



ADVERTISEMENT - REQUEST FOR PROPOSALS
Construction Management/General Contracting Services
State of Colorado
University of Colorado Anschutz Medical Campus (GFE)
Notice Numbers: 18-152058

Notice Status: OPEN
Publish Date: January 14, 2022
Notice Revisions: 0
Revision Publish Date: N/A

Project Numbers: 18-152058

Project Titles: CU Anschutz Bundled Energy Projects

Estimated Construction Cost: \$7,000,000.00

Settlement Notices

For all projects with a total dollar value above \$150,000 Notice of Final Settlement is required by C.R.S. 38-26-107(1).

Final Settlement, if required, will be advertised via: Electronic Media

Project Descriptions

Please see full project descriptions outlined in the RFP

Scope of Services

The scope of services will include assistance to the State during the process of assessment, design, construction, and warranty period. Specific tasks to be performed by the Construction Manager/General Contractor (CM/GC) include those generally performed by the CM/GC construction community where the Construction Manager is also the Contractor. A sample copy of the State's CM/GC contract is contained within the RFP. A Guaranteed Maximum Price (GMP) will be required at the completion of Design Development phase.

A public construction project in the amount of five hundred thousand dollars or more shall be subject to the State prevailing wage rate, of the regular, holiday, and overtime wages paid and the general prevailing payments on behalf of employees to lawful welfare, pension, vacation, apprentice training, and educational funds in the State, for each employee needed to execute the contract. Payments to the funds must constitute an ordinary business expense deduction for federal income tax purposes by contractors and subcontractors. Contractors are required to pay

their employees at weekly intervals and shall comply with the enforcement provisions of C.R.S. §24-92-209

Minimum Qualifications

Notice is hereby given to all interested parties that all firms will be required to meet ALL of the minimum qualifications to be considered for these projects. To be considered as qualified, interested firms shall have, as a minimum:

1. Provided Construction Management/General Contracting services within the last three (3) years for at least two (2) projects relating to construction of Energy Conservation Measures in existing facilities each in excess of **\$7 million** (hard costs), utilizing the expertise present in their Colorado Office; and
2. Demonstrated specific Construction Management/General Contracting experience in projects of similar scope and complexity and considering abilities to work in sensitive areas on a medical research campus that can include wet research labs, classrooms, offices, etc.; and
3. Demonstrated bonding capability up to **\$8 million** for an individual project coincidentally with current and anticipated workloads; provide letter from surety that affirms this capacity.

Firms meeting the minimum qualifications may obtain the RFP documents on the website accompanying this advertisement.

University of Colorado Anschutz Medical Campus Facilities Projects – **Request for Proposals** website: <https://www.cuanschutz.edu/offices/facilities-management/construction-projects/RFP>

CORE/ColoradoVSS: <https://codpa-vss.cloud.cgifederal.com/webapp/PRDVSS2X1/AltSelfService>

Other Information

Preference shall be given to Colorado resident bidders and for Colorado labor, as provided by law.

Pre-Submittal Conference Meeting (mandatory)

To ensure sufficient information is available to CM/GC firms preparing submittals, a mandatory pre-submittal conference has been scheduled. The intent of this conference is to present the project, submittal process and to have University staff available to discuss these projects. Firms preparing submittals must attend and sign the attendance roster in order to have their submittals accepted.

The RFP Pre-Submittal Conference will be a Zoom Conference to be held on January 19, 2022, at 2:00 PM

Pre-Submittal Zoom Conference Link: <https://ucdenver.zoom.us/j/94258399044>

Schedule/Submission Details

1. The schedule of events for the CM/GC RFP process is as follows:
- 2.

Advertisement	Jan 14, 2022
Mandatory Pre-submittal Conference (Zoom Meeting)	Jan 19, 2022 – 2:00PM
Date Email Questions Due	Jan 26, 2022 – 2:00PM
Date Email Answers Issued	Jan 28, 2022
Submittals Due (Prequalification: Step I)	Feb 15, 2022 – 2:00PM
Interview Short List Announced	March 1, 2022
Sealed Proposal Due (Evaluation and Award: Step II)	Est. March 9, 2022
Oral Interviews	Est. March 9 -11, 2022
Selection Announced	March 15, 2022
Negotiation of CM/GC Contract	March 16 – 31, 2022
Contract Approval (projected)	April 5, 2022
Anticipated Design Start	April 5, 2022
Anticipated CM/GC Start	April 5, 2022
Anticipated Construction Start/Finish	Sep 2022 – Sep 2023

3. One (1) PDF copy of the Submittal of Prequalification is due on **February 15, 2022**, and shall be received no later than **2:00 PM**, as follows:

Submittals shall be submitted online at the following website:

https://ucdenverdata.formstack.com/forms/rfp_rfq_submission

Please prepare submittals as follows:

- a. Submittals should not exceed 20 (letter size) PDF pages of content.
 - b. Cover page and section title pages do not count towards the 20-page limit.
 - c. Please, no smaller than 10 point fonts.
 - d. Submittals should be ordered and contain the five sections as outlined in section II. SUBMITTAL REQUIREMENTS. Separate each section by a title page.
 - e. Submittals are limited to 25 MB by submission website.
4. The above schedule is tentative. Responding firms shall be notified of revisions in a timely manner by email. Respondents may elect to verify times and dates by email, but no earlier than 36 hours before the schedule date and time.

Comments: Late submissions will be rejected without consideration. The University of Colorado Denver | Anschutz Medical Campus (GFE) and the State of Colorado assume no responsibility for costs related to the preparation of submittals.

Agency: University of Colorado Anschutz Medical Campus
Contact Name: Jarrett Smith
Email: jarrett.smith@cuanschutz.edu

Point of Contact/Clarification

Name:	Jarrett Smith
Agency:	University of Colorado Anschutz Medical Campus (GFE)
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Email:	Jarrett.smith@cuanschutz.edu

This Notice is also available on the web at www.colorado.gov/pacific/osa/cdnotices

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Colorado CORE/ColoradoVSS
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**NOTICE TO STATE CONTRACTORS
VACCINATION REQUIREMENTS**



NOTICE LETTER TO CONTRACTORS TEMPLATE

October 06, 2021

All Contractors Working within CU Denver/Anschutz Medical Campus Facilities

Subject: Vaccination Requirements

Dear Contractor:

On August 31, 2021, pursuant to the [Sixth Amended Public Health Order 20-38](#), Limited COVID Restrictions, all State Contractors and State Contractor Workers who physically enter a State Facility shall comply with the Vaccination Requirements included in Section III of the Order. All State Contractors and State Contractor Workers, including individuals who have been infected with and recovered from COVID-19, shall have received their first dose in a two dose COVID-19 series no later than September 30, 2021 and be Fully Vaccinated by October 31, 2021.

On September 30, 2021 the [Seventh Amended Public Health Order 20-38](#) (PHO or Order), allowed for State Contractor Workers to participate in twice weekly COVID-19 testing if they have an employer approved medical or religious exemption or are unvaccinated.

You are receiving this letter because your company has a contract with University of Colorado Denver/Anschutz Medical Campus and, as part of the performance of that contract, certain of your company's personnel (including any subcontractor personnel) are required to or likely will provide contracted goods or services in person and on-site. Therefore, as a contractor, your company is subject to the vaccination or testing requirements set forth in the Order.

As permitted by the Order, University of Colorado Denver/Anschutz Medical Campus State Contractors shall assume responsibility for verification of full COVID-19 vaccination, approving all exemptions for medical or religious beliefs and determining any accommodations needed for such exemptions.

State Contractors shall verify that each of the identified State Contractor Workers is Fully Vaccinated, or that each of the identified State Contractor Works that is unvaccinated or has a medical or religious exemption is participating in twice weekly COVID-19 testing.

Please be aware that the University of Colorado Denver/Anschutz Medical Campus retains the right to inquire into compliance with the Order's requirements at any time, to include requesting a State Contractor to provide proof of vaccination or a recent negative COVID-19 test.

The State of Colorado values your firm as a contract partner to deliver needed goods or services. Accordingly, we are hopeful that your company will comply with the Order and help the state reduce the spread of the virus. In the meantime, please see COVID-19 Vaccination Requirements for State Contractors FAQs. (<https://dhr.colorado.gov/covid-19-vaccination-requirements-for-state-contractors>)

University of Colorado Denver/Anschutz Medical Campus

**STATE OF COLORADO
OFFICE OF THE STATE ARCHITECT
STATE BUILDINGS PROGRAM**



**REQUEST FOR PROPOSALS
FOR AN
INTEGRATED PROJECT DELIVERY METHOD
UTILIZING
CONSTRUCTION MANAGEMENT/GENERAL CONTRACTING (CM/GC) SERVICES**

For The

University of Colorado Anschutz Medical Campus

For The

CU Anschutz Bundled Energy Projects, Project #: 18_052158

**REQUEST FOR PROPOSALS FOR AN
INTEGRATED PROJECT DELIVERY METHOD UTILIZING
CONSTRUCTION MANAGEMENT/GENERAL CONTRACTING (CM/GC) SERVICES**

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B. ORAL INTERVIEWS/COST PROPOSALS CRITERIA

- 1. Qualifications of the Firm(s)**
- 2. Qualifications of the Management Team Members**
- 3. Project Management Approach**
- 4. Prior Project Experience/Success**
- 5. Miscellaneous Considerations**

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**REQUEST FOR PROPOSALS FOR AN
INTEGRATED PROJECT DELIVERY METHOD UTILIZING
CONSTRUCTION MANAGEMENT/GENERAL CONTRACTING (CM/GC) SERVICES
University of Colorado Anschutz Medical Campus**

Settlement Notice

For all projects with a total dollar value above \$150,000 Notice of Final Settlement is required by C.R.S. §38-26-107(1). Final Settlement, if required, will be advertised in the same location as the original solicitation.

I. GENERAL INFORMATION

A. INTRODUCTION/DESCRIPTION OF PROJECT

The University of Colorado Anschutz Medical Campus (CU Anschutz) is seeking General Contractor to pursue the construction of 49 recommended energy conservation measures (ECMs) in seven university facilities. The involved buildings total 1,712,076 gross square feet (GSF). This project would improve the energy efficiency and sustainability of over 40% of the total GSF maintained by the university.

The ECMs were developed in a 2020 Bundled Energy Report prepared for the university. They are bundled by building and type to provide an opportunity to realize material and labor cost savings. Bundling also will allow multiple projects to be concurrently completed to minimize disruptions.

When all projects are complete the university will reduce its emissions of carbon dioxide (CO₂E) by 10,429 metric tons per year. This will help the university meet the GHG reductions in its Climate Action Plan (CAP), the 2026 Strategic Plan, as well as the goals of Colorado HB 19- 1261 and HB 21-1286.

Annual utility cost savings of just over \$2 million will allow the university to realize a simple payback from these measures in just under 5 years. This is a cost-effective way to meet established goals and to remain a leader in use of natural resources and energy.

The Fixed Limit of Construction Cost (FLCC) is \$7 million. The planned schedule to complete all ECMs is approximately 20 months, from January 2022 to September 2023.

This effort includes 49 ECM projects spread across 7 campus buildings to improve their efficiency and reduce the university's energy costs. The ECMs will retrofit older lighting with light emitting diode (LED) systems, optimize lighting operation and controls, optimize HVAC operation, update HVAC equipment, recover energy from waste heat, re-commission and continuously commission HVAC, and install low-flow water fixtures.

In early 2020, the university completed a Bundled Energy Audit Report for the campus. This effort included complete Technical Energy Audits (TEAs) of the Research 2 and Skaggs School of Pharmacy and Pharmaceutical Sciences (SSOPPS) buildings. The team then identified an initial 73 common energy conservation measures (ECMs) that could be implemented in these buildings and seven others. These were then bundled into 12 categories to reflect similar goals and/or project type.

Through the evaluation, the project team recommended that 49 ECMs be pursued. In all, 22 of the recommended ECMs will improve HVAC systems.

ECM Type	Barbara Davis Center	Education 2	EHS	Perinatal Research Facility	Skaggs School of Pharmacy & Pharmaceutical Sciences	Research 1	Research 2	Total ECMs
Lighting: Upgrades	1	1	1	1	1		1	6
Lighting: Controls	1	3	2		1		1	8
HVAC: Controls	4	1	1	3	1		1	11
HVAC: Upgrades	5	2	2	1		1		11
Energy Recovery: Elevators								
Energy Recovery: HVAC			1			2	1	4
Building Envelope					1			1
Commissioning	3				2		2	7
O&M								
Process/Plug Loads								
Water Conservation							1	1
Distributed Generation - PV								
TOTAL	14	7	7	5	6	3	7	49

It is generally thought that due to the number of projects involving HVAC, seasonal assumptions will need to be considered for scheduling construction of these projects.

Please see Appendix G: CU Anschutz Bundled Energy Program Plan; and Appendix H: AECOM Bundled Energy Projects Study for more specific information on the 49 individual ECMs to be pursued. This will serve as schematic design for the project.

CU Anschutz anticipates using a Construction Manager/General Contractor (CM/GC) approach to project delivery. A Guaranteed Maximum Price (GMP) and an updated project duration schedule will be established by the Architect/Engineer and the Construction Manager/General Contractor in conjunction with CU Anschutz. The CM/GC will evaluate, among other things, availability of materials and labor, project schedule, project costs as they relate to the established budget, constructability, and will work closely with the

Architect/Engineer and CU Anschutz throughout the planning, design and construction phases of the project. Construction is estimated to commence **September 2022**.

The process to be used in the selection of the CM/GC is comprised of two steps. STEP I is the Submittal of Prequalification as described in Section II (D). STEP II is the Oral Interview/Cost Proposal as described in detail in Section III. A Jury Panel of individuals who will be involved in the project and/or understand the required services associated with Construction Management/General Contracting will evaluate responses to this RFP for both STEPS. Upon completion of the evaluation of the Submittals of Prequalification, a limited number of firms will be invited to the oral interviews. Sealed fee proposals will be required only from those firms who are interviewed and are to be submitted as indicated in this RFP. Both qualifications and cost will be considered in the final ranking of firms with qualifications given 70% of the value of the weighted criteria and fees for the Cost/ Proposal given 30%.

Selection and award of this project will be based on a combination of qualifications and costs that represents the best overall value to the State.

B. MINIMUM QUALIFICATIONS

Notice is hereby given to all interested parties that all firms will be required to meet ALL of the minimum qualifications to be considered for these projects. To be considered as qualified, interested firms shall have, as a minimum:

1. Provided Construction Management/General Contracting services within the last three (3) years for at least two (2) projects relating to construction of Energy Conservation Measures in existing facilities each in excess of **\$7 million** (hard costs), utilizing the expertise present in their Colorado Office; and
2. Demonstrated specific Construction Management/General Contracting experience in projects of similar scope and complexity and considering abilities to work in sensitive areas on a medical research campus that can include wet research labs, classrooms, offices, etc.; and
3. Demonstrated bonding capability up to **\$8 million** for an individual project coincidentally with current and anticipated workloads; provide letter from surety that affirms this capacity.
- 4) Per C.R.S. §24-92-115 unless prohibited by applicable federal law, contract for any public project in the amount of one million dollars or more, that does not receive federal money, including shall require the general contractor to which the contract is awarded to submit, at the time the mechanical, electrical, or plumbing subcontractor is put under contract, documentation that identifies the contractors or subcontractors that will be used for all mechanical, sheet metal, fire suppression, sprinkler fitting, electrical, and plumbing work required on the project and certifies that all firms identified participate in apprenticeship programs registered with the United States department of labor's employment and training administration or state apprenticeship councils recognized by the United States department of labor and have a proven record of graduating a minimum of 15% of its apprentices for at least three of the past five years.

C. SCOPE OF SERVICES

The scope of services will include assistance to the State during the process of assessment, design, construction, and warranty period. Specific tasks to be performed by the Construction Manager/General Contractor (CM/GC) include those generally performed by the CM/GC construction community where the Construction Manager is also the Contractor. A sample copy of the State's CM/GC contract is contained within the RFP. A Guaranteed Maximum Price (GMP) will be required at the completion of Design Development phase.

A public construction project in the amount of five hundred thousand dollars or more shall be subject to the State prevailing wage rate, of the regular, holiday, and overtime wages paid and the general prevailing payments on behalf of employees to lawful welfare, pension, vacation, apprentice training, and educational funds in the State, for each employee needed to execute the contract. Payments to the funds must constitute an ordinary business expense deduction for federal income tax purposes by contractors and subcontractors. Contractors are required to pay their employees at weekly intervals and shall comply with the enforcement provisions of C.R.S. §24-92-209

II. PREQUALIFICATION SUBMITTALS (STEP I)

A. SCHEDULE

1. The schedule of events for the RFP process and an outline of the schedule for the balance of the project is as follows:

Advertisement	Jan 14, 2022
Mandatory Pre-submittal Conference (Zoom Meeting)	Jan 19, 2022 – 2:00PM
Date Email Questions Due	Jan 26, 2022 – 2:00PM
Date Email Answers Issued	Jan 28, 2022
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Interview Short List Announced	March 1, 2022
Sealed Proposal Due (Evaluation and Award: Step II)	Est. March 9, 2022
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Contract Approval (projected)	April 5, 2022
Anticipated Design Start	April 5, 2022
Anticipated CM/GC Start	April 5, 2022
Anticipated Construction Start/Finish	Sep 2022 – Sep 2023

2. **One (1)** Electronic Copy of the submittal is due **February 15th** and shall be received no later than **2:00 PM** AM/PM (MD/ST), at the following address:

https://ucdenverdata.formstack.com/forms/rfp_rfq_submission

3. The above schedule is tentative. Responding firms shall be notified of revisions in a timely manner by email. Respondents may elect to verify times and dates by email, but no earlier than 36 hours before the schedule date and time.

