Terascale Simulation Facility (TSF) Complex
High Performance Computing (HPC) Operational Efficiency Objectives to Achieve Petascale and Exascale Computing Master Plan
Power Management
SC 2010

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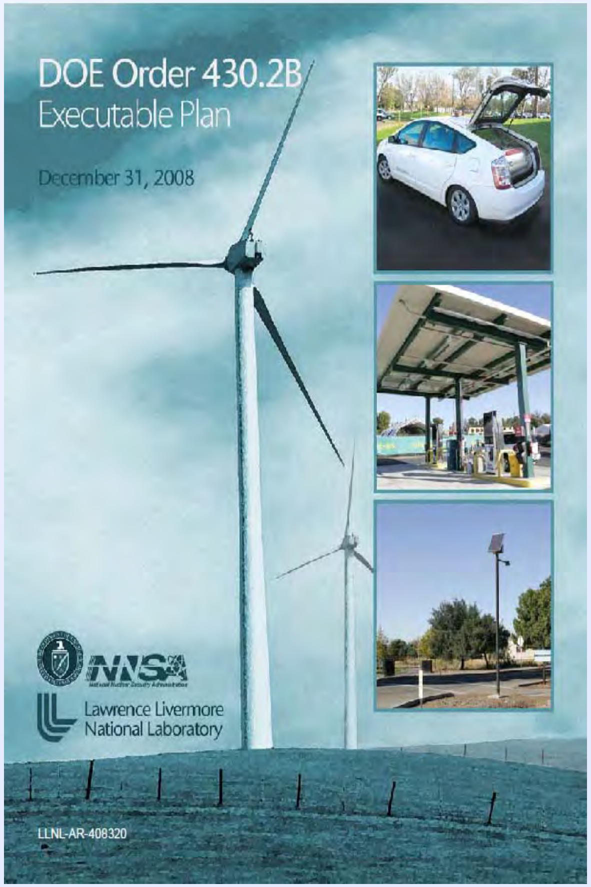
This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344 • LLNL-PRES-

HPC at LLNL strives to reduce energy consumption while increasing computational operation productivity

- Executive Order DOE 430.2B
  - Reduce energy intensity 30% by 2015 from baseline (FY03)
  - Difficult to balance with future HPC growth

- Energy conservation is critical to improve efficiencies and reduce operational costs
  - Operational efficiencies are vital to future of HPC
  - Capitalize on the electrical/mechanical system efficiencies
  - Return energy savings back to the computational load
  - Capitalize on the computational efficiencies
    - Flops/Watt
    - Square Foot/Flops



HPC at LLNL has identified that power management is critical to the success of Exascale

- Power management is critical but difficult to implement
  - Numerous data streams
  - Unable to aggregate data into single source and view on common dashboard
  - Determining what data is significant
  - Unable to correlate events from various sources
    - Different timestamps and formats

Solution: Implement centralized system of real time data from the rack to the entire site to achieve power management

Create an operational, event, and real-time data management infrastructure of all external and internal existing data sources

