Continuous Commissioning Tools for PNNL Facilities

A presentation for the

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Battelle

U.S. Department of Energy
Pacific Northwest National Laboratory

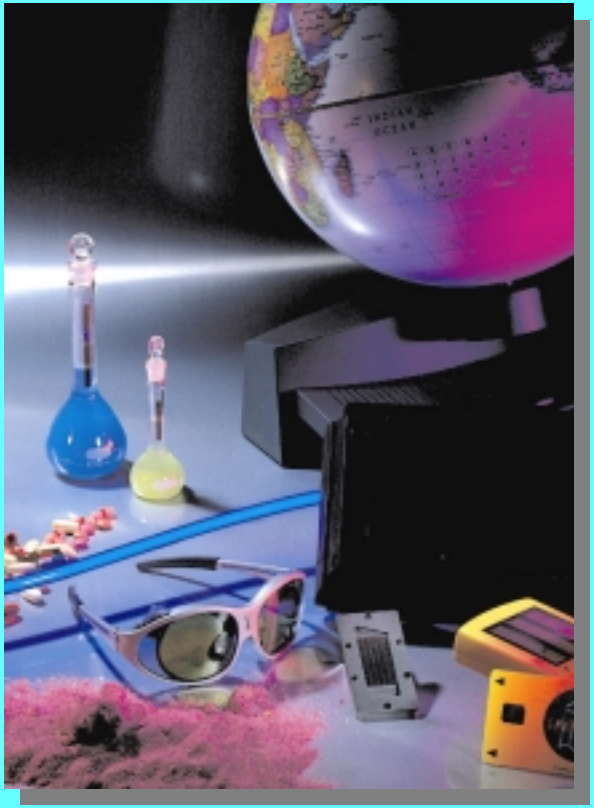
Agenda

Focus on two areas:

- Building performance tools for continuous commissioning
- Examples of recommissioning

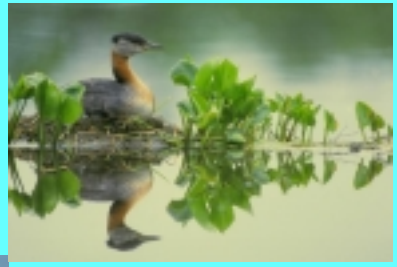
About PNNL: Multi-Program R&D

- 3,500 staff doing 1,500 R&D projects with $500M funding
- Lab operated by Battelle for DOE



Basic Science

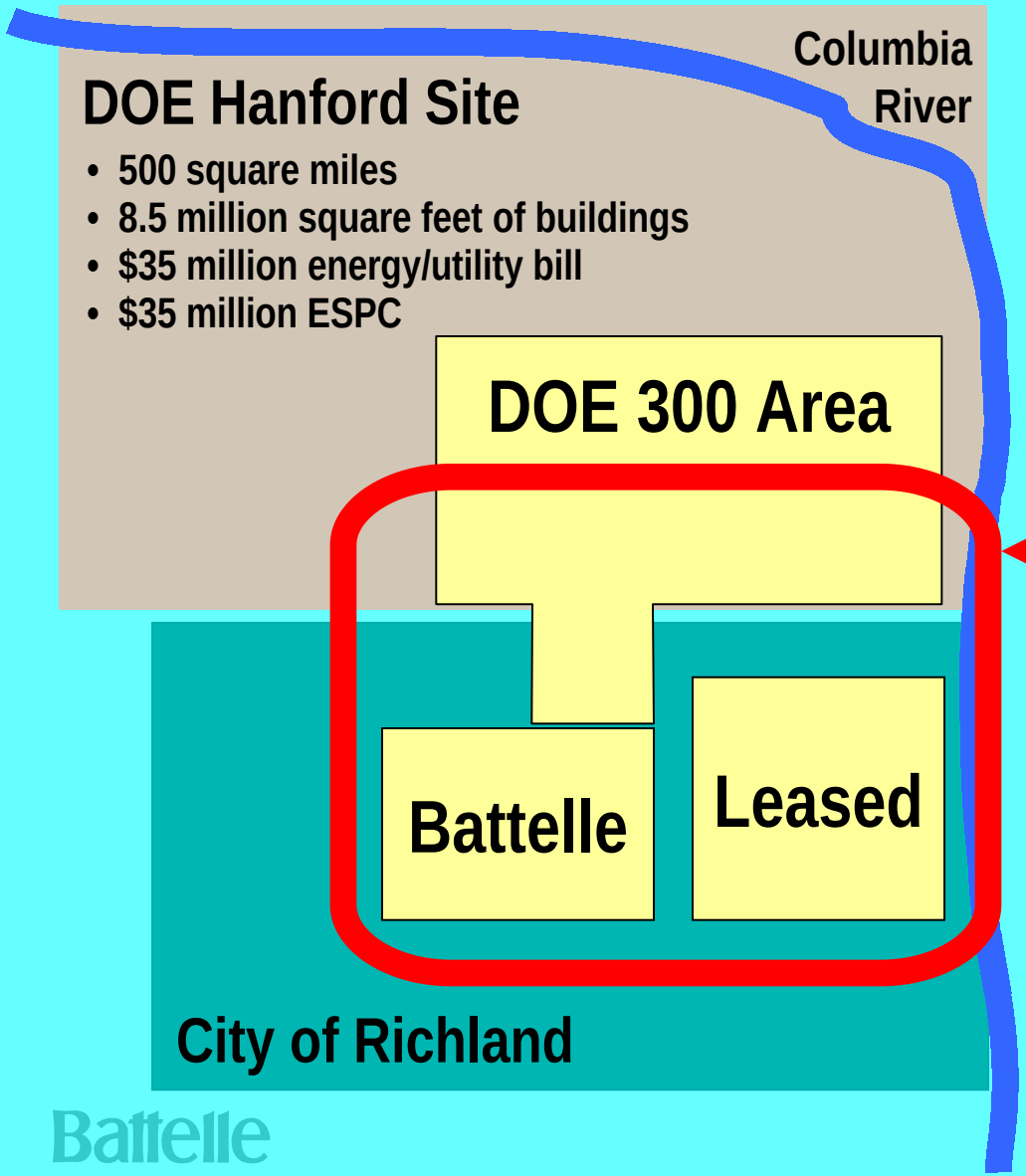
Environmental Technology



National Defense

Energy

PNNL's Diverse Campus



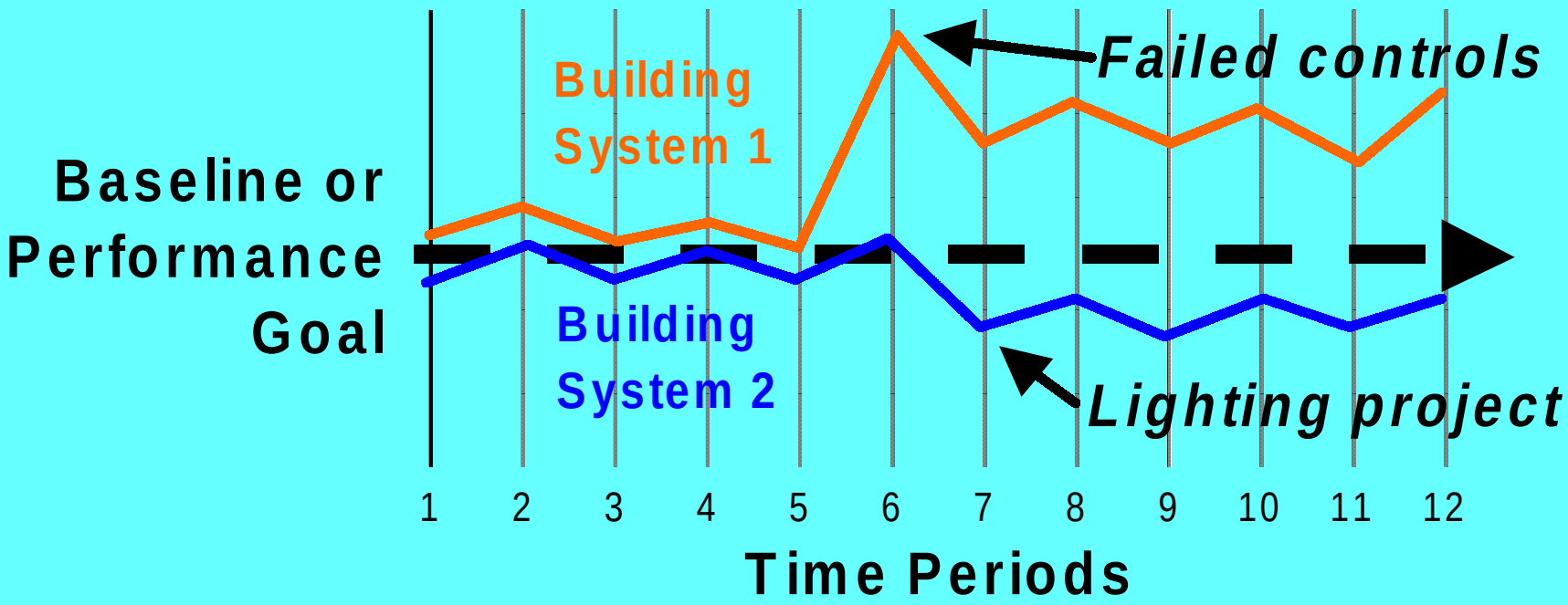
Scale of PNNL Operations
1M DOE Square Feet
1M Private Sq. Ft.
$8M Energy/Utility Costs
85M kWh annually
10 MW average
1M Therms annually
$12M Alternative Capital
$3M Annual Savings
$4M+ Future Alt. Capital

PNNL Entering New Millennium

- Implementing energy trending and diagnostics software tools
  - Goal get 1-3 year payback on investments
- Tools fits Lab21 themes:
  - Form partnerships
    - Implement existing tools
    - Maintain infrastructure for tools
    - Expand the suite of tools
  - Train staff in performance measurement
  - Find and promote Best Practices

Tool Concepts

- Make performance obvious



Good Tools in the Right Hands (1/2)

Requiring facility management staff to use the tools to accomplish the following:

- Implement continuous commissioning
  - "Operate boiler at 85% efficiency"
- Do condition-based maintenance
  - Minimize corrective maintenance
  - Move even beyond preventative and predictive maintenance
- Reduce energy use and costs

Good Tools in the Right Hands (2/2)

- Define and track performance (M&V) of ESPCs
- Define and track performance of staff and departments:
  - “Save $100K”
  - “Reduce energy cost/SF by 10%”
  - “Improve chiller efficiency by 5%”

What Tools Are Available Today?

