Prioritizing Laboratories: Meeting Campus Energy Goals with a Smart Labs Program

Wendell Brase
University of California, Irvine

Sonia Ballesteros Rodriguez
Los Alamos National Laboratory

Samuel Paulsen
Pacific Northwest National Laboratory
UC Irvine Smart Labs Initiative: What We’ve Learned in Ten Years

Wendell Brase
Associate Chancellor for Sustainability
Energy Efficiency at UC Irvine

Graph showing energy consumption from 1990 to 2016. The graph includes key milestones such as:
- Adopted goal: Beat Title 24 by 30% in new construction
- Thermal energy storage
- Campus-funded energy projects
- Management performance improvement tool
- Statewide Energy Partnership launched

The graph compares energy consumption that would have been consumed without measures (in blue) to the actual energy consumed (in green, with FY2018 projections).
Energy Efficiency at UC Irvine

Adopted goal: LEED Gold NC
Prioritized "deep efficiency" (Especially labs!)
What We *Suspected* in 2008

- Buildings had waste designed-in ... and not just a few percent!
- Entrenched professional culture of overdesign tolerated energy waste
- Beliefs about how much energy savings might be feasible were possibly low.
Why 50% Savings Might Be Possible . . .

- Non-dynamic systems operate at fixed volumes/levels/speeds and “worst case” parameters
- Prior to digital controls and sensors, a margin of safety was needed
- Energy to pump water and air is non-linear
- Re-heat is excessive when air-changes are high.
“Smart” Buildings

Just enough energy, at just the right place, at just the right time!

How:

✓ Challenge all accepted design practices
✓ Use software and sensors to make building systems dynamic and “smart”
What is a “Smart Lab”? 

“Smart Labs” are newly constructed or retrofitted laboratories that:

- reduce energy consumption by 50% or more
- reinforce safety protocols and designs
- Provide dynamic, precision HVAC control zone-by-zone
- provide a data stream that enables continuous commissioning.
Components of a “Smart Lab”: More Than Just Aircuity

- Fundamental platform of dynamic, digital control systems
- Demand-based ventilation, zone-by-zone
- Low lighting power density
- Exhaust fan discharge velocity optimization
- Pressure drop optimization
- Fume hood flow optimization
- Commissioning with automated cross-platform fault detection
Smart Labs is *Not* . . .

- Just building controls changes
- Just the installation of new technology
- Only an energy retrofit program
- A high risk program
- A “project”
What We Learned in 2009-10

- What we’d suspected in 2008 was confirmed – and then some!
- Sensors and software changed everything!
- Pilot first, then scale-out
- “Information layer” as important as systems, themselves.
<table>
<thead>
<tr>
<th>Laboratory Building</th>
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<th>AFTER Smart Lab Retrofit</th>
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<tbody>
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Type: P = Physical Sciences, B = Biological Sciences, E = Engineering, M = Medical Sciences
Learned Recently: Co-benefits More Valuable than Anticipated

- Many HVAC deferred maintenance problems fixed/funded through energy savings
- “Information layer” provides real-time commissioning and air quality track-record
- Lighting quality improved
- Quieter buildings inside and outside
- Cleaner indoor air
- Longer service life for heat-producing and friction-producing building system components
- Avoided capital investments for generation, central plant chillers, and infrastructure.
Smart Labs Life-Cycle Costs and Benefits

- All data 2017 U.S. dollars
- All numbers ±15 percent
- Smart Lab retrofit prior conditions: variable-air volume (VAV) and direct digital controls (DDC). Retrofits that require initial upgrading to VAV and/or DDC (and possibly asbestos abatement) will cost more but yield greater savings.
- Carbon costs based on 2017 California emissions allowance price ($15.40/MT)
- Electricity expense based on 2017 UCI cogeneration cost of $0.06/kWh. Higher electricity rates will increase energy savings.
## Smart Labs Life-Cycle Costs and Benefits

