Establishing Metrics, Setting Goals, and Achieving High Data Center Energy Performance

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Better Buildings Data Center Challenge and Accelerator

- *More than 10 Challenge partners set a 10-year, 20% energy-savings target across their data center portfolio and share results, including:*
  - *Digital Realty*
  - *Intel Corporation*
  - *Sabey Data Centers*
  - *Schneider Electric*
- *Over 20 Accelerator partners set a 5-year, 25% energy-savings target across one or more data centers and provide regular updates on progress, including:*
  - *National Energy Research Scientific Computing Center (NERSC)*
  - *National Renewable Energy Laboratory (NREL)*
  - *Lawrence Berkeley National Laboratory (LBNL)*
  - *Lawrence Livermore National Laborary (LLNL)*

METRICS OF THE FUTURE

October 2018

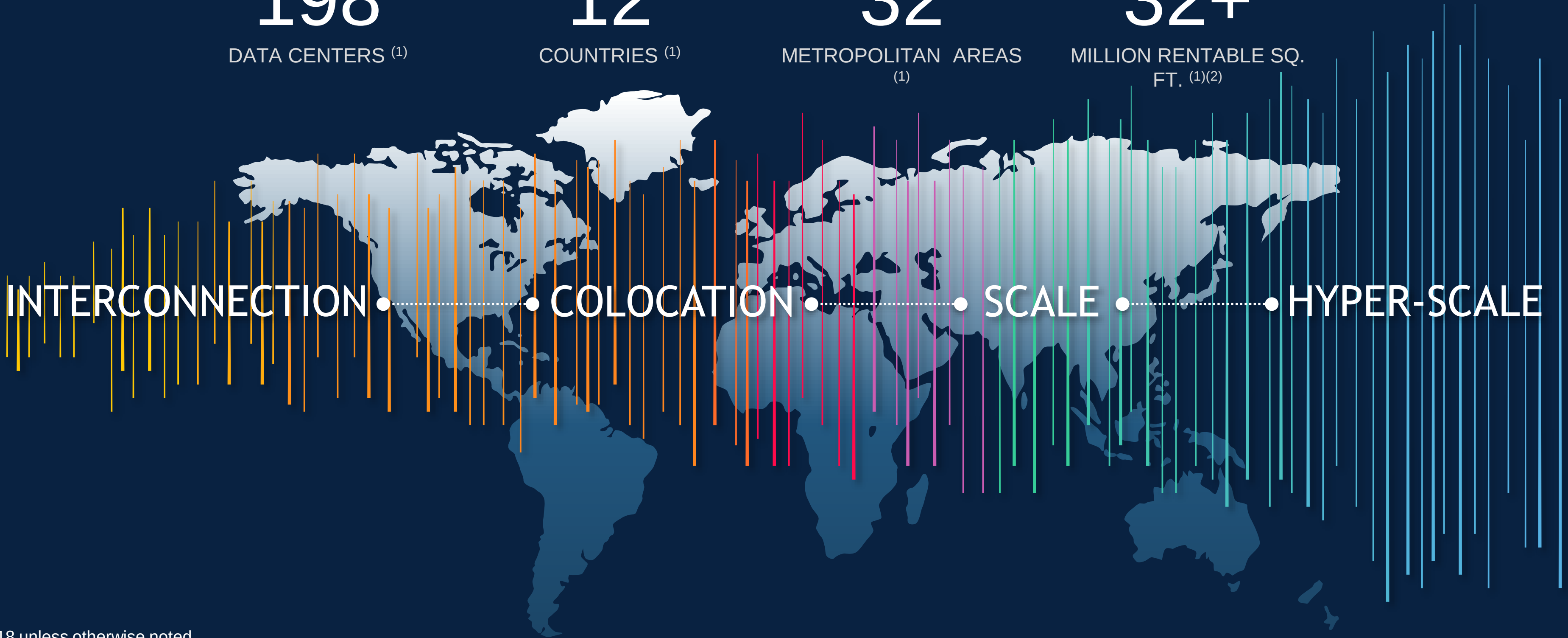
DIGITAL REALTY

Digital Realty

Full Spectrum of Data Center Solutions Across a Global Platform

DIGITAL REALTY

198	12	32	32+
DATA CENTERS (1)	COUNTRIES (1)	METROPOLITAN AREAS (1)	MILLION RENTABLE SQ. FT. (1)(2)



Note: Data as of June 30, 2018 unless otherwise noted..
1) Includes investments in eighteen properties held in unconsolidated joint ventures.
2) Includes 3.6 million square feet of active development and 1.5 million square feet held for future development.

Successful Track Record of Sustainability Performance

Management and organizational commitment to sustainability

- Full time REIT-sustainability expertise in-house
- Board oversight and senior executive with sustainability management responsibility
- Integrated cross-functional teams

Track record of sustainable project investment

- Successfully allocated $493 million of proceeds from data center industry's first green bond
- Signed long term contract to purchase 100% renewable energy for US colocation and interconnectivity business

Industry-leading clean energy solutions

- 184 MW of renewable wind and solar projects under contract in the US
- #6 in EPA Green Power Partnership Tech and Telecom sector for renewable energy(1)

Award-winning data center designs and third party certification

- 57 green building certifications globally
- 3 new LEED™ certified green buildings developed in 2017 and 2 LEED certifications in 2018 (2)

Thought leadership and innovation in energy efficiency

- US DoE Better Building's Challenge for data centers; Achieved 25% savings in 2017 vs 20% target by 2024
- Successful track record of Energy Star accreditation

Ranking for EPA's Top 30 Tech and Telecom list of largest green power users as of December 31, 2017.
As of June 30, 2018.

ECO Project Program

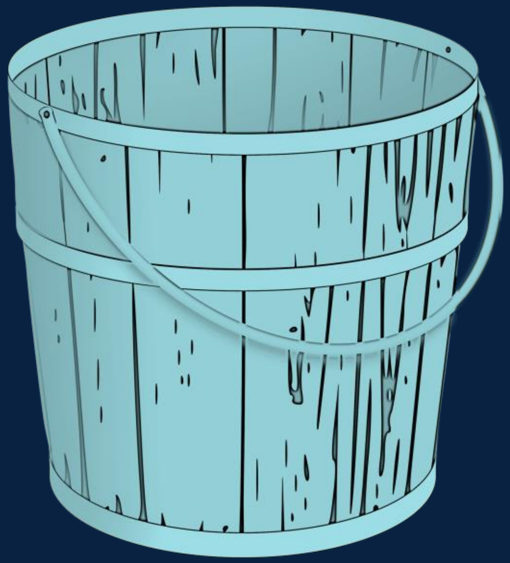
Identify Energy Conservation Opportunities within our portfolio, determine the beneficiaries, and direct projects to appropriate capital expenditure budgets. Implement projects to maximize financial value and energy savings.