- R&D-developed tools/methods facility management:
  - Facility Energy Performance Assessments
  - Alternative Financing for Energy Efficiency Projects
  - Pollution Prevention & Waste Minimization Tools
- PNNL Facility Directorate's self-made tools:
  - Integrated Operations System
  - Chemical Management System
  - Map Information Tool
  - Electronic Service Request System

Tools Meet Many Wants & Needs (1/3)

- Seek and prioritize energy projects
- Implement continuous commissioning
- Perform M&V of ESPCs
- Perform M&V of internal O&M programs

Tools Meet Many Wants & Needs(2/3)

- Manage utility budgets, bills, and checkbooks
- Allocate utility bills to buildings & occupants
- Support ES&H management
- Get technology to prepare for energy supply issues:
  - Minimize impact of rate increases, power shortages, and poor power quality
  - Prepare to buy/sell energy

Tools Meet Many Wants & Needs (3/3)

- ✓ Elevate everyone's awareness of energy efficiency
- ✓ Improve lab safety
- Make America less dependent on foreign oil
- Comply with national laws and goals

My Multiple Goals

- Facility management goal: improve PNNL's operational cost effectiveness
- PNNL goal: develop business & partnerships and be a leader
- Supporting objectives:
  - Get best tools to my desktop
    - Energy trending and diagnostics
    - Include other facility services to make system more attractive
    - Seek partners to get new tools quickly and cheaply
  - Get field facility staff to use the tools

Getting Tools Into the Right Hands

Raw Data

Diverse and remote sources:

Meters

Building controls

Weather stations

Buildings' facts

Benchmarking studies

Storefront FRED Web-Site

Facility Resources and Energy Data

Collect and Format Data

Analyze Data & Create Information

Use Commercial and Custom Software

Deliver Information, Enable Transactions

Users

Diverse and remote Users:

Facility Operators

Budget Mgrs

Maint. Staff

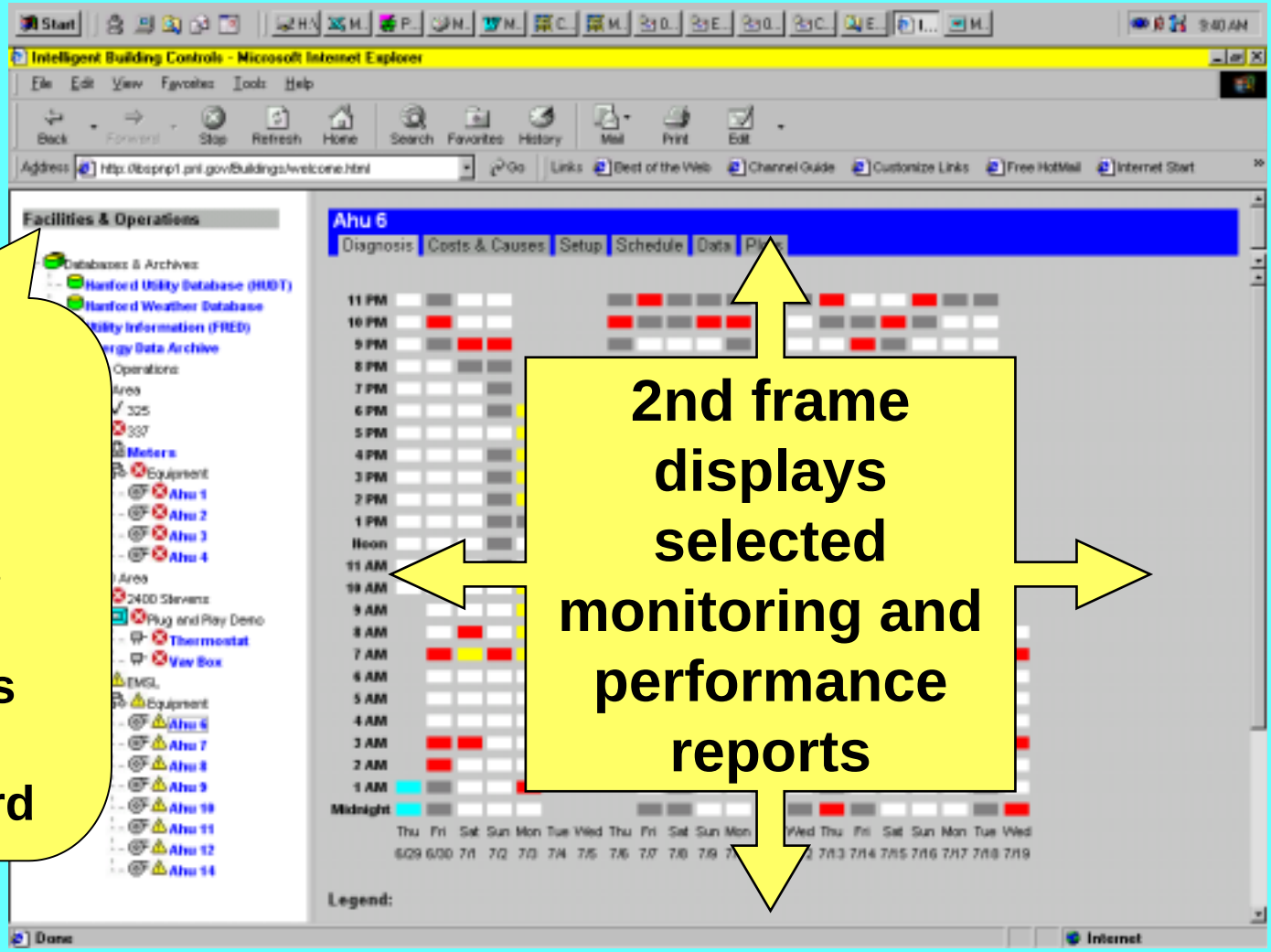
Peer Network

ESCOs

Energy Brokers

Corporate & HQ Mgmt

FRED Home Page



1st frame: clickable outline of

- **Organizations**
- **Bldgs & parts**
- **Software tools**
- **Library**
- **Message board**

2nd frame displays selected monitoring and performance reports

Energy-Data Goals and End-Users

See handout for full-scale list

Goals	Objectives		Primary PNNL Users/Audience: Facility Management					Finance		Company Business
			Bldg Mgr	Bldg Operator	Bldg Design Engr	Energy Manager	Space Charge-Back Staff	Finance & budgeting	Accts Payable staff	Bldg Occupant (ultimate bill payer)
Not in FRED Scope		*Generate and deliver energy*								
		Meter energy used at a site or building								
Collect Data	*1*	*Access individual electrical meters*			X	X	X			
	2	Download Hanford's centralized electrical data; check for missing data or unresponsive meters				X	X			
	3	Access misc. utility & building data			X	X	X			
	4	Access City of Richland data				X	X			
	5	Access building controls data		X	X	X	X			
Create Information	*1*	*Generate billings, recharges*						X	X	
	2	Make electrical load profiles		X	X	X	X			
	3	Get weather and process data to "normalize" usage			X	X	X			
	4	Compare current to past usage; validate ESPCs; do benchmark comparions	X			X	X			
	5	Compare budget vs bills vs checkbook	X			X	X			
	6	Perform building diagnostics		X	X					
	7	Find cost-effective energy projects				X	X			
Deliver Information	*1*	*Deliver info and bills to Customers & Facilities Staff*					X	X		X
	2	Provide info to ESCOs and Aggregators				X				
Enable Transactions	*1*	*Enable Customers/Occupants to approve and pay bills electronically*						X		X
	2	Aggregate bills; shop for best price; buy energy				X	X			

Current & Potential Tools for Storefront

Tools:					WBD			
Functions	**FEDS**	**FRED**	**HUDT**	**Metrix**	**WBE**	**OAE**	**Chlr**	**DSOM**
Find cost-reduction projects	✓							
Monitor Use & Costs								
Collect & archive data		★						
Prepare Hanford electric bills & electricity load profiles		★						
Compare budgets, bills, & checkbooks for all utilities			★					
Trend whole buildings & major systems using minimal metering			✓	✓	★	★	★	
Adjust for weather & operation schedules to trend real performance				✓	★	★	★	
Seek & Diagnose Problems								
Economizers, using minimal metering						★		
Central plants (significant metering and modeling required)								★