Data Sources
Rack, Equipment, Metering, Building Management, Utility

Interfaces
Hundreds of Real Time Data Streams

Manage
Gather and Evaluate Large Amounts of Data

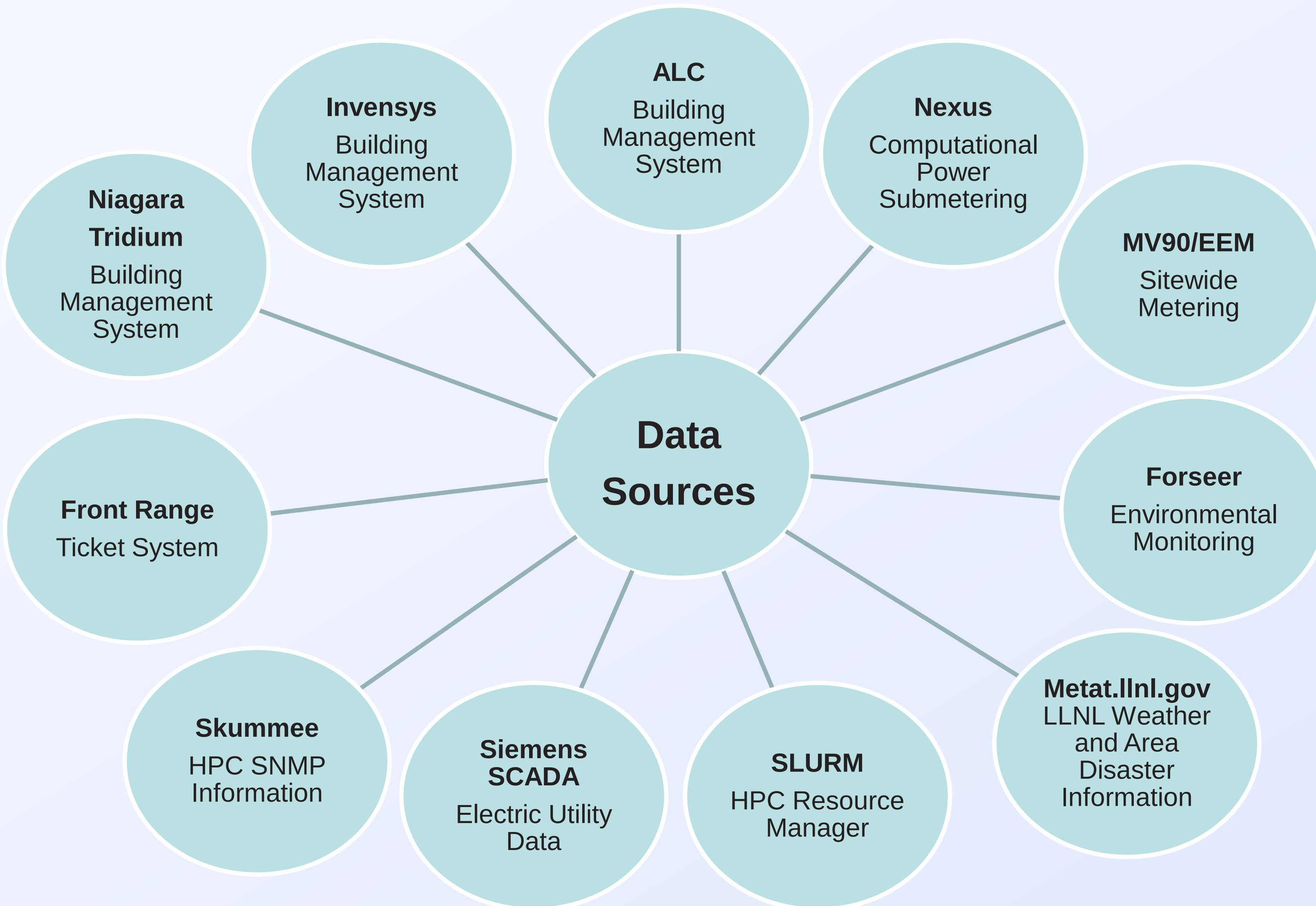
Analyze
Convert Real Time Data

Notify
Centralized Event Notification

Visualize
View Data and Reports

Lower power utilization and get to Exascale

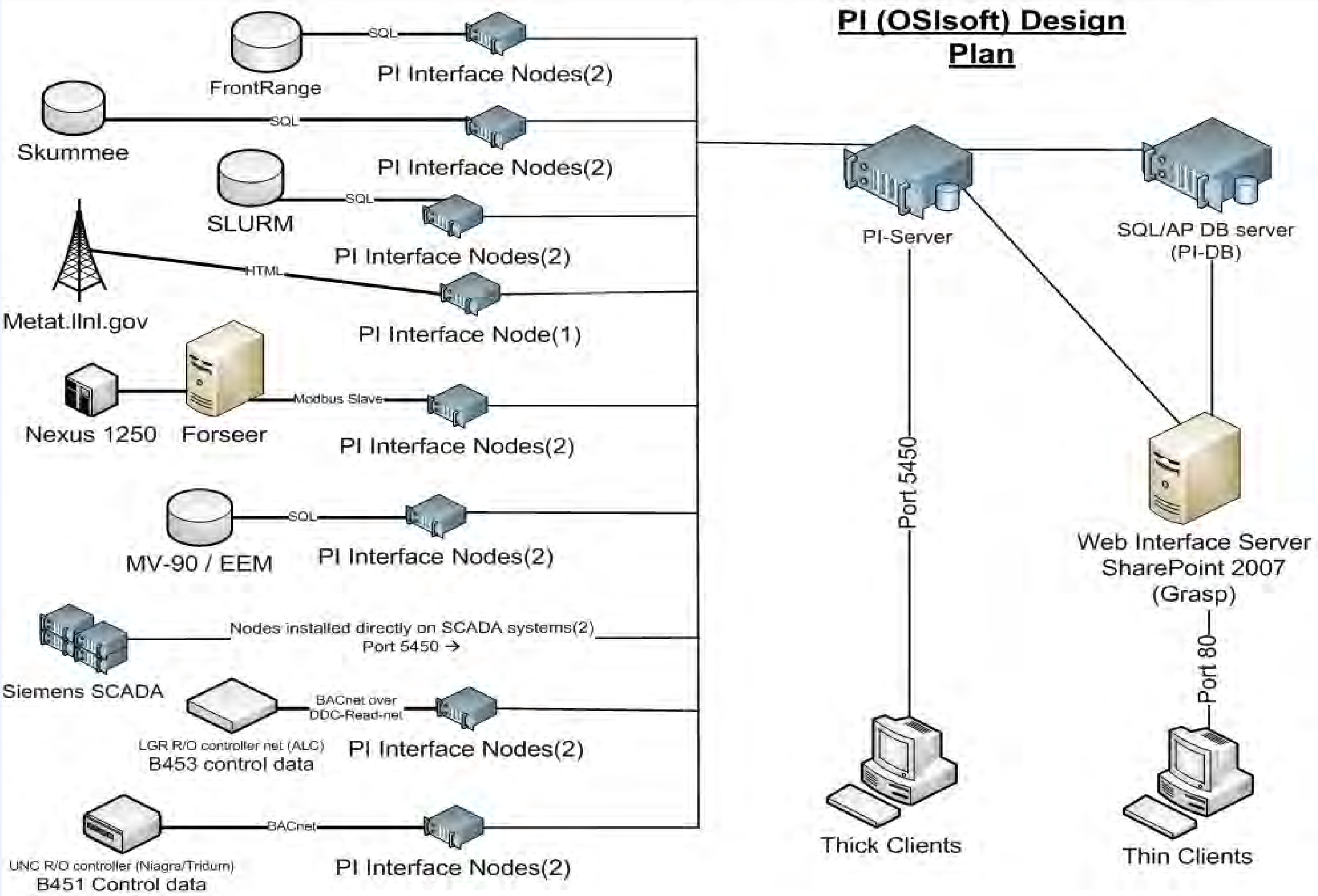
Current HPC data sources exist across the complex that will impact power management