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<th>Cost Factors and Derived Benefits</th>
<th>New Construction</th>
<th>Smart Labs Retrofit</th>
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<tr>
<td></td>
<td>Costs</td>
<td>Derived Benefits</td>
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<tr>
<td>“Smart Lab” systems/components/installation</td>
<td>$12.50/GSF</td>
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<td>Deferred maintenance problems addressed</td>
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<td>Reduced energy expense</td>
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<td>$43.20/GSF</td>
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<td>Safety specialist to evaluate and manage laboratory air-change settings</td>
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<td>Extended equipment lifespan</td>
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<td>Maintenance expense increase for controls</td>
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<td>Avoided re-commissioning every 5 years</td>
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<tr>
<td>Avoided carbon costs</td>
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<td>$4.60/GSF</td>
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<td>Capital cost avoidance due to smaller chillers and boilers</td>
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<td>Capital equipment capacity freed-up due to reduced chiller and boiler central plant load</td>
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<td><strong>50-YEAR TOTALS</strong></td>
<td>$25.85/GSF</td>
<td>$79.90/GSF</td>
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Your Mileage May Vary Based On . . .

- Prior air-change rates
- Your climate
- Your cost of energy
- Rebates, subsidies, incentives
25 Years of Energy Efficiency

- Adopted goal: LEED Gold NC
- Prioritized "deep efficiency" (Especially labs)

- Thermal energy storage
- Campus-funded energy projects
- Energy Partnership launched
- Statewide
- American College & University Presidents' Climate Commitment
- Adopted goal: Beat Title 24 by 30% in new construction

Source + Site Energy (billions of BTUs)
25 Years of Energy Efficiency
Looking Back Over a Decade of Experience

- Savings are predictable and reliable
- No compromises of safety
- Actually low risk
- New paradigm of design and operation
- Co-benefits » anticipated
- Essential to meet our climate commitment goal.
QUESTIONS?

wcbrase@uci.edu

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Prioritizing Laboratories
Meeting Campus Energy Goals with a Smart Labs Program
Sonia Ballesteros Rodriguez
Lead Sustainability Analyst & Industrial Engineer
Sustainability Group – UI DO
Los Alamos National Laboratory
Quick Overview of Presentation

- Los Alamos National Laboratory
- Why Smart Labs at LANL?
- Smart Labs Core Team
- Management Attention
  - Better Buildings Smart Labs Challenge
  - Risks
- Building Selection
- Tracking Progress
The role of Los Alamos for the nation

Office of Science Laboratories
1. Ames Laboratory
   Ames, Iowa
2. Argonne National Laboratory
   Argonne, Illinois
3. Brookhaven National Laboratory
   Upton, New York
4. Fermi National Accelerator Laboratory
   Batavia, Illinois
5. Lawrence Berkeley National Laboratory
   Berkeley, California
6. Oak Ridge National Laboratory
   Oak Ridge, Tennessee
7. Pacific Northwest National Laboratory
   Richland, Washington
8. Princeton Plasma Physics Laboratory
   Princeton, New Jersey
9. SLAC National Accelerator Laboratory
   Menlo Park, California
10. Thomas Jefferson National Accelerator Facility
    Newport News, Virginia

Other DOE Laboratories
1. Idaho National Laboratory
   Idaho Falls, Idaho
2. National Energy Technology Laboratory
   Morgantown, West Virginia
3. National Renewable Energy Laboratory
   Golden, Colorado
4. Savannah River National Laboratory
   Aiken, South Carolina

NNSA Laboratories
1. Lawrence Livermore National Laboratory
   Livermore, California
2. Los Alamos National Laboratory
   Los Alamos, New Mexico
3. Sandia National Laboratory
   Albuquerque, New Mexico
4. Nevada National Security Site
5. Pantex Plant
6. Sandia National Laboratories
7. Savannah River Site
8. Y-12 National Security Complex

Nuclear Security Enterprise
1. Kansas City Plant
2. Lawrence Livermore National Laboratory
3. Los Alamos National Laboratory
4. Nevada National Security Site
5. Pantex Plant
6. Sandia National Laboratories
7. Savannah River Site
8. Y-12 National Security Complex
The Laboratory is an integrated and dynamic system of people, facilities, equipment, materials and services that supports our national security mission.
LANL Infrastructure Statistics