Detect Vs. Diagnose Progress

Subject or Discipline	Other Words for 'Problem'	Detect Vs Diagnose	
		Simplest	Best
Accounting, Finance	Variance	The bottom-line cost is overbudget	Specific low-level WBS elements are overbudget.
Building control systems	Alarm	An alarm sounds	Multiple data points are accessed and evaluated
Science and Engineering	Anomaly, Opportunity	The experiment or product fails	

Detection Now

Diagnosis Now

Diagnosis Soon

Existing tools in use at PNNL

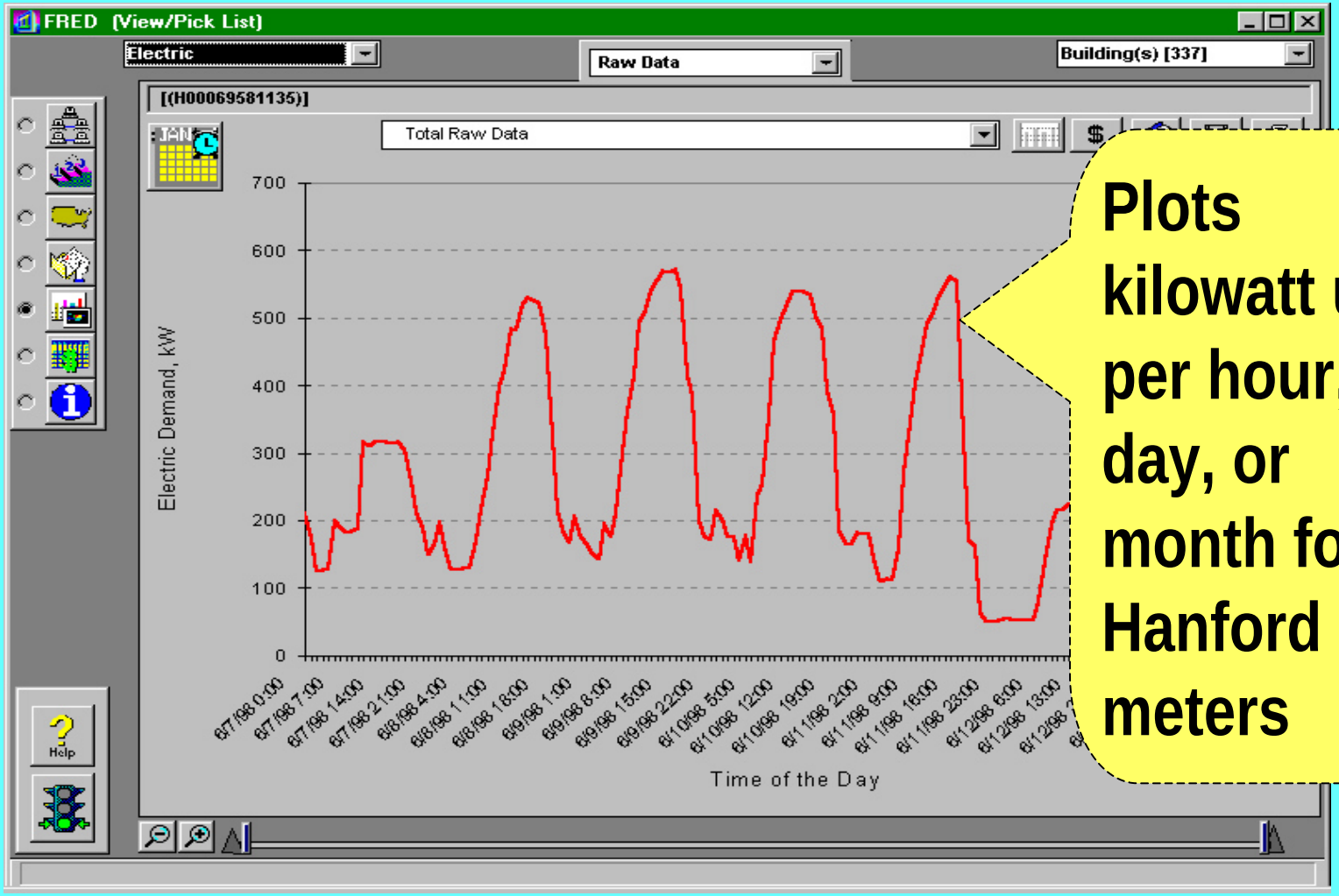
In development

Future Use

Facility Resource & Energy Data (FRED)

- Provides
  - Hanford electrical bills (BPA costs plus FDH/Dyn's O&M costs)
  - Charts of detailed electrical use per meter & supersets
- Compiles all utility data including City of Richland and other providers
- Funded by DOE (Richland) Site Infrastructure Division; built by PNNL R&D Energy Division
- DOE Richland also funded the integration of the WBE tool into FRED

Electricity Load Chart



Plots kilowatt use per hour, day, or month for Hanford meters

Hanford Utility Data Tool (HUDT)

- Graphs
  - Budgets vs. bills vs. checkbook
  - Each utility, building, and organization.
  - Benchmarks for usage and costs per square foot
- Gets data from from FRED and PNNL Finance system
- Funded and implemented by FO in FY 99/00; built by PNNL Energy Division

Budget, Bills, Checkbook - Annual

Pick
- Building
- Utility
- Campus
- Org.

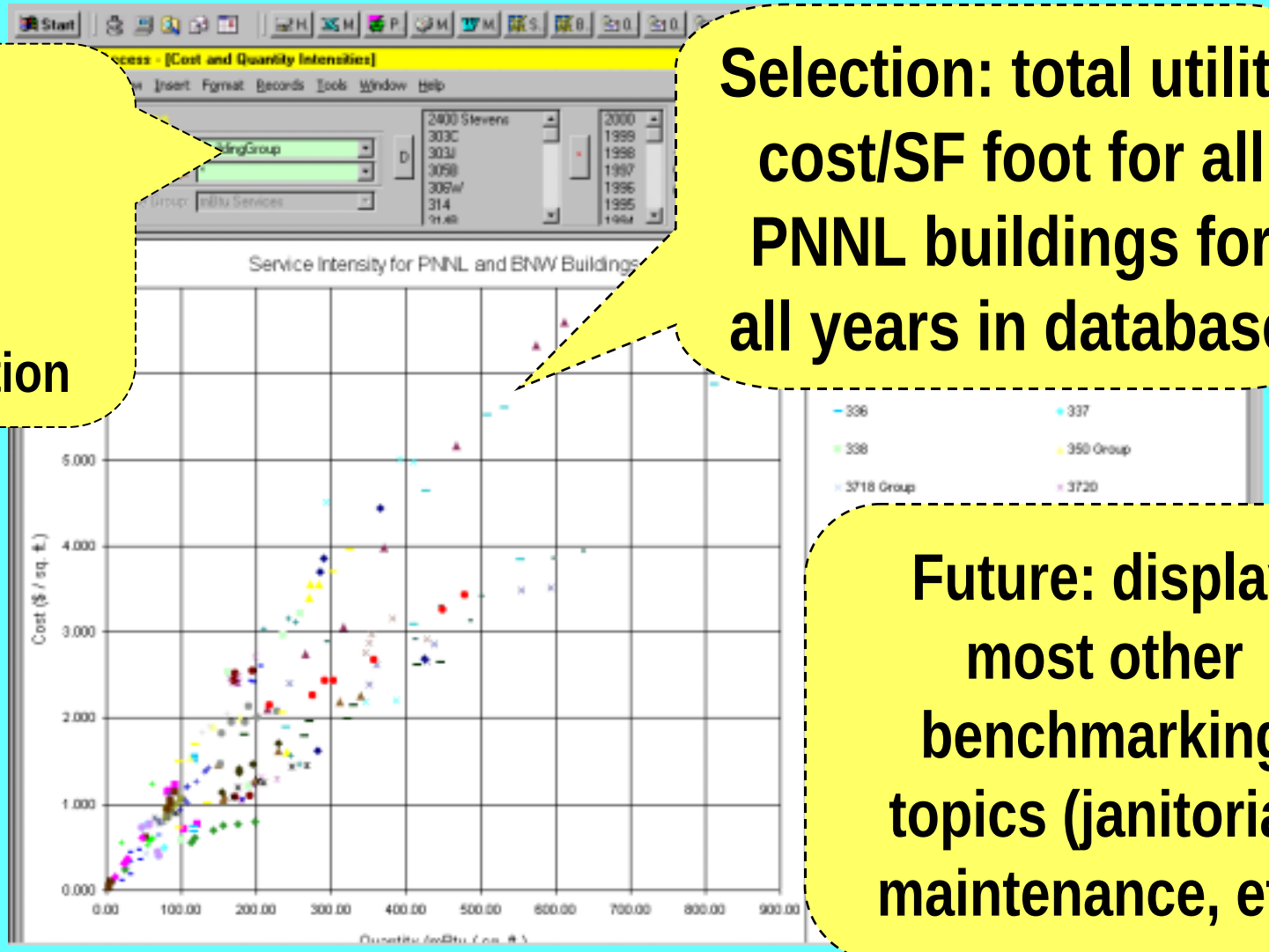
Plot
- Budget
- Bills
- Checkbook
- History

