



The UCSD/Calit2 GreenLight Instrument

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California Institute for Telecommunications and Information Technology: Calit2



UC Irvine

- Over 1000 Researchers in Two Buildings Linked via Dedicated Optical Networks
- International Science, Art and Engineering via Telecommunications and Information Technology
- Nanotechnology and Photonics to Wireless, Microbial Genomics to Earth Sciences, Virtual Reality to 4K Digital Cinema and next-generation videoconferencing



UC San Diego

Preparing for a World in Which Distance is Eliminated...and Collaboration is as Common as Texting



GreenLight's Amin Vahdat Says:

- **Computing and storage will be delivered by a relatively small number of mega-scale data centers**
- **Implications for current Internet architecture**
 - Much of the activity will be around networking within and between data centers
 - Storage will be redesigned from the ground up
 - Query languages and models will be reinvented
- **To allow network fabric to keep up with end hosts, build a *balanced* system and reduce energy consumption**
 - Scheduling algorithms to leverage path diversity
 - Dynamic energy management; Optics for energy-efficient networks
- **How do we find out what we need to know, as scientists, teachers, and citizens?**



The GreenLight Project: Instrumenting the Energy Cost of Cluster Computing

- **Focus on 5 Communities with At-Scale Computing Needs:**
 - Digital Media
 - Metagenomics
 - Ocean Observing
 - Microscopy
 - Bioinformatics
- **Goal: Measure, Monitor, & Web Publish Real-Time Sensor Outputs**
 - Via Service-oriented Architectures with Rich Services
 - Allow Researchers Anywhere To Study Computing Energy Cost
 - Enable Scientists To Explore Tactics For Maximizing Work/Watt
- **Develop Middleware that Automates Optimal Choice of Compute/RAM Power Strategies for Desired Greenness**
- **Use as Central Control for Campus Building Sensors**