- ~40 square miles
  - 7,500 ft. elevation
  - 13 nuclear facilities
- 920 owned buildings with 8.2M gross sq. ft. (owned)
  - 50% more than 40 years old
  - 295 occupied buildings
  - 0.43M gross sq. ft. of leased properties
  - 0.35M gross sq. ft. shutdown assets
- Roads
  - 22 miles of primary roads
  - 62 miles of secondary roads
- Utilities
  - 32 miles of primary power lines
  - 166 miles of secondary power lines
  - 57 miles of gas distribution lines
  - 109 miles of water distribution lines (fire and potable)
  - 28 miles of steam lines
  - 63 miles wastewater

Land comparison of Washington, D.C. and the Los Alamos National Laboratory Site
Why Smart Labs at LANL?
LANL thought we could have safer and more efficient buildings...we should develop a Smart Lab Program.

We have old, inefficient buildings and over 700 fume hoods!
UC Irvine set the example

- Wendell Brase is the University of California, Irvine’s first Associate Chancellor for Sustainability. Brase co-chairs the University of California’s Global Climate Leadership Council and chairs UC’s Energy Services Governing Board.

- For 25 years, he provided leadership for an award-winning sustainability program in his role as Vice Chancellor for Administrative and Business Services.

- Marc Gomez is the Assistant Vice Chancellor for Facilities Management and Environmental Health & Safety at the University of California, Irvine. He has a Master of Public Health degree from the University of Michigan and a Bachelor of Science degree from Tulane University.

- Marc has served in many leadership positions for the Campus Safety, Health and Environmental Management Association as well as the American Industrial Hygiene Association.

- Matt Gudorf is the Assistant Director of Engineering, Energy, and Inspection at UC Irvine.

- He was named the 2012 Energy Engineer of the Year by the Association of Energy Engineers.
## UC Irvine results

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*Key: P = physical sciences, B = biological sciences, E = engineering, M = medical sciences.*
Needed energy efficiency to support growing mission work

- Increase of Energy Demand during the next 10 years: mission growth
  - Actual Strategic Computer Complex (SCC): 25 MW peak
  - Future Supercomputer Infrastructure (FSI) (2027): 85MW peak

- To secure future mission work:
  - Main Investments (Smart Labs, BAS and etc) to help reduce base energy consumption and allow mission growth
  - ESPC for Combined Heat and Power Plant
  - 10 MW Photovoltaic Array
Smart Labs Core Team
Smart Labs Core Team - Common Goal & Roles and Responsibilities

- Common Goal:
  - Understand the potential of the Smart Labs
  - Get the organizational culture prepared to implement both the organizational component and the facility component of Smart Labs

- Provide SME expertise
- Support professionals

- Serves as the liaison of the core team
Smart Labs Core Team-Laboratory Ventilation Management Plan

- Umbrella document
  - Defines scope, roles and responsibilities, and requirements for planning, design, construction, renovation, commissioning, maintenance and managing of laboratory exhaust ventilation for exposure control and associated heating ventilation, air conditioning and refrigeration systems
  - Applies to all existing, modified and new facilities that utilize laboratory exhaust ventilation systems for exposure control in LANL facilities
  - Cycle of activity: these activities or requirements, starting with stakeholder coordination, include risk assessment, system design, preventive and corrective maintenance, management of change, and documentation.
# Laboratory Ventilation Management Plan—Stakeholders Roles and Responsibilities

<table>
<thead>
<tr>
<th>Stakeholder Group</th>
<th>Primary Role</th>
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</thead>
<tbody>
<tr>
<td>Users</td>
<td>Safely use LVS</td>
</tr>
<tr>
<td>Deployed Support</td>
<td>Assess risk and guide lab safety</td>
</tr>
<tr>
<td>Site Support</td>
<td>Design, support procurement, install, commission and test ECDs and LVSS</td>
</tr>
<tr>
<td>Facility Owner</td>
<td>Staff and fund laboratory ventilation</td>
</tr>
<tr>
<td>Leadership</td>
<td>Support the LVMP to enhance LANL’s mission</td>
</tr>
</tbody>
</table>
Management Attention
# Smart Labs Risks