- Projects Identified with ECO components: 400+
- Utility Incentives identified: ~$8 million
- Estimated Initial Project Budgets: ~$78 million
- Calculated/Audited potential energy savings: ~90 million kWh
- Calculated/Audited potential cost avoidance: ~$7 million
- Intangible benefits: Engaged management team

ECO Capital Project Budgeting

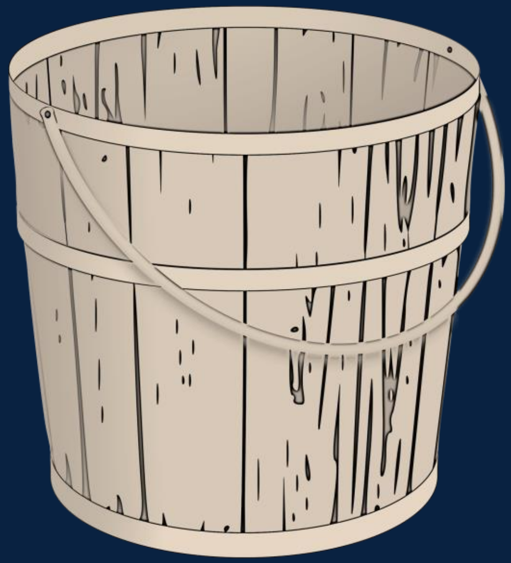
Energy Conservation Opportunities (ECO)

- Energy, water efficiency
- End-of-Life upgrades with efficiency benefits



Traditional Capital Expenses

- Other refurbishments and modernizations
- End-of-Life upgrades without efficiency element



ECO Project Program Highlights (2017)

- Colo PUE reduction of ~5%, on track for another 5% in 2018
- Completed 10 pure energy savings ECO projects
  - Project budget: $800,000
  - Utility incentives: $95,000
  - Annualized cost savings: $700,000
  - Annualized energy savings: 6.1 million kWh
- 100% of savings for colo projects accrues to Digital Realty's bottom line

Building Green Lowers Occupancy Costs

- Three data centers located in Franklin Park and Elk Grove Village, IL
- Total: 46.7 MW IT
- ComEd Incentive Program: ~1.4 PUE baseline design
- Current operation is between ~1.2 and ~1.3 PUE
- Expansion work at both Elk Grove and Franklin Park will add 40+ MW IT when fully built out

Energy Efficiency Pays

- Three year collaboration on design and operational efficiency
- 40 million kWh saved/year from operational efficiency
- Equivalent to electricity used by 4,400 US homes
- $2.6 million annualized savings
- $3.1 million in incentives over three years
- Digital Realty received the two largest data center energy efficiency incentives ever awarded by the ComEd Data Center Energy Efficiency Program

Data Center ECO Leaders

Intel High DENSITY DATA CENTERS

Nissim Hamu, Intel IT Data Center Engineer

IT@INTEL

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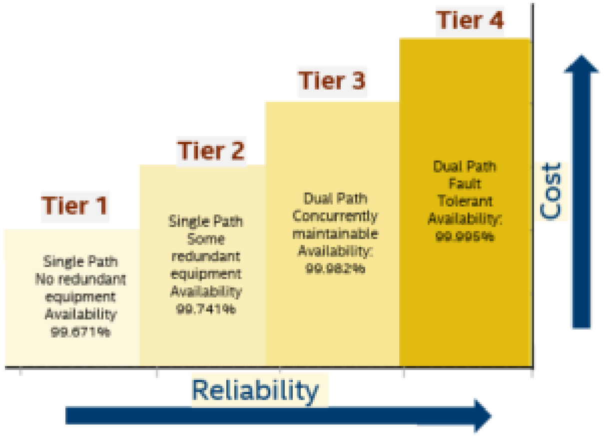
Business Challenges and What to Consider

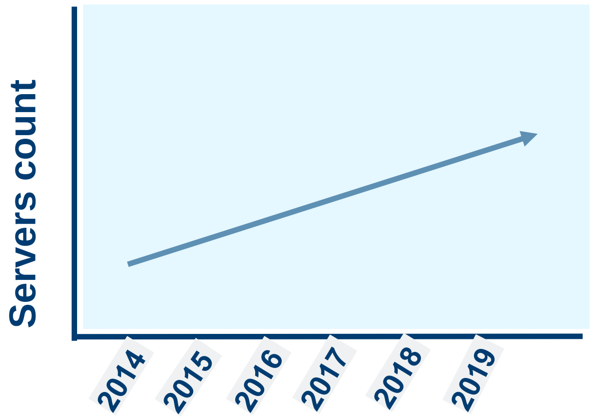
Industry Standards

Industry Body	Industry Standard (if applicable)
ASHRAE (American Society of Heating, Refrigeration and Air Conditioning Engineers)	ASHRAE TC9.9 Guidelines for Mission Critical Facilities
Building Industry Consulting Services International	ANSI/BICSI 002 – Data Center Design and Implementation Best Practices
European Commission	Code of Conduct for Data Centres
Telecommunications Industry Association	ANSI/TIA 942 – Infrastructure Standard for Data Centers
Association for Computer Operations Management	
The Green Grid	
United States Department of Energy	
United States Environmental Protection Agency	
Uptime Institute	

Uptime Institute Tier Levels

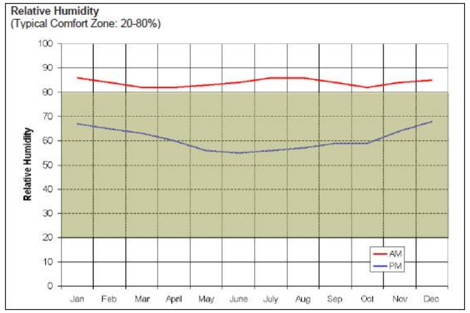


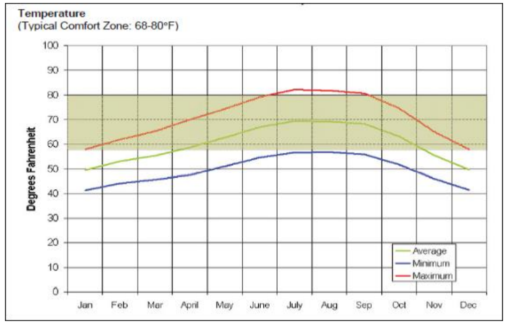
Gross in Compute demand – 30% YOY



Temperature and Environmental Conditions

Climate Data for Santa Clara	
Wet Bulb	Hours/Year
70°F - 72°F	3
68°F - 70°F	9
66°F - 68°F	68





California Climate Zone 4

Reference City: San Jose
Latitude: 37.35 N
Longitude: 121.9 W
Elevation: 70 ft

Basic Climate Conditions

	(F)
Summer Temperature Range	23
Record High Temperature (2000)	109
Record Low Temperature (1990)	19

Design Day Data
Winter 99% 34
97.5% 36

Summer
1%: 85 MCWB 66
2.5%: 81 MCWB 65

Climatic Design Priorities
Winter: Insulate, Reduce Infiltration, Passive Solar
Summer: Shade, Allow natural ventilation, Distribute Thermal Mass, Use Evaporative Cooling

Title 24 Requirements

Package	C	D
Ceiling Insulation	R38	R30
Wood Frame Walls	R25	R13
Glazing U-Value	0.38	0.67
Maximum Total Area	14%	20%

Climate
The Central Coastal Range is inland of the coast but has some ocean influence which keeps temperatures from hitting more extreme highs and lows. This zone covers many microclimates from northern to southern parts of the state. The reference city is in the northern-most part of the zone.

	San Jose	Gilroy	Sunnyvale	Paso Robles
HDD	2335	2278	2643	2934
CDD	574	913	220	956

HDD = Heating Degree Days (base 65F)
CDD = Cooling Degree Days

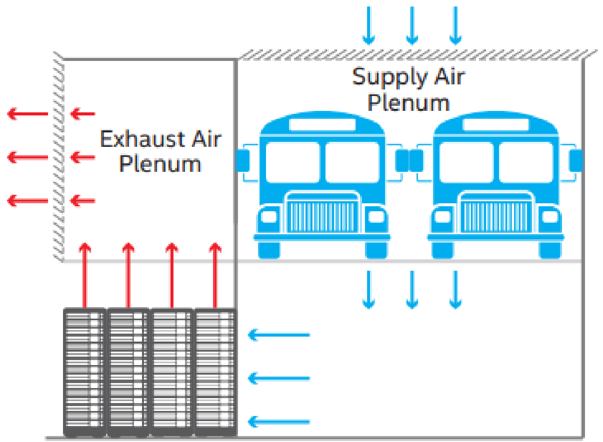
Seasons are sharply defined. Summers are hot and dry with a large daily temperature swing. Summers are hot enough that cooling is necessary. Winters are cool but not severe. Heating is necessary on many days in the winter.