Challenges

- Understanding how different types of hardware and software impact power utilization
- Correlating multiple types of data sources
- Coordinating with multiple owners of the data
- Accessing the data
- Selecting the best interface
- Comparing and viewing the data on a common platform
- Creating various dashboards

Sample Power Management Architecture



Questions

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Terascale Simulation Facility (TSF) Complex
High Performance Computing (HPC) Operational Efficiency Objectives to Achieve
Petascale and Exascale Computing Master Plan
Free Cooling
SC 2010

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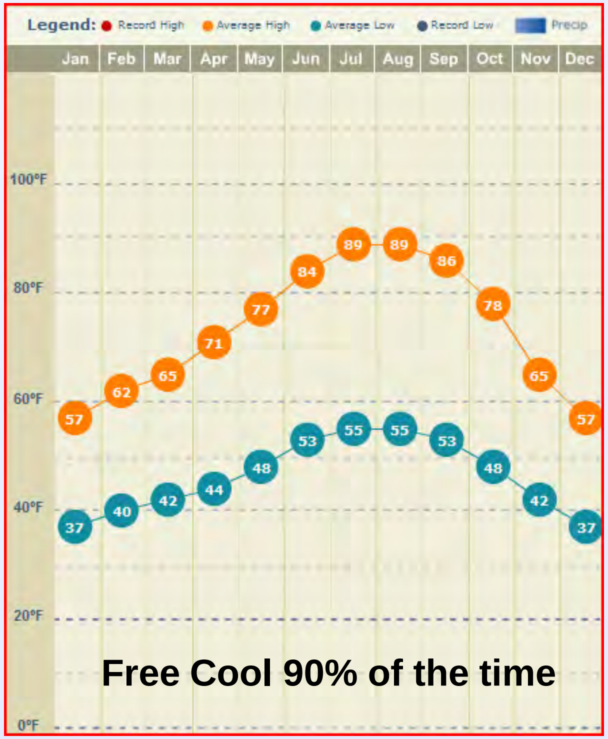
B-453 computer room design is extremely efficient

- Single story, two-level design
- Pressurized plenum
  - (30) 80,000 CFM air handlers
- Common Supply/Return System
  - Efficient design
  - Improved operational abilities
- Mechanical and electrical systems co-located to reduce losses and improve efficiencies

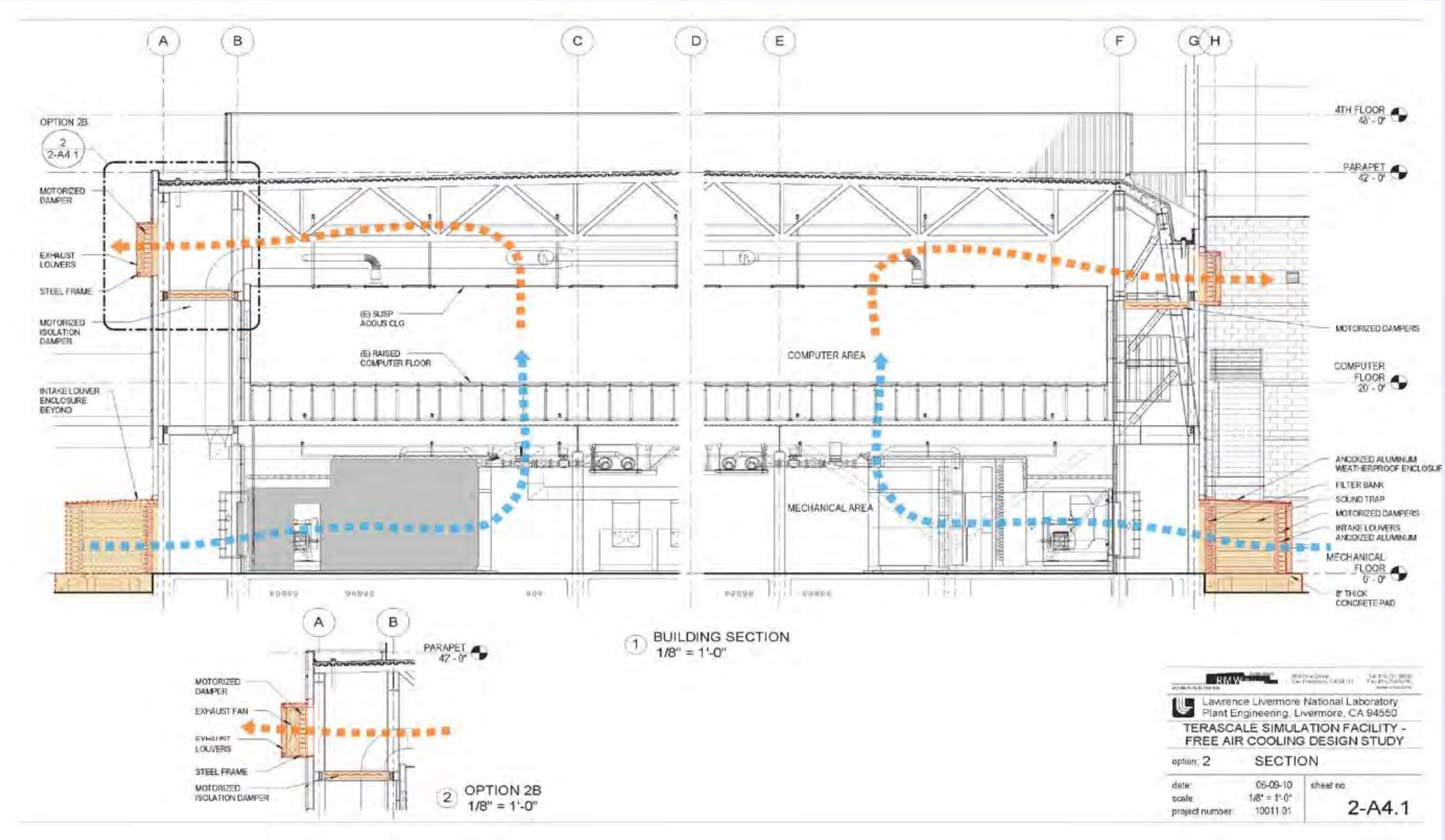
Free cooling evaluations for B-453 indicate improvement of PUE to 1.15 or better

