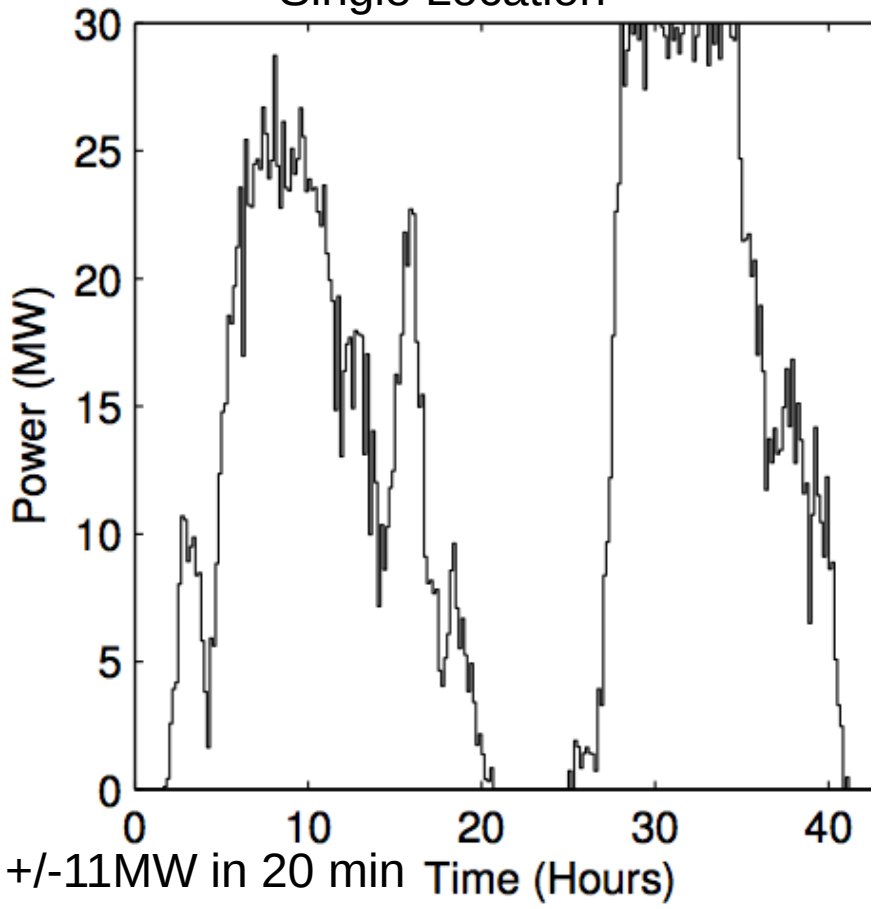
1. Degree of Freedom: On-demand + scheduled workloads