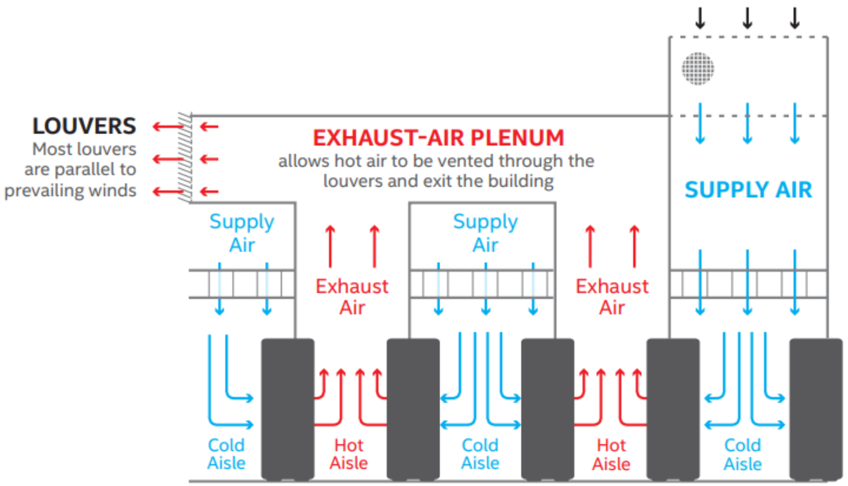
Days are typically clear with the coastal range blocking much of the fog and high winds.

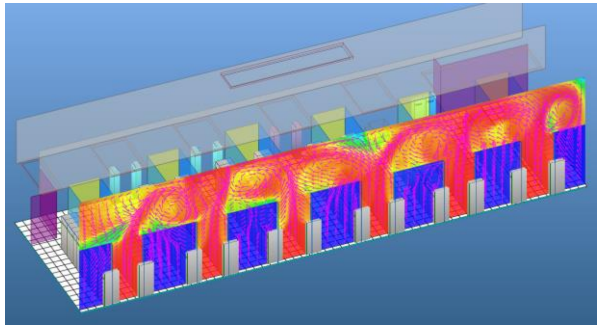
Industry Standard References: ASHRAE TC9.9: Data Center Power Equipment Thermal Guidelines and Best Practice.
The Impact of ASHRAE 2011 Allowable Ranges
PGE: Califonia Climate Zone 4

Data Center A – Free Air Cooling

- Designed for PUE 1.07 but achieving 1.06
- 1,100 W/sqft cooling density and a 1,300 W/sqft electrical density (10 times the industry average)
- When outside temperature exceeds 90°F, supplemental cooling is done by running chilled water through the supply air coils.
- During the winter the hot air in the hot aisle is mixed with the supply cold air to manage the temperature dew point and avoid very low temperature in the cold aisle
- Run servers at an air intake temperature of up to 95°F (35°C). Hot aisle average – 110°F in the winter and 125°F in the summer
- Custom Rack Design in both DCs– 20 inch wide, 60U high, power density – 43 KW per Rack – 1.5 times greater than what we have delivered in the past for high density computing

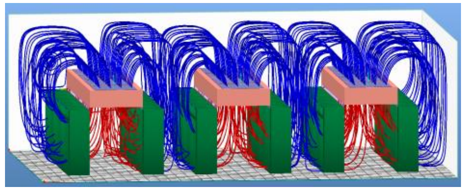




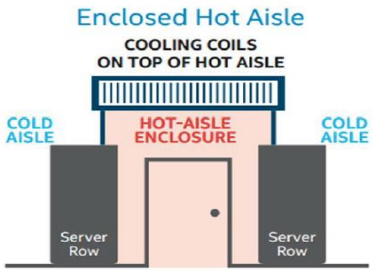


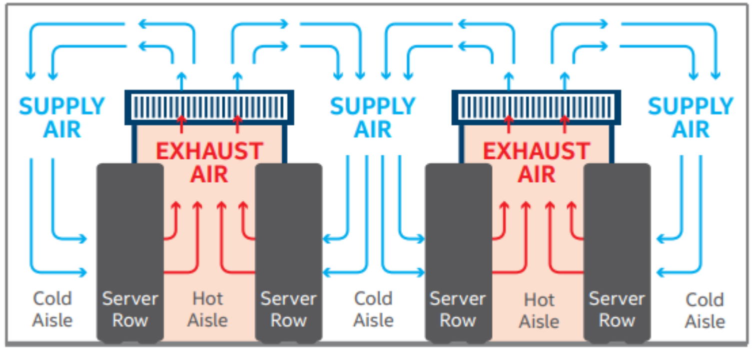
Alternating hot aisles (exhaust air) and cold aisles (supply air) provide efficient air segregation and the exhaust-air plenum allows hot air to easily exit the building.

Data Center B – Closed – Coupled Cooling

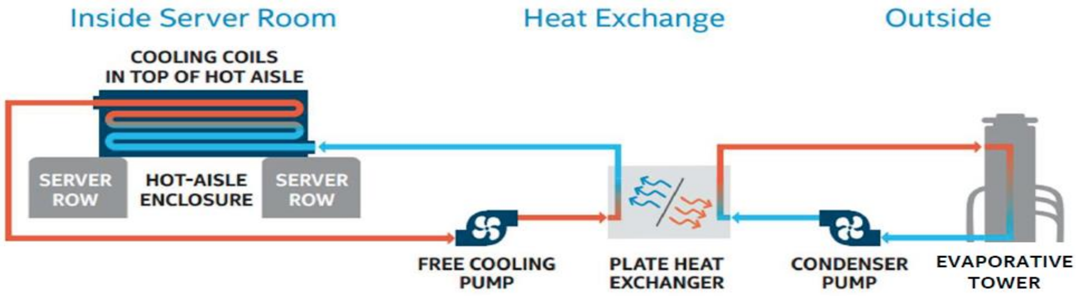


- 1,100 W/sqft cooling density and a 1,300 W/sqft electrical density (10 times the industry average)
- Cooling towers supply water temperature – 79°F in the Summer and provide 90°F supply air to the servers
- Overhead cooling coils, can remove heat up to 330KW per 6 racks
- The hot aisle has static pressure relief fans that are controlled by differential pressure sensors and ECM motors
- Cold/Hot aisle air tight segregation , Hot aisle temperature – 110°F – 130°F, Supply air – 80°F – 90°
- State of the art electrical density and distribution systems – 800A and 1200A 415V/240V, high efficiency transformers and 100 % rated equipment
- Data Center B – Total power capacity of all high-density and Intel legacy Data centers. The Xeon-based processors data centers offer 51% higher performance per core than previous models





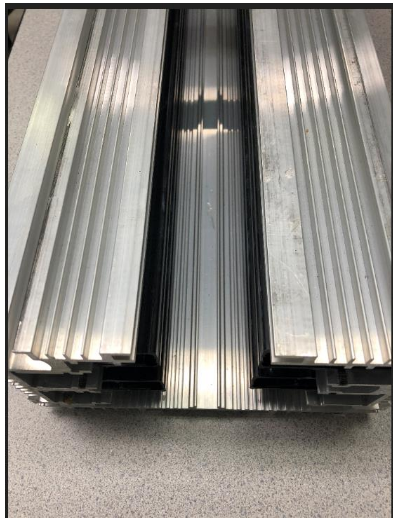
Water-cooled coils are built in the ceiling structure of the modules