B. MANDATORY PRE-SUBMITTAL CONFERENCE

1. To ensure sufficient information is available to firms preparing submittals, a mandatory pre-submittal conference has been scheduled. The intent of this conference is explain the project and to have CU Anschutz staff able to discuss the project. Firms preparing submittals must attend and sign-in in order to have their submittals accepted. The pre-submittal conference will be held at:

ZOOM Conference: <https://ucdenver.zoom.us/j/94258399044>

Date/Time: **January 19, 2022 at 2 PM**

C. CLARIFICATIONS

1. Owner initiated changes to this RFP will be issued under numerically sequenced email addenda. Addenda generally consist of the following items:
 - a. Clarifications
 - b. Scope Changes
 - c. Time and/or Date Changes

Respondents must acknowledge all issued addenda in their submittal and proposal.

2. Respondent initiated email requests for clarification will be received any time on or before to **January 26, 2022, 2:00PM** All State responses will be issued by email addenda on or before **January 28, 2022, 2:00PM**.

D. GENERAL INFORMATION

1. All respondents accept the conditions of this RFP, including, but not limited to, the following:
 - a. All submittals shall become the property of the State of Colorado and will not be returned.
 - b. Late submittals shall not be evaluated. Facsimile submittals shall not be accepted.
 - c. Any restriction as to the use of submitted materials must be clearly indicated as proprietary. The requested limitation or prohibition of use or release shall be identified in writing on a cover sheet. Blanket claims of proprietary submittals will not be honored. Fee proposals will be considered proprietary.
 - d. The State reserves the right to reject any or all proposals on the basis of being unresponsive to this RFP or for failure to disclose requested information.

- e. The State shall not be liable for any costs incurred by respondents in the preparation of submittals and proposals nor in costs related to any element of the selection and contract negotiation process.
- f. The respondent has reviewed Appendix B and by responding has agreed that the terms and conditions of the sample Construction Management/General Contracting Agreement are expressly workable without reservation.

E. PREQUALIFICATION SUBMITTALS (STEP I)

1. Respondent must comply with the following items, "a" through "l". The State of Colorado retains the right to waive any minor irregularity or requirement should it be judged to be in the best interest of the State. **(Note that the primary focus of the Prequalification evaluation will be the firm(s)' capabilities).**
 - a. Submit **One (1)** PDF complete copy of all materials.
 - b. Submittals shall be formatted and tabbed in the exact form and numeric sequence of the Evaluation Form (1 through 5) in Appendix A.
 - c. A one-to-two-page cover letter addressed to the University of Colorado Anschutz Medical Campus, Attn: Jarrett Smith outlining the firm(s) qualifications is required at the front of the submittal.
 - d. Submittals should not exceed 20 (letter size) PDF pages of content.
 - e. The cover page and section title pages do not count towards the 20-page limit.
 - f. Do not use smaller than 10-point fonts in the submittal.
 - g. Submittals should be ordered and contain the five sections as outlined in section II. SUBMITTAL REQUIREMENTS. Separate each section by a title page.
 - h. Submittals are limited to **25 MB** by the submission website.
 - i. Submittals shall be evaluated in accordance with criteria as listed in SECTION IV., A. PREQUALIFICATION SUBMITTAL CRITERIA and ranked on the corresponding Evaluation Form in Appendix A.
 - j. Response to all items shall be complete.
 - k. All project references shall be current and relevant.
 - l. Complete and execute the appropriate Acknowledgment and Attestation Form as provided in Section VI and submit at the back of the Prequalification Submittal.

III. ORAL INTERVIEWS/COST PROPOSALS (STEP II)

A. SHORT LIST

From the submittals received, a short list of qualified respondents shall be identified using the scoring indicated on the enclosed Evaluation Form, Appendix A.

Firms failing to meet the minimum required qualifications will not receive further consideration.

B. ORAL INTERVIEW

1. Mandatory oral interviews shall be conducted for the short listed firm(s) only. Interview times and location, will be arranged by CU Anschutz and all short listed firms will be notified in advance. At the option of the State, a visit to the short listed firm(s) managing home office and/or representative field office may be required. **(Note that the primary focus of the Oral Interview evaluation in addition to the Cost Proposal will be the proposed Project Management Team members' capabilities).**

C. COST PROPOSALS (See Appendix I)

1. Only those firms short listed for interview are required to submit their sealed proposals. (Only one copy is required on the scheduled submission date.) Cost Proposals will remain sealed until after the qualitative scoring and will then be opened. The Cost Proposal will then be considered (equivalent to 40 percent of the weighted criteria) in conjunction with the qualitative score from the response and interview (equivalent to 60 percent of the weighted criteria).
2. Cost Proposals shall be submitted on the form provided in Section VII, without modification. A Cost Proposal shall be accompanied with sufficient detail to clearly identify the fee for service and include a detailed schedule of estimated (not-to-exceed) reimbursable and non-reimbursable costs. Percentage of the cost of work is not an acceptable value. The Cost Proposal should be prepared independently in accordance with the following:
 - a. Any specific services requested in the RFP and its appendices that are not included should be clearly identified. Exclusion of any required service may result in the proposal being found non-responsive.
 - b. Provide a CM/GC staff schedule with staff by name, position and man-hours (assume 8 hour days) per month estimated on the project.
 - c. Provide a detailed estimate of reimbursable costs including breakdown of direct salaries and payroll fringes (DPE) for on-site CM/GC personnel associated with the services. Not-to-exceed reimbursable expenses shall be provided at direct cost.
 - d. Provide a detailed estimate of non-reimbursable expenses (included in fee).
 - e. The State reserves the right to reject any Cost Proposal not prepared in the above manner. Proposals that exceed the available funds may be rejected outright but the State reserves the right to negotiate a reasonable fee for service within the available funds. The CM/GC contract will be a bonded lump sum contract including not-to-exceed reimbursables with a Guaranteed Maximum Price to encompass all construction work; some not-to-exceed allowances may be included as directed by the State.
3. This Fee Proposal is a binding offer to perform the services associated with the Scope of Services described in this RFP and the Designated Services and Method of Payment Matrix in Appendix B. The State reserves the right to negotiate a cost adjustment based on scope clarification subsequent to selection and prior to contract execution.

D. METHOD OF SELECTION AND AWARD

The Jury Panel shall complete a combined evaluation of qualifications and fee in accordance with the criteria as indicated in SECTION IV, B. ORAL INTERVIEWS/COST PROPOSALS/EVALUATION CRITERIA. Numerical ranking and selection of the most qualified firm (including fee) will then occur on the corresponding evaluation forms in Appendix A1.

The final fee amount and scope of services may be negotiated at the State's discretion. Award and contract will be contingent on availability of key proposed Project Management Team staff.

IV. EVALUATION CRITERIA

A. PREQUALIFICATION SUBMITTAL CRITERIA

(Note that the primary focus of the Prequalification evaluation will be the Firm(s) capabilities).

1. QUALIFICATIONS OF THE FIRM(S)

- ☐ Provide a description of the composition and management structure of your firm. Identify the firm's roles and responsibilities and relevant experience with projects of similar scope and complexity and similar fast track project delivery methods. Describe how the firm's experience will relate to the success of this project.
- ☐ Provide a description and separate graphic organizational chart complete with working titles identifying the lines of authority, responsibility and coordination.
- ☐ Provide a detailed description of the process of how your firm selects qualified sub-contractors and manages them effectively on complex multi-phased projects.
- ☐ Provide a detailed description of how your firm will maximize the Colorado construction work force on this project.
- ☐ Provide your firms' safety record over the last ten years and describe your firms' efforts to retain and support employees.

2. QUALIFICATIONS OF THE MANAGEMENT TEAM MEMBERS

- ☐ Describe the qualifications and relevant experience of the superintendent including demonstrated experience working on projects of similar scope and complexity and time commitment for this project.
- ☐ Describe the qualifications and relevant experience of other key in-house staff and time commitments for this project.
- ☐ Identify all current office locations of the assigned staff and any other resident expertise intended to be provided under this RFP.

3. PROJECT MANAGEMENT APPROACH

- ☐ Provide a strategic project approach summary: Include discussion of your firm's approach in providing successful Construction Management/General Contracting services based on prior experience in cost, schedule and quality effectiveness. Include specific examples (1-2 page excerpts) of actual products (estimates, progress reports, schedules, constructability reviews, value engineering studies, forms, general conditions budgets, organizational structures, etc.).

- ☐ Provide a description of construction work Project Management Team has capability to competitively bid and self-perform, including qualifications to do such. It is the perception of CU Anschutz subcontracting CM/GC construction work is in the State's best interest in terms of price competition. The university may, at its discretion, limit the types and amount of work Project Management Team bids and self-performs.

4. PRIOR PROJECT EXPERIENCE/SUCCESS

Select your three (3) most relevant projects and provide, at a minimum, the following:

- ☐ The project/contract name
- ☐ Description of services provided
- ☐ Overall construction cost of project, as applicable, including initial contract value and change orders including reasons for change orders
- ☐ Organizational structure of service delivery under the contract (include the owner's organization as it interfaced with the respondent's contract)
- ☐ Key assigned in-house staff (name and title)
- ☐ Subcontracts (service) used in the performance of the contract
- ☐ Schedule history
- ☐ Reference(s) for Owner and Architect as described in IV.E
- ☐ Continuing services, if any

a. Timeliness

In general, Construction Management/General Contracting work is seen as successful if it is on time, on budget, and of high quality of workmanship. Timeliness is generally based on completion by the originally scheduled date and is indicated by a Certificate of Occupancy. Please demonstrate for each of the above projects how timely delivery occurred.

b. Budget Considerations

Similar to timeliness, being on budget historically means the work was completed within the originally identified available budget. For purposes of this RFP, the State is interested not only in being within budget but also in the respondent's ability to address and implement the following issues as well:

1. Conceptual estimating
2. Value analysis
3. Alternate solutions
4. Scope reduction that maintains project function
5. Cost/benefit analysis

Demonstrate for the above projects examples of how you accomplished the above cost control services.

c. Quality

Construction quality has the obvious traditional connotations (workmanlike, in compliance with the specifications, normal standard of care, etc.). Demonstrate for the above project examples how a high quality of workmanship was achieved.

d. Services Disruption

Demonstrate how your services on the above project examples dealt with issues of disruption at existing facilities, etc. if applicable.

e. Project Acceptability

Please discuss how your Construction Management/General Contracting services helped achieve owner satisfaction with regard to project quality and acceptability on your project examples.

f. Compliance

Provide information on how compliance with industry standards of care, building codes, etc. was achieved.

5. MISCELLANEOUS CONSIDERATIONS

a. Claims/Litigation History of Firm

Provide information on any past, current or anticipated claims (i.e., knowledge of pending claims) on respondent contracts; explain the litigation, the issue, and its outcome or anticipated outcome.

b. Apprenticeship Training Program (Optional for Step I)

Where an Apprentice Training Program certified by the Office of Apprenticeship located in the Employment and Training Administration in the United States Department of Labor exists in the State, or a comparable program for the training of apprentices is available in the State:

1. Each submitter shall demonstrate access to the certified program or a comparable alternative (Note that it is the responsibility of the submitter to demonstrate the comparability of a non-certified program) and,
2. Each submitter's subcontractor at any tier with a contract value of two hundred fifty thousand dollars or more shall demonstrate access to the certified program or a comparable alternative.

c. Other

This category is included for other items provided by the submitter. Inclusions may include standard firm promotional literature, testimonials, awards, corporate memberships in professional organizations or sponsorships, additional project/contract histories, etc., intended to demonstrate why your firm is uniquely qualified for this project.

B. ORAL INTERVIEWS/COST PROPOSALS EVALUATION CRITERIA

(Note that the primary focus of the Oral Interview evaluation in addition to the Cost Proposal will be the proposed project management team members' capabilities).

1. QUALIFICATIONS OF THE FIRM

- ☐ Explain the composition and structure of your project management team and how the firm will support their efforts in the field throughout this project.
- ☐ Are the lines of authority, responsibility and coordination clearly identified?

2. QUALIFICATIONS OF THE MANAGEMENT TEAM MEMBERS

- ☐ Explain the prior experience with projects of similar scope and complexity and similar fast track project delivery methods of the superintendent and all other project management team members. Explain their roles and responsibilities and authority and why they are the right team members for this project.
- ☐ Explain anticipated project management team staff current and projected workload.
- ☐ Identify all current office locations and the resident expertise intended to be provided under this RFP. Identify the location of the staff for the performance of this contract, their expertise, and generic equipment that will be located in Colorado and act in support of the anticipated contract.

3. PROJECT MANAGEMENT APPROACH

- ☐ Explain the strategic project approach for this project in summary: Include discussion of your team's approach in providing successful CM/GC services based on the needs of this specific project utilizing the team's prior past experience including cost, schedule, and quality control.
- ☐ Explain the construction work the project management team has the capability to competitively bid and self-perform including qualifications to do such work.
- ☐ Provide a detailed description of how your project management team will select qualified sub-contractors and manage them effectively on this project.

4. PRIOR PROJECT EXPERIENCE/SUCCESS

- ☐ Explain the most relevant projects the superintendent and the team members have completed together and/or separately and what their role was. CU Anschutz at its discretion contact references and/or conduct independent performance analysis on projects on which the team member has worked).
- ☐ Provide descriptions of other related experience of superintendent and other project management team members.

5. MISCELLANEOUS CONSIDERATIONS

- ☐ Craft Labor Capabilities
Describe the availability of resources that will be utilized to successfully complete the project.
- ☐ Apprenticeship Training Program (Mandatory for Step II)
Describe access to federal or state-approved apprenticeship programs, as available.
- ☐ Other
This category is included for other items provided by the presenter. Inclusions may include testimonials, awards, corporate memberships in professional organizations or sponsorships, additional project/contract histories, etc., intended to demonstrate why this management team is uniquely qualified for this project.

V. CM/GC CONTRACT INFORMATION

- A. Carefully review the CM/GC Contract sample (Appendix B) before initiating your response submittal. Any exceptions to the contract must be communicated formally in accordance with the written questions schedule in II.A.
- B. Appendix C of this RFP is the Certification and Affidavit Regarding Illegal Immigrants, a mandatory portion of the contract agreement.
- C. Appendix E and F of this RFP includes mandatory State apprenticeship and prevailing wage requirements based on the construction value of the project.
- D. The State reserves the right to make non-material changes to the appended model agreement, including additions and /or modifications that may be necessary to more completely describe the services defined or implied herein.
- E. Any approved reimbursable expenses made under the terms of the final agreement shall be a direct pass-on cost with no adjustment to the fee described therein.
- F. Any and all products, systems, methods, and procedures developed, as a result of this agreement shall remain the exclusive property of the State.

VI. ACKNOWLEDGEMENT AND ATTESTATION FORM

- A. Several versions of the Acknowledgment and Attestation Form follow this section. Proper completion of the appropriate form is a mandatory requirement for a respondent to be considered responsive to this RFP Prequalification Submittal.
- B. Qualifications made by a respondent in executing this form may render a submittal non-responsive as determined by the State.

VII. COST PROPOSAL FORM

- A. Immediately following the Acknowledgement and Attestation Form is a Cost Proposal Form to be utilized to summarize the fee proposal for the services. Only those firms short-listed will be required to submit fee proposals as directed by CU Anschutz.
- B. This RFP document, it's appendices, and any written addenda issued prior to the submittal of proposals, and written clarifications prior to the interview shall serve as the only basis for proposals.
- C. The respondent, by submitting this proposal, does hereby accept that minor changes by the State to the exhibited contract and its exhibits, which do not adversely affect the respondent, shall not be cause for withdrawal or modification of the amounts submitted herein. Exceptions to the RFP documents and/or modification of the proposal may render the proposal non-responsive.
- D. Upon due consideration and review of this document along with its appendices, written addenda, and written clarifications prior to the interview, the respondent does hereby submit the following proposal for Construction Management/General Contracting fees, consistent with the schedules provided in the Scope of Services. Respondents are hereby advised that it is the State's desire to accelerate design and construction schedules where reasonably possible, without adverse cost impact.