- Currently developing architectural, mechanical and controls modifications
  - Existing supply/return system to be built into the north and south walls
  - Install louvers, intake dampers, humidifiers, filters and fans
  - Take advantage of seasonal/nighttime outside variations to provide cooling

Exterior Elevations



B-453 Free cooling design allows for construction in an active HPC center without negative operational impacts



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Terascale Simulation Facility (TSF) Complex
High Performance Computing (HPC) Operational Efficiency Objectives to Achieve
Petascale and Exascale Computing Master Plan
Looking Ahead Towards Sustainability
SC 2010

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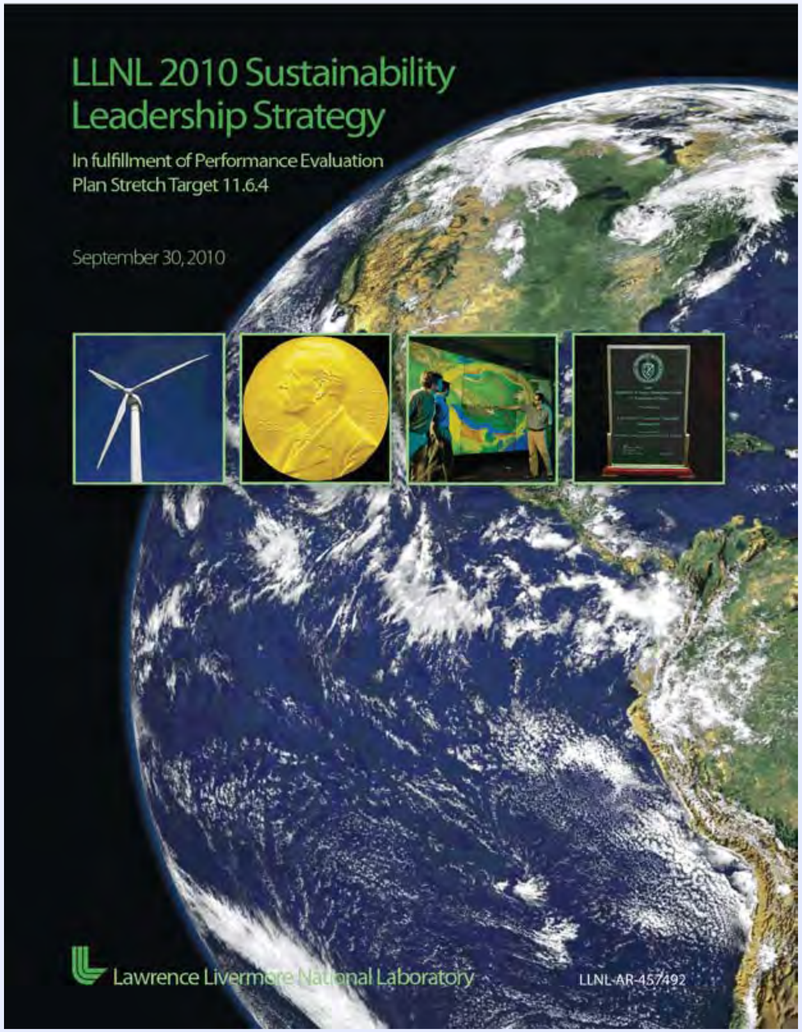
LLNL's Sustainability Leadership Strategy