2. Principle: Power proportionality from non-power proportional components

3. Sustainability: Maximize use of renewable sources

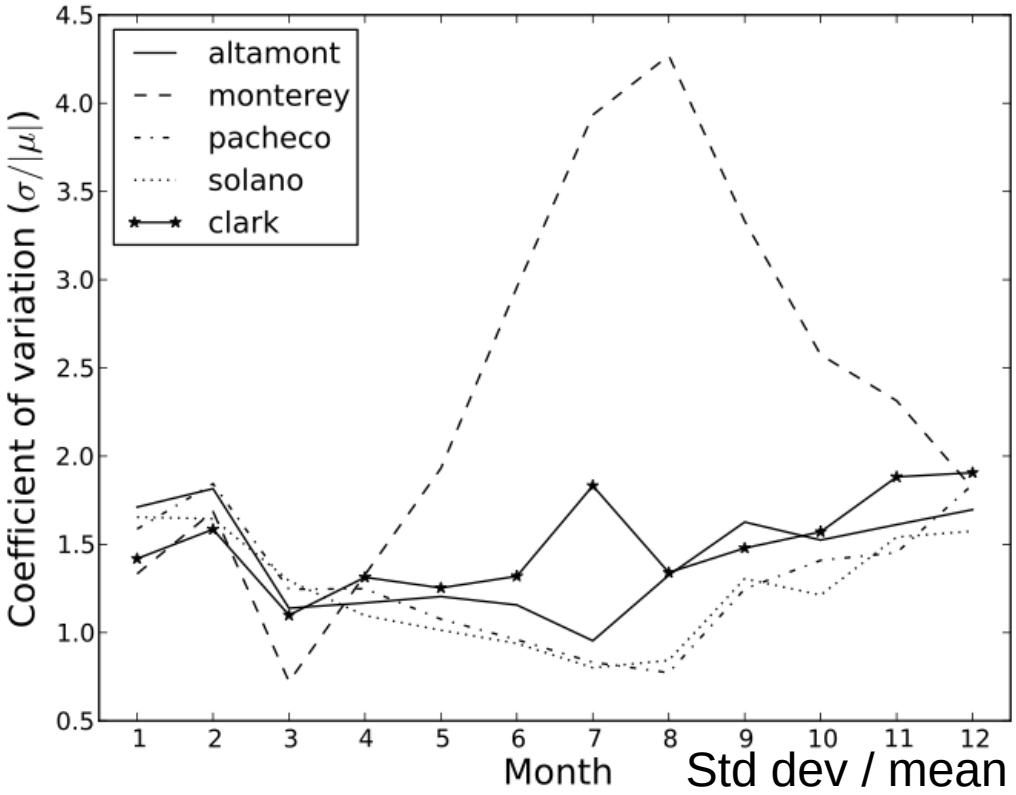
Supply-side Challenge: Wind

Single Location



+/-11MW in 20 min