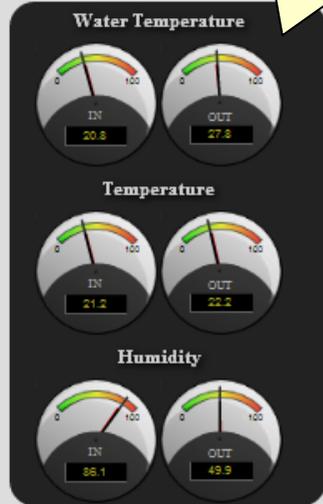


GreenLight Dashboard: Ingolf Krueger, Claudiu Farcas, Filippo Seracini



Environmental Data

GLIMPSE
GreenLight Infrastructure Management & Performance Evaluation

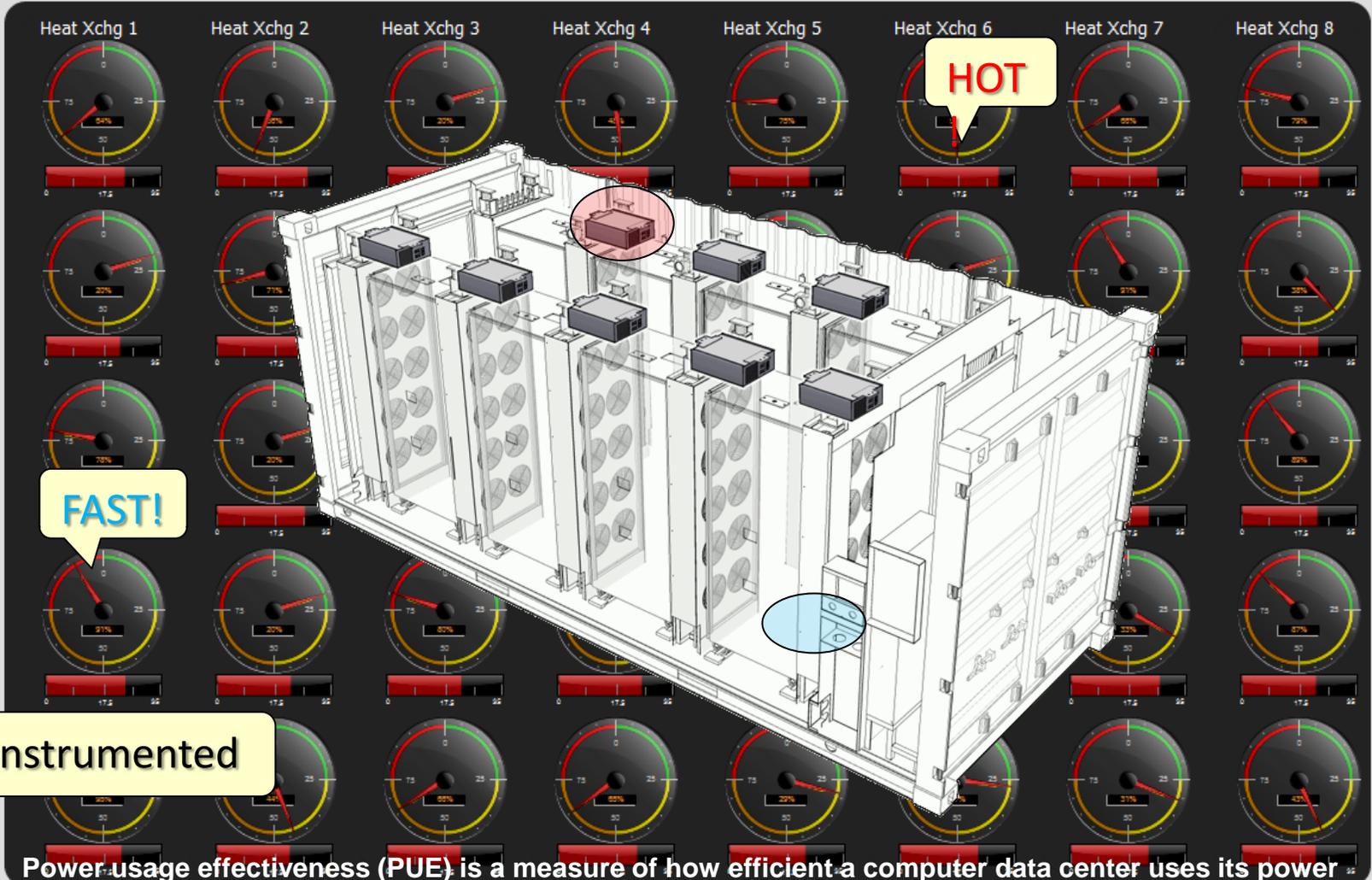


Total Power
Measured: 22011 W
Used: 28660 W
PUE*: 1.30

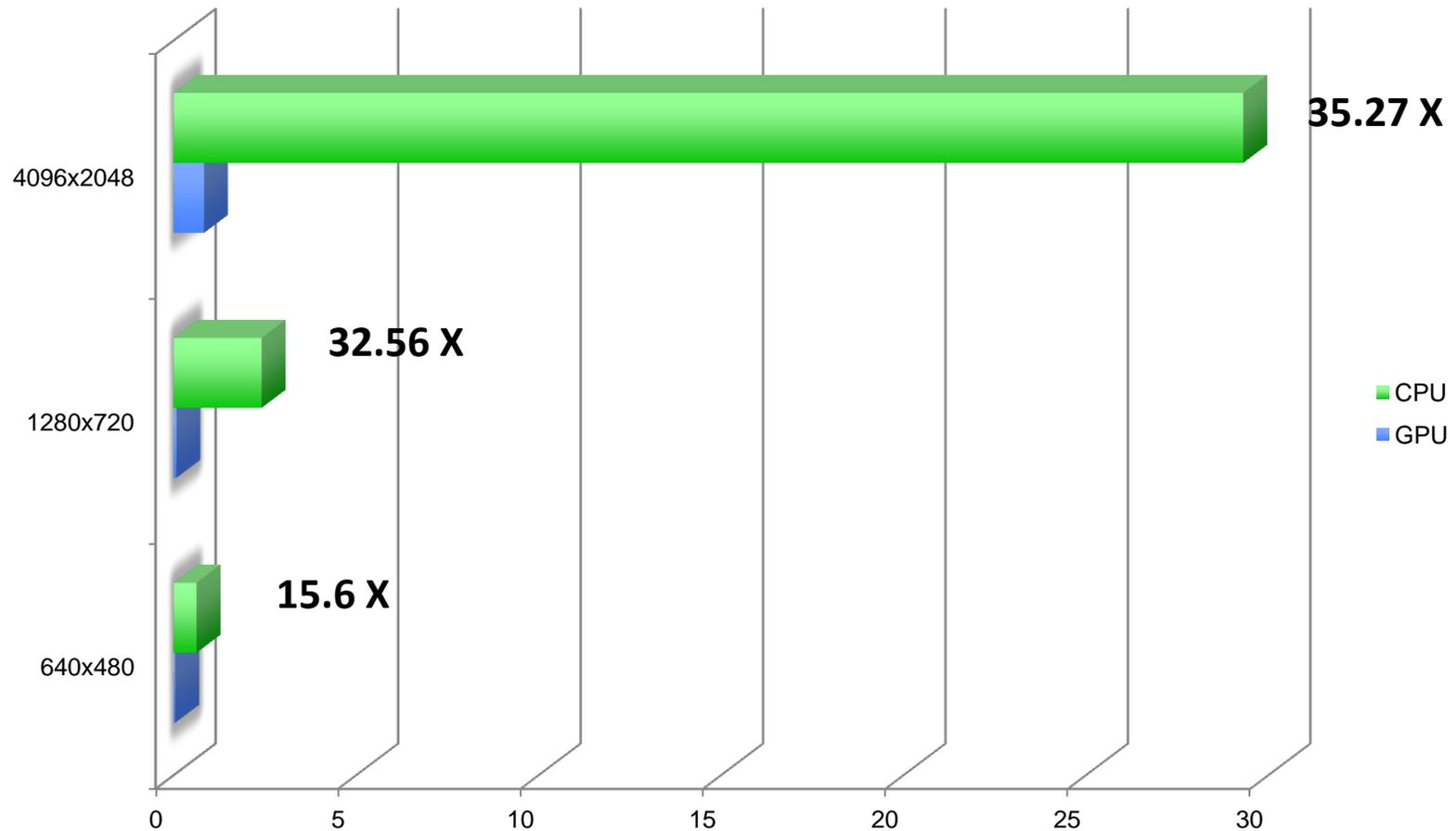
Note: * this is a rough estimate

Campus vs Instrumented

28Kw*2=\$56/hr
\$40K/month



Energy consumption: Quaternions on GPGPUs



Energy consumed by 12 nodes (in KWh)

GreenLight GPGPU Experiments—Raj Singh and Dan Sandin



GreenLight Experiment: Direct 400v DC-Powered Modular Data Center

- **Concept—Avoid DC to AC to DC Conversion Losses**

- Computers use DC power internally
- Solar and fuel cells produce DC
- Both plug into the AC power grid
- Can we use DC directly?
- Scalable/Distributable?

UCSD DC Fuel Cell 2800kW
Sun MDC <100-200kW



2 Megawatts of Solar Power
Cells Being Installed

- **DC Generation Can Be Intermittent**

- Depends on source
 - Solar, Wind, Fuel Cell, Hydro
- Can use sensors to shut down or sleep computers
- Can use virtualization to halt/shift Jobs
- Can switch to AC as backup