Pick
- Years
- Views: annual or monthly

Simple Benchmarking ($/ SF)

Pick
- Building
- Utility
- Campus
- Organization

Selection: total utility cost/SF foot for all PNNL buildings for all years in database



Energy Cost Per SF

Energy Use Per SF

Future: display most other benchmarking topics (janitorial, maintenance, etc)

Diagnostics

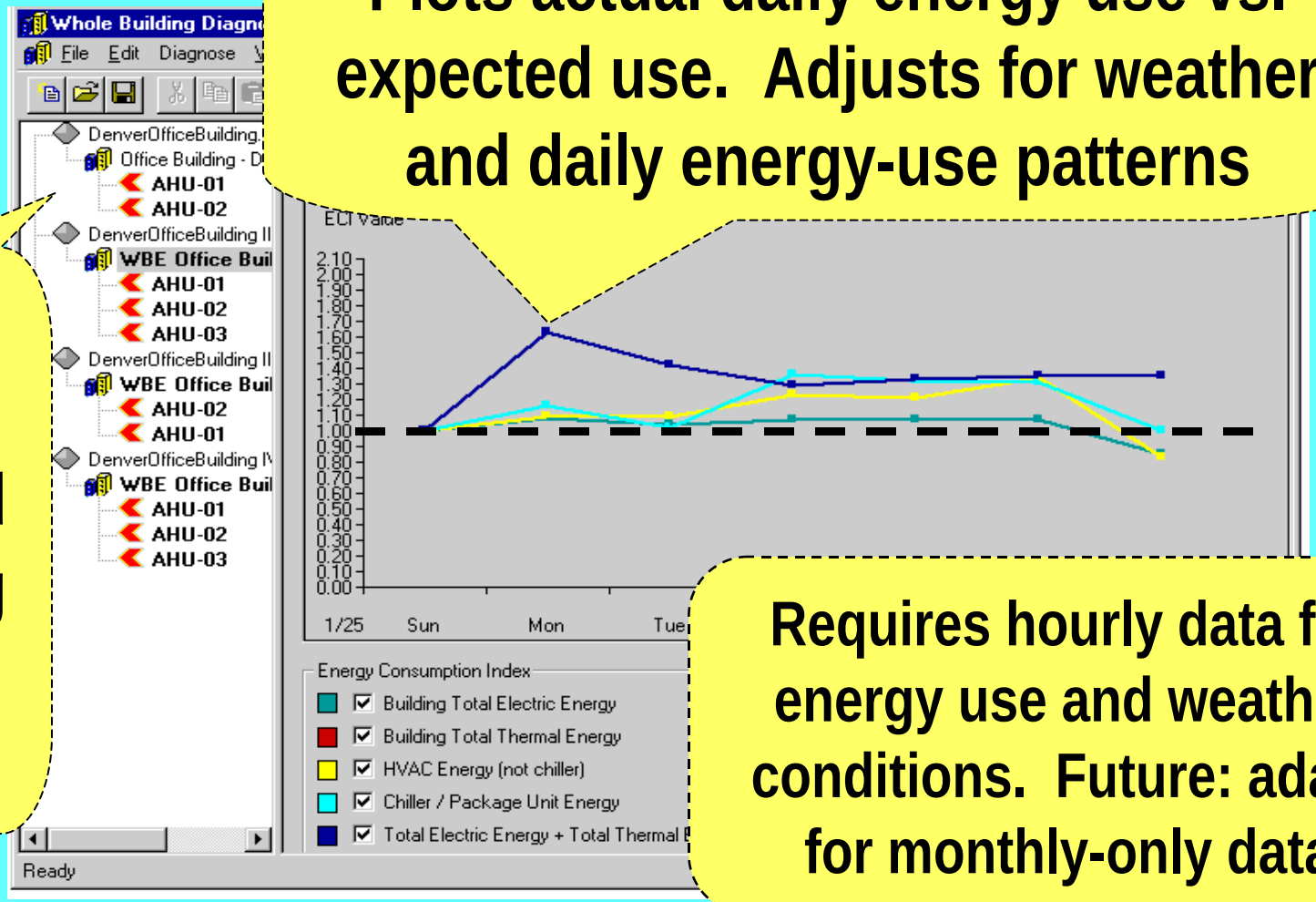
- Using the Whole Building Diagnostician (WBD) to trend & diagnose buildings using minimal building metering and modeling. 3 modules:
  - Whole Building Energy (WBE) monitors overall energy use of a building and metered subsystems. (No diagnostics currently built.)
  - Outdoor Air Economizer (OAE) monitors economizers and diagnoses problems
  - Chiller Diagnostician under construction; due Oct 1, 2000

Module 1: Whole Building Energy

- Tracks energy use of whole-buildings and major subsystems
- Factors-out (normalizes) the effects of weather and the historical energy-use patterns for each hour and day of week
- Designed to work with minimal building and subsystem metering and modeling
- Installed in several government and private facilities

Whole Building Energy Performance

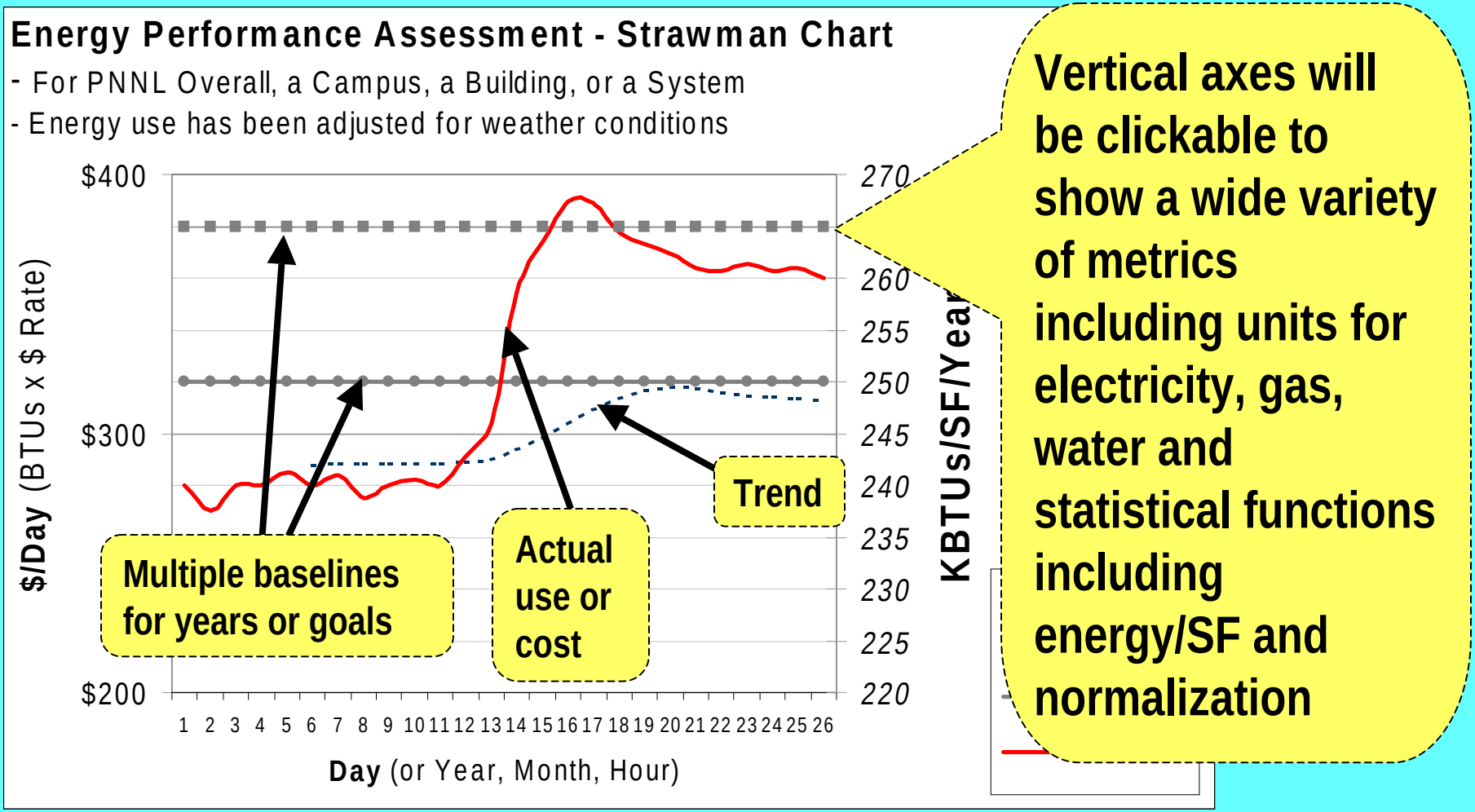
Plots actual daily energy use vs. expected use. Adjusts for weather and daily energy-use patterns



Tracks any metered building or sub-system

Requires hourly data for energy use and weather conditions. Future: adapt for monthly-only data