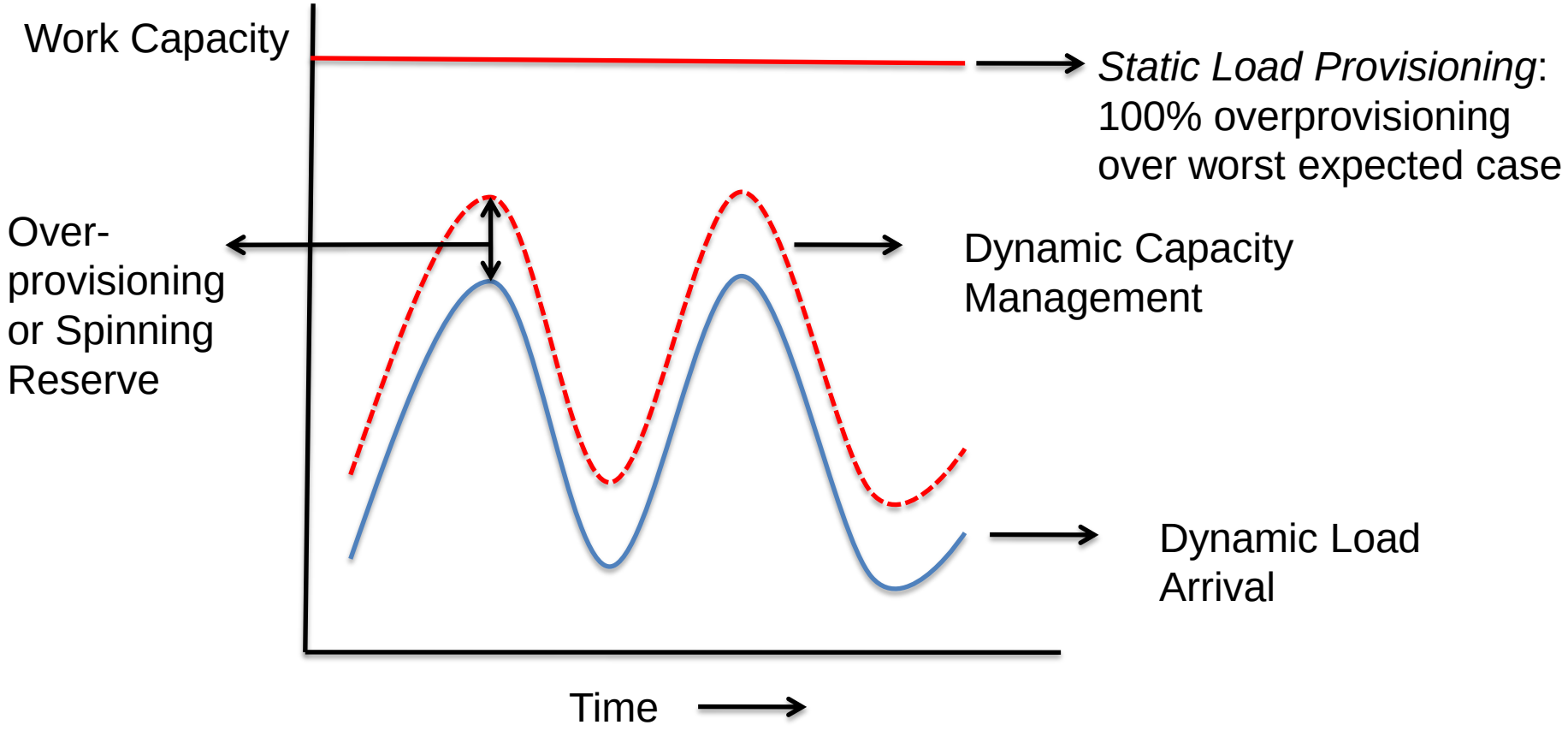
Multiple Locations vs. Time of Year



Std dev / mean

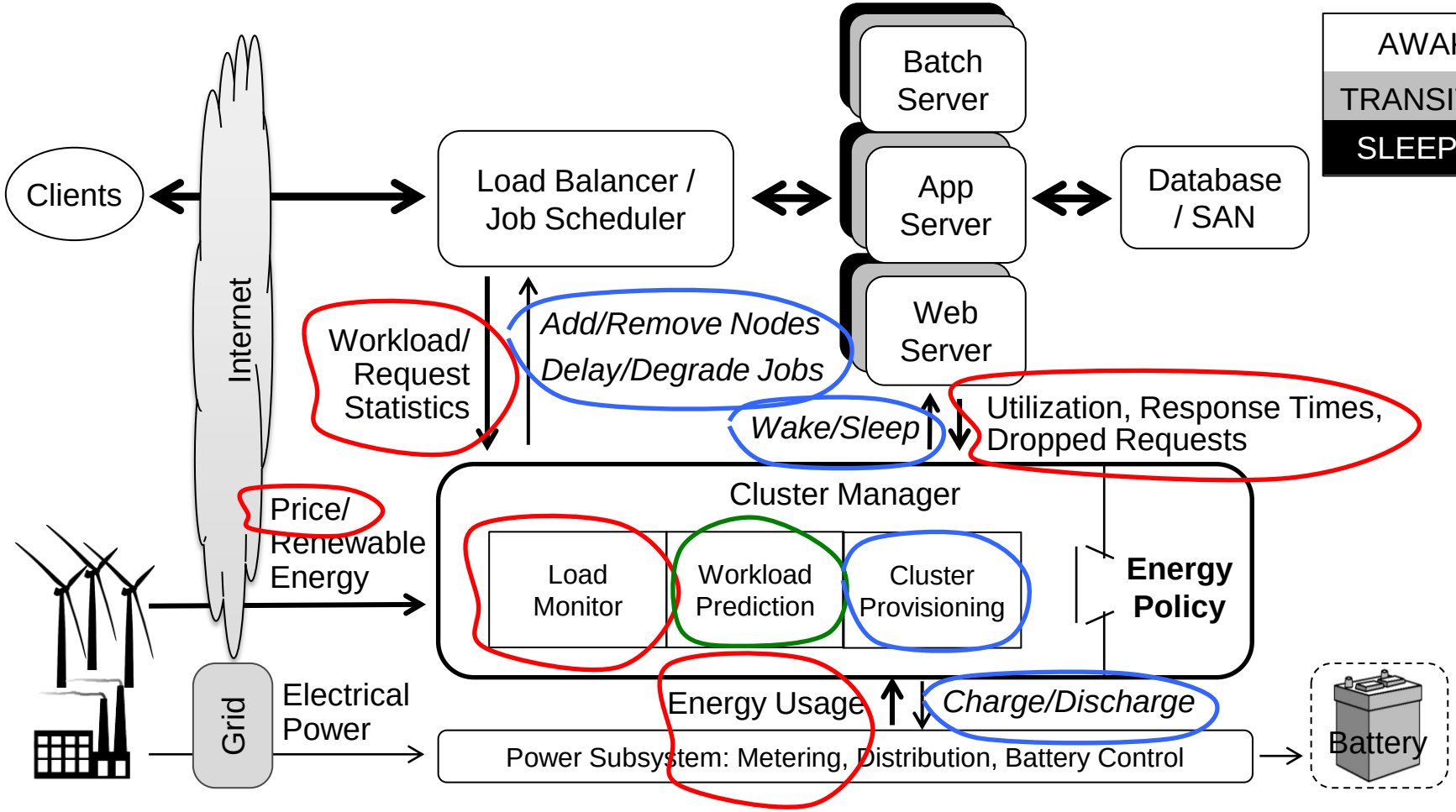
- High variability of wind energy is an impediment to its large-scale penetration in traditional Grid/Load architectures