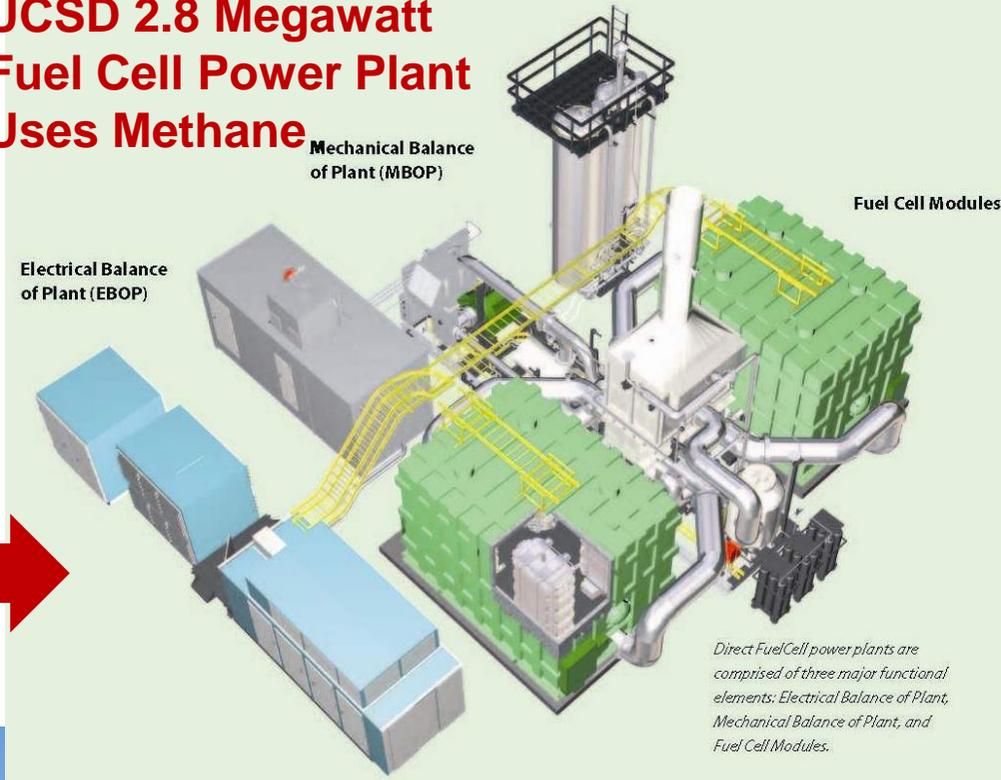


UCSD is Installing Zero Carbon Emission Solar and Fuel Cell DC Electricity Generators

San Diego's Point Loma Wastewater Treatment Plant Produces Waste Methane



UCSD 2.8 Megawatt Fuel Cell Power Plant Uses Methane



2 Megawatt of Solar Power Cells Installed



Zero Carbon GreenLight Experiment: Direct DC-Powered Modular Data Center

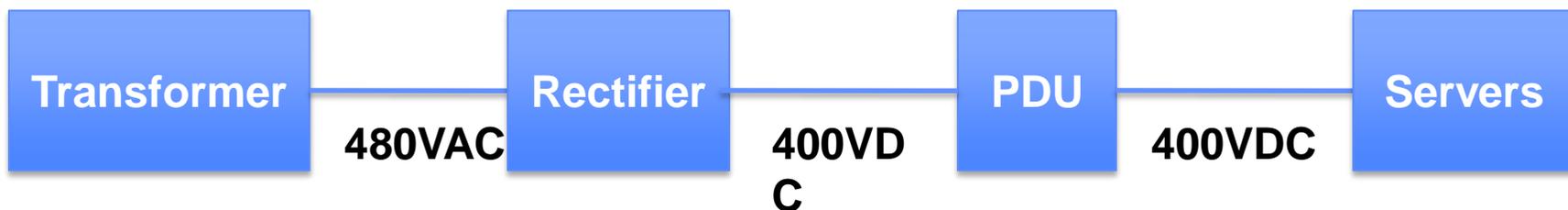
- **Concept—Avoid DC to AC to DC Conversion Losses**
 - **Computers Use DC Power Internally**
 - **Solar and Fuel Cells Produce DC**
 - **Both Plug into the AC Power Grid**
 - **Can We Use DC Directly (With or Without the AC Grid)?**
- **DC Generation from Renewable Can Be Intermittent**
 - **Depends on Source**
 - **Solar, Wind, Fuel Cell, Hydro**
 - **Can Use Sensors to Shut Down or Sleep Computers**
 - **Can Use Virtualization to Halt/Shift Jobs**
- **Experiment First Phase Completed 2011**
 - **Collaboration with Oracle, LBNL, EPRI, Direct Power, Intel, Delta, Emerson**
 - **NSF GreenLight Year 2 and Year 3 Funds**
 - **CEC and PIER support**

DC Fuel Cell 2800kWatts
Sun Box <200kWatt



Two Rack DC Experiment now Operational

- **Proof of concept experiment within context of Project GreenLight**
- **Uses Emerson rectifier as source of DC power => 400VDC**
- **Uses Emerson DC PDUs**
- **Drives 400VDC custom server power supplies (from Delta and Emerson)**
- **Drives 13 servers**
 - 6 SunFire X4270 (Nehalem) servers
 - 6 Intel 2600 (Nehalem) servers
 - 1 SunFire x4540 storage servers