WBE: Proposed Actual vs Baseline Trending

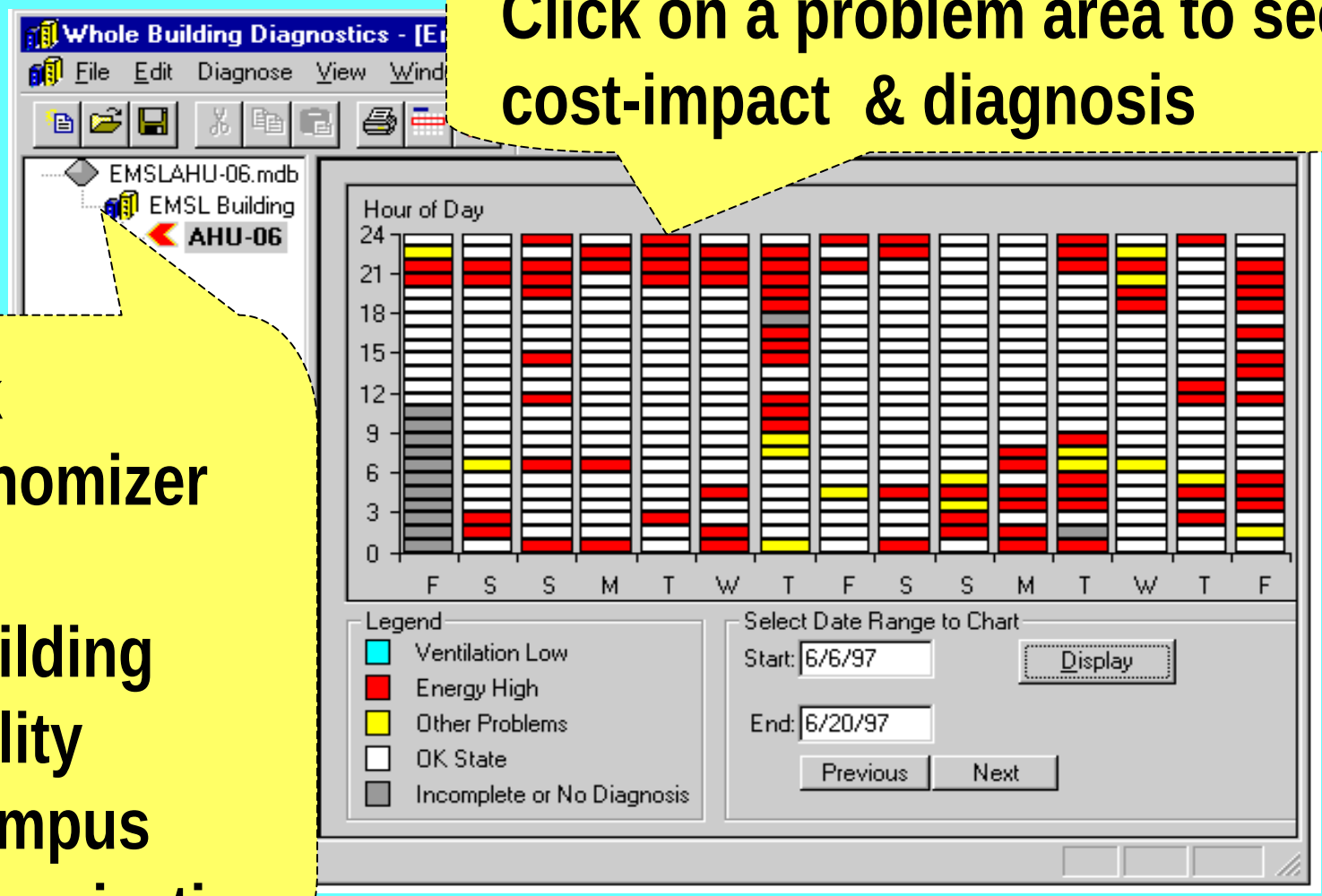


Module 2: Outside Air Economizer

- Outside Air Economizer (OAE)
- Monitors and diagnoses economizers (a mechanical system that brings in outside air to heat/cool a building)
- Uses minimal, commercial-practice metering and controls
- Installed in several private and federal facilities including EMSL and 337

Economizer Module – Main Screen

Click on a problem area to see cost-impact & diagnosis



Pick economizer by

- Building
- Utility
- Campus
- Organization

Economizer Details Screen

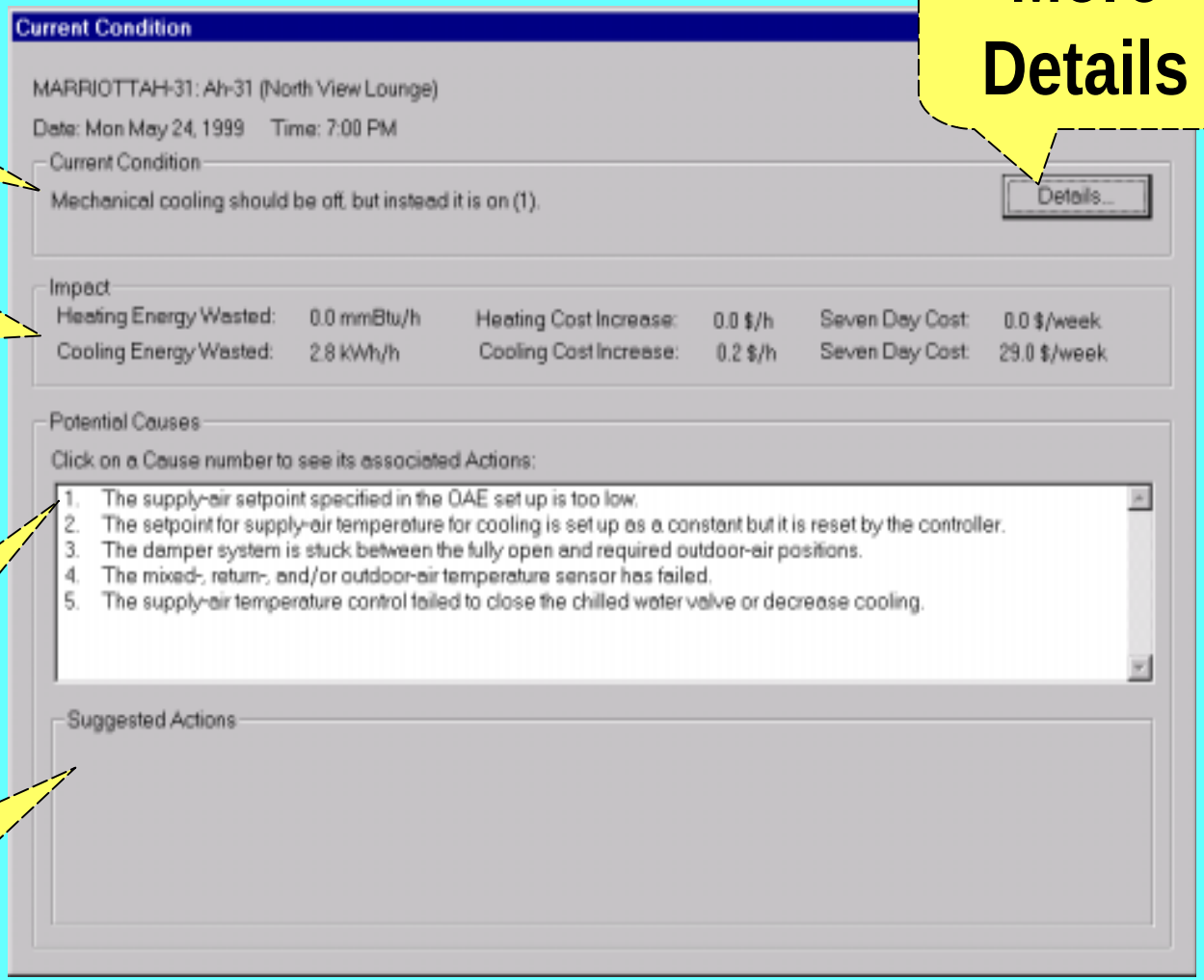
Current Condition

Cost-Impact of Problem

Potential Causes

Suggested Actions

More Details



Chiller Performance Tool

- Monitor chiller performance using minimal metering and sensors
  - Water-to-water chillers
  - Water-to-air chillers
- Funded by PNNL Facilities Department, in development by PNNL Energy Division and due October 2000