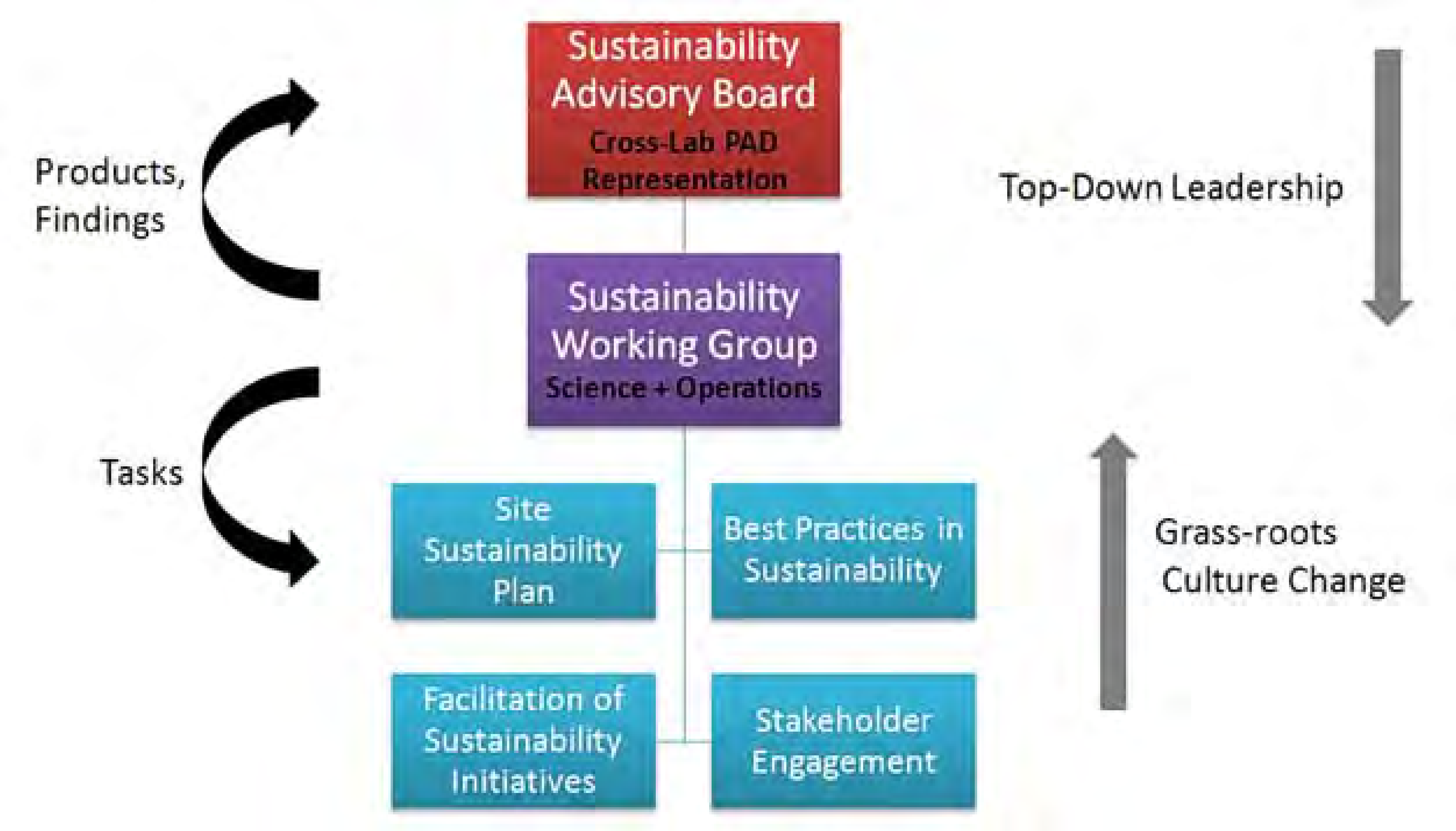
- Developing a Strategic Plan
  - Sustainability is integral to the Laboratory's mission
- Developing key points of integration to include
  - Facilities and infrastructure management
  - Environment, safety, and health
  - Mission and program engagement
  - Workforce and employee involvement
  - External stakeholder relations.
- Generating synergy needed to foster social responsibility, sustainability and mission success
- Integrating a process for the entire organization

Sustainability Program Vision at LLNL

- Governance process
  - Sustainability Advisory Board (SAB) and Sustainability Working Group (SWG)
- Leverage current successes
- Track metrics
- Communicate strategies and successes to employees
- Outreach programs to the community

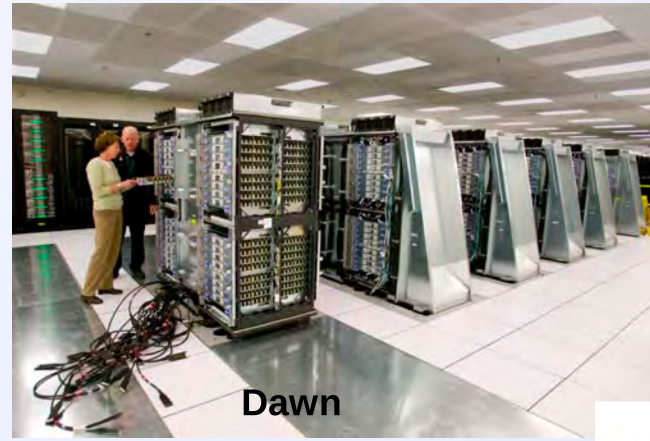


Sustainability Program Vision at LLNL



Sustainability and HPC
LLNL creates efficiencies and turns Megawatts into PetaFLOPS