Load-side Challenge: Power Proportionality



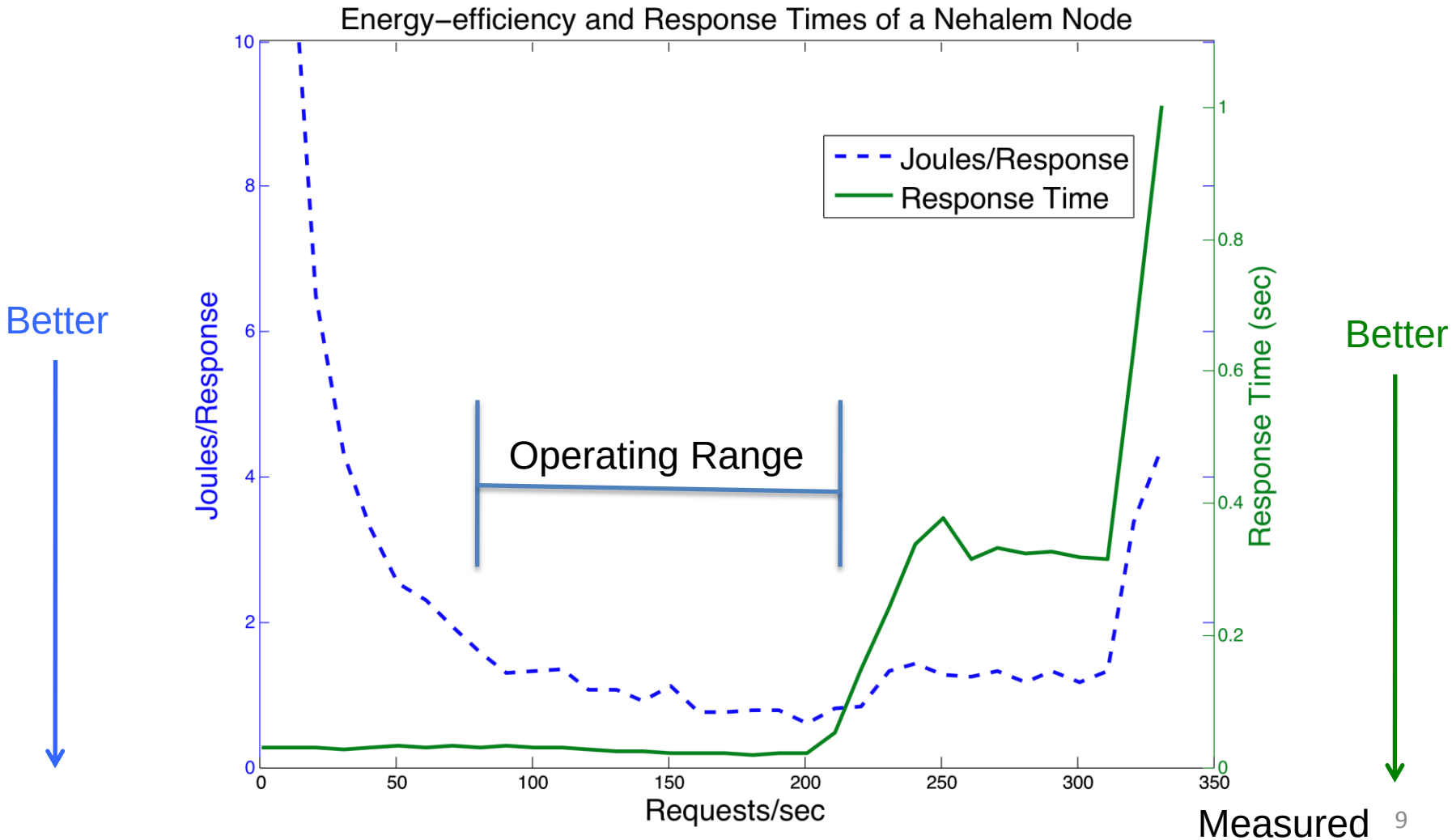
- Scheduling agility: workload awareness and resource allocation
- Wikipedia interactive workload + HPC batch workload