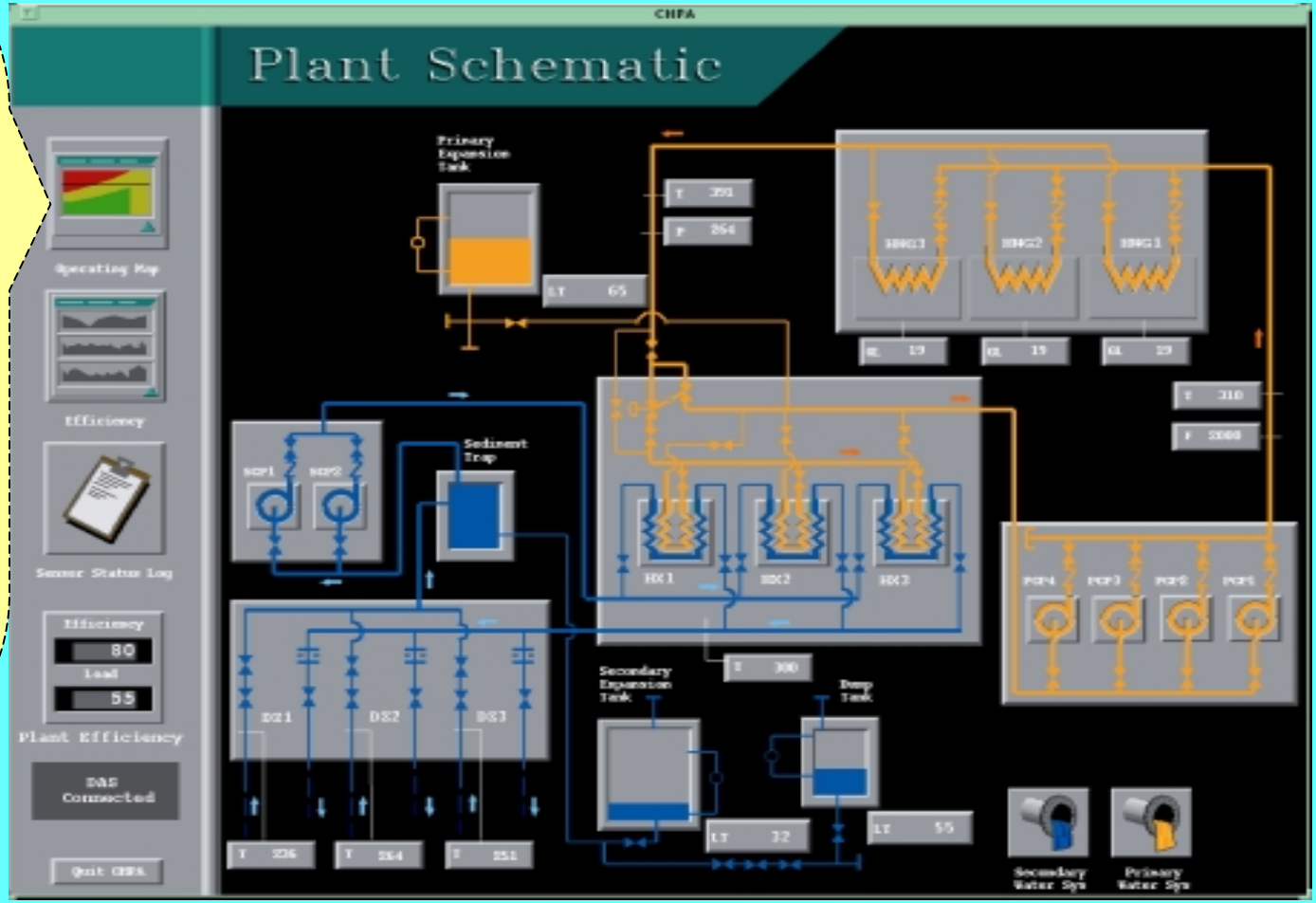
Decision Support for O&M (DSOM)

- Monitors and diagnoses complex facility systems such as central boiler and
  chiller plants.
- Unlike WBD, DSOM utilizes many more sensors and requires significant system modeling and commissioning.
- New effort: integrate DSOM with Maximo for real-time condition-based maintenance (vs. corrective, preventative, or predictive)
- Funded by DOD Marine Corp for their central plants. Soon to be installed in a New York Housing Authority plant. Built by PNNL Energy Division
- More:

DSOM http://lancair.emsl.pnl.gov:2080/proj/neuron/projects/DSOM.html

Central Plant Diagnostics (DSOM)

Click on objects to see performance assessments, diagnostics, & maintenance actions (future link with Maximo)



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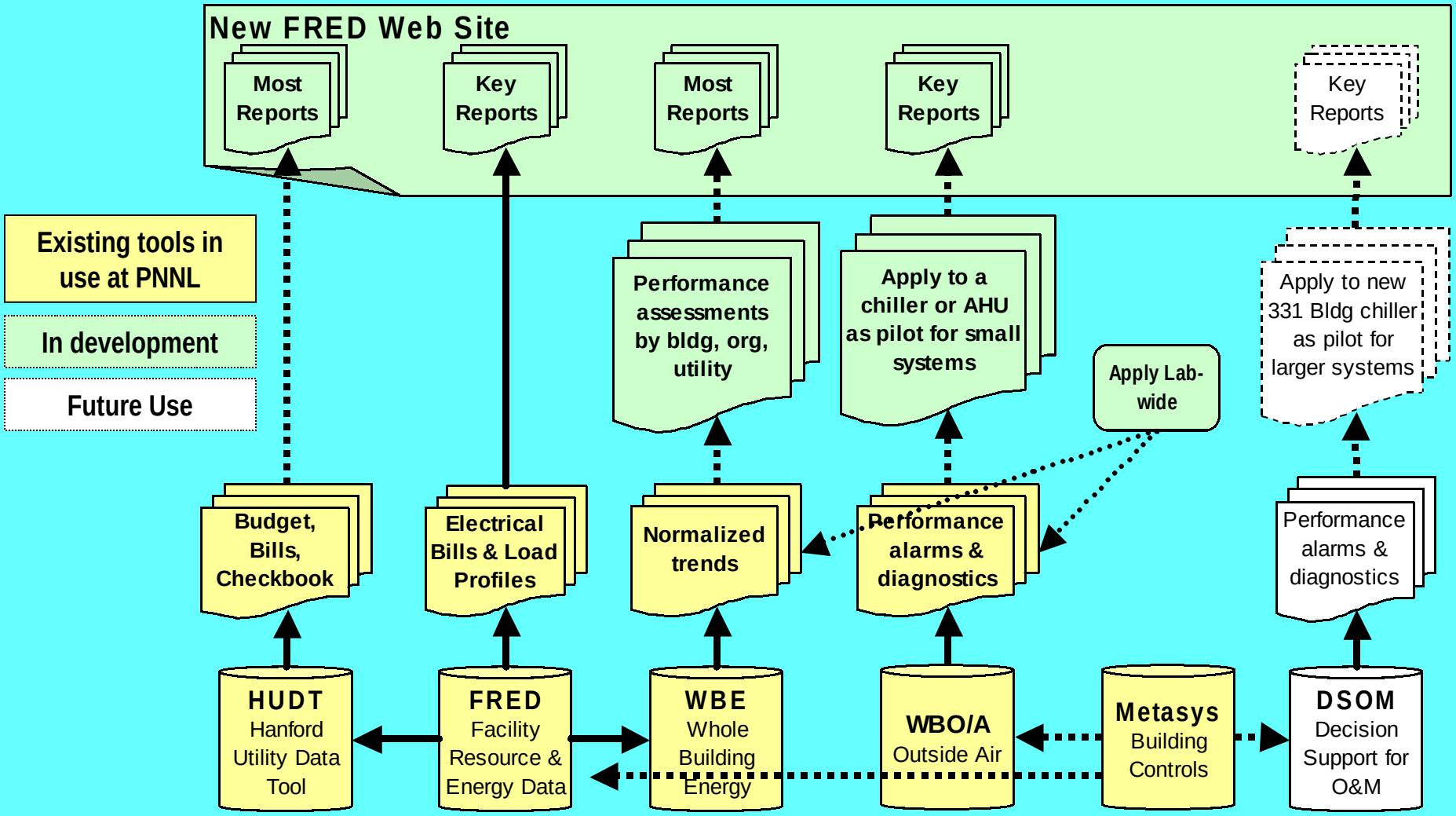
http://www.pnl.gov/TechAssist_ss/29palms/29palms.htm
http://www.pnl.gov/TechAssist_ss/29palms/29palms.pdf

Near-Term Plan for FRED Store

FRED: http://www.utilityinfo.pnl.gov



What's Next? … Make Partnerships

- Partner with other sites and organizations to:
  - Implement existing suite of building performance tools
    - To guide your O&M programs in continuous commissioning
    - To measure & verify (M&V) your ESPCs
  - Fund administration of FRED infrastructure
  - Plan and fund new tools and enhancements

What's Next? … Make Partnerships

- Implement building performance tools for:
  - Sites affiliated with Battelle: Battelle, Brookhaven, NREL, ORNL
  - DOE complex and key FEMP customer-agencies
  - States via the OSCP State Energy Projects program
  - 4th: general market
- Seek larger-scale, multi-sector partnerships
  - Private companies (industry and professional groups)
  - States, local governments, universities, etc.