- E.** Respondent should complete the Cost Proposal Form by filling in all blanks on the form that follows.
- F.** Respondents should include a separate detailed not-to-exceed reimbursable estimate

End of RFP

**ACKNOWLEDGEMENT AND ATTESTATION FORM
(Partnership Format)**

Date: _____

Page 1 of 1

By responding to this RFP, the respondent(s) certify that he/she has reviewed the Construction Management/General Contracting sample contract, and its exhibits contained herein, and is familiar with their terms and conditions and finds them expressly workable without change or modification.

We certify and declare that the foregoing is true and correct.

Subscribed on _____ at _____
Date City

_____, State of _____
County State

1) _____
Partner Signature

Typed Name: _____

2) _____
Partner Signature

Typed Name: _____

Notary: _____ Date _____

Commission Expires: _____

Note: Add additional signatures if there are more than two partners.

ACKNOWLEDGEMENT AND ATTESTATION FORM
(Joint Venture Format)

Date: _____

Page 1 of 1

By responding to this RFP, the respondent(s) certify that he/she has reviewed the Construction Manager/General Contractor sample contract, and its exhibits contained herein, and is familiar with their terms and conditions and finds them expressly workable without change or modification.

We certify and declare that the foregoing is true and correct.

Subscribed on _____ at _____,
Date City

_____, State of _____
County State

1) _____
Venture Partner Binding Signature Date

Type of Business Typed Name: _____
Title: _____

Witness Date

Typed Name: _____

2) _____
Venture Partner Binding Signature Date

Type of Business Typed Name: _____
Title: _____

Witness Date

Typed Name: _____

Note:

1. Add additional venture partners as necessary.
2. Witnesses of venture partners shall be corporate secretary for corporations, partners for partnerships, and notaries for sole proprietorships.
3. Attach venture agreement
4. Type of business shall identify the venture partner as a corporation, venture, partnership, sole proprietorship, or other legal entity.

ACKNOWLEDGEMENT AND ATTESTATION FORM (CORPORATE FORMAT)

Date: _____

Page 1 of 1

By responding to this RFP, the respondent(s) certify that he/she has reviewed the Construction Management/General Contracting sample contract, and its exhibits contained herein, and is familiar with their terms and conditions and finds them expressly workable without change or modification.

We certify and declare that the foregoing is true and correct.

Subscribed on _____ at _____,
Date City

_____, State of _____,
County _____ State _____

Corporate Officer Signature

Date _____

Secretary

Date _____

Note: Use full corporate name and attach corporate seal here.

(SEAL)

ACKNOWLEDGEMENT AND ATTESTATION FORM (Sole Proprietorship Format)

Date: _____

Page 1 of 1

By responding to this RFP, the respondent(s) certify that he/she has reviewed the Construction Management/General Contracting sample contract, and its exhibits contained herein, and is familiar with their terms and conditions and finds them expressly workable without change or modification.

We certify and declare that the foregoing is true and correct.

Subscribed on _____ at _____,
Date City

_____, State of _____
County State

Respondent

Date _____

Typed Name: _____

Notary: _____

Date _____

Commission Expires: _____

COST PROPOSAL FORM
CONSTRUCTION MANAGER/GENERAL CONTRACTING (CM/GC) SERVICES
(See Appendix I)

Date: _____

Project Title

1.	CM/GC Preconstruction Fee	\$ _____
2.	CM/GC Construction Fee	\$ _____
3.	General Conditions On-Site CM/GC Staff	\$ _____
4.	Other Reimbursable General Conditions (NTE)	\$ _____
	Total CM/GC Fee	\$ _____

Fees are to be calculated per Exhibit A (SC-6.5), CM/GC Designated Services and Method of Payment.

Please provide a detailed breakdown to adequately describe the CM/GC staff provided, term of their services, and associated anticipated reimbursable costs so as to demonstrate as complete an understanding as possible of the services provided.

Reimbursable general condition expenses are generally confined to the on-site CM/GC construction phase staff reimbursed at direct personnel expense, plus those on-site materials, equipment and facilities to support the work of the CM/GC staff and construction subcontractors.

Acknowledge receipt of Addendum Nos. _____

Anticipates Services outside the United States or Colorado* ☐ Yes ☐ No

If the respondent anticipates services under the contract or any subcontracts will be performed outside the United States or Colorado, the respondent shall provide in a written statement which must include, but need not be limited to the type of services that will be performed at a location outside the United States or Colorado and the reason why it is necessary or advantageous to go outside the United States or Colorado to perform such services. (Does not apply to any project that receives federal moneys)

Will comply with 80% Colorado Labor ☐ Yes ☐ No

For State Public Works Project per C.R.S 8-17-10, Colorado labor shall be employed to perform at least 80% of the work. "Colorado Labor" means any person who is a resident of the state of Colorado at the time of the Public Works project. Respondents indicating that their bid proposal will not comply with the 80% Colorado Labor requirement are required to submit written justification along with the bid submission. A governmental body that allows a waiver shall post notice and justification for the waiver on its web site. (Does not apply to any project that receives federal moneys)

Bidder is a Service-Disabled Veteran Owned Small Business* ☐ Yes ☐ No

A Service-Disabled Veteran Owned Small Business (SDVOSB) per C.R.S. 24-103-905, means a business that is incorporated or organized in Colorado or maintains a place of business or has an office in Colorado and is officially registered and verified by the Center for Veteran Enterprise within the U.S. Department of Veteran Affairs. Attach proof of certification along with the proposal submission.

**Does not apply to projects for Institutions of Higher Education that have opted out of the State Procurement Code.*

Applicant or Corporate Officer Signature

Title

Appendix A

STATE BUILDINGS PROGRAM PREQUALIFICATION SUBMITTAL/EVALUATION FORM CONSTRUCTION MANAGEMENT/GENERAL CONTRACTING (CM/GC) SERVICES

Name of Firm: _____

Name of Project: _____

Evaluator No: _____ Date: _____

RFP REFERENCE

MINIMUM REQUIREMENTS

Y ____ N ____

If the minimum requirements (including letter from surety) have not been met, specify the reason(s):

Acknowledgement and Attestation included:

Y ____ N ____

SCORE

Weight² x Rating³ = Score

1. QUALIFICATIONS OF THE FIRM(S)¹

<input type="checkbox"/> Qualifications of the firm	<u>2</u>	x	_____	=	_____
<input type="checkbox"/> Organizational structure/lines of authority	<u>2</u>	x	_____	=	_____
<input type="checkbox"/> Subcontractor selection and management	<u>2</u>	x	_____	=	_____
<input type="checkbox"/> Colorado workforce	<u>2</u>	x	_____	=	_____
<input type="checkbox"/> Safety/employee support	<u>2</u>	x	_____	=	_____

2. QUALIFICATIONS OF THE MANAGEMENT TEAM MEMBERS¹

<input type="checkbox"/> Qualifications and relevant experience of superintendent	<u>3</u>	x	_____	=	_____
<input type="checkbox"/> Qualifications and relevant experience of in-house staff	<u>2</u>	x	_____	=	_____
<input type="checkbox"/> Location/Access	<u>2</u>	x	_____	=	_____

3. PROJECT MANAGEMENT APPROACH¹

<input type="checkbox"/> Approach to successful CM/GC Services					
a. Cost effectiveness	<u>3</u>	x	_____	=	_____
b. Schedule effectiveness	<u>3</u>	x	_____	=	_____
c. Quality effectiveness	<u>3</u>	x	_____	=	_____
<input type="checkbox"/> Competitively Bid/Self Performed Work	<u>3</u>	x	_____	=	_____

4. PRIOR PROJECT EXPERIENCE/SUCCESS¹

<input type="checkbox"/> Project #1		<u>2</u>	x	<u> </u>	=	<u> </u>
a. Timeliness	d. Disruption					
b. Budget Considerations	e. Acceptability					
c. Quality	f. Compliance					
<input type="checkbox"/> Project #2		<u>2</u>	x	<u> </u>	=	<u> </u>
a. Timeliness	d. Disruption					
b. Budget Considerations	e. Acceptability					
c. Quality	f. Compliance					
<input type="checkbox"/> Project #3		<u>2</u>	x	<u> </u>	=	<u> </u>
a. Timeliness	d. Disruption					
b. Budget Considerations	e. Acceptability					
c. Quality	f. Compliance					
<input type="checkbox"/> Related experience of the firm		<u>2</u>	x	<u> </u>	=	<u> </u>

5. MISCELLANEOUS¹

<input type="checkbox"/> Claims/litigation history	<u>1</u>	x	<u> </u>	=	<u> </u>
<input type="checkbox"/> Apprenticeship Training Program	<u>1</u>	x	<u> </u>	=	<u> </u>
<input type="checkbox"/> Other	<u>1</u>	x	<u> </u>	=	<u> </u>

TOTAL SCORE: ⁴

NOTES:

1. **Criteria:** Agencies/Institutions are encouraged to include additional criteria that reflect unique characteristics of the project under each category to help determine the submitter's overall qualifications.
2. **Weights:** Agency/Institutions to assign weights, using whole numbers, to all criteria on evaluation forms for inclusion into RFQ document and prior to evaluations.
3. **Ratings:** Evaluator to assess the strength of each firms qualifications and assign a numerical rating of 1 to 5 with 5 being the highest rating. (Use whole numbers)
4. **Total Score:** Includes the sum of all criteria. Note: a passing score (as a percentage of the total points available) is optional and should be assigned by the agency/institution prior to evaluation.

Appendix A1

STATE BUILDINGS PROGRAM ORAL INTERVIEWS/COST PROPOSALS EVALUATION FORM CONSTRUCTION MANAGEMENT/GENERAL CONTRACTING (CM/GC) SERVICES

Name of Firm: _____
Name of Project: _____
Evaluator No: _____ Date: _____

SCORE

Score	Weight ²	x	Rating ³	=
1. <u>QUALIFICATIONS OF THE TEAM</u> ¹	<u>2</u>	x	_____	= _____
2. <u>QUALIFICATIONS OF THE MANAGEMENT TEAM MEMBERS</u> ¹	<u>2</u>	x	_____	= _____
3. <u>PROJECT MANAGEMENT APPROACH</u> ¹	<u>3</u>	x	_____	= _____
4. <u>PRIOR PROJECT EXPERIENCE/SUCCESS</u> ¹	<u>2</u>	x	_____	= _____
5. <u>MISCELLANEOUS</u> ¹				
<input type="checkbox"/> Craft Labor Capabilities	<u>1</u>	x	_____	= _____
<input type="checkbox"/> Apprenticeship Training Program	<u>1</u>	x	_____	= _____
<input type="checkbox"/> Other	<u>1</u>	x	_____	= _____
TOTAL SCORE:				_____ ⁴

NOTES:

- Criteria:** Agencies/Institutions are encouraged to include additional criteria that reflect unique characteristics of the project under each category to help determine the submitter's overall qualifications.
- Weights:** Agency/Institutions to assign weights, using whole numbers, to all criteria on evaluation forms for inclusion into RFQ document and prior to evaluations.
- Ratings:** Evaluator to assess the strength of each firm's qualifications and assign a numerical rating of 1 to 5 with 5 being the highest rating. (Use whole numbers)
- Total Score:** Includes the sum of all criteria. Note: a passing score (as a percentage of the total points available) is optional and should be assigned by the agency/institution prior to evaluation.

Appendix A2

STATE BUILDINGS PROGRAM SUBMITTAL AND ORAL INTERVIEW RANKING MATRIX

QUALIFICATIONS 70%/FEE 30% *(Optional 80%/20%)*

FIRM	QUALIFICATIONS ¹						AVERAGE QUALS ²	QUALS SCORE ³	FEE SCORE ⁴	QUALS & FEE SCORE ⁵	RANK ⁶
	EVAL #1	EVAL #2	EVAL #3	EVAL #4	EVAL #5	EVAL #6					

NOTES:

1. Insert total score from each evaluator's PREQUALIFICATION SUBMITTAL or ORAL INTERVIEW/ COST PROPOSALS/EVALUATION FORMS. (Note that the use of the Matrix for the PREQUALIFICATION SUBMITTAL EVALUATION does not consider cost proposals only qualifications). DO NOT combine the scores of the two evaluation forms.
2. Add all evaluators' total scores and divide by the number of evaluators to determine the average score for each firm's qualifications.
3. The highest score for qualifications on the evaluation form is to receive 70 points and the other team scores are to be determined as a percentage of the 70 points. To score each average qualification score, use the example formula.

Assume the highest score is 700.

SCORING OF QUALIFICATIONS

FIRM B: $\frac{700}{700} \times 70 \text{ points} = 70 \text{ points}$

FIRM C: $\frac{600}{700} \times 70 \text{ points} = 60 \text{ points}$

FIRM A: $\frac{500}{700} \times 70 \text{ points} = 50 \text{ points}$

4. Determine score for each firm's sealed cost proposal with the lowest fee being equivalent to a score of 30 points. To score each fee, use the example formula.

Assume the lowest fee was \$100,000.

SCORING OF FEES

FIRM A: $\frac{\$100,000}{\$100,000} \times 30 \text{ points} = 30 \text{ points}$

FIRM B: $\frac{\$100,000}{\$125,000} \times 30 \text{ points} = 24 \text{ points}$

FIRM C: $\frac{\$100,000}{\$150,000} \times 30 \text{ points} = 20 \text{ points}$

5. Add the average qualification score to the fee score to determine cumulative qualifications and fee score.
6. Numerically rank all firms with the highest scoring firm being the most qualified.

Appendix B

CONSTRUCTION MANAGER/GENERAL CONTRACTOR (CM/GC) AGREEMENT (FORM SC-6.51) (Sample)

[HTTPS://DOCS.GOOGLE.COM/DOCUMENT/D/1JOCVBRQIV3WPELMSAXFIHP1SJZLIQU
BU/EDIT?USP=SHARING&OUID=113697161025769927384&RTPOF=TRUE&SD=TRUE](HTTPS://DOCS.GOOGLE.COM/DOCUMENT/D/1JOCVBRQIV3WPELMSAXFIHP1SJZLIQU
BU/EDIT?USP=SHARING&OUID=113697161025769927384&RTPOF=TRUE&SD=TRUE)

Appendix C

CERTIFICATION AND AFFIDAVIT REGARDING Unauthorized Immigrants (Form UI-1)

<https://docs.google.com/document/d/0ByG39KP3LPICQIN0eUxSV2JmN1k/edit?usp=sharing&ouid=113697161025769927384&resourcekey=0-oyYb-0jV7ZJ210ewmlqWCg&rtpof=true&sd=true>

Appendix D

DIRECT LABOR BURDEN (SBP-6.18)

<https://docs.google.com/document/d/1dZ6w4PSvNQUAeDbOvY9ZZyFWKE2oN4lw/edit?usp=sharing&oid=113697161025769927384&rtpof=true&sd=true>

Appendix E

APPLICABLE PREVAILING WAGE RATES

TO BE VERIFIED BY CONTRACTOR THROUGH OFFICE OF STATE ARCHITECT

https://drive.google.com/file/d/1H1Jjs388YUX1GxgtXI-eD_XtmT1-Ntyh/view?usp=sharing

Appendix F

APPRENTICESHIP CERTIFICATION (SBP-6.17)

[HTTPS://DOCS.GOOGLE.COM/DOCUMENT/D/1J4MSGuLYZTO3FgTcvGKRYBAoALDKC8AM/EDIT?USP=SHARING&OID=113697161025769927384&RTPOF=TRUE&SD=TRUE](https://docs.google.com/document/d/1J4MSGuLYZTO3FgTcvGKRYBAoALDKC8AM/edit?usp=sharing&oid=113697161025769927384&rtopf=true&sd=true)

Appendix G

CU ANSCHUTZ BUNDLED ENERGY PROGRAM PLAN

CU Anschutz Bundled Energy Conservation Measures (ECMs)