Energy-Aware System Architecture

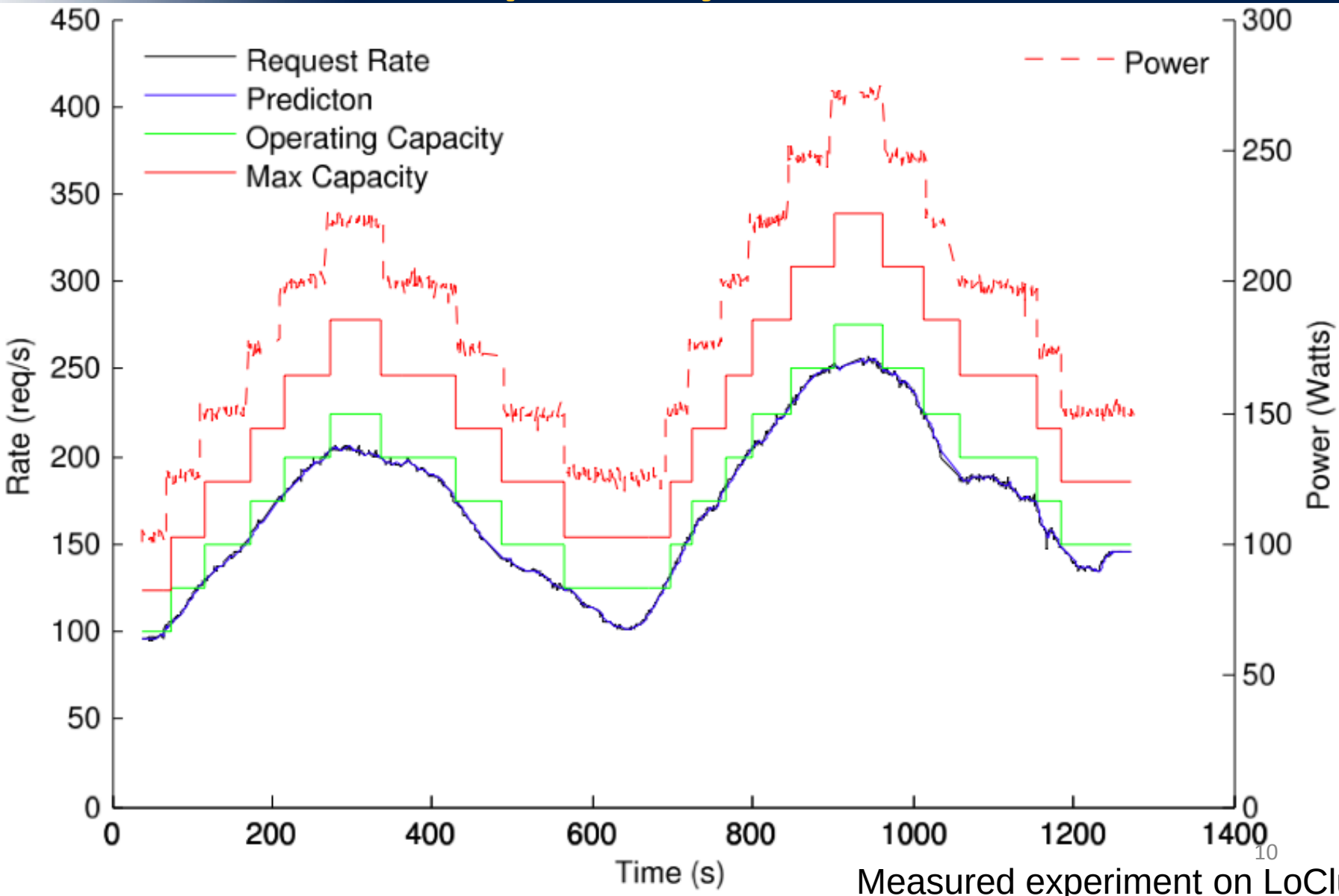


Server Efficiencies

Server Class Machines (similar figure for netbook/embedded class nodes)



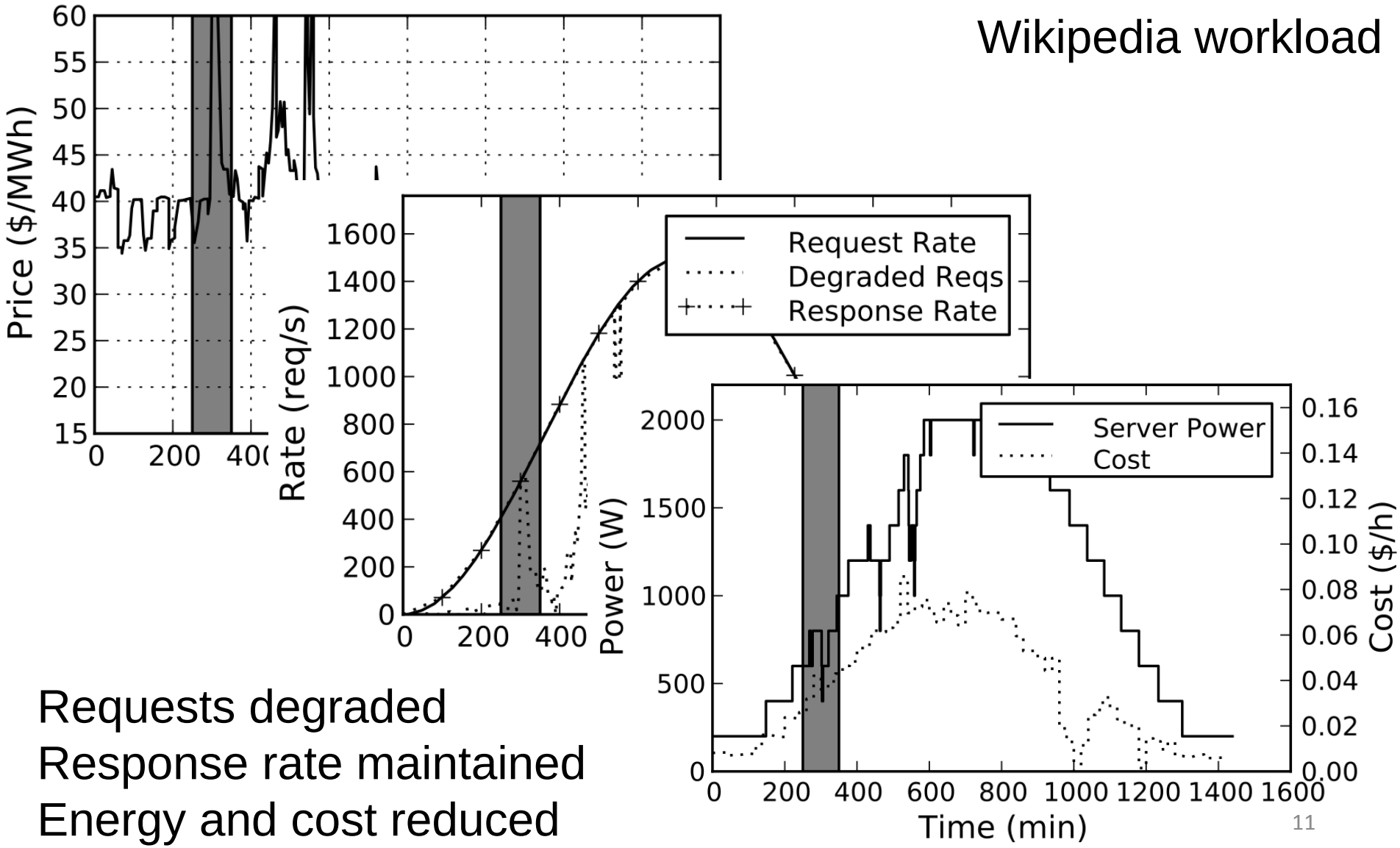
Effectively Scaling Work Capacity and Power