- Capitalize on flexible and scalable infrastructure of the facility and computational efficiencies
- Extensive benchmarking
- Comprehensive computational fluid dynamics (CFD)
- Improved operational efficiencies
  - DOE FEMP 2009 Energy Award
  - LEED Gold Certified December, 2009
- Efficiencies will prepare LLNL for Petascale and Exascale



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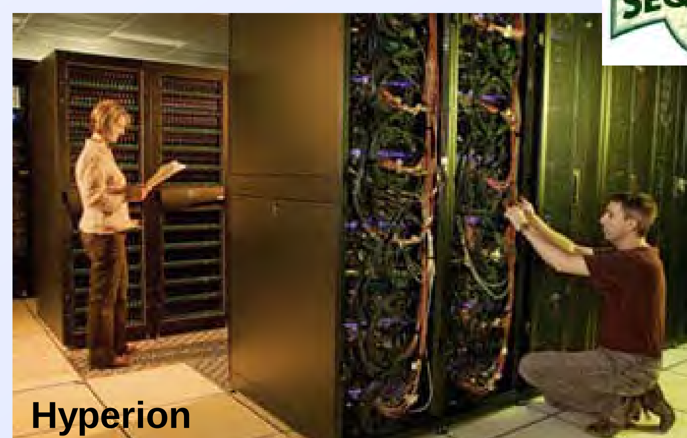


Benchmarking tools are utilized to identify energy saving initiatives within the computer rooms and establish metrics (PUE)

- Used DOE Industrial Technologies Program and Lawrence Berkeley Laboratory (LBL) to identify energy savings through benchmarking tools
  http://hightech.lbl.gov/datacenters.html

- DOE FEMP now offers DC Pro Tools,

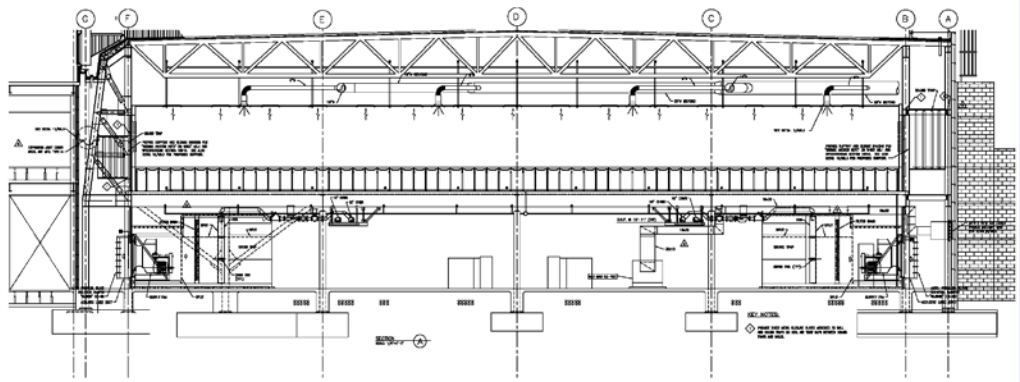
- Identified many energy savings initiatives
  - Raise air supply temperature
  - Raise chilled water supply
  - Address air leakage issues
  - Rebalance the computer floor

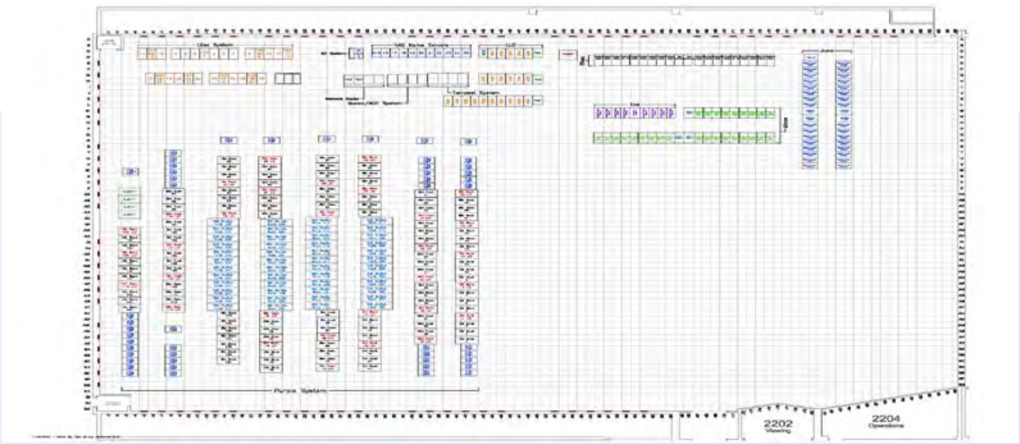
- All of these initiatives have been deployed without negative operational impacts. Reduction in power costs by $3.5M/yr.