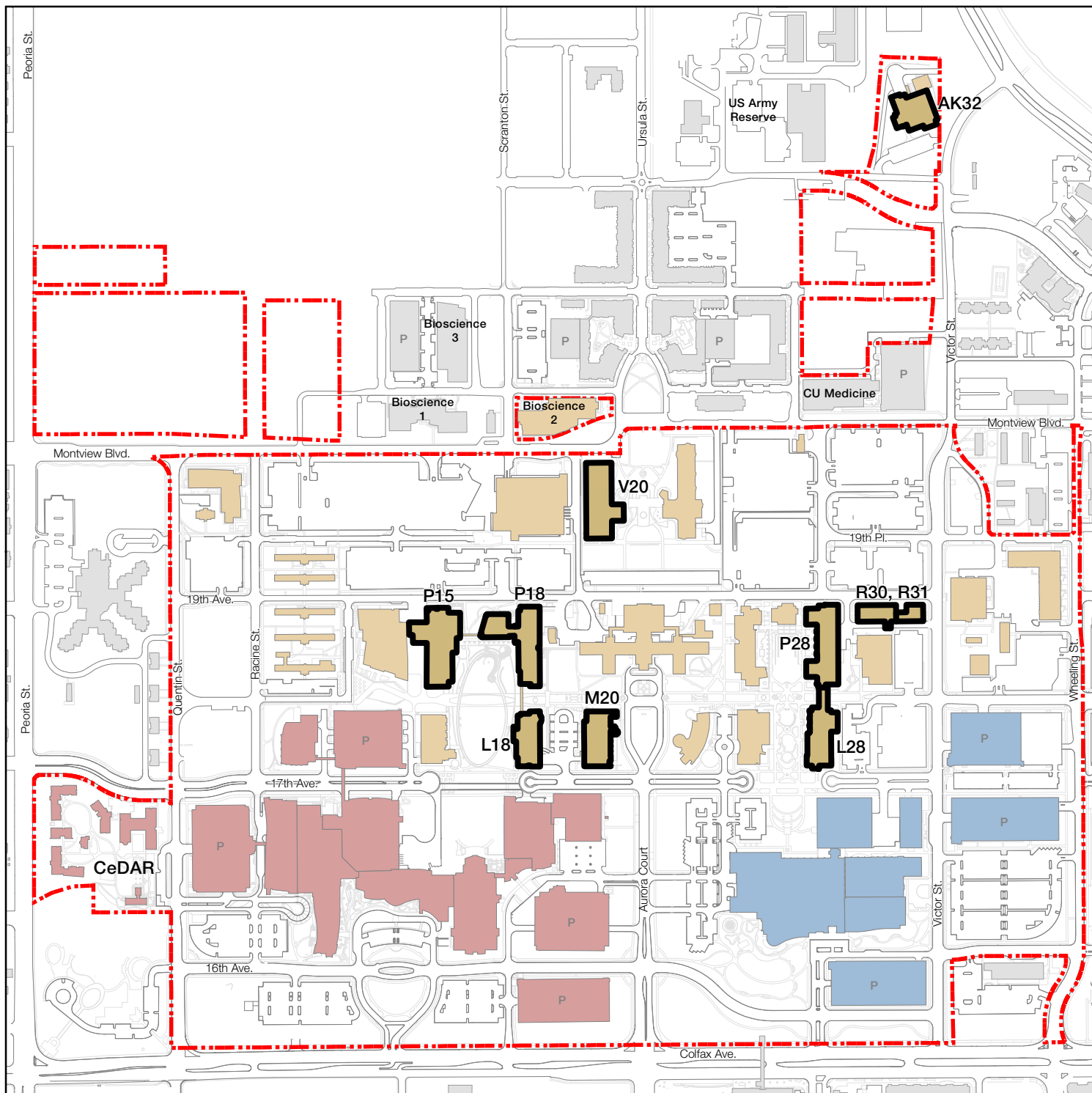
PROGRAM PLAN

November 4, 2021

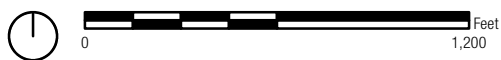


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- Anschutz Medical Campus
- Building with Proposed ECM Projects
- University of Colorado (CU)
- UCHHealth (UCH)
- Children's Hospital Colorado (CHCO)
- Other Building



Projects by Building and ECM Type

Lighting: Upgrades	1	1	1	1	1		1
Lighting: Controls	1	3	2		1		1
HVAC: Controls	4	1	1	3	1		1
HVAC: Upgrades	5	2	2	1		1	
Energy Recovery: HVAC			1			2	1
Building Envelope					1		
Commissioning	3				2		2
Water Conservation							1

Barbara Davis Center
M20
 Education 2
L28, P28
 EHS
R30, R31
 Perinatal Research Facility
AK32
 Skaggs School of Pharmacy
V20
 Research 1
L18, P18
 Research 2
P15

I. EXECUTIVE SUMMARY

The University of Colorado Anschutz Medical Campus (CU Anschutz) is seeking spending approval from the University of Colorado Board of Regents (CU BOR) to proceed with the construction of 49 recommended energy conservation measures (ECMs) in seven university facilities.

The involved buildings total 1,712,076 gross square feet (GSF). This project would improve the energy efficiency and sustainability of over 40% of the total GSF maintained by the university. This figure includes the Anschutz Health Sciences Building that will open in Fall 2021.

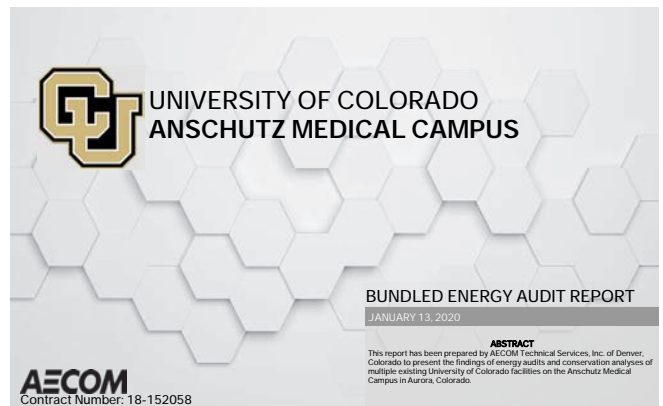
The ECMs were developed in a 2020 Bundled Energy Report prepared for the university that is available for review. They are bundled by building and type to provide an opportunity to realize material and labor cost savings. Bundling also will allow multiple projects to be concurrently completed to minimize disruptions.

When all projects are complete the university will reduce its emissions of carbon dioxide (CO₂E) by 10,429 metric tons per year. This will help the university meet the GHG reductions in its Climate Action Plan (CAP), the 2026 Strategic Plan, as well as the goals of Colorado HB 19-1261 and HB 21-1286.

Annual utility cost savings of just over XX million will allow the university to realize a simple payback from these measures in XX years. This is a cost-effective way to meet established goals and to remain a leading AHC in its use of natural resources and energy.

The total project budget is XXXXXXXXXXXX to be funded using university reserves designated for deferred maintenance and facility renewal.

The planned schedule to complete all ECMs is approximately 20 months, from January 2022 to September 2023.



I. EXECUTIVE SUMMARY

Overview

The University of Colorado Anschutz Medical Campus is a world-class medical destination at the forefront of transformative science, science, medicine, education and healthcare. Since the establishment of the campus on the former Fitzsimons Army Medical Center (FAMC) in 2000, CU Anschutz has strived to be a wise steward of energy and natural resources.

All university buildings are designed to Leadership in Energy Environmental Design (LEED) Gold certification standards. However, these standards along with other sustainability practices are continually becoming more strict as technologies become more widespread and adopted.

While the university updates most building systems during project renovations or as separate projects, it can be difficult to complete such projects across many facilities at one time. This effort will improve the efficiency of a large portion of the GSF on campus in one project to bring these facilities more in line with current conservation guidelines and practices.

Program

The ECMs proposed by this project will retrofit older lighting with light emitting diode (LED) systems, optimize lighting operation and controls, optimize HVAC operation, update HVAC equipment, recover energy from waste heat, re-commission and continuously commission HVAC, and install low-flow water fixtures.

As the university completes these building system improvements, it may help improve the Facility Condition Index (FCI) of these facilities.

Scope and Schedule

Final design and construction documentation of the recommended ECM projects would begin once BOR spending authority is approved.

The design phase of this effort would last eight months from January 2022 to August 2022. Construction will take 12 months from September 2022 to September 2023. This schedule accommodates the seasonal requirements of some ECM measures.

1/2022 - 8/2022	Design/Construction Documentation
9/2022 - 9/2023	Construction

II. GOALS AND OBJECTIVES

The University of Colorado Anschutz Medical Campus is a world-class medical destination at the forefront of transformative science, science, medicine, education and healthcare. As the university advances modern health care it aims to be a responsible steward of resources.

The university is pursuing this effort to help meet the greenhouse gas (GHG) emissions reduction targets and overall goal of climate neutrality from the 2010 University of Colorado Denver | Anschutz Medical Campus Climate Action Plan (CAP) and the 2021 - 2026 CU Strategic Plan.

ECMs already in place, like those in Research 1 North and South, helped the university attain its 2020 goal to reduce GHG emissions by 20%. The Research 1 ECMs allowed the university to realize annual utility cost savings of \$989,906 and have reduced annual carbon dioxide emissions by 7,342 metric tons.

The CAP called for a 20% reduction in GHG emissions from a 2006 baseline by 2020, a 50% reduction by 2030 and an 80% reduction by 2050. Since then, in HB 19-1261, the State of Colorado established more strict GHG emissions reduction goals of 25% by 2026, 50% by 2030 and 90% by 2050. More recently, HB 21-1286 set interim performance standards of 7% reduction in GHG emissions by 2026 vs. 2021 baseline emissions.

CU Anschutz is also a signatory to the American College and University Presidents' Climate Commitment (ACUPCC). The BOR passed a resolution to adhere to the goals of the ACUPCC and that each campus would initiate and support projects to reduce GHG emissions.

In addition, this project will help extend the reach of recently completed expansions to the steam and chilled water generating capacity at the CU Anschutz Central Utility Plant (CUP). Any reductions in steam and chilled water demands from the proposed ECMs will make additional CUP capacity available for future growth.



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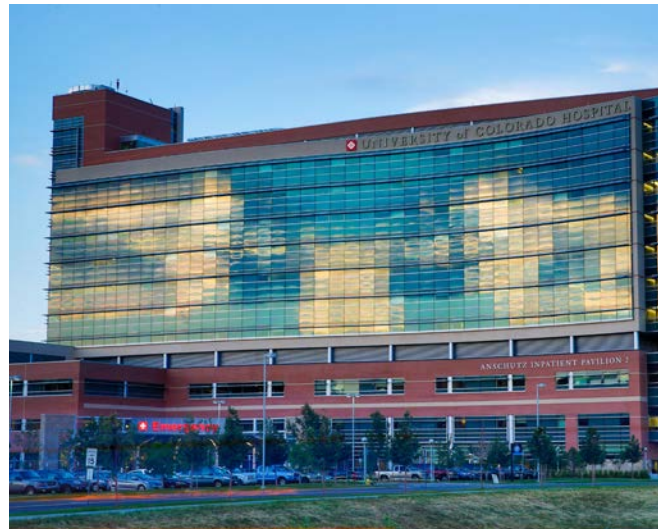
III. PROGRAM INFORMATION

Background and Assumptions

The CUP is obligated to serve the heating, cooling, and process loads for CU Anschutz, UCH and CHCO by the Amended and Restated Central Utility Plant Services Agreement of 2004. The CUP is operated as a CU Anschutz auxiliary service and is funded through utility charges to its steam and chilled water customers.

In fall 2021 the university will open the 395,479 gross square foot (GSF) Anschutz Health Sciences Building. In summer 2022, UCHHealth plans to open a third inpatient tower and a new parking facility. As a result, in 2021, the university completed an expansion of the CUP's chilled water and steam generation capacity to meet the needs of these facilities and continued campus growth.

The CUP does not provide natural gas or electrical power to the institutions. These are provided by Xcel energy and the system has adequate capacity to supply current and planned campus projects.



III. EXISTING CONDITIONS

CUP Capacity

After its recent generation capacity expansion the CUP can supply current campus facilities and those planned and under construction.

To adequately size the CUP's capacity, the largest generation unit for each utility (boilers for steam, chillers for chilled water) is not counted towards capacity. This is called fixed firm capacity (FFC) and it must be able to support and provide all campus needs. This estimate of capacity accommodates potential maintenance of, or a shut down, of a generation unit.

In the tables on the opposite page, FFC for each utility is shown as a dotted line. The bars represent the actual peak demand from 2010 - 2020 and projections from 2021 onwards. The distance between the lines and bars represents capacity that is available for future projects or for demands during extreme heat or cold events.

It should be noted the 2023+ projections include 339,762 GSF of facilities proposed in the 2012 facilities master plan that have not been constructed, and are not currently scheduled for construction.

ECMs that reduce the use of steam and chilled water will drop the height of the bars. This would then result in additional available generation capacity for future growth or extreme weather events.

Electric Capacity

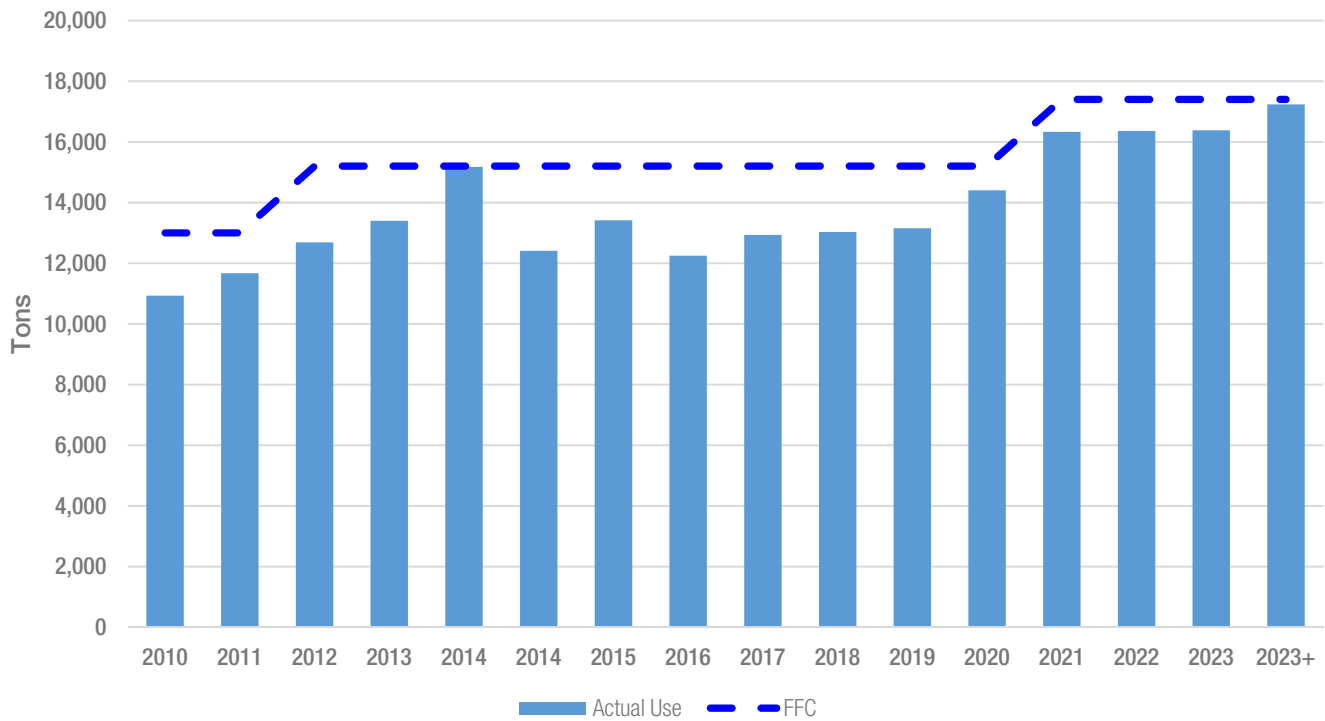
Xcel supplies the campus with electricity service. There is enough capacity in Xcel's system to supply current and current projected campus growth.

However, the utility's generation facilities burn coal and other fossil fuels. Efforts to conserve or reduce electric use on campus would result in less fossil fuel use and reduce overall emissions.

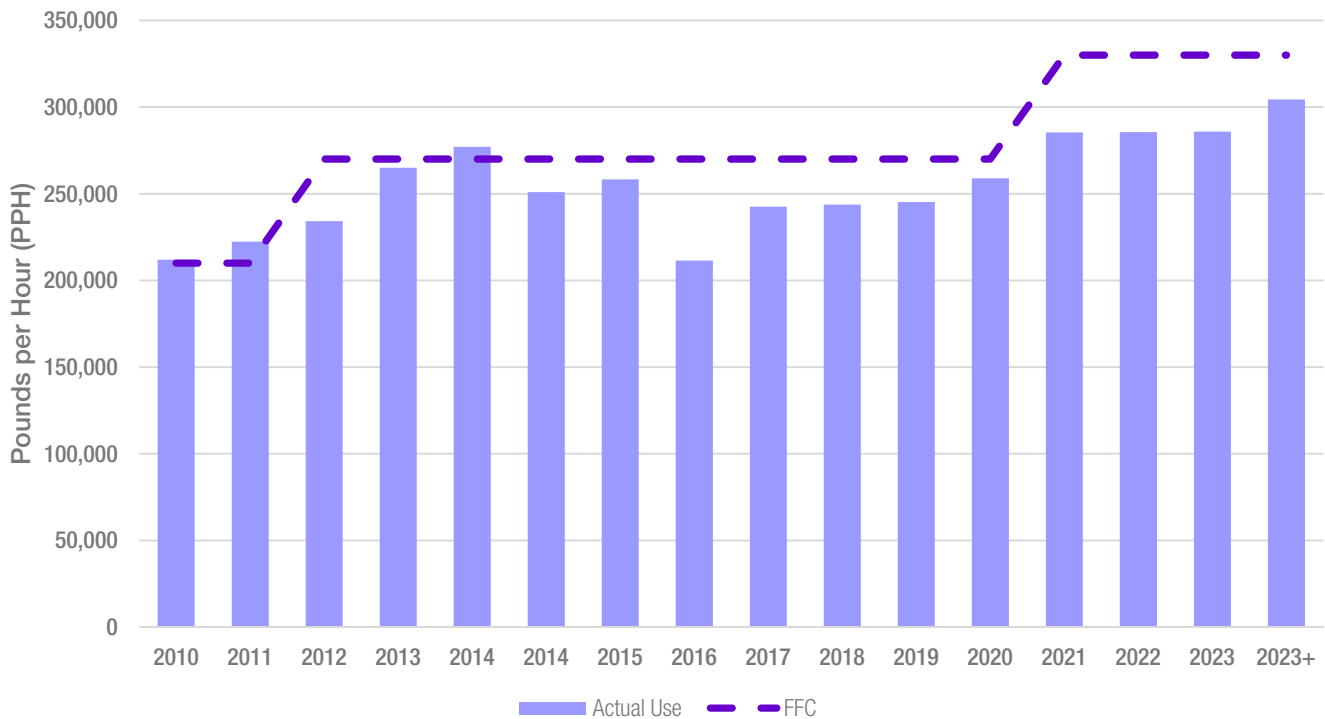
ECMs that reduce steam and chilled water demands will also result in less GHG emissions. Reductions in chilled water demand will require less electricity to generate cooling. As steam demands are reduced, less gas will be required to be burned to generate heat.