Measured experiment on LoClu

Price/Elastic Workload Response

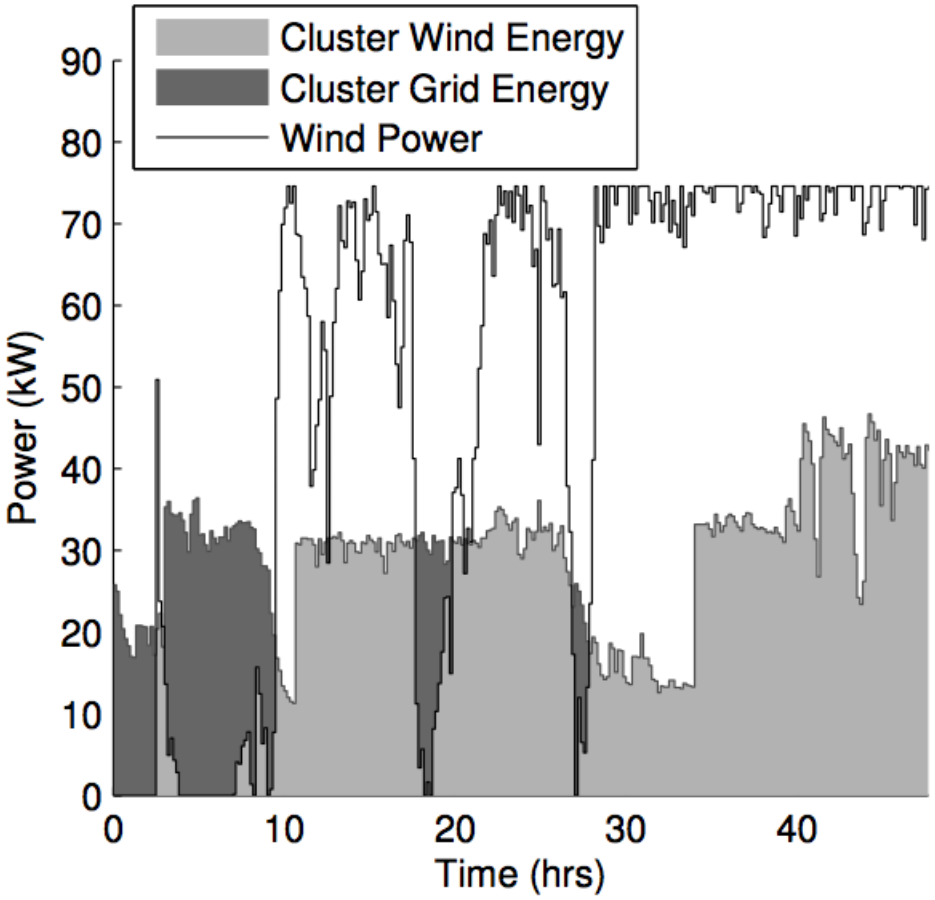
Wikipedia workload



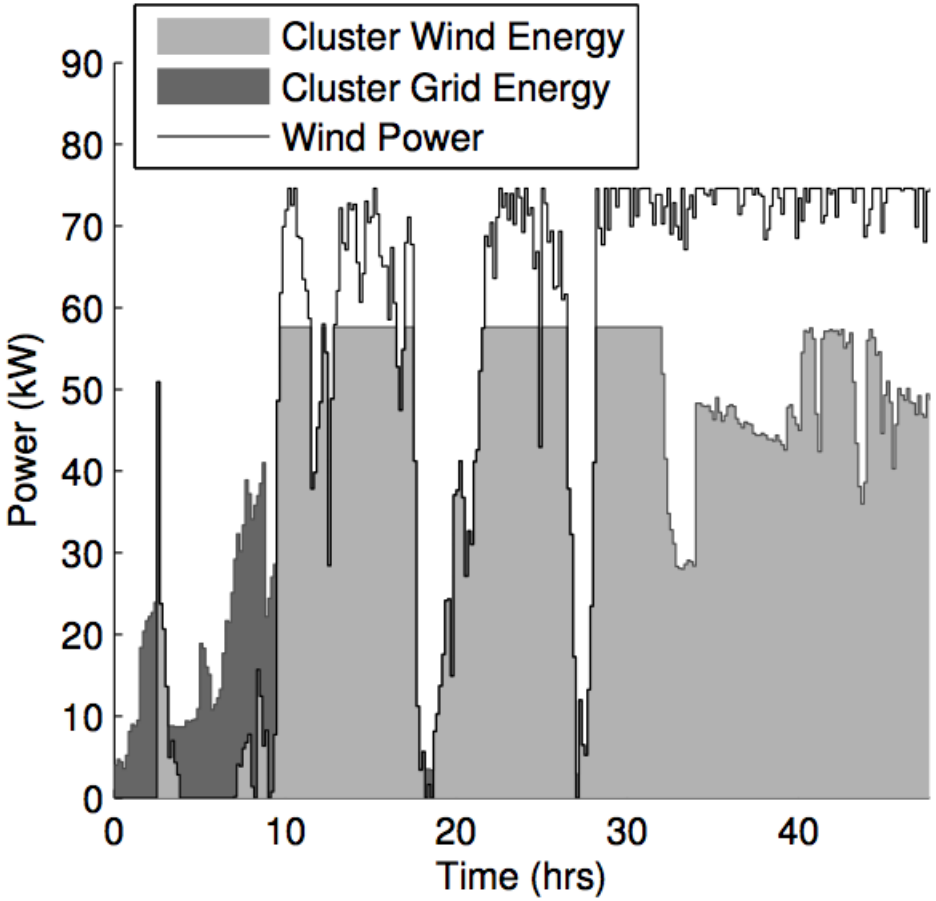
Requests degraded
Response rate maintained
Energy and cost reduced

Batch Processing and Slack