What's Next? … Improve Tools (1/2)

- Improve WBD charts to display more parameters:
  - Dollar impacts of being above or below performance goals
  - Energy & water units: kWh, therms, gallons
  - Forecast future use & cost (1 day, month, year, & to EOY)
- Integrate FEDS into FRED to seek projects based on
  - Building types (e.g. FEDS' ability)
  - Actual energy use patterns (e.g. WBD's ability)

What's Next? … Improve Tools (2/2)

- Develop additional tools for building components:
  - "Plug & Play" building controls & diagnostics that use the Internet to bypass proprietary and archaic controls system
  - Diagnostics for high-cost heating/cooling systems

“Simpler” FRED Tools

	In FRED Web?
Collect & archive utilities data	Yes
Prepare Hanford electric bills & chart load profiles	Yes
Chart utility budgets, bills, & checkbooks + historical data	Yes
Chart benchmarks: energy & cost per SF for buildings	PC now; Web Oct

Advanced FRED Tools (1/2)

	In FRED Web?
Chart actual daily energy use vs. baseline - adjust (normalize) for weather and daily energy-use patterns	By Oct 00
Monitor chiller performance – normalize	By Oct 00
Monitor and diagnose economizers that use outdoor air to heat/cool a building	Yes

Advanced FRED Tools (2/2)

	In FRED Web?
Monitor and diagnose central boiler and chiller plants	FY 01
Monitor and diagnose other building systems and components	Future
Integrate WBE, OAE, and DSOM into maintenance management system (Maximo)	Future
Find good energy projects (FEDS)	Future

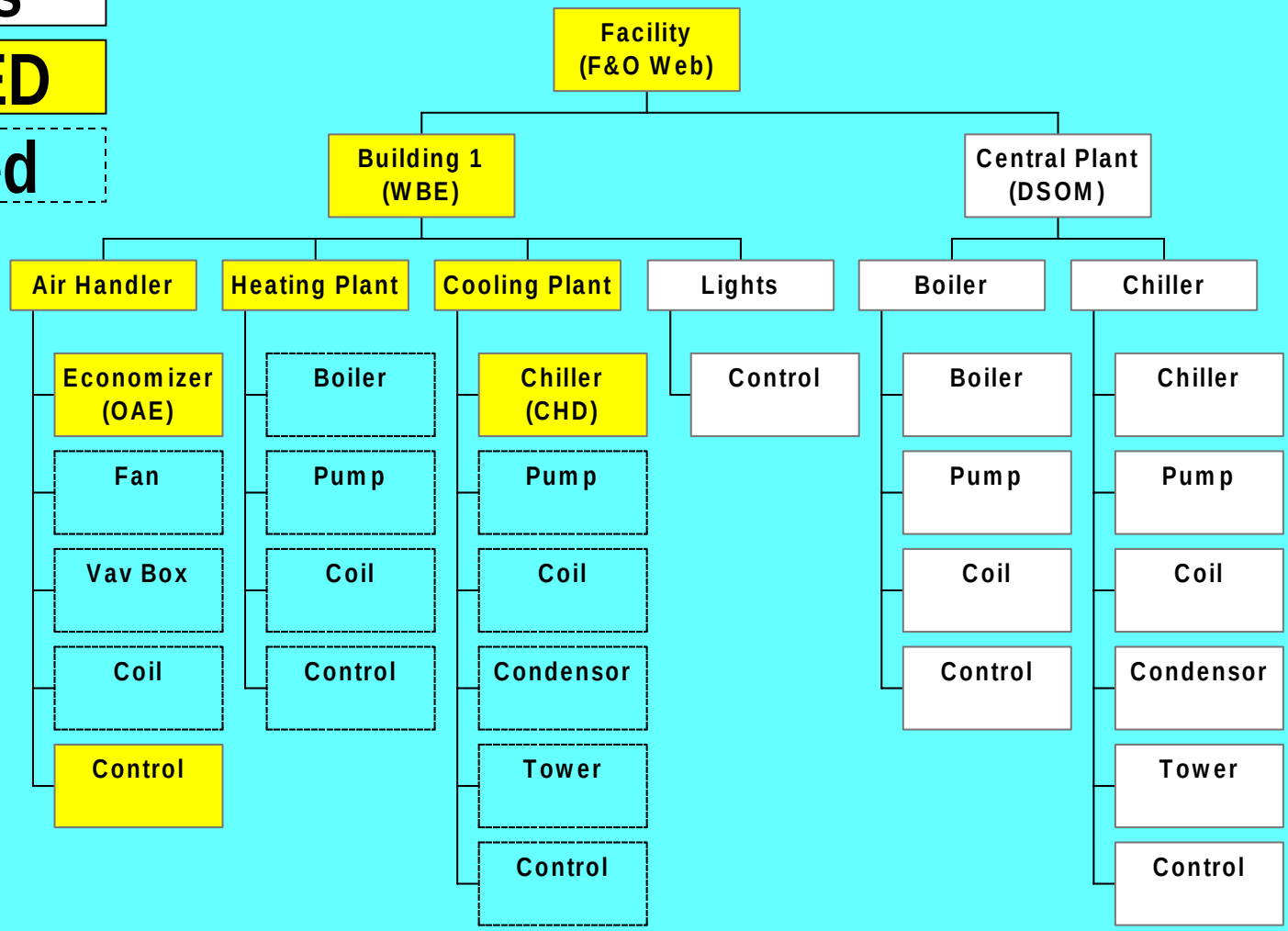
Diagnostics – Now & Future at PNNL

Tool Exists

Tool in FRED

Tool needed

Partnerships needed



Of Particular Interest …

Develop additional tools for building components:

- "Plug & Play" tools: building controls & diagnostics that use the Internet
  - Bypasses proprietary and archaic building controls systems
- Diagnostics for high-cost heating/cooling systems

Side-Note: What is Diagnostics?

- If you see only one ‘problem’, it’s only “detection”
  - 1 fire alarm sounds
  - 1 meter shows high use
  - 1 occupant complains about the air conditioning
  - 1 bottom-line is over the budgeted or planned amount
- If you see multiple ‘problems’, you can start the diagnostic process
  - The more data points you can see, the faster and better diagnostics

What does it cost?

- FRED software is mostly free to federal sites
  - DOE, Marines, and PNNL funded development to date
- Software installation is not free … you need to:
  - Fund PNNL staff to install and train site staff on one or more FRED modules
  - And/Or train your site staff to do some or all installations
  - Option: partner to share PNNL's FRED infrastructure

What does it cost? – WBD Modules

- Rough order of magnitude for WBD tools: $50K
- $25K and less when your staff can learn and do most of installation
  - Assumes site has hourly building meters, building control system, and knowledgeable staff
- Payback within 1-2 years, easily within 5 years

What's Next? … Assimilate

- FY 00: incorporate PNNL energy & utilities use and costs
- FY 01: incorporate other readily available static data:
  - Site by site (ORNL, LBL, etc)
  - Centralized databases (DOE EMS3, FEMP Tracks, etc.)
  - Broad-scope benchmarking surveys (multiyear data): Facilities Issues, BOMA, ASHRAE
- Future: go on-line, real-time with partners
  - Share data
  - Share software analysis tools

What's Next? … Assimilate Data

- FY 00: incorporate PNNL energy & utilities use and costs
- Outyears: incorporate other readily available static data:
  - Site by site, partner by partner
  - Centralized databases (DOE EMS3, FEMP Tracks, etc.)
  - Broad-scope benchmarking surveys (multiyear data): Facilities Issues, BOMA, ASHRAE
- Future: go on-line, real-time with partners to share data and tool infrastructure

Conclusion (1/3)

- Technology infrastructure already exists to do diagnostics
  - Major control companies have toolkits but few diagnosticians exist
  - Pioneers are needed to assemble pieces into a working system & culture

Conclusion (2/3)

- A small % of your energy budget can fund very effective tools
  - Use ESPCs to install good performance measurement tools
- Use tools as M&V for both the ESPC and the site's internal O&M program (continuous commissioning)

Conclusion (3/3)

- Informal partnerships can work well to share tool infrastructure and development
  - Consider whether to buy a proprietary energy management system or to join an open partnership
  - Regardless whether proprietary or partnership, investment probably similar magnitude

Questions on Tools?

Recommissioning Examples

- ✓ Fume hood police
- ✓ Recommissioning of new office buildings
- ✓ Automation of central plants
- O&M improvements to a new lab building
- Operations improvement planning

Success Stories

- EESB/ETB: tools identified problems;
  - Recommissioning saved $45K/Yr or 23 cents/SF
  - 10-20% of their utility budget
- EMSL: DOE-funded study identified several energy uses to monitor
  - Can save $61K annually or 31 cents/SF
  - 3% of EMSL's total utility budget

Fume Hood Police (1/2)

- Environmental Molecular Sciences Laboratory (EMSL)
  - 200,000 SF laboratory at PNNL
  - VAV systems with Phoenix hood controls
- Process
  - Each night, building controls records open hoods
  - Building engineer calculates cost impact
  - Building Manager emails users a list of offenders & cost

Fume Hood Police (2/2)

- The results:
  - 61% decrease in hoods left open (was 25 open hoods average now only 10)
  - >$17K estimated annual energy savings
- Building Operators close chronic hoods on their end-of-week tours
- Want to automate data collection, cost calculation, and email notices – any partners?