Chilled Water FFC and Actual Use



Steam FFC and Actual Use



III. EXISTING CONDITIONS

Buildings

All university buildings are designed to Leadership in Energy Environmental Design (LEED) Gold certification standards. The facilities involved in this effort total 1,712,076 gross square feet (GSF) and were built prior to 2010. Sustainable building practices and energy conservation strategies have advanced since their completion

The Barbara Davis Center

The Barbara Davis Center for Childhood Diabetes is the largest diabetes and endocrine care research and training program in Colorado. The 112,646 GSF research and clinical facility was completed in December 2006.



Education 2 North and South

Education 2 consists of two five-story structures connected by the education bridge. Completed in 2007, they are located east of Education 1 and form the eastern edge of the Education Quad. The first two floors of the buildings provide educational amenities including classrooms of various sizes, lecture halls, computer stations, small group learning rooms, and student community space. The upper floors provide faculty offices. The buildings contain 275,000 GSF.



Environmental Health and Safety

This building houses the offices, support space, labs, and waste facilities for the Environmental Health and Safety (EH&S) department. It was last expanded in 2007 to 21,000 GSF to support CU Anschutz research programs, teaching educational labs, and facilities operations.

Perinatal Research Facility

The Perinatal Research Facility is located in the northeast corner of campus north of Montview Boulevard. It was completed in January 2002. The 24,000 GSF building provides research laboratories, environmental chambers, and office space.

Research 1 (North and South Towers)

The university built this two building research complex on the former FAMC in 2004. It is located west of the Fitzsimons Building and forms the eastern and northern edges of the Research Quad. The buildings contain wet and dry research laboratories, core laboratories, lab support space (including space for linear equipment), offices, conference rooms, a central vivarium, auditoriums, and building support space. Including both it is the largest building at CU Anschutz with a combined 628,000 GSF.



Research 2

This 479,000 GSF building opened in June 2008 as the second major research facility on campus. It is located west of Research 1 North and forms the northwest edge of the Research Quad. In addition to research laboratories, offices, and support spaces, Research 2 also contains the large divisible Krugman Conference Hall which can host special events, large gatherings, and lectures.



Skaggs Pharmacy and Pharmaceutical Sciences Building

The 171,000 GSF home of the SSOPPS opened in 2011. This facility houses research laboratories, laboratory support, faculty and administrative offices for the SSOPPS. The school was renamed in honor of the Skaggs family for its long-standing support of the school.



Facility Condition Index

Each building in which ECMs are being pursued has a Facilities Condition Index (FCI) target of 85 percent or better. The FCIs for the Barbara Davis Center, Perinatal Research Facility, and Research 1 North and South are below this target at 84%, 65%, 82%, and 83% respectively. All other facilities are above the target.

As building systems are upgraded through this effort, these FCIs may slightly improve so that the facilities should get closer to their targets.

Sustainability

The university has a dedicated commitment to sustainability. It has reported a Silver Rating to the Sustainability Tracking, Assessment and Rating System (STARS). All new campus buildings strive to achieve LEED Gold or higher certification to demonstrate responsible stewardship of energy and environmental resources.

This effort will retrofit and improve the systems in several of the older facilities on campus. This will bring them more in line with current sustainability practices. These have continually been updated and improved to reflect the increasing availability and accessibility of conservation technologies.

Economic Activity

In AY 2019, the total campus economic impact of the Anschutz Medical Campus was \$7 billion, of which \$3.3 billion was specific to the University of Colorado. As the campus continues to grow through additional research endeavors and educational programs, the university needs to ensure that the resources to sustainably support this growth are provided.

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IV. PROPOSED PROJECT

This effort includes 49 ECM projects spread across 7 campus buildings to improve their efficiency and reduce the university's energy costs.

The ECMs will retrofit older lighting with light emitting diode (LED) systems, optimize lighting operation and controls, optimize HVAC operation, update HVAC equipment, recover energy from waste heat, re-commission and continuously commission HVAC, and install low-flow water fixtures.

ECM Development

Initial ECMs

In early 2020, the university completed a Bundled Energy Audit Report for the campus. This effort included complete Technical Energy Audits (TEAs) of the Research 2 and Skaggs School of Pharmacy and Pharmaceutical Sciences (SSOPPS) buildings. The team then identified an initial 73 common energy conservation measures (ECMs) that could be implemented in these buildings and seven others. These were then bundled into 12 categories to reflect similar goals and/or project type.

Category	ECM Description	Projects	Facilities Studied
Lighting: Upgrades	LED Lighting Retrofits	6	Pharmacy, Barbara Davis, Education 2, EHS, Perinatal, Pharmacy, Research 2
Lighting: Controls	Optimize lighting operation, add lighting controls	8	Barbara Davis, Education 2, EHS, Pharmacy, Research
HVAC: Controls	Optimize HVAC operation, add HVAC controls (CO ₂ sensors)	14	Barbara Davis, Education 2, EHS, Perinatal, Pharmacy, Research 2.
HVAC: Upgrades	HVAC additions/modifications	18	Barbara Davis, Education 2, EHS, Perinatal, Pharmacy, Research 1, Research 2
Energy Recovery: Elevators	Regenerative Braking for Elevators	2	ECM Category Not Pursued: Pharmacy, Research 2
Energy Recovery: HVAC	Energy recovery from waste heat (sewage, exhaust, etc.)	7	Education 2, EHS, Research 1, Research 2, Perinatal
Building Envelope	Improvements to building envelope to minimize external heat loss/gain	4	Pharmacy
Commissioning	Re-commissioning and continuous commissioning of HVAC systems	7	Barbara Davis, Pharmacy, Research 2
O&M	Behavioral changes for energy efficiency	1	ECM Category Not Pursued: Perinatal
Process/Plug Loads	Facility/lab equipment standardization and optimization	3	ECM Category Not Pursued: Pharmacy, Research 2
Water Conservation	Implementation of low-flow water receptacles	1	Research 2
Distributed Generation - PV	Implementation of building-connected solar PV	2	ECM Category Not Pursued: Perinatal

IV. PROPOSED PROJECT

Evaluation Criteria

The project team established a set of evaluation criteria to measure the energy, water and utility costs savings for each of the 73 ECMs. The group also calculated the total implementation costs for each and a estimated simple payback period. As shown below, three levels for each criteria were established.

In general ECMs with low energy, water, and utility savings and/or high implementation costs were not recommended for implementation. These projects would not be cost-effective as they would have payback periods greater than 10 years. They could be pursued in the future as part of larger building renovation and maintenance efforts.

Evaulation Criteria	Low	Medium	High	Unit
Chilled Water Savings	<100,000	<----->	>400,000	ton-hr/yr
Steam Savings	<1,000	<----->	>4,000	Mlbs/yr
Electricity Savings	<1,000,000	<----->	>4,000,000	kWh/yr
Water Savings	<1,000	<----->	>6,000	kgal/yr
Utility Cost Savings	<\$100,000	<----->	>\$500,000	dollars
Implementation Costs	<\$100,000	<----->	>\$10,000,000	dollars
Simple Payback	0 to 5	<----->	> 10	years

Recommended ECMs

Through the evaluation, the project team recommended that 49 ECMs be pursued. The most ECM projects will be completed in the Barbara Davis Center while those in Research 1 are likely to be most expensive.

In all, 22 of the recommended ECMs will improve HVAC systems. HVAC upgrades in particular will be costly to implement.

None of the ECMs in the Energy Recovery: Elevators, Operations and Maintenance, Process/Plug Loads and Distributed Photovoltaic (PV) Generation categories were recommended for implementation.

Some ECM projects in the remaining categories were also not recommended for implementation in some buildings.

ECM Type	Barbara Davis Center	Education 2	EHS	Perinatal Research Facility	Skaggs School of Pharmacy & Pharmaceutical Sciences	Research 1	Research 2	Total ECMs
Lighting: Upgrades	1	1	1	1	1		1	6
Lighting: Controls	1	3	2		1		1	8
HVAC: Controls	4	1	1	3	1		1	11
HVAC: Upgrades	5	2	2	1		1		11
Energy Recovery: Elevators								
Energy Recovery: HVAC			1			2	1	4
Building Envelope					1			1
Commissioning	3				2		2	7
O&M								
Process/Plug Loads								
Water Conservation							1	1
Distributed Generation - PV								
TOTAL	14	7	7	5	6	3	7	49

IV. PROPOSED PROJECT

Bundled ECMs

Bundling projects by category and building provides the university an opportunity to realize material and labor cost savings. Bundling will also allow multiple projects to be concurrently completed in each building to minimize disruptions.

The table below summarizes the evaluation of all ECMs within each category.

As indicated, 4 types of ECM will have a quick payback period of less than 5 years. Three categories will achieve payback between 5 and 10 years.

However, the proposed water conservation measures will have a payback period of more than 10 years. This ECM project will be pursued as it will achieve a reduction in water use of more than 6,000 kgal each year. This reinforces the university's commitment to wise stewardship of resources.

ECM Category	Total Projects	Chilled Water Savings	Steam Savings	Electricity Savings	Water Savings	Utility Cost Savings	Implementation Costs	Simple Payback
Lighting: Upgrades	6	Low		Medium		Medium	Medium	Medium
Lighting: Controls	8	Low		Low		Low	Medium	Medium
HVAC: Controls	11	Low	High	Medium		Medium	Medium	Low
HVAC: Upgrades	11	High	Medium	Low		High	Medium	Medium
Energy Recovery: Elevators	0							
Energy Recovery: HVAC	4	High	High	Low		High	Medium	Low
Building Envelope	1	Low	Low	Low		Low	Low	Low
Commissioning	7	High	High	Medium		Medium	Medium	Low
O&M	0							
Process/Plug Loads	0							
Water Conservation	1				High	Medium	Medium	High
Distributed Generation: PV	0							

Benefits and Savings

When all recommended ECM projects are complete the university will reduce its emissions of carbon dioxide (CO₂E) by 10,429 metric tons a year. This is equivalent to the annual GHG emissions associated with the electric use of 1,889 homes, 2,262 passenger vehicles, and 1,170,249 gallons of gas consumed.

This will help the university meet the GHG reductions in its CAP and the goals of Colorado HB 19-1261. In particular, CU Anschutz will achieve 100% of its 2026 GHG reductions from the Strategic Planning Initiative, 20% of the 2050 goal, and 40% of the 2026 Energy Use Intensity (EUI).

Annual utility cost savings of just over \$XX million will allow the university to realize a simple payback from these measures in XX years. This is a cost-effective way to meet established goals and to remain a leading AHC in its use of natural resources and energy.

Consistency

Mission

The 2008-2020 Strategic Plan for the University of Colorado Denver (the plan covers both CU Denver and CU Anschutz) states that the campus:

is a diverse teaching and learning community that creates, discovers and applies knowledge to improve the health and well-being of Colorado and the world.

This project will provide necessary support and infrastructure to the CU Anschutz Medical Campus to facilitate teaching and learning while enhancing health and wellness.

Strategic Plan

This project clearly supports Strategic Goal 7.2 from the University of Colorado Denver Strategic Plan 2008-2020:

Invest in providing the infrastructure (services and facilities) necessary for a world-class learning and discovery environment for the benefit of our students, faculty, staff and communities.

Facilities Master Plan

The 2012 Anschutz Medical Campus Facilities Master Plan outlines the following Stewardship goal:

We will successfully collaborate with local, regional, state, and national public, private, and nonprofit partners to improve the health, wellness, and quality of life of our students, faculty, staff, patients, and community partners. Our enduring commitment to good stewardship will result in a more economically, socially, and environmentally sustainable community.

This project will create a high-performance built environment that reduces energy use in the buildings in line with the principles associated with this goal. Some ECMs will also incorporate information technology into existing building systems to achieve greater efficiency.

The 2012 Anschutz Medical Campus Facilities Master Plan included a CUP Boiler and Chiller Expansion project which has recently been completed. The proposed ECMs will help reduce demand for CUP supplied utilities which can then be provided to other campus facilities and to support additional growth.

Climate Action Plan

This project will help the university meet the goals of its CAP and is fully consistent with it.

The 2010 CAP outlines how the university will reduce its GHG emissions that can contribute to atmospheric climate change. In 2006, the university calculated its annual GHG emissions in accordance with the World Resources Institute (WRI) GHG protocol to establish a baseline for reductions.

Phase I of the plan focuses on energy efficiency projects and conservation measures, incorporation of on-site renewable energies, purchased wind power and carbon offsets to achieve a 20% reduction from the university's baseline GHG emissions.

It also includes reductions in energy, fuel, water and paper use as directed by the Colorado Governor's Greening of Government Executive Order. Later phases of the plan are designed to achieve an 80% reduction in the university's baseline GHG emissions through partnerships with production facilities that do not emit GHG and adoption of technologies now in research and development phases.

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<u>Item</u>	<u>Start</u>	<u>Completion</u>
Program Plan Submission	October 2021	N/A
CDC Approval	December 2021	N/A
Design	January 2021	August 2021
Construction	September 2022	September 2023

Project Alternatives

By implementing all recommended ECMs from the Bundled Energy Report the university will reduce its GHG emissions by 10,429 metric tons annually. This will allow the university to meet its Colorado HB 19-1261 and HB 21-1286 obligations and further exceed its CAP goals.

If the university does not implement any ECMs, it will not realize monthly any utility cost savings nor contribute toward its commitment to reduce its greenhouse gas emissions.

Third Party Review

Our continuing efforts to improve energy efficiency and water conservation on campus allows CU Anschutz to accurately estimate the scope and budget for this project. AECOM also completed a third party review of the project to verify the project budget and schedule.

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AECOM
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September 1, 2021

Reference

CU Anschutz Bundled Energy Project
3rd Party Verification

Mike Barden
Director
Facilities Projects
University of Colorado Denver | Anschutz Medical Campus
1945 N. Wheeling St, Aurora, CO 80045 | Mail Stop F418

Mr. Barden,

I am in receipt of and have reviewed the current CU Anschutz Bundled Energy Program Plan documents. I am writing in response to your request for 3rd party verification to express AECOM Technical Services (ATS) support for the CU Anschutz Bundled Energy Program Plan including the analysis that is included in the final report to CU leadership. As you are aware ATS performed some of the calculations and engineering that support CU's assessment of the paybacks and level of effort needed to complete CU's Bundled Energy Program of projects.

After a thorough review of the CU Anschutz Bundled Energy Program Plan documents ATS has confirmed that the payback and level of effort in the current plan are adequate for successful completion of the project program. The \$10.1M budget with revisions for escalation for timing and labor is appropriate for this effort. The proposed design and construction schedules are adequate to complete the effort.

Please feel free to contact me with any questions or clarification.

Yours sincerely,

Mark Ferguson, PE, CEM
Project Manager
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cc: Kevin Keady, Ryan Meador

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Appendix H

AECOM Bundled Energy Study



UNIVERSITY OF COLORADO ANSCHUTZ MEDICAL CAMPUS

BUNDLED ENERGY AUDIT REPORT

JANUARY 13, 2020

ABSTRACT

This report has been prepared by AECOM Technical Services, Inc. of Denver, Colorado to present the findings of energy audits and conservation analyses of multiple existing University of Colorado facilities on the Anschutz Medical Campus in Aurora, Colorado.

AECOM

Contract Number: 18-152058

Preface

The University of Colorado Denver and the Anschutz Medical Campus recognizes that a sustainable approach to creating and maintaining the university is the only way that we will be able to continue to provide a high-quality education for current and future students.