GLIMPSE

Decision Support System



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Dashboard interface



"Tap" for details

Power utilization

Enterprise reach

Multiple perspectives



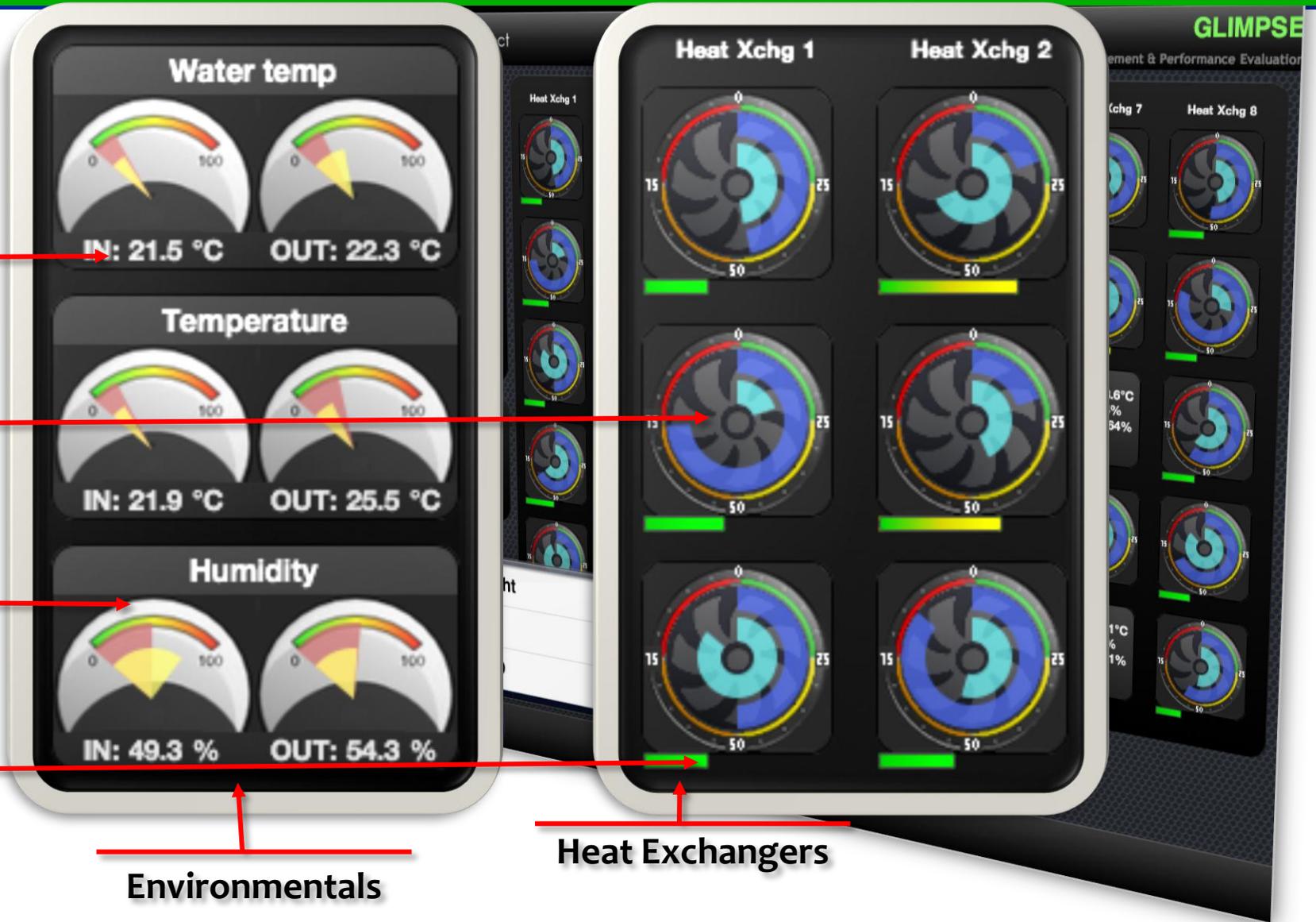
Datacenter vitals

Input/Output temperature sampling

Live/average Fan speeds

Live/Average data

Live Temperature



Environmentals

Heat Exchangers

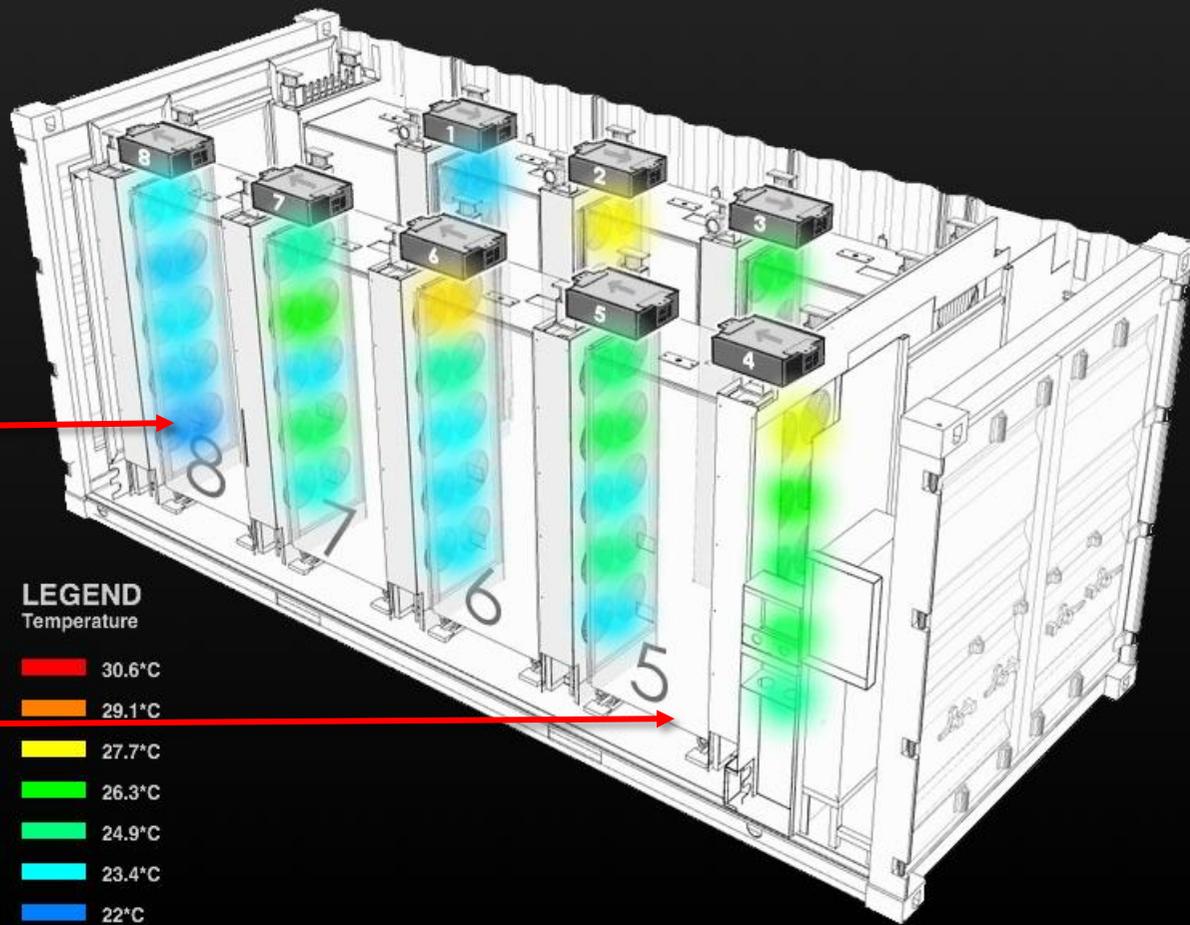
Control elements



Real-time heatmap



Realistic models

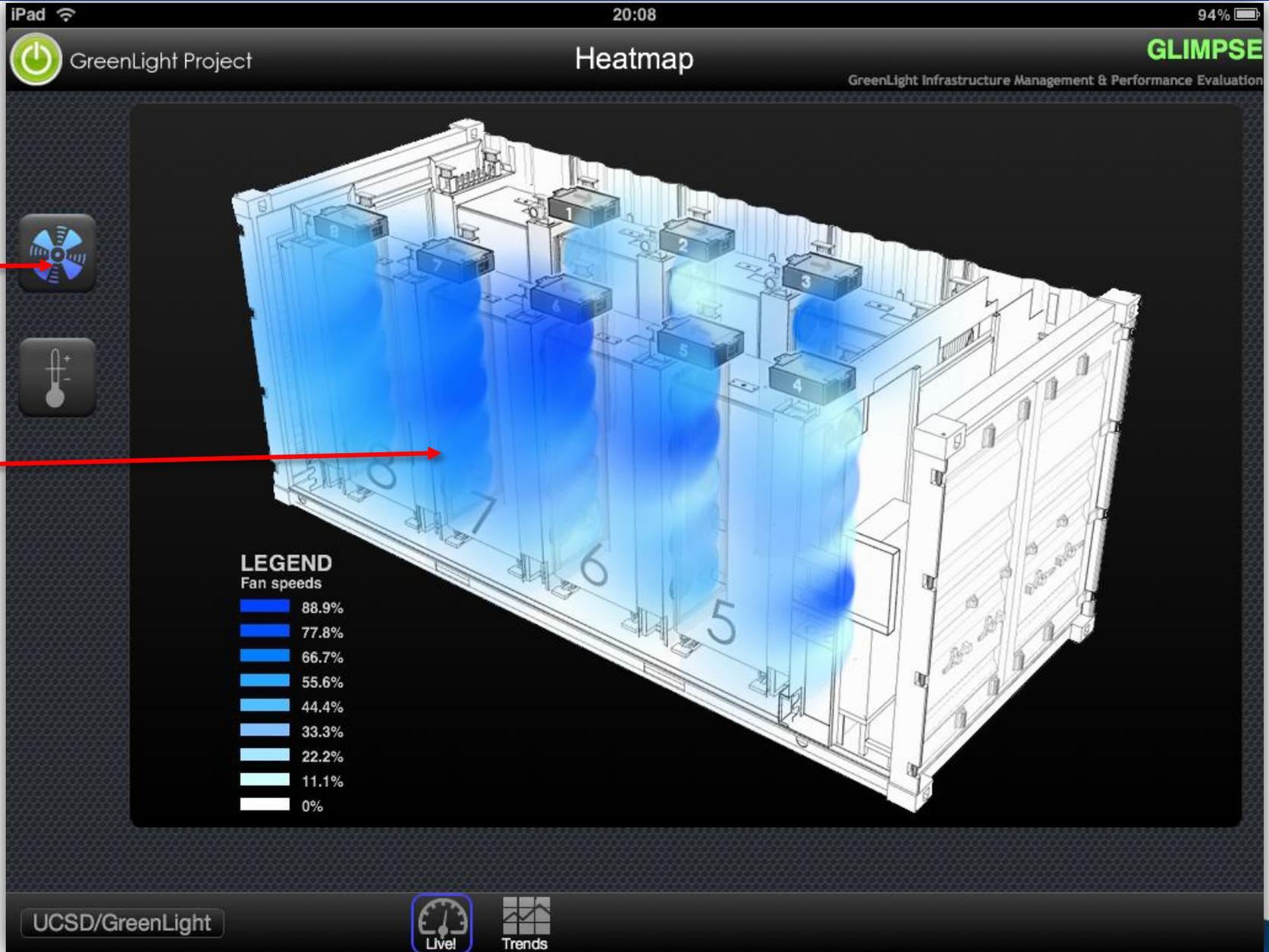


Airflow dynamics

Live fan speeds



Airflow dynamics

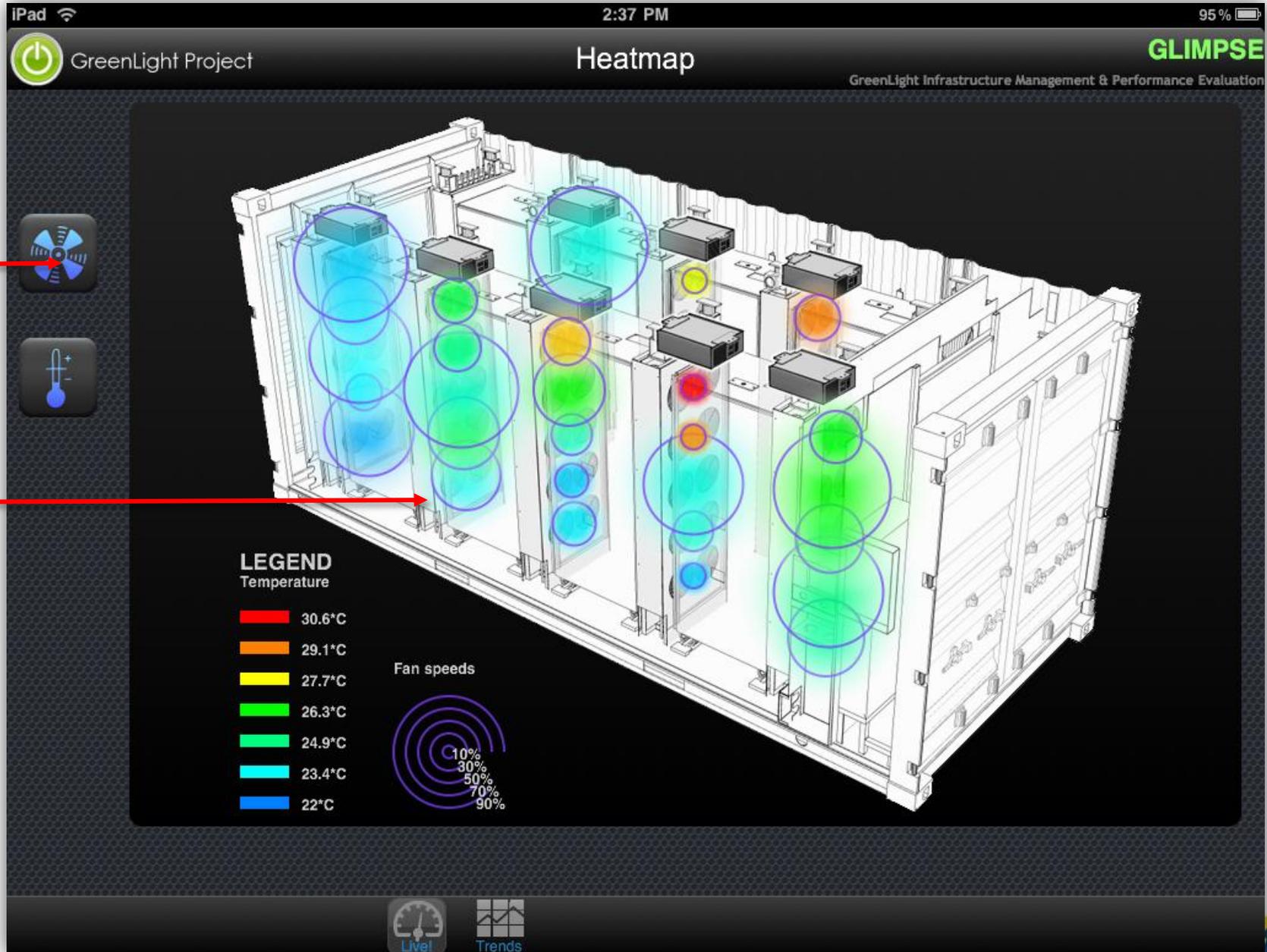


Heat distribution