LLNL B453 Data Center Performance Metrics				
ID	**Name**	**Unit**	**Data Required**	**Data**
B1	Source Energy Use Intensity	Source BTU/sf-yr	dB1- Electrical Energy Use (kWh)	36,965,898
			dB2- Natural Gas Energy Use (MMBTU)	6773
			dB3- Fuel Energy Use (MMBTU)	N/A
			dG1- Data Center Gross Area (sf)	48000
			dG7- Source Energy Factors	N/A
B2	Purchased Energy Cost Intensity	Energy $/sf-yr	dB4- Purchased Energy Cost ($)	$54 per MW
			dG1- Data Center Gross Area (sf)	48000
B3	Site Energy Use Intensity	Site BTU/sf-yr	dB1- Electrical Energy Use (kWh)	36,965,898
			dB2- Natural Gas Energy Use (MMBTU)	6773
			dB3- Fuel Energy Use (MMBTU)	N/A
			dG1- Data Center Gross Area (sf)	48000
B4	Peak Electrical Load Intensity	Peak W/sf	dB5- Peak Electrical Load (kW)	11515
			dG1- Data Center Gross Area (sf)	48000
B5	Energy Effectiveness	%	dB1- Electrical Energy Use (kWh)	36,965,898
			dB2- Natural Gas Energy Use (MMBTU)	6773
			dB3- Fuel Energy Use (MMBTU)	N/A
			dP1- IT Equipment Power: Actual (kW)	27,586,491
B7	Redundancy Level - HVAC	-	dG5- Redundancy Level - HVAC	N+2

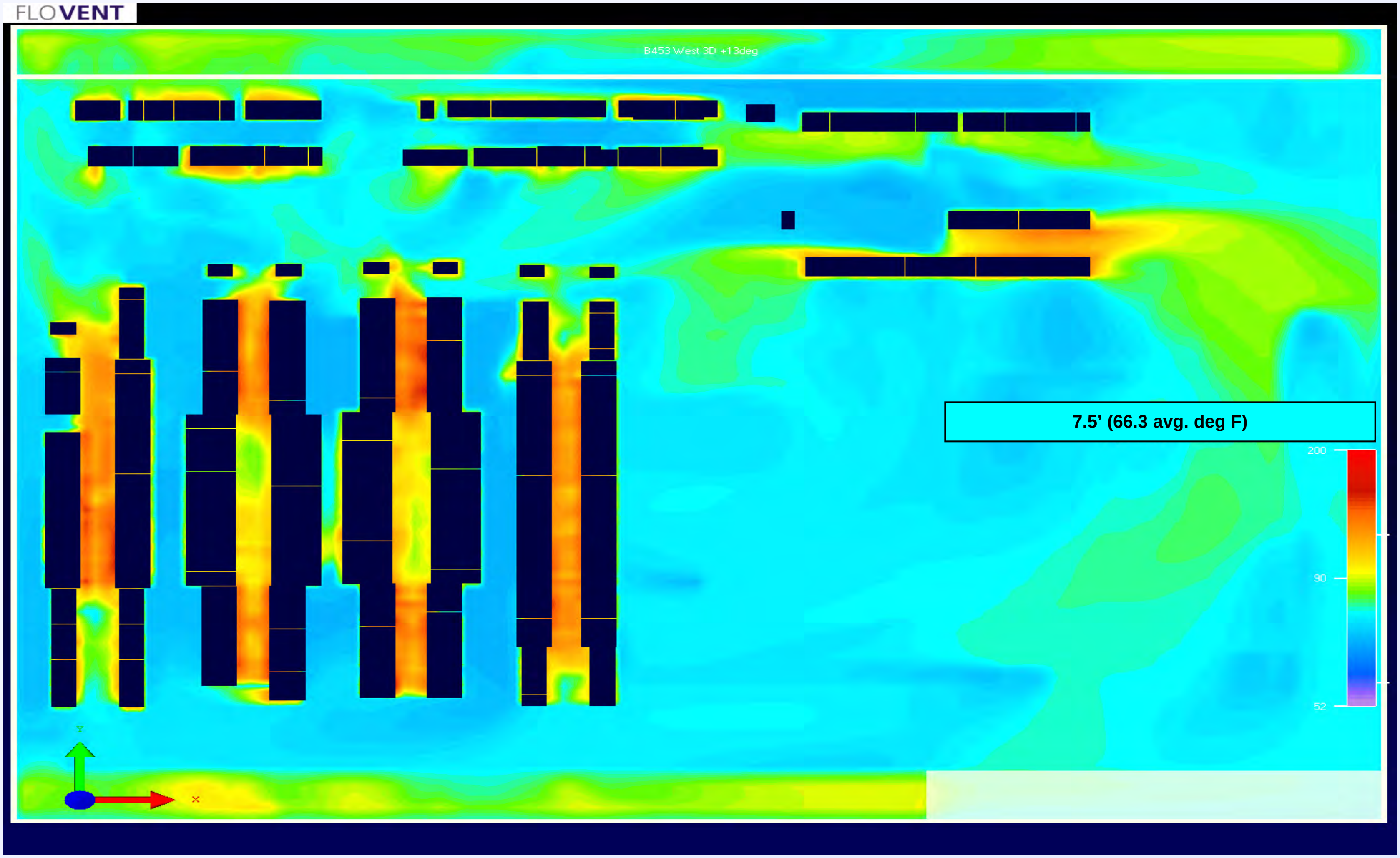
Dynamic comprehensive computational fluid dynamic (CFD) models are performed to analyze airflow patterns

- Physical layouts imported
- Baseline CFD
  - Starting temperature
- Model airflow
  - 2” Above finished floor (AFF) – inlet of racks
  - 7.5’ AFF – above the racks
  - 10.5 ’AFF – ceiling
- Utilize tool to site future platforms