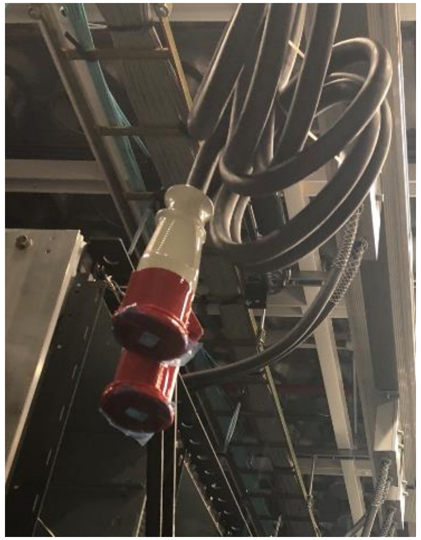


Chiller-less system with two separate water loops

Electrical Distribution

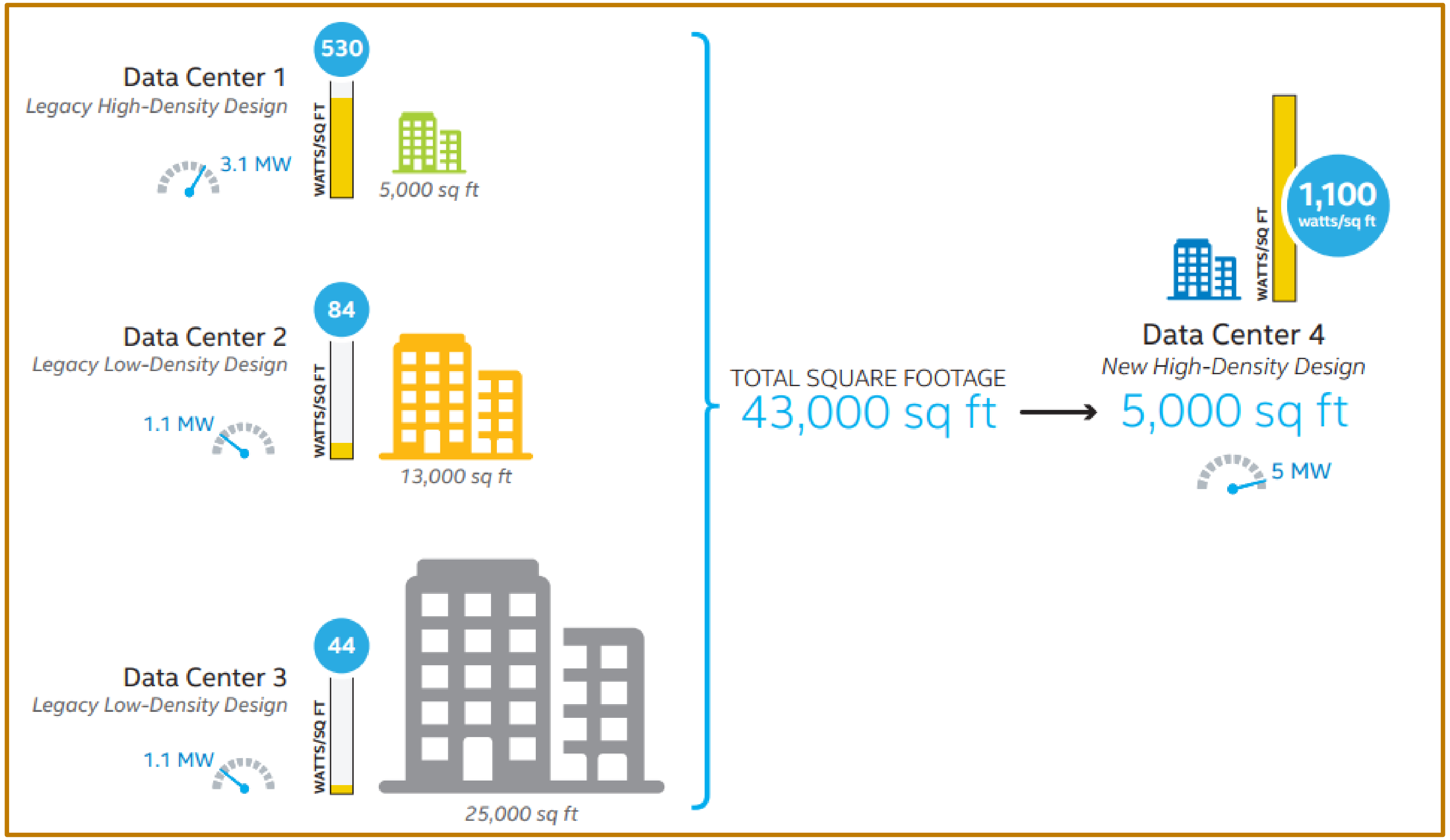
- Overhead busways systems - 575 KW on single bus supporting 440 sq. ft.
- The electrical density is 10X the average industry
- Bas-taps and power strips are designed by Intel and built by a third party OEM
- High capacity power strips (PDU) – 3 phase, 60A (43KW), 415V/240V, >22KAIC,
- The power strip is designed for 3 phase balancing of the load
- We used high efficient transformers and all the electrical equipment are rated at 100% (Breakers, busways, bas-taps, cables…)
- Easy of use – the design is flexible and allows for easy configuration and connectivity, which reduced our installation cost by 75 present compared to previous solutions
- Flexibility – the busway and power strip design enables to support legacy and future IT equipment without having to rewire branches circuit or replace the equipment
- Reliability – based on our business requirements and the quality of the utility power provider, we are using utility power to operate the IT equipment. The electrical distribution systems is designed to accommodate UPSs and generator if necessary.





Data Center Consolidation

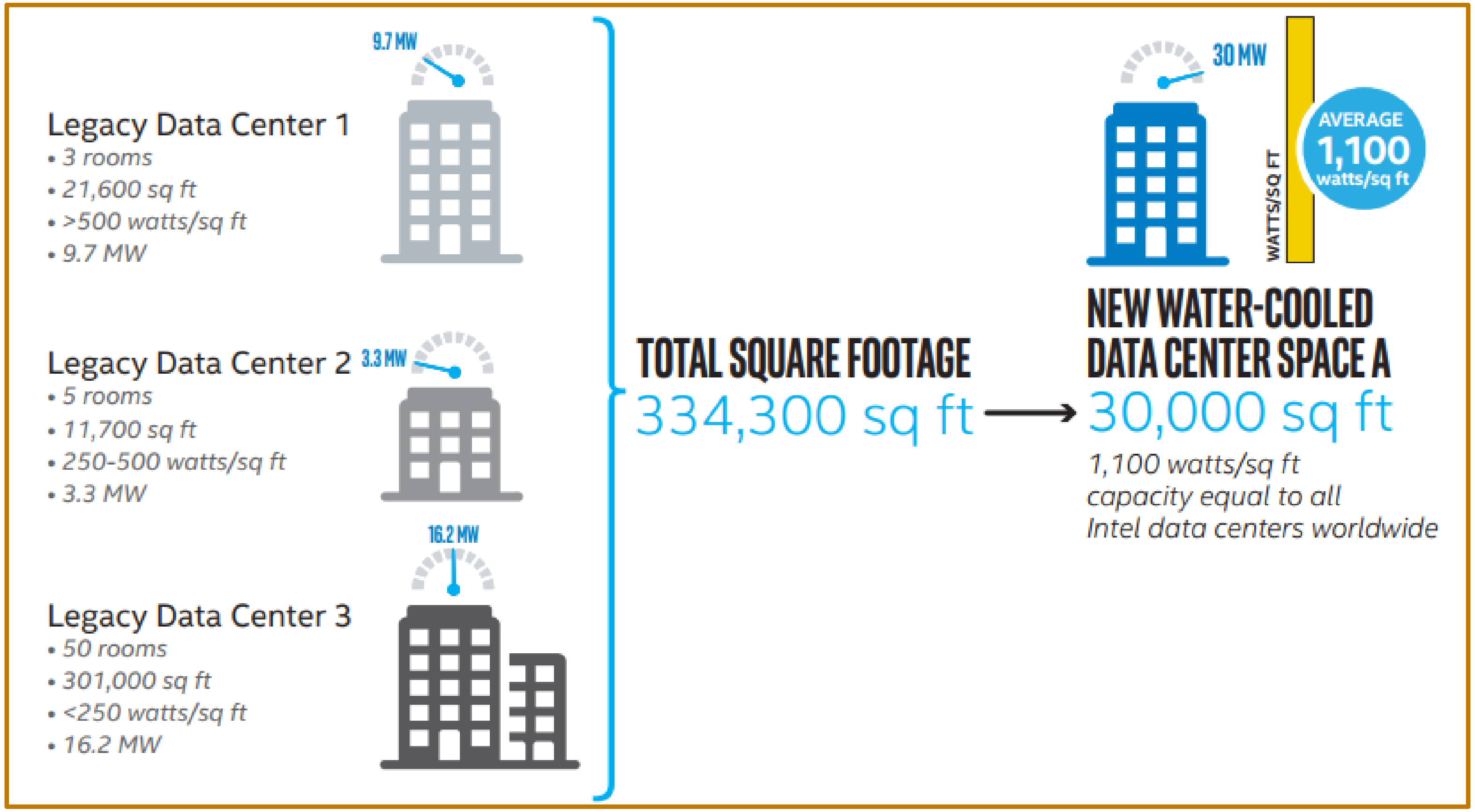
Data Center A, Free Air Cooling, 5MW, 5,000 sq. ft.