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<th>Risks – Implementing Smart Labs</th>
<th>Risks – <em>NOT</em> implementing Smart Labs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Facility investments not meeting full potential - Introducing high tech building control systems in a low tech operating environment</td>
<td>Attracting new talent, authority not defined – can’t be accountable if we don’t identify roles and responsibilities</td>
</tr>
<tr>
<td>Facility inoperability, ES&amp;H and Facility Operations staff need training</td>
<td>Poor productivity</td>
</tr>
<tr>
<td>Contract change – loss of continuity, maintaining as a high priority project/program</td>
<td>Equipment lifetime decreased, running equipment too much</td>
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<tr>
<td></td>
<td>Uncontrollable temperatures for temperature sensitive experiments</td>
</tr>
<tr>
<td></td>
<td>Insufficient lighting for high tech science</td>
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</table>
Better Buildings Smart Lab Accelerator Partner

Partnership Agreement signed in September 2016

Partners set a target to improve energy efficiency by at least 20% in selected facilities

Partners work together to develop standardized approaches to overcoming common barriers to energy efficiency in laboratories

DOE works with partners to document model approaches to:

- reduce energy consumption
- Including operational changes and technological upgrades
- Strategic energy management
Building Selection
Buildings Selection: First Cut
Road Map Implementation

• **Phase 1:**
  - 1a. Top Ten High Energy Use Facilities
  - 1b. RELSA: Rapid Energy Laboratory Assessment in 8 facilities
  - 1c. Selection of the “best” four (4) facilities for “immediate” Smart Lab Implementation
  - 1d. DVA: Demand Ventilation Assessment in the four selected facilities to select PIMs and ECMs

• **Phase 2:**
  - 2a. Pilot Project: Selection of a pilot building for Smart Labs Implementation. Alignment of Funding Sources
  - 2b. Actual Status: Pilot Project Smart Lab design for implementation.

• **Phase 3:**
  - LVMP in process of implementation:
    - PM in process
    - Training
    - BMP in process
Wind Tunnel Test

• **Objective:**
  - Develop a laboratory exhaust fan renovation strategy to reduce exhaust fan energy to the extent possible either by extending the stack height or slowing down exhaust speed
Laboratory Ventilation Management Program

• We created Roles and Responsibilities for all LVMP members and for all phases

• We have created communication between all team members, including laboratory tenants:
  • We have involved tenants with Status Update Board and Weekly meetings

• We had training: (ESH, IH, Maintenance, Cx, BAS)
  • LVRA
  • HVAC Systems and Laboratory Test Analysis
  • Building and Implementing a Performance Management Plan (PMP)

• We have developed:
  • Preventive Maintenance Plan
  • Hibernation Protocol
  • An Exposure Assessment with Risk Control Banding
  • Fume Hood Annual Certification Process Revisions (in process)
  • Fume Hood Database with connection to exhaust fans and all ID numbers being used (in process)

• Cerebro:
  • Safety net to align the different databases and make sure chemicals and ACH match the risk control band for the space

• We are tracking status for all buildings and metrics for all buildings
Tracking progress
Development of a Laboratory Ventilation Management Program

- Selected 5 buildings to implement Smart Labs
- All existing buildings in various stages of needing maintenance, upgrades, and old/new lab equipment

### Phase 1A - Plan

**Qualitative Scoping Study**

<table>
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<tr>
<th>Building</th>
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### Phase 1B - Assessment

**Quantitative Performance Audit**

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Next Step: Benchmark operations and BMP

### Phase 2 - Optimization

**Construction / Renovation / Upgrade Project**

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Next Step: Design Implementation

**RCD for Smart Labs design and Implementation**

### Phase 3 - Manage

**Performance Management and Operations Plan**

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<td>35-0213</td>
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<td>Yes</td>
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<td>Yes</td>
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</table>

Next Step: Design Implementation

### Notes

- 48-0107 was added the last
- 03-1698:
  - Next Step: Benchmark operations and BMP
- 35-0085
  - Pilot Building
  - Controls Design In Process
  - Next Step: Design Implementation
- 48-0001:
  - Large RCx projects repairs
- 35-0213
  - BAS implementation
  - Large RCx project repairs
  - RCD for Smart Labs design and Implementation
Thank you!!!!
Questions?