Sustainability can be defined in many ways, but commonly refers to using physical resources in a wise and efficient way today so that those resources will be here for future generations. The energy we use to heat and cool our buildings, the water we use for our landscapes and indoor plumbing, the fuel we use for our vehicles are all finite resources and the quantity and quality of those resources will dissipate if we do not act now to conserve them.

As a signatory of the American College & University Presidents' Climate Commitment (ACUPCC), the University is required to develop comprehensive Climate Action Plan. This plan requires the University to conduct a greenhouse gas (GHG) emissions inventory to measure and define its yearly contribution climate change. The university is nearing the end of Phase 1 (2010 – 2020) of the Climate Action Plan. Utilizing 2007 as the calendar year benchmark, the first phase calls for a 20% reduction, Phase 2 (2020 – 2030) calls for a 50% reduction and Phase 3 (2030 – 2050) calls for an 80% reduction in GHG emissions.

The ACUPCC is a commitment by nearly 700 colleges and universities across the nation to develop comprehensive plans and take active steps in reducing their contributions to climate change. Chancellor M. Roy Wilson signed the ACUPCC in June of 2007 and UC Denver has worked actively to fulfill the requirements set forth in the commitment. These include the formation of a sustainability and climate action committee, greenhouse gas accounting, incremental steps to reduce greenhouse gas emissions and the writing of the UC Denver Climate Action Plan.

The document provides information on the current state of development as of the data gathering date, however, it is expected that this document and its energy conservation measures will be validated prior to and during any design-related activities of recommendations listed within. Except as noted, information, interviews, and data development were conducted by the Contractor. While there are many proven, cost-effective energy conservation practices and numerous new technologies and advancements of existing technologies available for detailed study, the case studies in this document were selected based on specific criteria. The criteria included targeting for simple payback of 10 years or less. Longer payback periods have been considered and documented for record and may be revisited in future revisions of these audits as technological advancements or alternatives reduce implementation costs.

Disclaimer

This report has been prepared at the request of the Client. The observations, conclusions, and recommendations contained herein constitute the opinions of AECOM engineers and energy consultants. In preparing this report, AECOM has relied on some information supplied by the Client, the Client's employees, and others – which we gratefully acknowledge for their support. No warranties are given with this source information. As such, AECOM cannot make certifications or give assurances except as explicitly defined in this report. The cost data provided in this report reflects an engineer's opinion of probable cost based on no detailed design(s) and does not reflect actual contractor bids.

This information represents new, innovative or emerging approaches, techniques, or technologies that assist Owners and Operators in reducing capital or operating costs of campus facilities. Some of the information, especially related to emerging technologies, was provided by manufacturers or equipment vendors and could not be verified or supported by a full-scale case study. In some cases, cost data were based on estimated savings without actual field data. When evaluating technologies, estimated costs, and stated performance efforts should be made by the designers of future projects to collect current and more up-to-date information. The mention of trade names, specific vendors, or products does not represent an actual or presumed endorsement, preference, or acceptance by AECOM or the Client.

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Jarrett Smith	Sustainability Manager, CU Anschutz Medical Campus	

Document Revision History

Revision	Revision date	Details	Authorized	Name	Position
Revision A	13 JAN 2020	Initial Draft for Client Review	Approved for Release	Ryan Meador, PE	Project Manager

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SCOPE OF REPORT

The University of Colorado Anschutz Medical Campus engaged a study to identify, develop and bundle energy conservation measures (ECM)s for multiple existing facilities across the campus.

AECOM Technical Services, Inc (AECOM) provided Energy Audits of two existing facilities, Research 2 and Pharmacy, and reviewed existing studies of of the remaining facilities with the intent of identifying opportunities for implementing common ECMs across the entire portfolio.

In total, the facilities included within this report represent more than 1.6 million square feet of occupied space.

Building Name	Building Number	Existing Energy Study	Facility Energy Audit
		ECM Validation Area (SF)	and ECM Development Area (SF)
Research 2	P15	--	506,000
Pharmacy	V20	--	171,000
Sub Total		--	677,000
Research 1 North	P18	600,640	--
Education 2	P28/L28	275,375	--
Barbara Davis	M20	112,000	--
EH & S	R30	12,025	--
Perinatal	AK32	24,910	--
Sub Total		1,024,950	--

PURPOSE & OUTCOMES

The primary objective of undertaking Energy Audits is to rapidly identify opportunities with the greatest probability that - if designed and implemented - would reduce utility costs, while providing a reasonable economic aggregate payback 10 years or less.

The selected measures were a result of utility analysis and walk-through audits with focus on systems and components including lighting and occupancy controls, HVAC systems and controls, domestic water heating, laboratory equipment process and plug loads, thermal building envelope, commissioning, and energy recovery.

On the following pages, we have summarized the recommended energy conservation measures for the selected facilities.



RESEARCH 1: NORTH (P18)



SOUTH (L18)



PHARMACY (V20)



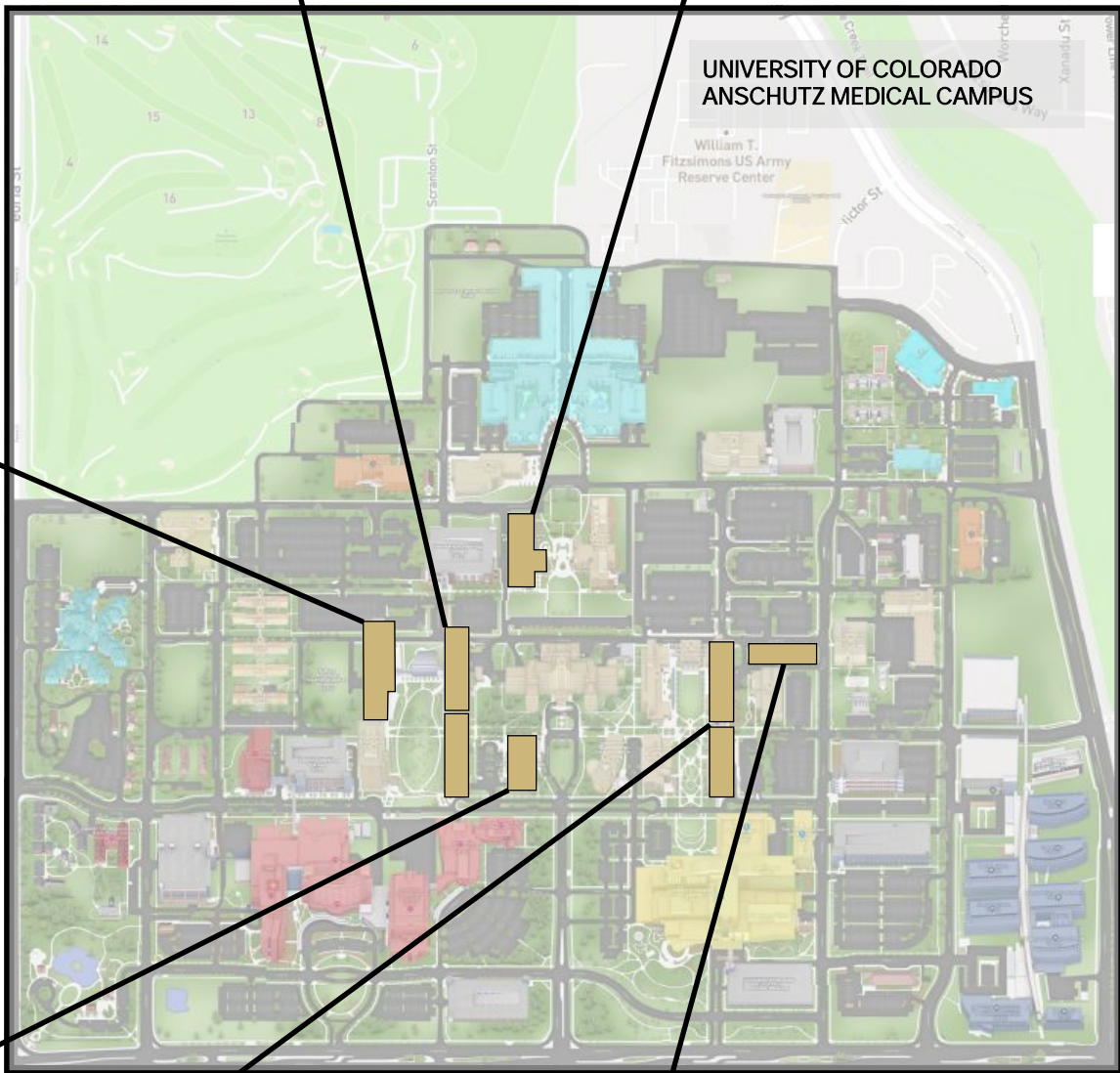
RESEARCH 2 (P15)



BARBARA DAVIS (M20)



EDUCATION 2: NORTH (P28)



SOUTH (L28)

EH&S (R30)



FINDINGS & RECOMMENDATIONS

Bundled Energy Projects

The Energy Conservation Measures (ECM)s representing the greatest opportunity for savings, based on simple payback across the portfolio of buildings, are indicated below. We’ve utilized a qualitative approach to determine ECM candidates based on the energy, water, and cost savings indicated below. On the next page, these same ECMs are quantified.

BUNDLED ENERGY PROJECTS - BY TYPE				ENERGY & WATER SAVINGS				UTILITY COST SAVINGS	IMPLEMENTATION COSTS	SIMPLE PAYBACK	
Matrix Color Legends -->			Low	<100,000 ton-hr/yr	<1,000 Mlbs/yr	<1,000,000 kWh/yr	<1,000 kgal/yr	<\$100,000	<\$100,000	0 to 5 yr	Low
			Medium	<----->	<----->	<----->	<----->	<----->	<----->	5 to 10 yr	Medium
			High	>400,000 ton-hr/yr	>4,000 Mlbs/yr	>4,000,000 kWh/yr	>6,000 kgal/yr	>\$500,000	>\$10,000,000	>10 yr	High
ECM #	ECM Type	ECM Description	Applicable Facilities	Chilled Water Savings (ton-hrs/yr)	Steam Savings (Mlbs/yr)	Electricity Savings (kWh/yr)	Water (kgal/yr)	Utility Cost Savings (\$/yr)	Estimated Implementation Cost (\$)	Simple Payback (yrs)	Notes
1	Lighting - Upgrades	LED Lighting Retrofits	Research 2, Pharmacy, Education 2, Barbara Davis, EHS, Perinatal Research Facility	Low		Medium		Medium	Medium	Medium	
2	Lighting - Controls	Optimize lighting operation, add lighting controls	Research 2, Pharmacy, Education 2, Barbara Davis, EHS	Low		Medium		Low	Medium	Medium	
3	HVAC - Controls	Optimize HVAC operation, add HVAC controls (CO2 sensors)	Research 2, Pharmacy, Education 2, Barbara Davis, EHS, Perinatal Research Facility		High	Medium		Medium	Medium	Low	
4	HVAC - Upgrades	HVAC additions/modifications	Research 2, Pharmacy, Education 2, Barbara Davis, EHS, Perinatal Research Facility, Research 1	High	Low			Medium	Medium	Medium	
5	Energy Recovery - Elevators	Regenerative Braking for Elevators	Research 2, Pharmacy			Low		Low	Medium	High	
6	Energy Recovery - HVAC	Energy recovery from waste heat (sewage, exhaust, etc.)	Research 2, CUP, Education 2, EHS, Perinatal Research Facility, Research 1	High	High	Low		Medium	Medium	Medium	
7	Building Envelope	Improvements to building envelope to minimize external heat loss/gain	Research 2, Pharmacy	Low	Low	Low		Low	Medium	High	
8	Commissioning	Re-commissioning and continuous commissioning of HVAC systems	Research 2, Pharmacy, Barbara Davis	High	High	Low		Medium	Medium	Low	
9	O&M	Behavioral changes for energy efficiency	Perinatal Research Facility					Low	Low	Low	No utility analysis from previous report
10	Process/Plug Loads	Facility/lab equipment standardization and optimization	Research 2, Pharmacy			High		Medium	Medium	High	
11	Water Conservation	Implementation of low-flow water receptacles	Research 2				High	Medium	Medium	Medium	
12	Distributed Generation - PV	Implementation of building-connected solar PV	Perinatal Research Facility					Low	Low	High	No utility analysis from previous report

FINDINGS & RECOMMENDATIONS

Bundled Energy Projects

The Energy Conservation Measures (ECM)s representing the greatest opportunity for savings, based on simple payback across the portfolio of buildings, are indicated below.

ECM #	ECM Type	ECM Description	Applicable Facilities	Chilled Water Savings (ton-hrs/yr)	Steam Savings (Mlbs/yr)	Electricity Savings (kWh/yr)	Water (kgal/yr)	Utility Cost Savings (\$/yr)	Estimated Implementation Cost (\$)	Simple Payback (yrs)	Notes
1	Lighting - Upgrades	LED Lighting Retrofits	Research 2, Pharmacy, Education 2, Barbara Davis, EHS, Perinatal Research Facility	19,333.33	(0.45)	3,212,103.00	-	\$ 142,526.00		-	
2	Lighting - Controls	Optimize lighting operation, add lighting controls	Research 2, Pharmacy, Education 2, Barbara Davis, EHS	66,325.00	(0.93)	1,095,491.00	-	\$ 75,561.00	\$		
3	HVAC - Controls	Optimize HVAC operation, add HVAC controls (CO2 sensors)	Research 2, Pharmacy, Education 2, Barbara Davis, EHS, Perinatal Research Facility	(6,983,757.00)	6,361.98	1,218,204.44	-	\$ 242,320.18	\$		
4	HVAC - Upgrades	HVAC additions/modifications	Research 2, Pharmacy, Education 2, Barbara Davis, EHS, Perinatal Research Facility, Research 1	1,544,533.33	6.27	(51,430.00)	-	\$ 469,105.00			
5	Energy Recovery - Elevators	Regenerative Braking for Elevators	Research 2, Pharmacy	-	-	157,492.98	-	\$ 6,299.72			
6	Energy Recovery - HVAC	Energy recovery from waste heat (sewage, exhaust, etc.)	Research 2, CUP, Education 2, EHS, Perinatal Research Facility, Research 1	446,393.09	29,021.69	710,270.00	-	\$ 497,320.75			
7	Building Envelope	Improvements to building envelope to minimize external heat loss/gain	Research 2, Pharmacy	32,005.48	531.03	815,704.34	-	\$ 16,986.43	\$		
8	Commissioning	Re-commissioning and continuous commissioning of HVAC systems	Research 2, Pharmacy, Barbara Davis	1,046,781.33	14,776.49	618,238.00	-	\$ 433,647.00	\$.	
9	O&M	Behavioral changes for energy efficiency	Perinatal Research Facility	-	-	-	-	\$ 936.00	\$.	
10	Process/Plug Loads	Facility/lab equipment standardization and optimization	Research 2, Pharmacy	-	(0.99)	5,045,625.00	-	\$ 174,917.83	\$		
11	Water Conservation	Implementation of low-flow water receptacles	Research 2	-	-	-	13,466.00	\$ 120,183.67	\$		
12	Distributed Generation - PV	Implementation of building-connected solar PV	Perinatal Research Facility	-	-	-	-	\$ 1,437.00	\$		

FINDINGS & RECOMMENDATIONS

Conservation Measures by Facility

The Energy Conservation Measures (ECM)s representing the greatest opportunity for savings, based on simple payback for each building, are indicated below.