Our high-density design allows for an increase in watts per square foot. Economies of density work similar to Moore's Law: the cost per kW goes down as more kW are put into each square foot of production area.

Data Center Consolidation

Data Center B Closed-Coupled cooling, 30MW, 30,000 sq. ft.



Whew construction is complete, the closed-coupled cooling solution data center will exceed the combined power capacity of all current Intel Data centers .

Designs and Techniques to Increase Data Center Efficiency

Vision: Maintain Intel's position as being in the top three for most energy efficient DC in the industry

Air Segregation

- No Raised Metal Floor
- Air segregation preferred hot aisle solution
- Chimney cabinets raise supply air temperature

Air Management

- Flooded supply air design
- Variable Frequency Drives and ECM motors
- Reduce airflow volume

Cooling management

- Evaporative cooling Wet side economization
- Free cooling Outside air Dry side economization
- Raise Return Air Temperature and Raise Supply Air Temperature
- Raise Return Chilled Water Temperature

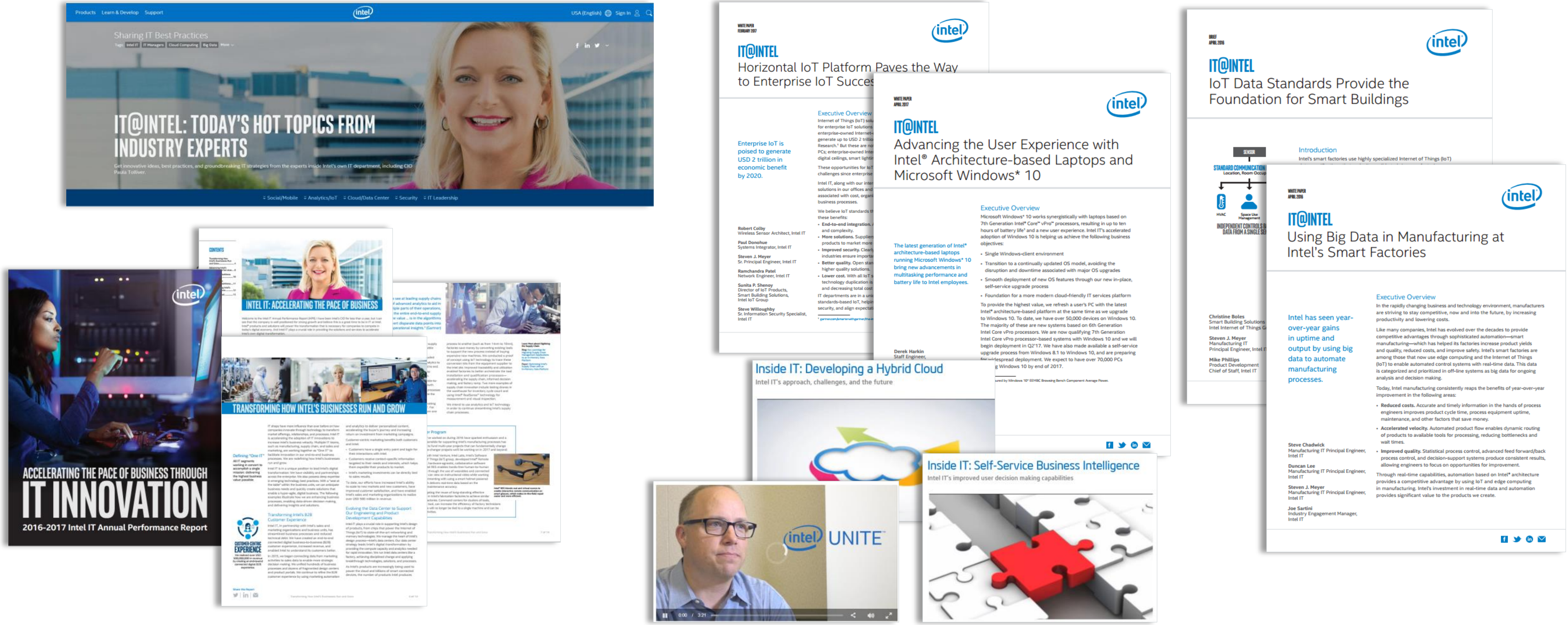
Power Loss and Electrical Efficiency

- 415V/240V rack power distribution
- 12kV to 415V/240V Substation
- High efficiency Transformers reduce transformer electrical loses
- Utility as second source

Room Design Efficiency

- 1100 watts /sf/ft. Power and cooling density
- Multi Tier room design takes advantage of "N Plus 1" infrastructure stranded capacity through lower tier load sheading
- Densification maximizes power, space and cooling distribution reducing construction cost and improving efficiency