Recommissioned Office Bldg (1/2)

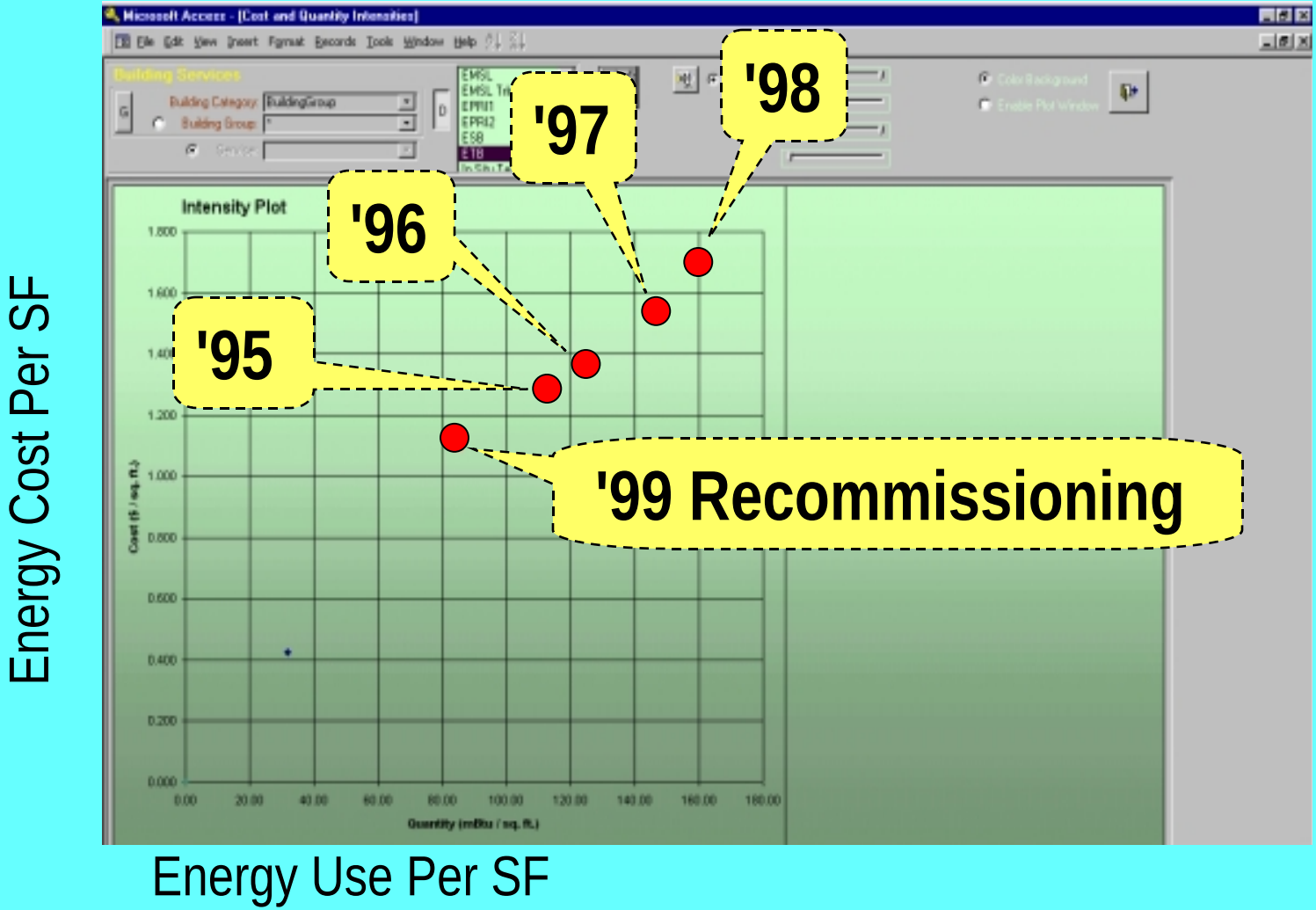
- 100,000 SF
- All-electric
- 2nd building of twins constructed in 1993 and 1994 as “Build to Suit” for Battelle
- ETB’s extra energy features
  - (T-8 lights, Low-E windows, CO2 controls, etc)
  - Predicted 20% less energy use than 1st building

Recommissioned Office Bldg (2/2)

However, after occupancy:

- ETB energy use increased 40% above 1st facility significantly by 1998
- Comfort complaints ETB was highest of any PNNL building

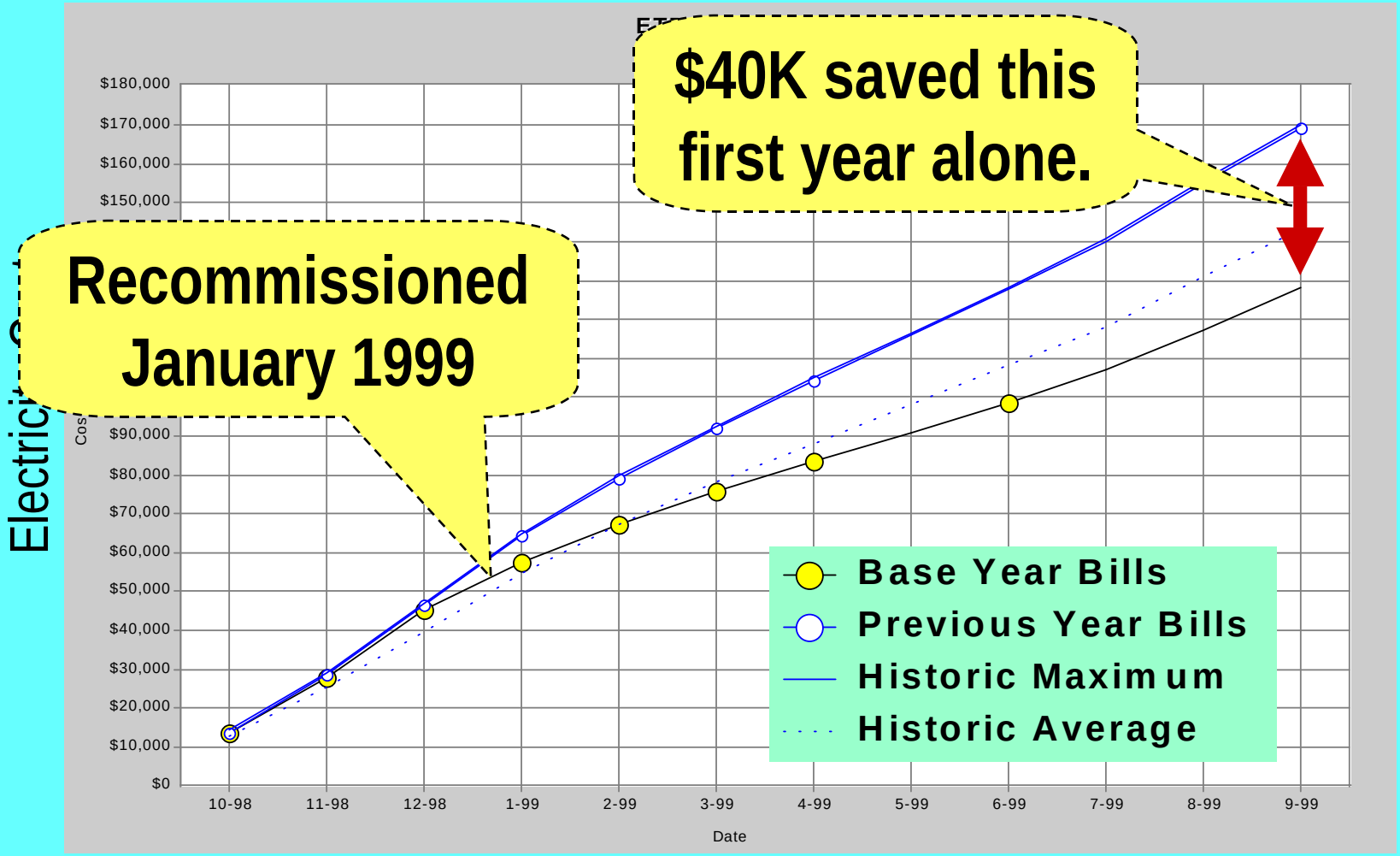
ETB Benchmarks (Cost & Use per SF)



ETB Recommissioning Actions

- PNNL R&D and Facilities staff used temporary metering to find source of high costs.
- Key discoveries:
  - Digital control adjustments out of balance
  - Schedules for HVAC systems out of balance
  - Failed sensors - most significant problem
- Corrected ventilation controls in 1999

Savings from Recommissioning



Month of FY

ETB Lessons Learned (1/2)

- Never assume that …
  - Design experts have considered all the real-world issues
  - Contractors installed and commissioned buildings as designed
  - Building operators run building as planned
- Comfort complaints may indicate improper system configuration

ETB Lessons Learned (2/2)

- Pursue incentive agreement with building owner to continuously commission bldgs
- Recommissioning investment can have excellent returns – can achieve savings greater than investment in first year.

Success Stories - DSOM at Marines

DSOM at Marine Corp's Twenty-Nine Palms

- Reduced natural gas 17%, $280K/Yr
- Reduced maintenance labor and materials, $100K/Yr
- Extended life and capacity … postponed $1M of capital replacements and upgrades
- Improved reliability by eliminating unscheduled outages
- Reduced water hammer risk

Success Stories - DSOM (2/2)

- DSOM project at NY Housing Authority campus
  - Savings includes reduction in required maintenance from 4 FTEs to 2

Operations Improvement Planning

- Goal: reduce energy costs by implementing:
  - Super-FRED tools
  - Low-cost/no-cost actions
  - Larger-scale O&M actions
- Investing $1M to upgrade O&M to get $1M annual savings
- Will take us more than a single year to implement program

Last Questions?

Miscellaneous Topics

- Metering & submetering planning
  - Better cost & energy management
  - Electricity and other sensors for buildings, systems, and components
- “Green” Field:
  - Close 300 Area (make it a “Brown” field)
  - Install photovoltaics and a PV manufacturing plant
- One-2-Five Self-Assessment program