Monica R. Witt
Sustainability Officer & Program Manager
Sustainability Group-UI DO
mwitt@lanl.gov
Off: +1 505-667-4017
Cell: +1 505-795-2884

Joseph W. Klose
Program Manager
Sustainability Group-UI DO
klose@lanl.gov
Off: +1 505-665-8410
Cell: +1 505-695-5237

Genna G. Waldvogel
LVMP Coordinator & Civil Engineer
Sustainability Group & Engineering Services-UI DO
gwaldvogel@lanl.gov
Off: +1 505-665-9963
Cell: +1 505-551-2373

Sonia Ballesteros Rodriguez
Lead Sustainability Analyst & Industrial Engineer
Sustainability Group-UI DO
soniab@lanl.gov
Off: +1 505-667-0540
Cell: +1 505-412-1762
PNNL Research

**Science**
- Strengthen U.S. Scientific Foundations for Innovation
- Earth and Biological
- Physical and Computational

**Energy and Environment**
- Increase U.S. Energy Capacity and Reduce Dependence on Imported Oil
- National Security

**National Security**
- Prevent & Counter Terrorism and the Proliferation of Weapons of Mass Destruction

**EMSL**
- Reduce the Environmental Effects of Human Activities and Create Sustainable Systems
PNNL Facilities

- Sequim
- Seattle
- Portland, OR
- Richland (Main Campus)
- College Park, MD
- Washington, DC
PNNL – Richland Main Campus Facilities

2.3 ft² Million Gross
PNNL – Leased Facilities
PNNL – Battelle Facilities
PNNL – DOE Facilities
SmartLabs@PNNL

PNNL Program Evaluation

▶ New Facilities and Upgrades ➔ PNNL is Very Similar to UCI

- High Performance Engineering Standards
- Demand Based Ventilation
- Energy Recovery
- Occupancy Sensors
- LED Lighting
- Building Automation Feedback
SmartLabs@PNNL – Hurdles
What is a UESC?

- Similar to Other Energy Savings Performance Contracts
- Secure a Loan for Energy Saving Construction Projects
- Owner Pays Back Loan with Existing Utility Budget Savings
  - Is the Savings Real?
  - Is the Construction Budget Correct?
  - Are we Disciplined Enough to Realize the Savings?
UESC Process

- Patience
- PNSO Contract ➔ DOE Facilities
- Solicited proposals from Utilities (1.5 year process)
- Awarded to Bonneville Power Association
- Phase 1 – ASHRAE Tier 1 to Tier 2 Level Audit, No Cost (~1 year)
- Phase 2 – Deep Dive Into Viable ECMs
- Phase 3
  - Project Design
  - Construction Contracts
  - Secure Financing
  - Execute Projects
UESC – Phase 1

- BPA and PNNL Relationship
- Analyze 13 DOE Facilities
- Baseline Energy Consumption/Characteristics
- ECM Identification (Energy, Maintenance, Water Savings)
- Cost Analysis ➔ Max Payback ~ 14 Years
- Provide Reports

Phase 1 – 90% Complete
UESC – Phase 1 Results

850,000 ft² 47,500,000 kWh/yr 700,000 therms/yr

Energy Consumption By Building, Electric and Gas

UESC – Phase 1 Results
UESC – Phase 1 Results
UESC – Phase 1 Results

Electric End-Use Energy

Motor Loads 35.6%
Chillers, Cooling, Process Cooling, and CRAC 15.0%
Total Lighting Load 15%
Compressed Air 0.1%

Lab Equipment & Misc. Other Loads 24.3%
Electric Space Heating 1.5%
Water Heating 1.0%