IT@INTEL: Sharing Intel IT Best Practices With the World



Learn more about Intel IT's initiatives at: **www.intel.com/IT** intel®

Achieving High Data Center Energy Performance

7x24 Exchange 2018 Fall Conference

October 22, 2018

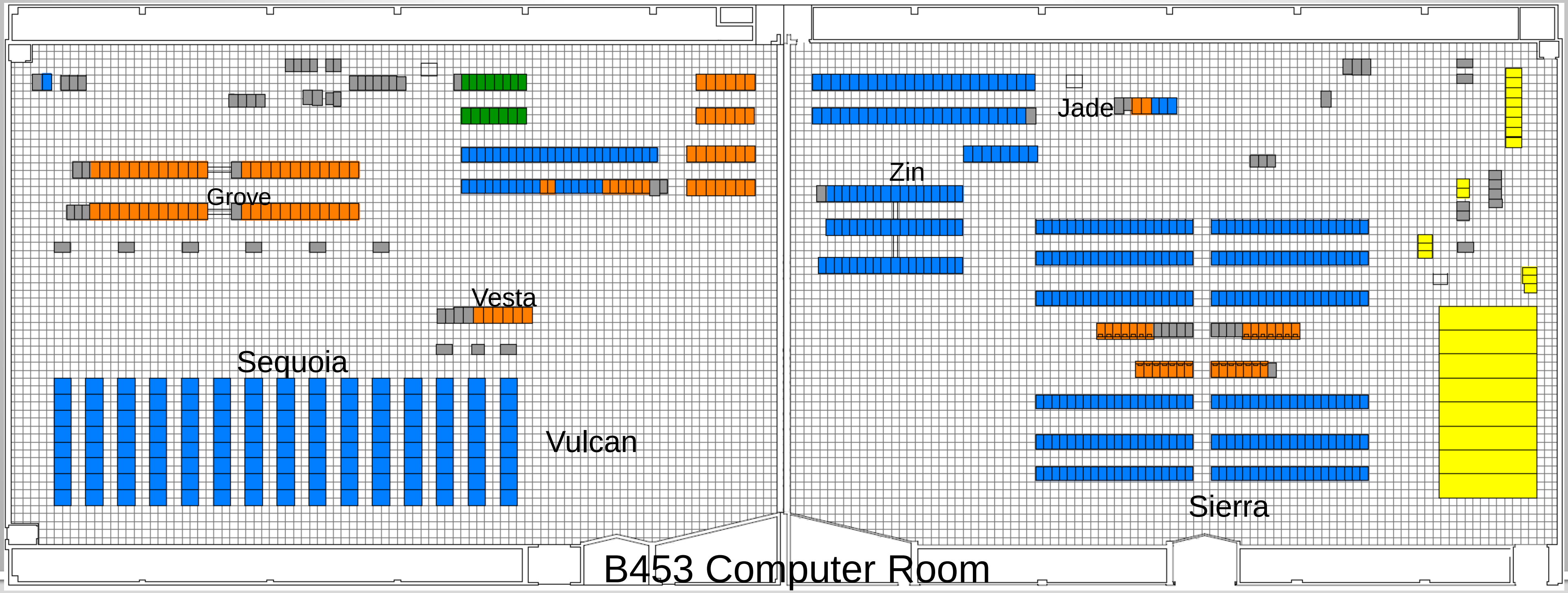
Brandon Hong, PE

LLNL-PRES-######

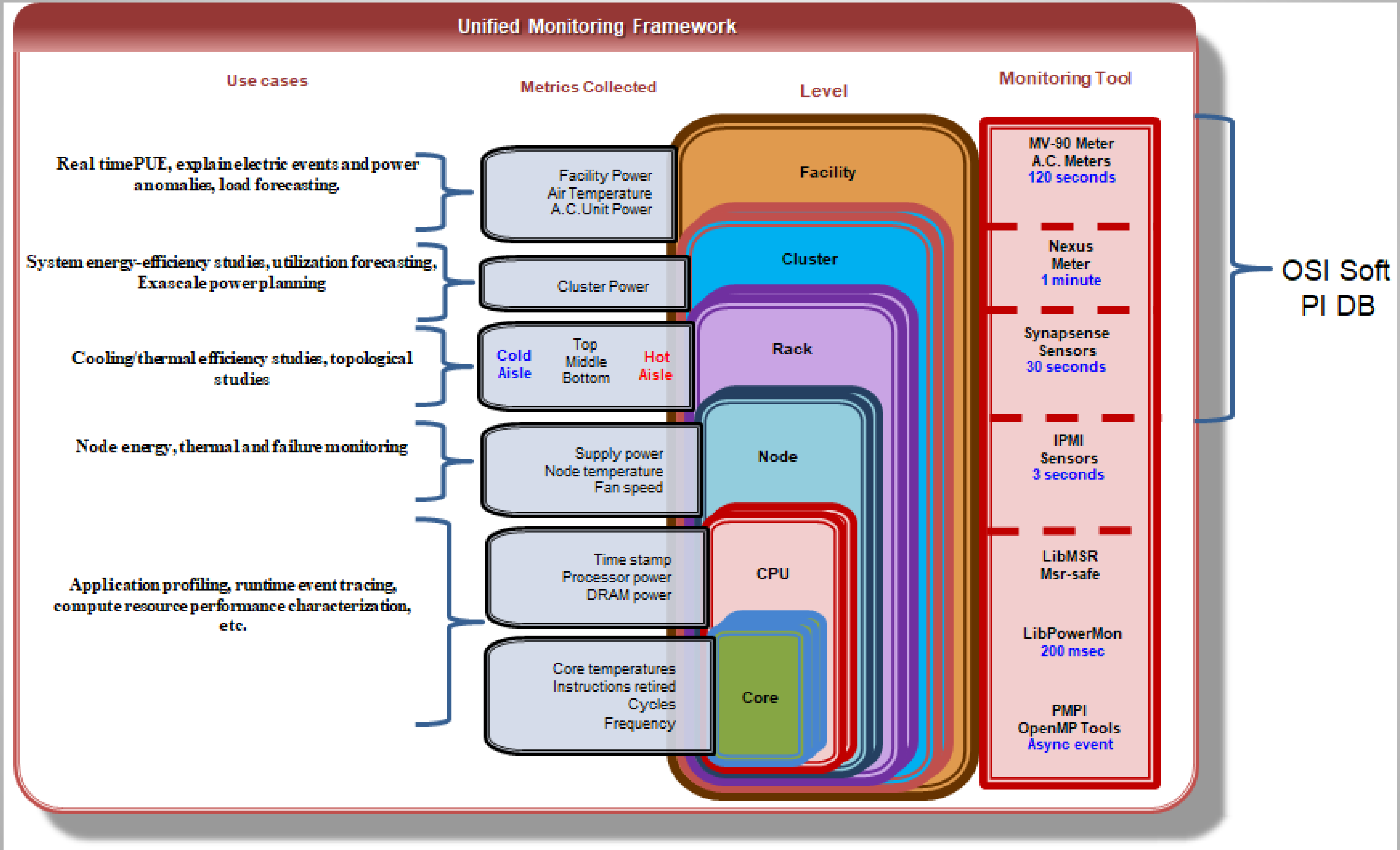
This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

Livermore Computing Facility Highlights

- 100K SF and 50 MW across the site in buildings ranging from 10 – 60 years old
- B-453 houses key Top 500 computers
  - No. 3 Sierra (72 PF – 12MW – 8000SF)
  - No. 8 Sequoia (20 PF – 9.6MW – 4000SF)
  - No. 33 Vulcan (5 PF – 2.4MW – 1000SF)
- B-453 completed in 2004 – Perpetual modifications to scale with technological advances.