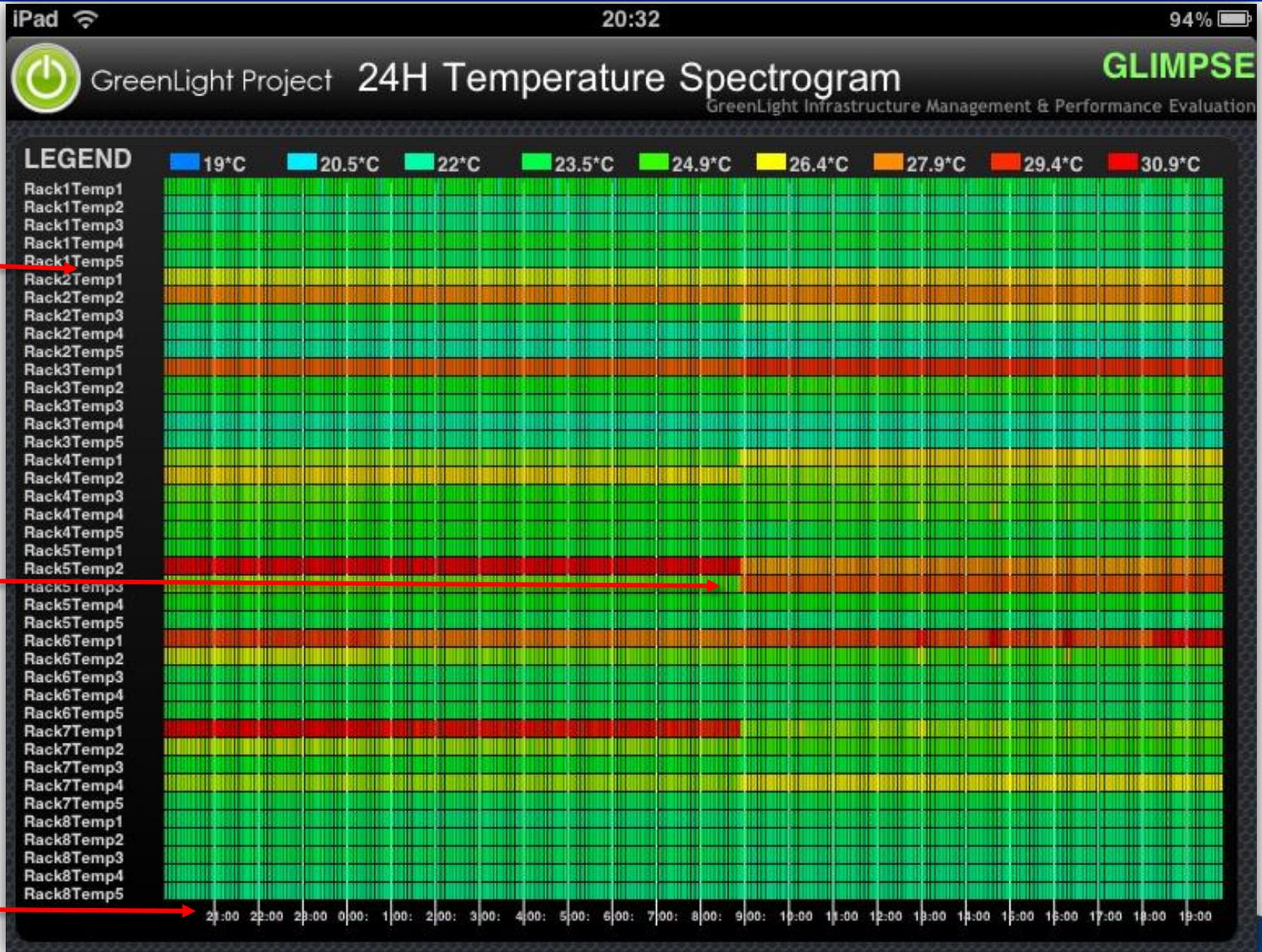
Combined heat + fans



Realistic correlation



Heat Trends



Power spikes

IT assets

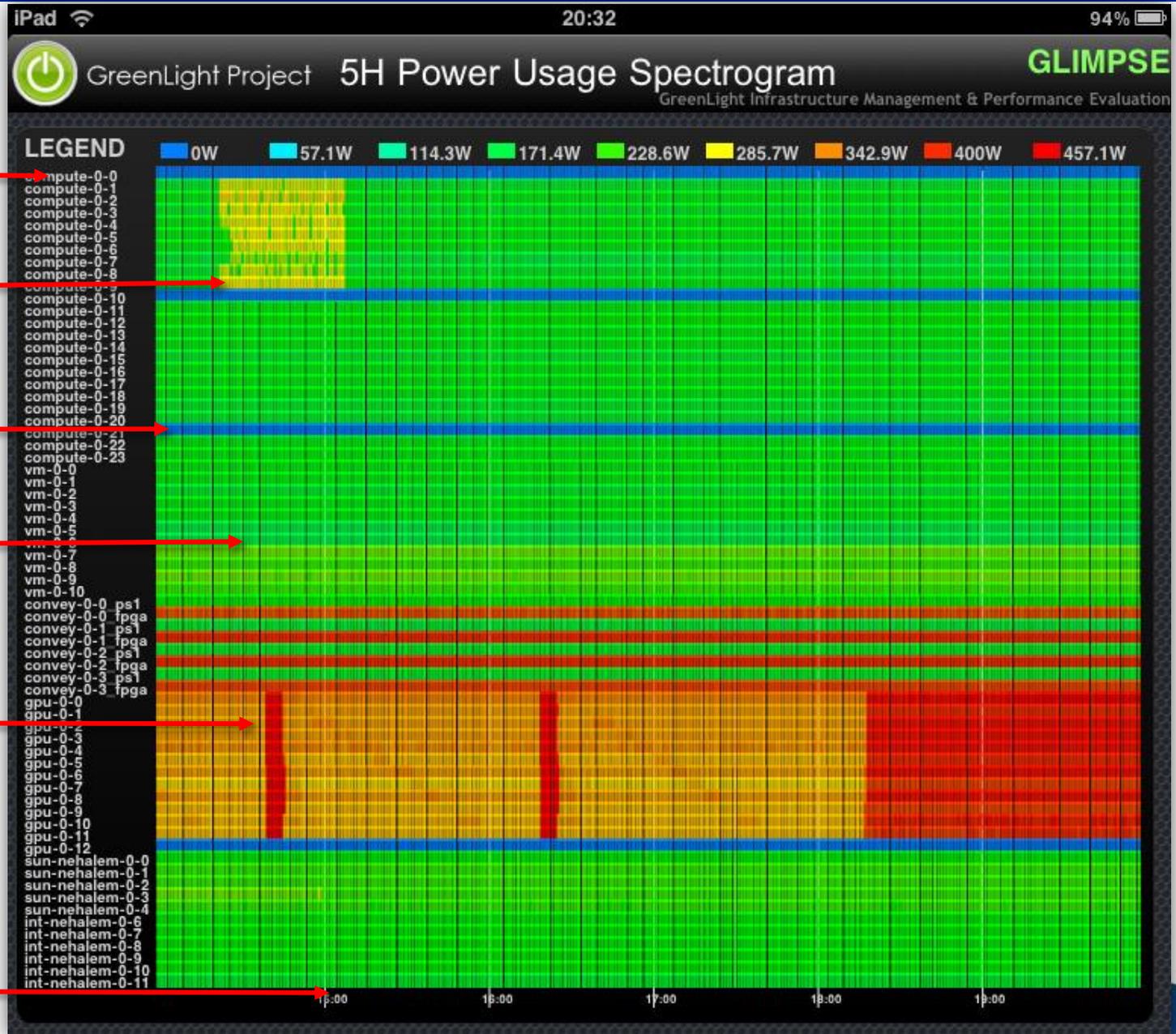
Computation zone

Unused asset

Average load

Peak computation

1 minute resolution



Zoom-in Analysis



History over several days.

Zoom on desired time range.

Hint on each sample point.

Automatic average area.

Multiple sensors per asset with up to 1 min sampling resolution.

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Cell/UCSD



Summary

GLIMPSE – decision support system

- » just a sliver of entire GreenLight Enterprise capabilities
- » critical to understand the massive amounts of data
- » provide real-time situational awareness
- » monitor & control datacenter assets

GreenLight Enterprise Solution:

- » federates datacenters
- » improves performance/watt by selecting most appropriate architectures
- » improves energy utilization by scheduling computation based on heat, energy usage, and load
- » reduces cooling needs and improves equipment lifetime



GreenLight Extended to Networks

- **The GreenLight switches: accurate measurement of the cost of campus-scale network transmission of data between servers**
- **WAN terrestrial and undersea transmission costs in long-distance watts/TB**
- **An additional green and transformative use is high-definition and 4K videoconferencing with SAGE, CSCW software.**
- **Cloud computing may provide 10-20x efficiency through**
- **Of course, the best GHG-reducing applications are no doubt yet to be thought up and tested.**



The GreenLight Vroom



GreenLight Extended to Collaboration

- The GreenLight Vroom: accurate measurement of situation rooms & large data teleconferencing
- Panels are getting much greener—
 - ~200w per panel vs. 1kW-to-80kW per projected screen
- The additional green and transformative use is virtual reality tele-immersion.