Grid energy down, wind energy up



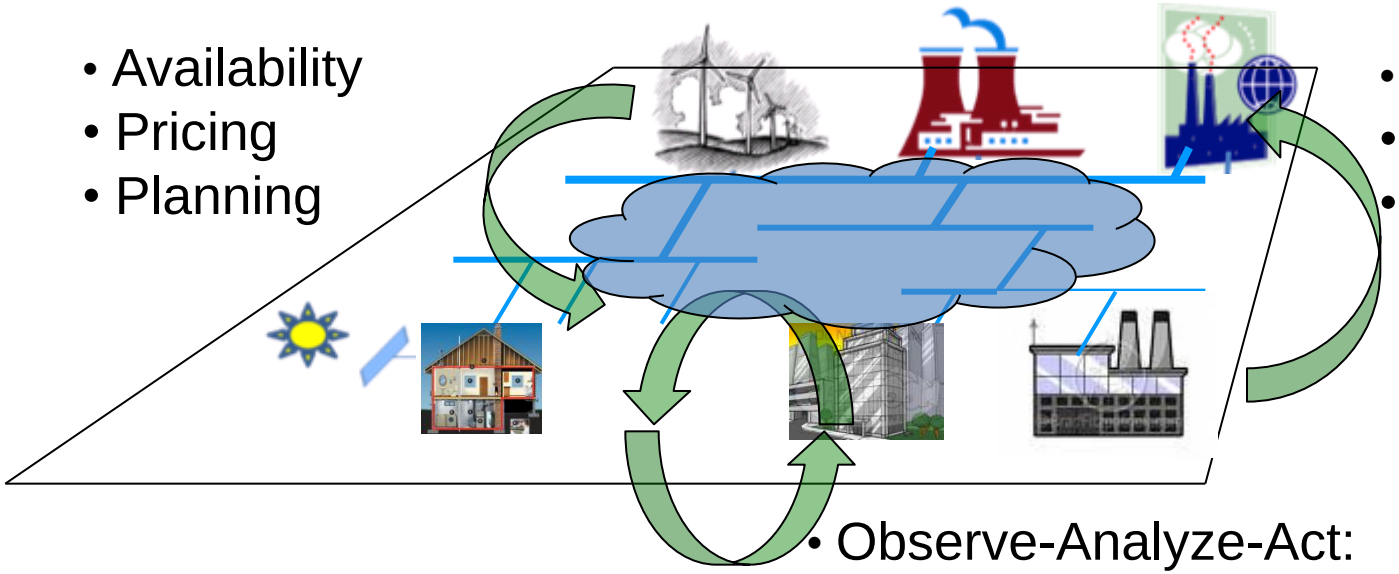
Run Immediately, Grid-Oblivious
54% Grid, 46% Wind



Greedy, Grid-Aware
30%, 70% Wind

Aware Co-operative Grid

Power Proportional Cluster as a Model System applied to the Smart Grid—now distributed