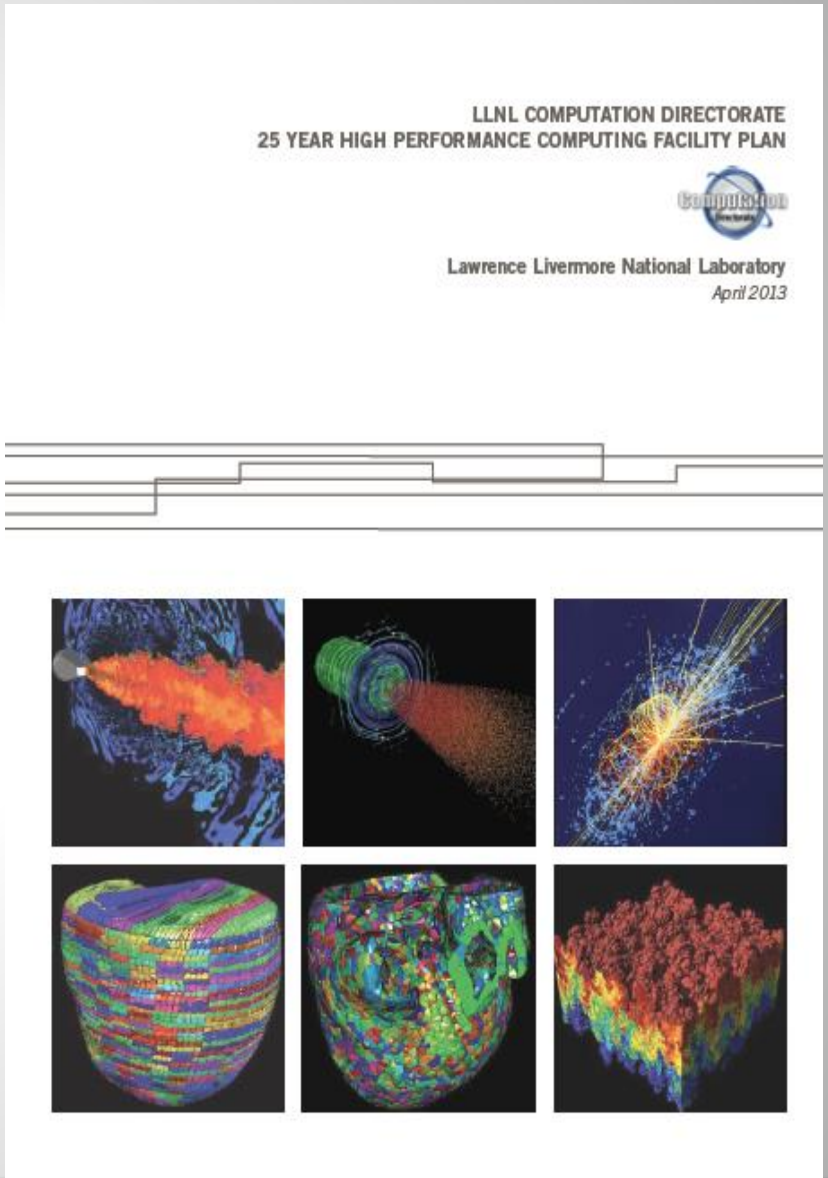


LLNL Monitoring Framework



LLNL High Performance Computing (HPC) Metering Usages

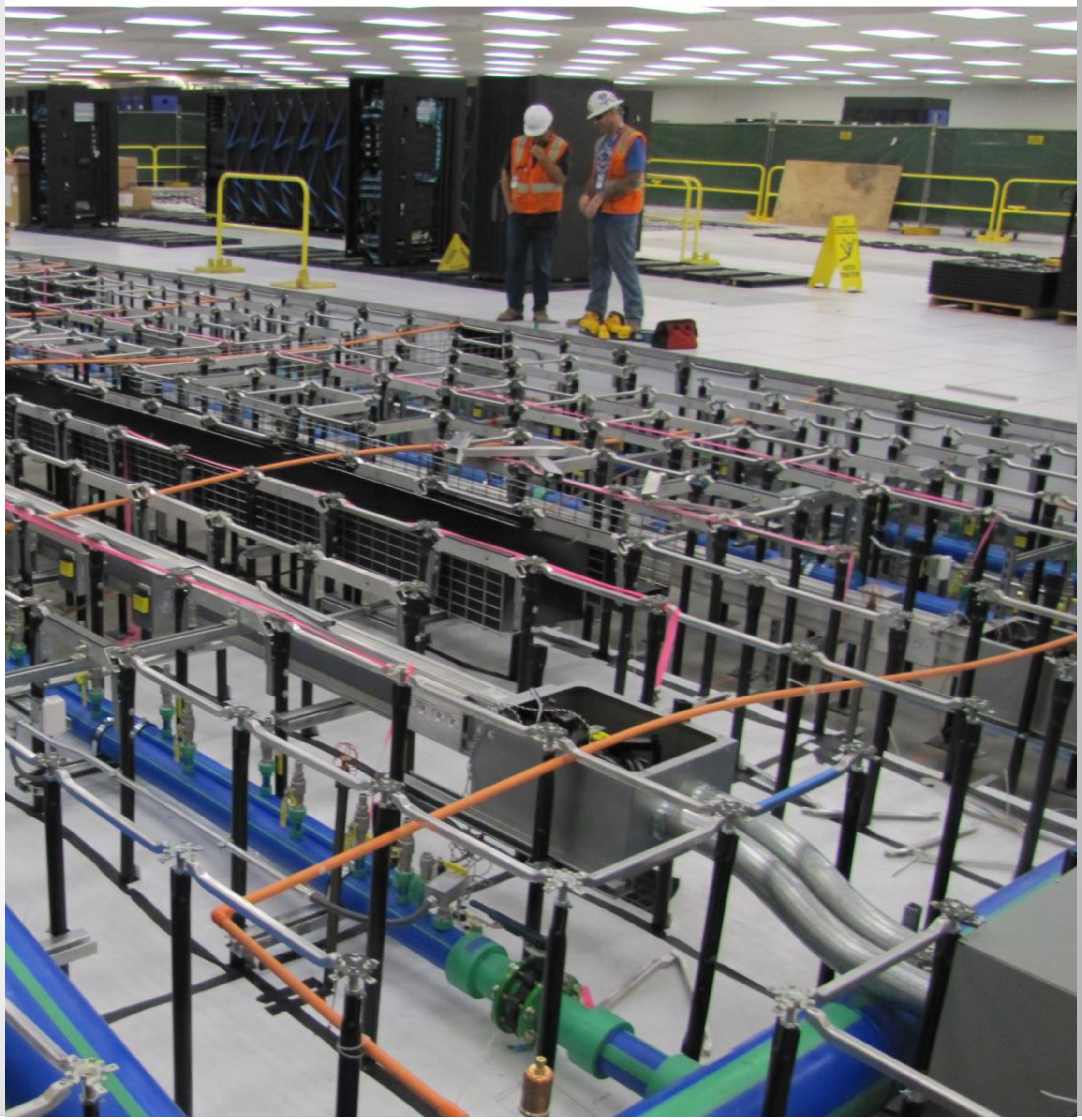
- Sighting of Next Generation HPC Systems
  - 25 Year Facility Master Plan
  - Technical Alternative Analysis of Remodeling versus Building New
  - Maximize usage of existing infrastructure
- LC Usage Forecasting and Reporting
  - Reporting to manufacture for future systems
  - Utility reporting of usage and swings
- Optimization of System Efficiency
  - Turn Watts into Flops
  - Air Cooling vs Water Cooling
  - Cost Savings
- Troubleshooting and Maintenance
  - Alarms and trends of events
  - Monitoring of ultrasound and vibration of essential equipment


LLNL COMPUTATION DIRECTORATE
25 YEAR HIGH PERFORMANCE COMPUTING FACILITY PLAN

Lawrence Livermore National Laboratory
April 2013

Siting of Next Generation HPC Systems - Advanced Technology Systems (ATS)

- Usage data needed for Alternative Analysis to Site Systems
  - Building New
  - Remodeling
  - Cost Analysis
- Designed to Evolving Planning Guides
  - After Installation, actual usage is compared to designed usage
  - Reporting back to the manufacture to aid in planning for the next generation ATS.
  - Opportunities to consolidate systems to utility sources