Data Centers/Super Computer 16.7%

Gas End-Use Energy

Reheat and Process Heat 19.1%
Hot Water Heating 1.0%
Space Heating and Preheat 79.9%

Total End-Use Energy

Compressed Air 0.1%
Data Centers/Super Computer 11.7%
Water Heating Gas-Elec 0.5%

Space Heating Gas-Elec 25.2%
Lab Equipment & Misc. Other Loads 24.8%
Motor Loads 24.8%
Reheat and Process Heat 5.3%
Lighting Load 4.6%
Chillers, Cooling, Process Cooling, and CRAC 10.5%
UESC – ECM Bundles

1. Lighting Upgrades
2. ESPC Steam Contract – 3 Facilities: $850k/yr
3. Office/Lab Air Systems Separation
4. SmartLab Upgrades
5. Building Envelope
6. Lab Equipment Set-Backs
7. Misc HVAC: VFDs, Boilers, Controls
8. Compressed Air
9. Sequence of Operation/Programming
10. Water Conservation Measures
11. [Automatic E-Light Testing]
# UESC – ECM Bundles

<table>
<thead>
<tr>
<th>ECM Bundle ID</th>
<th>ECM Description</th>
<th>Applicable Buildings</th>
<th>Natural Gas Savings (Therm/year)</th>
<th>Electric Savings (kWh/year)</th>
<th>Utility Cost Savings ($/year)</th>
<th>O&amp;M Savings ($/year)</th>
<th>Total Cost Savings ($/year)</th>
<th>ECM Cost ($)</th>
<th>Simple Payback (Years)</th>
<th>Total Incentive ($)</th>
<th>Payback w/ Incentive ($)</th>
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<td>Lab Airflow Reduction</td>
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<td>Lab Equipment Set-backs</td>
<td>310, 3420, 3425, 3430, 3440, EMSL</td>
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<td>Compressed Air</td>
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</table>

**Value Added**

**Low Estimates**
UESC – Value Added

- 3rd Party Review ➔ For Free
- Building Energy Profiles
- Reports ➔ Management Attention

Energy Consumption By Building, Electric and Gas MMBTUs/Year

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<thead>
<tr>
<th>Building</th>
<th>Electric Energy</th>
<th>Gas Energy</th>
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<tr>
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<td>20,000,000</td>
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<tr>
<td>3430</td>
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<tr>
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<tr>
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<td>20,000,000</td>
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<tr>
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<td>10,000,000</td>
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<td>3820</td>
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<tr>
<td>350</td>
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<tr>
<td>3440</td>
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</tbody>
</table>
UESC – Concerns

- Organizational Discipline to Realize Savings
- Loan Size vs. Savings per Project… They Don’t All Happen at Once
- Slow Process
- Low Estimates for Construction Costs

Keeping a Smart Lab Smart
In Discussion with PNSO/BPA for Phase 2 ➔ Requires Funding
Sequence of Operations Mods
Pursue Lighting… Get a WIN!
Program Development
Control the Narrative
UESC @ PNNL

- Phase 1 Nearing Completion
- Overall Value Added
- 2 Year ➔ Successes & Lessons Learned
LANL Back up slides
Los Alamos is essential to ensuring the U.S. nuclear deterrent – we are responsible for four of the seven weapons systems in the nation’s arsenal

- Los Alamos helps ensure the safety, security, and effectiveness of the nation’s deterrent

- Los Alamos is the design agency for four of seven weapons systems in the nation’s arsenal

We use science to annually certify to the Secretary of Energy, Secretary of Defense, and the President that the stockpile will perform as intended.
Smart Labs Core Team-Laboratory Ventilation Management Plan- Roles and Responsibilities

- Laboratory User
- Laboratory User Manager
- FOD
- Operations and Maintenance
- ES&H
  - OSH-IH
  - DESHS, deployed IH to Construction, Projects, Craft, EWFO, UI FOD
  - DESHF, deployed IH to LANSCE, STO, TA55, WFO FODs
  - ECP-CP, Stack Air Monitoring
- Start-up & Commissioning
- ASM-Purchasing