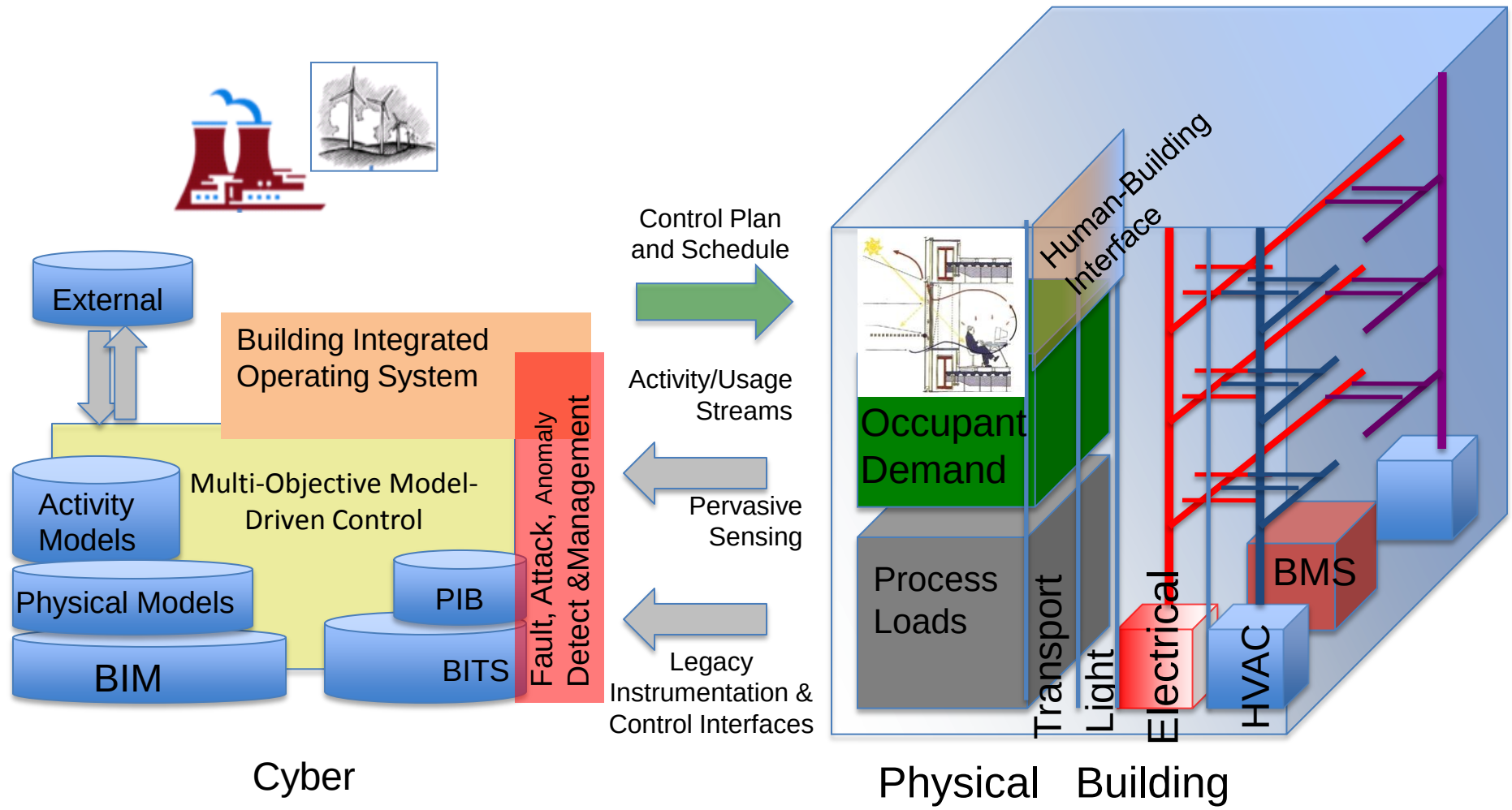
- Availability
- Pricing
- Planning

- Forecasting
- Tracking
- Market

- Observe-Analyze-Act:
  - Deep instrumentation
  - Waste elimination
  - Efficient Operation
- Shifting, Scheduling, Adaptation

Smart Buildings

Smart Buildings



Observe – Analyze – Act

Summary

- Awareness of Load and Supply
  - Load-Following: match load with managed supply
  - Demand Response: reduce load to meet supply
  - *Supply-Following*: schedule work to exploit knowledge of available supply—essential for non-dispatchable sources like wind and solar
- Key idea: make information actionable
  - Observe-Analyze-Act
  - Information overlay on cluster, machine room, building-scale “grids”
  - Interface sensors, facilities, clusters, and buildings to information buses at a variety of scales

Conclusions

- Smart Clusters, Smart Buildings, Smart Grids
  - Use less energy
    - Right provisioning for expected + reserve vs. peak
  - Use the energy you need:
    - Power proportionality
  - Use better energy
    - Integrate renewables

LoCal

Thank You!