ECM #	Facility	ECM Type	ECM Name	ECM Description	Chilled Water Savings (ton-hrs/yr)	Steam Savings (Mlbs/yr)	Electricity Savings (kWh/yr)	Water (kgal/yr)	Utility Cost Savings (\$/yr)	Estimated Implementation Cost (\$)	Simple Payback (yrs)	Notes
1	Research 2	Lighting - Upgrades	Interior Lighting Efficiency	Replace all existing interior linear fluorescent, compact fluorescent, Incandcescent and HID lighting with LED equivalent.	-	-	2,648,709.00	-	97,539.00		0.01	Recommended
2	Research 2	Lighting - Controls	Interior Lighting Controls -Occupancy Setback	Use existing controls to provide occupancy setback during nighttime operation.	-	-	274,223.00	-	10,098.00		0.1	Recommended
3a	Research 2	Commissioning	Continuous-Commissioning (skyspark)	a. Existing System Optimization and RCx	389,688.00	4,949.00	101,300.00	-	139,857.00		0.1	Full scopes of work will require terminal unit inventory and troubleshooting control issues. These costs are built into the implementation cost.
3b	Research 2	Commissioning	Continuous-Commissioning (skyspark)	b. Continuous Commissioning of existing systems and ECM performance monitoring.	389,688.00	4,949.00	101,300.00	-	139,857.00		0	Annual maintenance costs necessary tune SkySpark. Savings shown based on potential avoided annual costs due to future issues with HVAC and control systems. Savings should be considered interactive with other measures.
4	Research 2	HVAC - Controls	Reduce ACH by for unoccupied areas	Utilizing existing controls, reduce the ventilation for unoccupied areas during nighttime operation.	108.00	4,786.00	296,276.44	-	93,714.36			Recommended. EH&S discussions recommended as next actionable step.
5	Research 2	Energy Recovery - HVAC	Waste Heat from Sewage	Use sewer heat recovery system to provide domestic hot water heating in lieu of steam.	-	7,931.00	(200,967.00)	-	19,076.00			Payback period too great and not recommended.
6	Research 2	Energy Recovery - HVAC	Insulate Roof Exhaust pre Heat Recovery	Insulate exhaust ducts on roof to enhance heat recovery in run-around loop.	1,009.00	172.00	-	-	3,100.75			Further development recommended
7	Research 2	Energy Recovery - Elevators	Regenerative Braking for Elevators	Replace existing worm drive motor generators with gearless machines incorporating regenerative braking.	-	-	137,191.01	-	5,487.64			Not recommended
8	Research 2	Process/Plug Loads	Freezer Standardization	Work with labs to replace and standardize all Ultra-low laboratory freezers to a high-efficiency model.	-	-	3,799,980.00	-	139,934.26			Not recommended at this time but could be a guideline for equipment replacement with lab group when current freezers meet EUL. Additional research recommended to alter -80 deg C freezer temperatures to -70 deg C.
9	Research 2	HVAC - Upgrades	Fan Wall System	Replace single AHU supply fan with fan wall system.	-	-	-	-	-	-		Not recommended at this time, efficiency difference not significant enough. Would recommend if a fan needs to be replaced using fanwalls as a replacement effort.
10	Research 2	Building Envelope	Physical Shading	Retrofit building with exterior shading, such as fixed slats.	27,780.00	215.00	623,416.00	-	9,609.13			Extensive effort to go through Design Review Board process of modifying exterior facades. Implementaiton cost includes \$40k for review efforts. Note that new tower being constructed adjacent to building will affect shading.
11	Research 2	HVAC - Upgrades	Roof Exhaust Control/Fume Hood Control	Use chemical monitor to reduce fume exhaust fan speed to discharge less than 3000 fpm when air is clean.	-	-	-	-	-	-		Need to work with EH&S to see if they would accept this approach and what should be monitored before further analysis
12	Research 2	Water Conservation	Water Conservation Measures	Replace restroom fixtures with low flow water closets, urinals and lavatories.	-	-	-	13,466.00	120,183.67		5.7	Analyzed LEED building water use compared to non-LEED building water uses and determined if we could hit a particular gal/sf based on building type we could save roughly the kgal/yr shown.
13	Pharmacy	Lighting - Upgrades	Interior Lighting Efficiency	Replace all existing interior linear fluorescent, compact fluorescent, Incandcescent and HID lighting with LED equivalent.	-	-	271,995.00	-	10,016.00		0.1	Recommended
14	Pharmacy	Lighting - Controls	Interior Lighting Controls -Occupancy Setback	Use existing controls to provide occupancy setback during nighttime operation.	-	-	57,894.00	-	2,132.00			Recommended
15	Pharmacy	Commissioning	Continuous-Commissioning (skyspark)	a. Existing System Optimization and RCx	76,761.00	2,439.00	136,939.00	-	57,195.00			Full scopes of work will require terminal unit inventory and troubleshooting control issues. These costs are built into the implementation cost.
16	Pharmacy	Commissioning	Continuous-Commissioning (skyspark)	b. Continuous Commissioning of existing systems and ECM performance monitoring.	76,761.00	2,439.00	136,939.00	-	57,195.00			Annual maintenance costs necessary tune SkySpark. Savings shown based on potential avoided annual costs due to future issues with HVAC and control systems. Savings should be considered interactive with other measures.
17	Pharmacy	HVAC - Controls	Reduce ACH by for unoccupied areas	Utilizing existing controls, reduce the ventilation for unoccupied areas during nighttime operation.	35.00	1,573.00	199,849.00	-	34,594.82			Recommended
18	Pharmacy	Energy Recovery - Elevators	Regenerative Braking for Elevators		-	-	20,301.97	-	812.08			Not recommended
19	Pharmacy	Process/Plug Loads	Convert Autoclaves to Steam	Convert the currently installed electric autoclaves to steam-operated using the 150psi service steam co-located in the adjacent utility chase.	-	(0.99)	295,650.00	-	-			Negative payback due to ultra low cost of electric. Implementation on-going as a deferred maintenance activity.
20	Pharmacy	Process/Plug Loads	Freezer Standardization	Work with labs to replace and standardize all Ultra-low laboratory freezers to a high-efficiency model.	-	-	949,995.00	-	34,983.57			Not recommended at this time but could be a guideline for equipment replacement with lab group when current freezers meet EUL.
21	Pharmacy	Building Envelope	Snow Melt System Upgrade		-	-	-	-	-	-		Could not determine a cost effective solution. Units already utilize two-step activaiton (moisture + temperature).
22	Pharmacy	Building Envelope	Physical Shading	Retrofit building with exterior shading, such as fixed slats.	3,982.00	316.00	190,035.00	-	6,679.43			Extensive effor to go through Design Review Board proces sof modifying exterior facades. Implementaiton cost includes \$40k for review efforts.
23	Pharmacy	HVAC - Upgrades	Roof Exhaust Control/Fume Hood Control	Use chemical monitor to reduce fume exhaust fan speed to discharge less than 3000 fpm when air is clean.	-	-	-	-	-	-		Need to work with EH&S to see if they would accept this approach and what should be monitored before further analysis
24	Pharmacy	Building Envelope	Replace door seals for EVR's	Install new weather stripping for EVR's at Pharmacy to reduce/eliminate conditioned air leakage from EVR to interior hallways.	243.48	0.03	2,253.34	-	697.87			Recommended
25	CUP	Energy Recovery - HVAC	Heat Recovery on Chillers	Install heat recovery on chillers for heating hot water use or pre-heating boiler feedwater.	-	-	-	-	-	-		Not feasible for upgrade but potential for new equipement at EUL if local heat load is suffiecient.

FINDINGS & RECOMMENDATIONS

Conservation Measures by Facility (Continued)

The Energy Conservation Measures (ECM)s representing the greatest opportunity for savings, based on simple payback for each building, are indicated below.

ECM #	Facility	ECM Type	ECM Name	ECM Description	Chilled Water Savings (ton-hrs/yr)	Steam Savings (Mlbs/yr)	Electricity Savings (kWh/yr)	Water (kgal/yr)	Utility Cost Savings (\$/yr)	Estimated Implementation Cost (\$)	Simple Payback (yrs)	Notes
26	Education 2	HVAC - Upgrades	Evaporative Cooling	Evaporative Cooling Additions	233,666.67	0.12	(40,208.00)	-	34,244.00	27,469.00		
27	Education 2	Energy Recovery - HVAC	Energy Recovery	Energy Recovery Loop Additions	27,083.33	1.43	164,726.00	-	30,275.00			
28	Education 2	HVAC - Upgrades	AHU Modification	Community Room Return Additions	157,400.00	3.41	370,127.00	-	105,388.00			
29	Education 2	Lighting - Upgrades	Interior Lighting	Lighting Replacement in Large Auditorium	2,708.33	(0.03)	27,381.00	-	9,469.00			
30	Education 2	HVAC - Controls	HVAC - Controls	CO2 Sensor Additions	(7,059,866.67)	0.53	56,565.00	-	12,256.00			
31	Education 2	Lighting - Controls	Lighting - Controls	Occupancy Sensor Additions - Lighting Only	13,183.33	(0.10)	129,062.00	-	11,990.00			
32	Education 2	Lighting - Controls	Lighting - Controls	Light Switch Additions	13,183.33	(0.10)	129,062.00	-	11,990.00			
33	Education 2	Lighting - Controls	Lighting - Controls	Daylighting	13,183.33	(0.10)	129,062.00	-	11,990.00			
34	Barbara Davis	HVAC - Upgrades	Direct evaporative cooling (media)	Direct evaporative cooling (media)	226,058.33	(0.01)	(62,493.00)	-	44,984.00			
35	Barbara Davis	HVAC - Upgrades	Direct evaporative cooling (atomizing)	Direct evaporative cooling (atomizing)	207,066.67	-	(30,293.00)	-	42,355.00			
36	Barbara Davis	HVAC - Upgrades	Indirect evaporative cooling (media)	Indirect evaporative cooling (media)	120,316.67	(0.24)	(23,079.00)	-	21,835.00			
37	Barbara Davis	HVAC - Upgrades	Indirect evaporative cooling (atomizing)	Indirect evaporative cooling (atomizing)	108,250.00	(0.22)	(48,182.00)	-	17,536.00			
38	Barbara Davis	Commissioning	Supply air duct static pressure reset	Supply air duct static pressure reset	-	-	65,924.00	-	6,033.00			
39	Barbara Davis	Commissioning	Supply and exh. duct pressure optimization	Supply and exh. duct pressure optimization	5,850.00	(0.01)	91,232.00	-	7,197.00			
40	Barbara Davis	Commissioning	Supply air temperature reset	Supply air temperature reset	108,033.33	0.50	(15,396.00)	-	26,313.00			
41	Barbara Davis	HVAC - Controls	AHU-1 Ventilation optimization and DCV	AHU-1 Ventilation optimization and DCV	2,966.67	0.14	-	-	2,793.00			
42	Barbara Davis	HVAC - Controls	HVAC integration with lighting occupancy sensors	HVAC integration with lighting occupancy sensors	4,566.67	0.24	8,944.00	-	5,590.00			
43	Barbara Davis	HVAC - Controls	Lab air change rate reduction	Lab air change rate reduction	65,283.33	1.16	325,191.00	-	44,698.00			
44	Barbara Davis	HVAC - Upgrades	Flooded high pressure steam heat exchanger	Flooded high pressure steam heat exchanger	38,983.33	0.29	-	-	13,078.00			
45	Barbara Davis	HVAC - Upgrades	Variable flow vacuum pump	Variable flow vacuum pump	2,716.67	-	19,120.00	-	6,591.00			
46	Barbara Davis	HVAC - Controls	Variable flow exhaust fan (controls option #1)	Variable flow exhaust fan (controls option #1)	-	-	76,129.00	-	2,920.00			
47	Barbara Davis	HVAC - Controls	Variable flow exhaust fan (controls option #2)	Variable flow exhaust fan (controls option #2)	-	-	158,622.00	-	6,086.00			
48	Barbara Davis	Lighting - Controls	Daylight responsive controls	Daylight responsive controls	9,791.67	(0.22)	148,446.00	-	17,579.00			
49	Barbara Davis	Lighting - Upgrades	LED luminaires with daylight responsive controls	LED luminaires with daylight responsive controls	12,733.33	(0.30)	201,672.00	-	21,465.00			
50	EHS	Energy Recovery - HVAC	Exhaust Air Heat Recovery	Exhaust Air Heat Recovery	12,191.67	2.59	(177,889.00)	-	31,210.00			
51	EHS	HVAC - Upgrades	Direct Evaporative Cooling	Direct Evaporative Cooling	53,316.67	0.08	(58,827.00)	-	9,605.00			
52	EHS	HVAC - Upgrades	Indirect Evaporative Cooling	Indirect Evaporative Cooling	22,058.33	2.59	(177,595.00)	-	33,443.00			
53	EHS	HVAC - Controls	Variable exhaust/make-up	Variable exhaust/make-up	4,208.33	0.90	90,499.00	-	20,057.00			
54	EHS	HVAC - Controls	VAV AHU-2 operation	VAV AHU-2 operation	-	0.01	2,757.00	-	329.00			
55	EHS	HVAC - Controls	VAV AHU-2 w/DCV	VAV AHU-2 w/DCV	(1,058.33)	0.01	3,372.00	-	135.00			
56	EHS	HVAC - Upgrades	Flooded High Pressure Steam Exchanger	Flooded High Pressure Steam Exchanger	-	0.25	-	-	3,851.00			
57	EHS	Lighting - Upgrades	HID Lighting Change to LED	HID Lighting Change to LED	3,891.67	(0.12)	62,346.00	-	2,761.00			
58	EHS	Lighting - Controls	LED Lighting w/Occupancy Sensors	LED Lighting w/Occupancy Sensors	6,025.00	(0.21)	103,900.00	-	4,398.00			
59	EHS	Lighting - Controls	LED Lighting w/Daylighting Responsive Controls	LED Lighting w/Daylighting Responsive Controls	10,958.33	(0.21)	123,842.00	-	5,384.00			

FINDINGS & RECOMMENDATIONS

Conservation Measures by Facility (Concluded)

The Energy Conservation Measures (ECM)s representing the greatest opportunity for savings, based on simple payback for each building, are indicated below.

ECM #	Facility	ECM Type	ECM Name	ECM Description	Chilled Water Savings (ton-hrs/yr)	Steam Savings (Mlbs/yr)	Electricity Savings (kWh/yr)	Water (kgal/yr)	Utility Cost Savings (\$/yr)	Estimated Implementation Cost (\$)	Simple Payback (yrs)	Notes
60	Perinatal Research Facility	HVAC - Controls	Variable Speed HW Pumping	Variable Speed HW Pumping	-	-	-	-	1,904.00			
61	Perinatal Research Facility	HVAC - Upgrades	Eliminate Steam System	Eliminate Steam System	-	-	-	-	9,603.00			
62	Perinatal Research Facility	Lighting - Upgrades	Lighting	Lighting	-	-	-	-	1,276.00			
63	Perinatal Research Facility	HVAC - Upgrades	AHU1 - Control + RTU at front office	AHU1 - Control + RTU at front office	-	-	-	-	22,840.00			
64	Perinatal Research Facility	HVAC - Controls	Reduce Duct Static Pressure	Reduce Duct Static Pressure	-	-	-	-	8,728.00			
65	Perinatal Research Facility	HVAC - Controls	PH1 - VVT/DDC Conversion	PH1 -VVT/DDC Conversion	-	-	-	-	8,515.00			
66	Perinatal Research Facility	Energy Recovery - HVAC	Heat Chamber Heat Recovery	Heat Chamber Heat Recovery	-	-	-	-	1,619.00			
67	Perinatal Research Facility	O&M	Behavioral Changes/Greenlab	Behavioral Changes/Greenlab	-	-	-	-	936.00			
68	Perinatal Research Facility	HVAC - Upgrades	Ground Source Heat Pump System	Ground Source Heat Pump System	-	-	-	-	21,319.00			
69	Perinatal Research Facility	Distributed Generation - PV	Photovoltaics - Roof Mounted	Photovoltaics - Roof Mounted	-	-	-	-	1,437.00			
70	Perinatal Research Facility	Distributed Generation - PV	Photovoltaics - Parking Structure	Photovoltaics - Parking Structure	-	-	-	-	TBD	TBD		
71	Research 1	Energy Recovery - HVAC	Heat Recovery on AHU-202	Heat Recovery on AHU-202	219,298.91	11,712.21	517,664.00		230,742.40			Design is completed. Awaiting funding and implementation.
72	Research 1	Energy Recovery - HVAC	Heat Recovery on AHU-201	Heat Recovery on AHU-201	186,810.18	9,202.45	406,736.00		181,297.60			Design is completed. Awaiting funding and implementation.
73	Research 1	HVAC - Upgrades	Evaporative Cooling for Four AHUs	Evaporative Cooling for Four AHUs	374,700.00	-	-	-	82,433.00			Design is completed. Awaiting funding and implementation.

Appendix A ASHRAE Audit Research 2 Building

ASHRAE Level II Energy Audit Report

University of Colorado – Anschutz
Research II Facility

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1.0 Executive Summary

This section provides the findings and analysis from AECOMs energy audit and initial assessment of potential energy conservation measures (ECMs) at Research II Building, one of the relevant sites identified by the Anschutz Medical Campus team. The audit was performed in accordance with ASHRAE Level II requirements for energy auditing and reporting. Level II requirements both identify opportunities for energy savings and also project financials which become actionable information items for future projects to be based upon.

The comprehensive energy audit consisted of 1 building identified in Table 1. The facility was audited the week of August 12th, 2019.

Table 1: CU Anschutz Medical Campus

Building Number	Building Name	Functional Use	Area (SF)	Year Built
P15	Research II	Laboratory	476,620	2008

1.1 Key Audit Findings

For Research II Building, the audit process identified a potential annual cost savings of \$547,110 through 6 separate ECMs that have the potential of providing a reduction of:

- 3,822,786 kilowatt hours (kWh) of electricity, annually
- 11,960 MLBS of steam, annually
- 611,433 Ton-hrs. of chilled water, annually
- 13,466 kgals of water, annually

Table 2 lists all identified ECMs with paybacks less than 10 years and their associated implementation cost and savings metrics. A detailed description of each ECM is included in Section 7 of this report.