The B-453 west room modeled with an inlet temperature of 66.3°F avg. 7.5’ AFF



LEED certifications are actively pursued

LEED-EB

- B-453 was (LEED) Gold Certified on December 24, 2009 using the Operations and Maintenance v2 rating system

LEED for Existing Buildings: Operations & Maintenance
Registered Project Checklist

Project Name: B453 TeraScale Simulation Facility

Project Address: 7000 East Avenue, Livermore, CA 94550

Yes	?	No		
56	0	1	Project Totals (Pre-Certification Estimates)	92 Points
	GOLD		**Certified**: 34-42 points **Silver**: 43-50 points **Gold**: 51-67 points **Platinum**: 68-92 points	

Yes	?	No			
7	0	0	Sustainable Sites		12 Points
		0	Credit 1	**LEED Certified Design and Construction**	1
1		0	Credit 2	**Building Exterior and Hardscape Management Plan**	1
1			Credit 3	**Integrated Pest Mgmt, Erosion Control, and Landscape Mgmt Plan**	1
1	0		Credit 4	**Alternative Commuting Transportation**	1 to 4
			--> Credit 4.1	10% Reduction	1
			Credit 4.2	25% Reduction	2
			Credit 4.3	50% Reduction	[illegible]
			Credit 4.4	75% Reduction or greater	[illegible]
		0	Credit 5	**Reduced Site Disturbance**, Protect or Restore Open Space	1
1	0		Credit 6	**Stormwater Management**	1
1			Credit 7.1	**Heat Island Reduction**, Non-Roof	1
1			Credit 7.2	**Heat Island Reduction**, Roof	1
1			Credit 8	**Light Pollution Reduction**	1

B-453 has an excellent Power Usage Effectiveness (PUE) of 1.32

Power In

Total Facility Power

Power

Switchgear
UPS
Battery Backup

Cooling

Cooling Towers
Chillers
Air Handlers

Power Out

Total HPC Equipment Power

Servers
Racks
Platforms
Networks
File Systems
Storage

1.32

PUE	DCiE	Level of Efficiency
3.0	33%	Very Inefficient
2.5	40%	Inefficient
2.0	50%	Average
1.5	67%	Efficient
1.2	83%	Very Efficient

PUE = Total Facility Power / IT Equipment Power
DCiE = IT Equipment Power / Total Facility Power
Source: Green Grid

Strive to continue to reduce PUE further in all computational facilities

TSF computer room power easily scales to 30MW

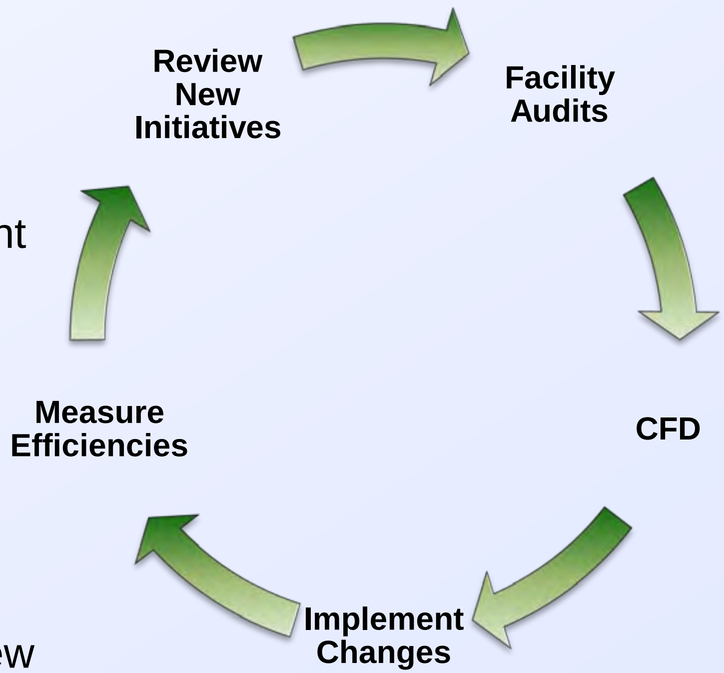
- Capitalize on the electrical/mechanical system efficiencies
- Return operational energy savings back to the computers
- Capitalize on the computational efficiencies (TF/MW and SF/TF)

Platform	MW	SF	TF	TF/MW	SF/TF
Purple	4.80	8000.00	100	21	80.0
BG/L	2.50	4000.00	600	240	6.7
Dawn	2.00	2000.00	500	250	4.0
Sequoia	9.60	4000.00	20000	2083	0.2

Turn MW to PetaFLOPs

The HPC Master Plan Path Forward

- Continue to raise supply air and chilled water temperatures across TSF complex
- Address free cooling options across TSF complex
- Continue to implement more 480V distribution and test the use of DC voltage distribution to reduce losses
- Continue to collaborate with vendors to achieve efficient liquid cooling solutions to achieve next generation of HPC
- Implement centralized monitoring system to aggregate data to identify power management solutions – <u>**Exascale Computing Initiative**</u>
- Pursue LEED certifications
    - Validation period complete and submitted for review for B-451
- **Further develop HPC Master Plan for more efficient computing solutions**



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