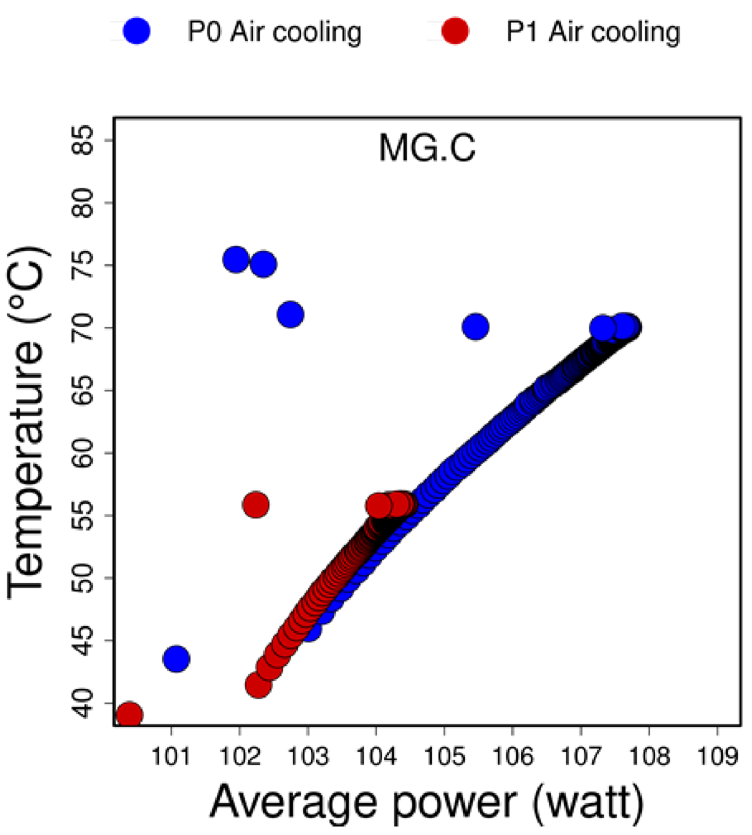


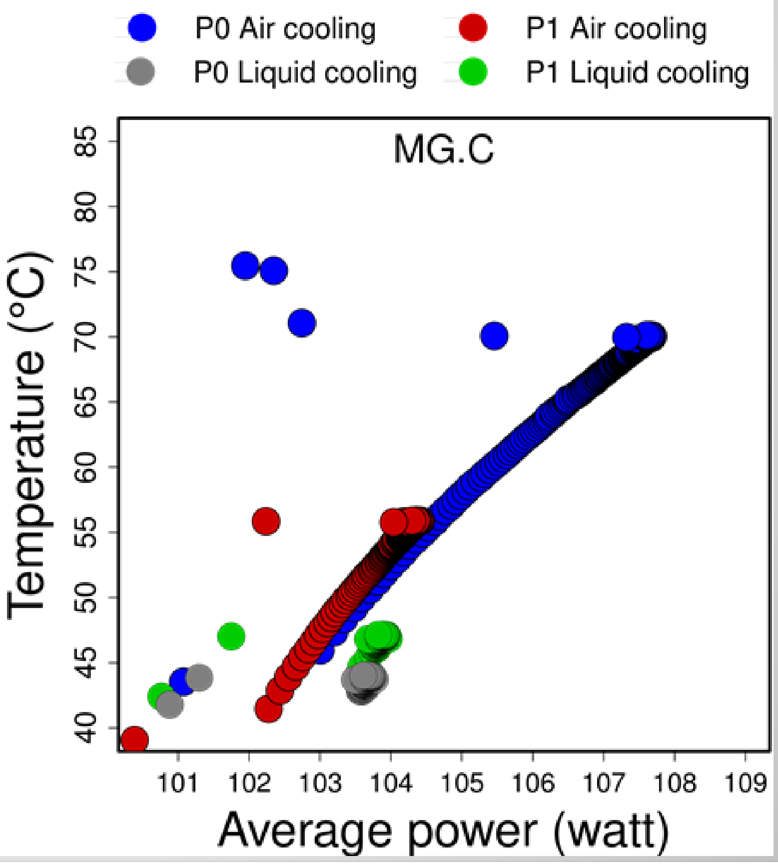
LC Usage Forecasting and Reporting

- Utility requiring sitewide usage forecasting and alerts of 750kW power changes of 15 minute span.
  - 8.4% of spikes from HPC (Sequoia and Vulcan)
  - Others (shift starts/ends, NIF shots)
  - More alerts expected with Exascale systems
- HPC cluster will experience large power swings depending on the system usage and its jobs.
- Scheduling of outages and designated maintenance windows are important

Optimization of Energy Efficiency

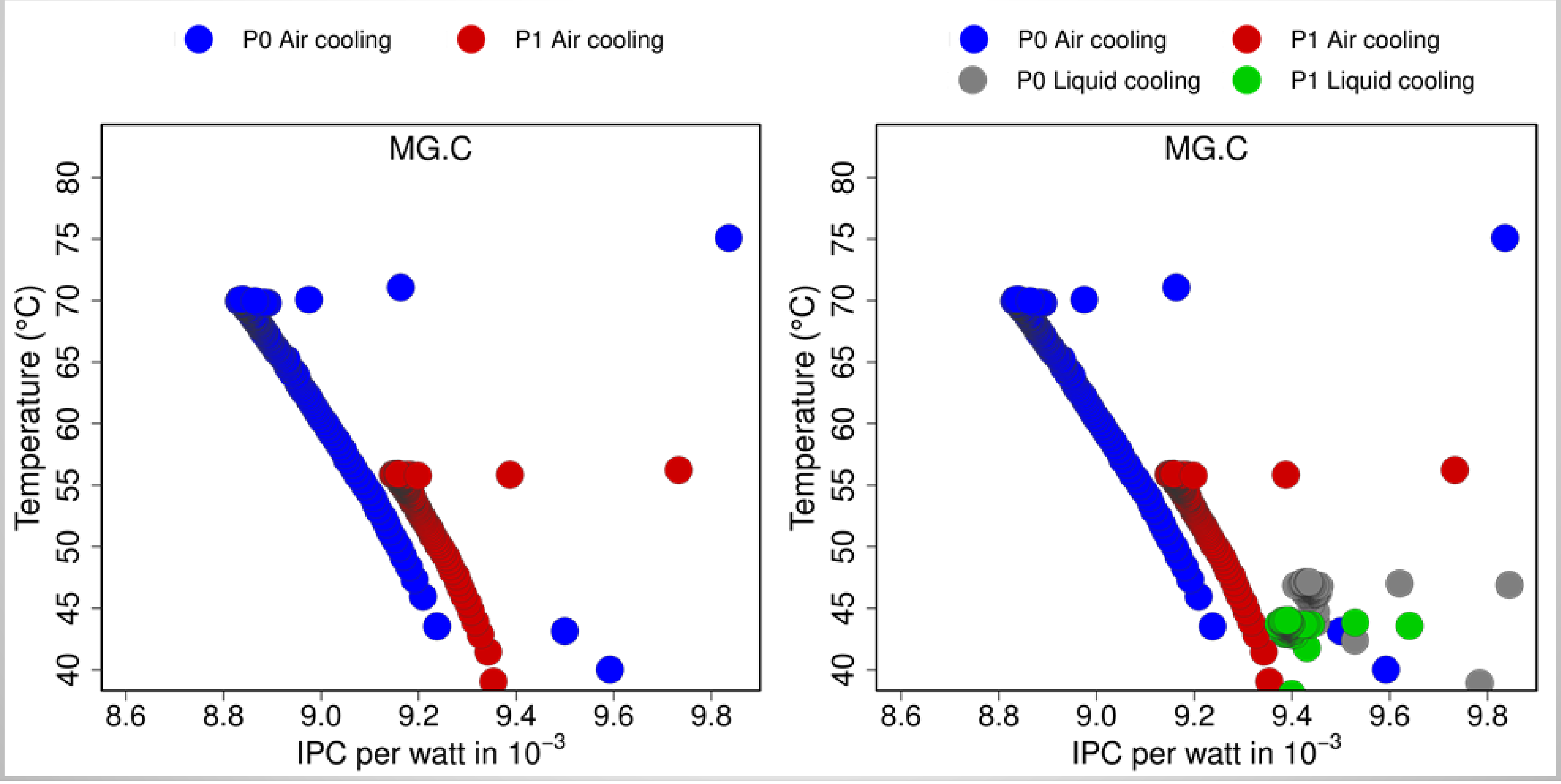
- Retrofit Cab from Air to Water Cooled (1024 nodes)
- Liquid cooling lowered processor temperatures and improved processor power efficiency





Optimization of Energy Efficiency

- Homogeneous cooling with water
- Lower temperatures reduced processor leakage power
- 4.3% power efficiency, 3.7 watts/node savings, ~4kW for the system



Troubleshooting and Maintenance

- Changing Electrical Meters to gather data remotely and in real-time versus monthly and in the field
- Submetering of each receptacle and rack
- Monitor through PI Coresight Database and the Building Management System
  - Troubleshooting
  - Diagnosis of events
  - Email alerts
- Adding metering/monitoring of essential mechanical equipment
  - Real-time monitoring of equipment
  - Stopping timed based scheduled maintenance

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