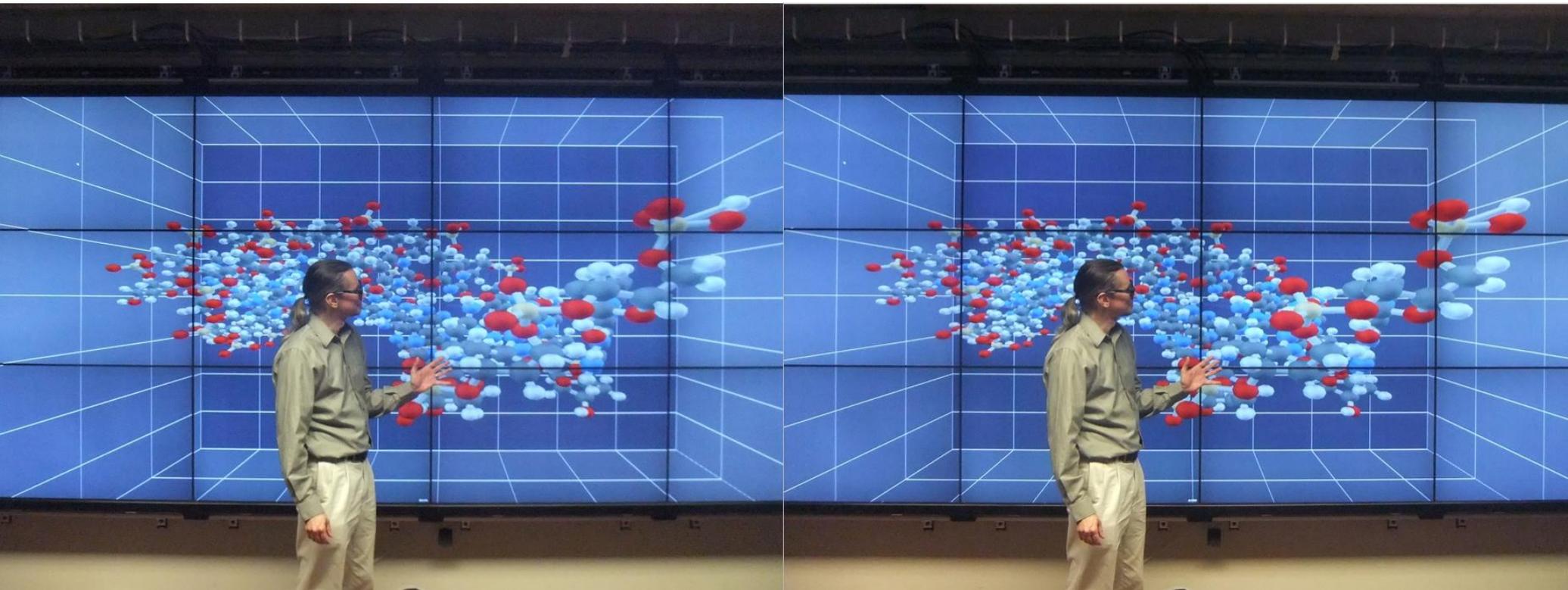
TourCAVE



Five 65" LG 3D HDTVs, PC, Tracker---~\$33,000



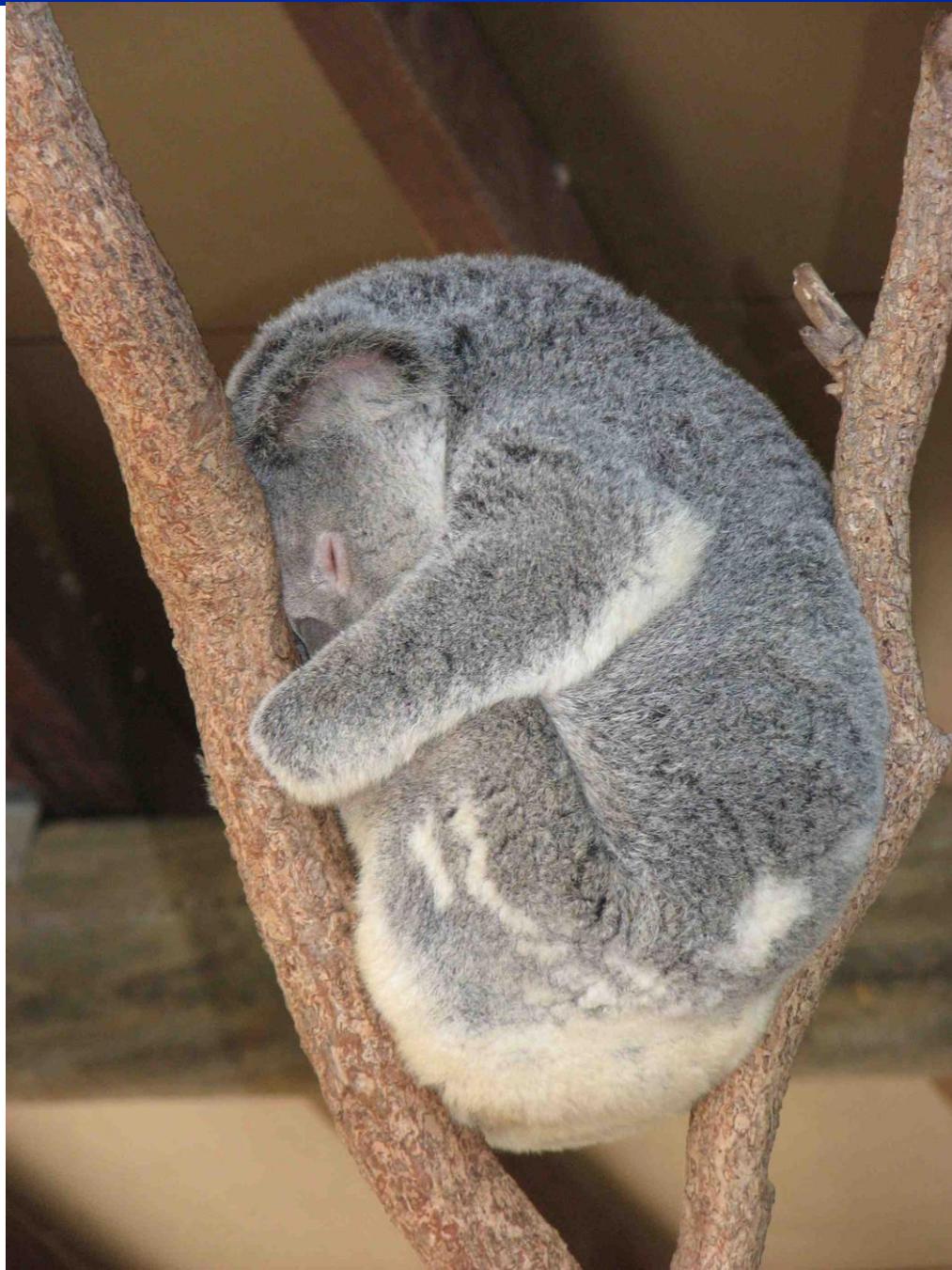
3D xpol UNB Panels: New EVL Display at University of Illinois at Chicago ~\$100K



Stereo Image: Jason Leigh, EVL



To be Energy Efficient, We Must Think about GreenLight-Style Computing



Size Your Brain Power, Visualization, Storage, Sleep Cycles, Visual System, and Communications to Your Problem



Thank You!

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