Table 2: Summary of Recommended Energy Conservation Measures

ECM No.	ECM Desc.	Annual Utility Savings				Est. Annual Cost Savings	Invest.	Simple Payback	20yr NPV	SIR
		(kWh/yr)	(kgal/yr)	(MLBs/yr)	(Ton-hrs/yr)	(\$/yr)	(\$)	(years)	(\$)	
1	Interior Lighting Efficiency	2,648,709	0	0	0	\$97,539				0.2
2	Interior Lighting Controls - Occupancy Setback	274,223	0	0	0	\$10,098				0.1
3	Continuous-Commissioning - Existing System RCx	101,300	0	4,949	389,688	\$139,857				1.9
4	Continuous Commissioning - Continuous Commissioning of existing systems and ECM performance monitoring.	502,278	0	2,225	221,637	\$85,718				1.3
5	Reduce ACH by for unoccupied areas	296,276	0	4,786	108	\$93,714				93.7
6	Water Conservation Measures	0	13,466	0	0	\$120,183				0.1
	Totals	3,822,786	13,466	11,960	611,433	\$547,110	\$			0.3

2.0 Audit Methodology & Scope

2.1 ASHRAE Level II Guidelines

Figure 1 provides the auditing and reporting requirements for ASHRAE Level I, II and III commercial building energy audits. This auditing report provides and surpasses the requirements of ASHRAE Level II, as whole-building energy models were developed to determine ECM savings interactions.

PROCESS	AUDIT LEVEL		
	I	II	III
Conduct Preliminary Energy-Use Analysis (PEA)	•	•	•
Conduct walk-through survey	•	•	•
Identify low-cost/no-cost recommendations	•	•	•
Identify Capital improvements	•	•	•
Review mechanical and electrical (M&E) design and conditions and O&M practices		•	•
Analyze capital measures (savings and cost, including interactions)		•	•
Meet with owner/operators to review recommendations		•	•
Conduct additional testing/monitoring			•
Perform detailed system modeling			•
Provide schematic layouts for recommendations			•
REPORT	AUDIT LEVEL		
	I	II	III
Estimate savings from utility rate change	•	•	•
Compare EUI to EUI of similar sites	•	•	•
Summarize utility data	•	•	•
Estimate savings if EUI were to meet target	•	•	•
Calculate detailed end-use breakdown		•	•
Estimate Capital Project costs and savings		•	•
Complete building description and equipment inventory		•	•
Document general description of considered measures		•	•
Recommend measurement and verification (M&V) method		•	•
Perform financial analysis of recommended EEMs		•	•
Write detailed description of recommended measures			•
Compile detailed EEM cost estimates			•

Figure 1: ASHRAE – Procedures for Commercial Building Energy Audits, Second Edition

2.2 Audit Process

Site inspections were carried out the week of August 12th, 2019 to determine the physical and operational condition of the building systems. Interviews with maintenance personnel were conducted during the site visits to understand the facility operation, details of any recent upgrades and/or modifications to the systems, plans for upcoming capital upgrades, and to identify current operational concerns.

The mechanical systems, including heating system, cooling system, and the domestic hot water were examined during the site visit. All equipment from these categories were inspected and inventoried. Data collection included the system-specific end-use, capacity, run time, equipment age, and all equipment nameplate information (where available). Operational notes that would help identify potential ECMs were taken for all equipment. Lighting systems were inspected with inventorying that includes all lighting types, capacities, location, operational hours and quantities. Lighting controls were evaluated and potential ECMs were noted.

2.3 ECM Identification

The identification and development of the ECMs presented in this report consisted of the following general evaluation stages:

- Existing system components were modeled through a whole-building energy model that utilized connected loads developed through the equipment inventorying process and calibrated to facility energy consumption data.
- ECMs identified from the facility inspections were modeled against component systems energy consumption in order to evaluate energy and cost savings.
- Implementation costs associated with the prescribed ECMs were developed using known contractor pricing and RSMeans cost data.
- Cost/benefit analyses were developed, including payback calculations for the proposed energy conservation opportunities.

Equipment and system costing values are estimates, based on industry standards and RSMeans costing database public weather data to determine the energy savings associated with proposed measures.

2.4 Financial Analysis – Methodologies & Assumptions

All financial analyses included in this report were developed using the National Institute of Standards and Technology (NIST) Handbook 135 Life-Cycle Cost (LCC) Analysis and the May 2017 Energy Price Indices and Discount Factors Annual Supplement. For this audit, the NIST Life-Cycle Cost methodology was used to perform an analysis of each ECM. Using the initial project cost, annual savings, life of the equipment, and the equipment's replacement cost, the LCC develops a variety of useful financial and energy savings metrics.

The LCC methodology uses the following assumptions to estimate the potential energy and financial savings:

- **Maintenance Escalation** – This variable represents the annual increase in maintenance costs. In the calculator, it is assumed that these costs will increase by 2.2 percent each year.
- **Discount Rate** – Also known as the rate of interest, this variable is used to convert or discount future cash flows to a common time. The industry standard value of 3 percent was used.
- **Time Period** – Savings for each project are calculated over a period of 20 years.

- **Utility Escalation Rate** – This variable represents the annual increase in utilities cost. Energy commodity escalation projections developed by the U.S. Energy Information Administration were used. Based on this data, it is assumed these costs will increase by 1.5 percent each year.
- **Utility Rates** – A rate structure analysis is provided in Section 4 of this report, which identifies rates with which savings were developed.

The cost calculation reports three different metrics to determine the financial effectiveness of each project. These are:

- **20-Year Net Present Value (NPV)** – Current total value of all annual savings and one-time costs, minus the initial cost. If a net present value is less than zero (0), it is due to either the annual savings costs being less than annual O&M or less than the amortized capital cost.
- **Savings to Investment Ratio (SIR)** – Twenty (20) year net present value divided by the initial investment. This is a unit-less measure of performance where if the SIR is greater than one, the project is cost effective. If greater than one (1), this means that for each extra dollar spent, the amount saved will be greater. If the SIR is less than one (1), for each extra dollar spent, the amount saved will be less.
- **Simple Payback** – The number of years after ECM construction that the aggregate annual savings would equal the cost of implementation.

3.0 Facility Descriptions

3.1 Research II Building

3.1.1 Facility Overview

Research II is an 11-story, 476,620 square-foot building at the University of Colorado Anschutz medical campus. It was constructed in 2008. The primary building use is laboratory and office space from floors 4 through 11 and floors 1 through 4 comprised of mechanical space and common space for occupants. The facility is constructed of structural steel and reinforced concrete with a glass curtain wall exterior on the east facing wall and a brick veneer and glass exterior on the west facing wall. Heating and cooling are supplied from a central plant at CU Anschutz that provides the campus with steam and chilled water. The facility is open 24 hours a day, 7 days a week.

Building Envelope

Walls

Double-paned glass curtain and aluminum ladder exterior on the east side of the building and a brick veneer with internal foil faced semi-rigid insulation on the west side of the building. Wall assemblies have minimum U-value of 0.042 (R-24)

Windows

Insulated Low-E glass units.

U-value Winter = 0.29

U-value Summer = 0.26

Shading Coefficient = 0.44

Roof

Concrete deck with built up insulation. Roof assemblies have minimum U-value of 0.50 (R-20).

Mechanical Systems

Cooling Systems

Central plant on site provides chilled water to the building where chilled water pumps distribute the chilled water to built-up air handlers or to a heat exchanger for a process cooling water loop.

Heating Systems

Central plant on site provides steam to the building where steam to water heat exchangers provide heating hot water and pumps distribute the heating hot water throughout the building. Large built up air handlers use steam for heating and humidification as well.

Air Distribution & Ventilation Systems

There are 8 large air handlers, roughly 80,000 CFM each, where the supply air ducts manifold together and are routed up shafts to service all floors. All units are 100% outside air units and multiple exhaust fans are manifolded together to exhaust the lab areas and maintain building pressurization.

Domestic Hot Water Systems

Central plant on site provides steam to the building where steam to water generators are used to provide domestic hot water throughout the building.

Electrical Systems

Lighting

The majority of the lighting fixtures of Research II are T8 32-Watt linear fluorescent lamps, either of 2 ft or 4 ft length, recess mounted into the drop ceiling of each floor of the building. The remainder of the lighting fixtures throughout the building are either Type A or 4-pin compact fluorescents that comprise many of the wall-mounted down lights and also task lighting in the offices and laboratories.

Manual lighting controls are installed on most lighting circuits throughout the building. There are several areas within the facility that have occupancy sensors, typically common spaces, and there are also dimming switches in several of the conference rooms.

Transformers

Dry type transformers are located in several mechanical/electrical spaces throughout the facility. All were installed during construction of the building in 2008 and are typically 480V harmonic distortion mitigating.

Energy Management System

The facility heating and cooling distribution systems are currently controlled by a Siemens Apogee Building Automation System (BAS). The current controls strategy is based on single setpoints. The University is planning to upgrade to the Siemens Desigo system in the near future.

Miscellaneous Systems

Elevators

There is an elevator bank that is run by 4 worm-drive machines that each have a 60HP motor. None of the machines are equipped with regenerative braking.

Lab Hoods

There are approximately 30 lab hoods on each floor of laboratory space within Research 2. These lab hoods are connected to the roof exhaust system.

Ultra-Low Temperature Freezers

Each floor of laboratory space within the facility has approximately 85 Ultra Low Temperature (ULT) freezers that provide cooling down to -80°F. Many of these freezers are of different manufacturers, different ages and different energy standards.

3.2 Controls Strategy

Table 3: Research II Building Operational Schedule

Operational Condition	Days	Start time	End Time	Heating Set point Temperature (°F)	Cooling Set point Temperature (°F)
Occupied	Mon-Sun	24/7	24/7	69	72
Night Setback		N/A	N/A	N/A	N/A
Unoccupied				N/A	N/A

4.0 Utility Analysis

The site utilities include electricity, steam, chilled water and water. AECOM analyzed the site utilities in order to evaluate utility consumption, costs, and rates, which yields a deeper understanding of the baseline utility consumption and savings potential. The baseline profile for energy consumption was developed using utility data from the past two years. It is important to note that the cost of consumption values in this utility analysis section reflect the past two years rate structure. Meanwhile, the cost savings calculations for all ECMs were developed using real costs from calendar year 2019 utility bill analyses in order to most accurately reflect expected cost savings.

Table 4: Baseline Utility Consumption and Blended Rates

Commodity	Consumption	Cost	Actual \$/unit	Demand Rate (\$/kW)
Electricity	18,548,824	\$1,278,189	\$0.069	N/A
Steam	21,138	\$262,875	\$12.43	N/A
Chilled Water	2,073,139	\$494,927	\$0.23	N/A
Water	26,379	\$271,291	\$10.28	N/A
Total		\$2,307,282		

4.1 Utility Data – Research II Building

Figure 2 illustrates utility spending each month for an entire year for Research II Building electricity, steam, chilled water and water consumption.

Figure 2: Monthly Utility Cost Breakdown – Research II Building

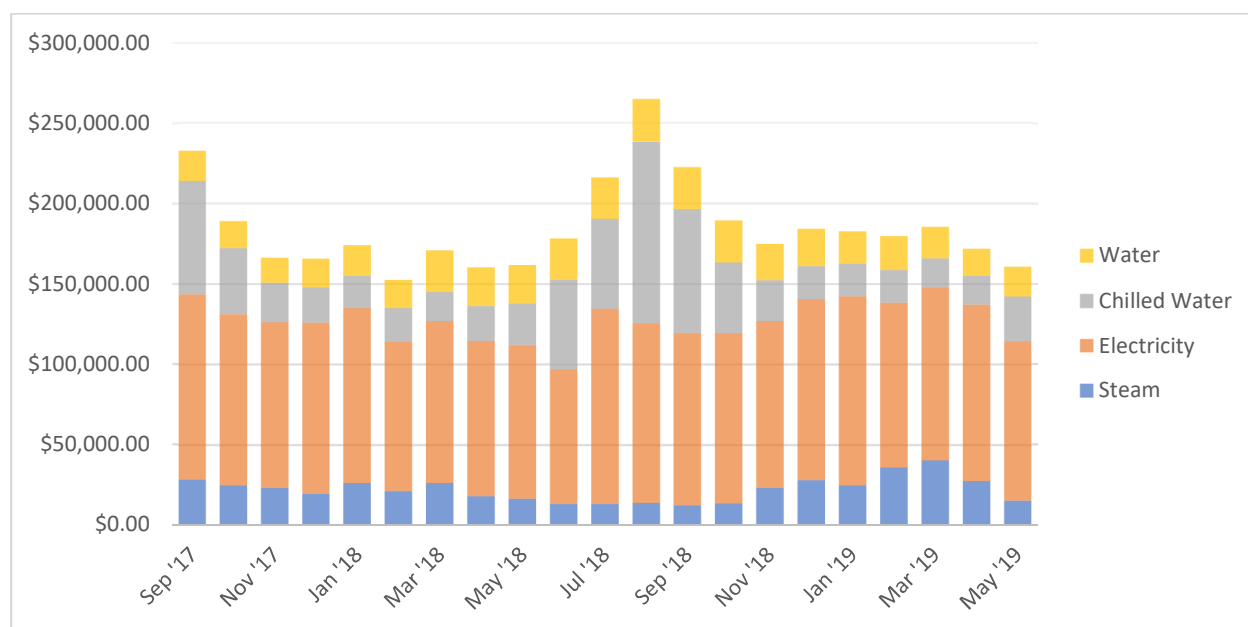


Figure 3 plots electricity consumption and spending each month for an entire year.

Figure 3: Monthly Electricity Usage and Cost – Research II Building

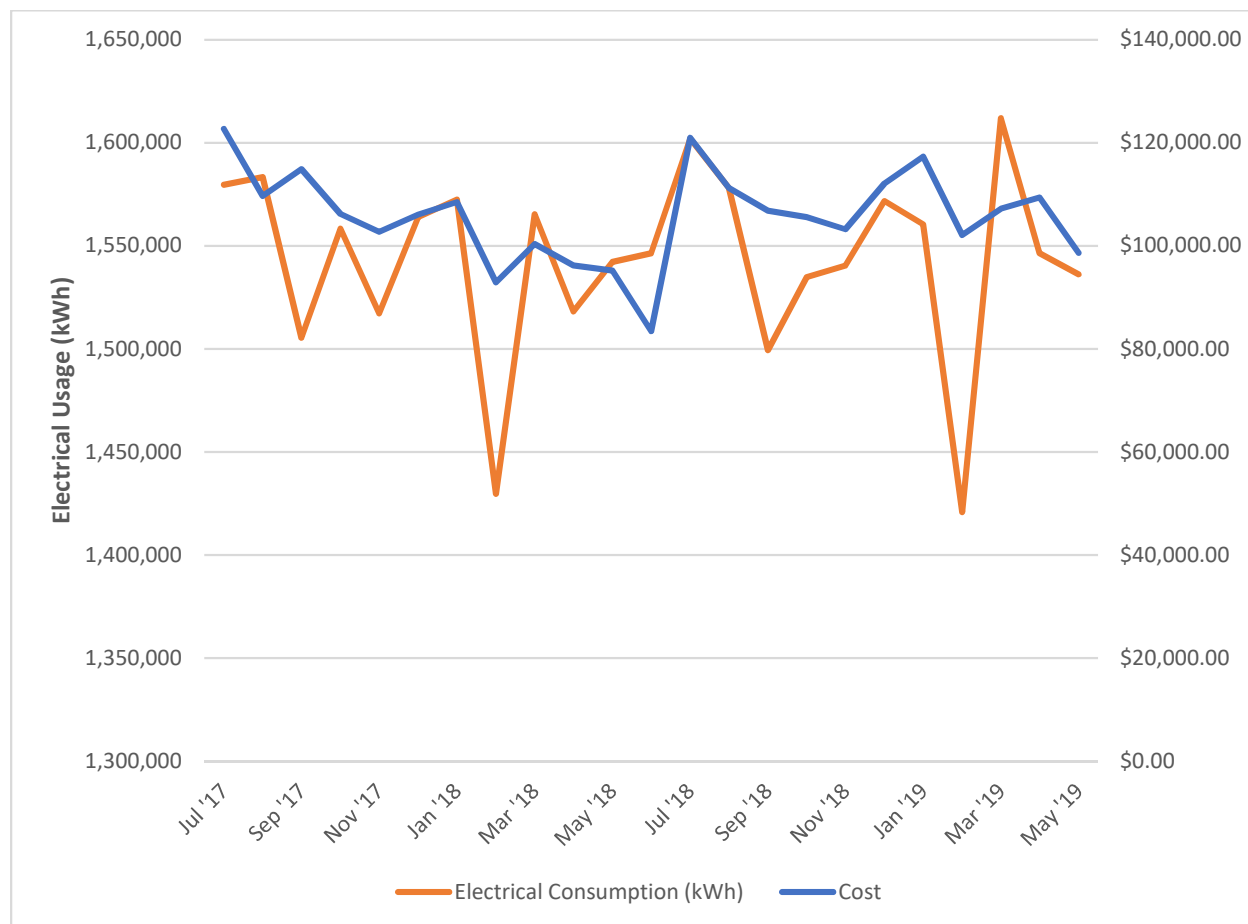


Figure 4 plots steam consumption and spending each month for an entire year.

Figure 4: Monthly Steam Usage and Cost – Research II Building

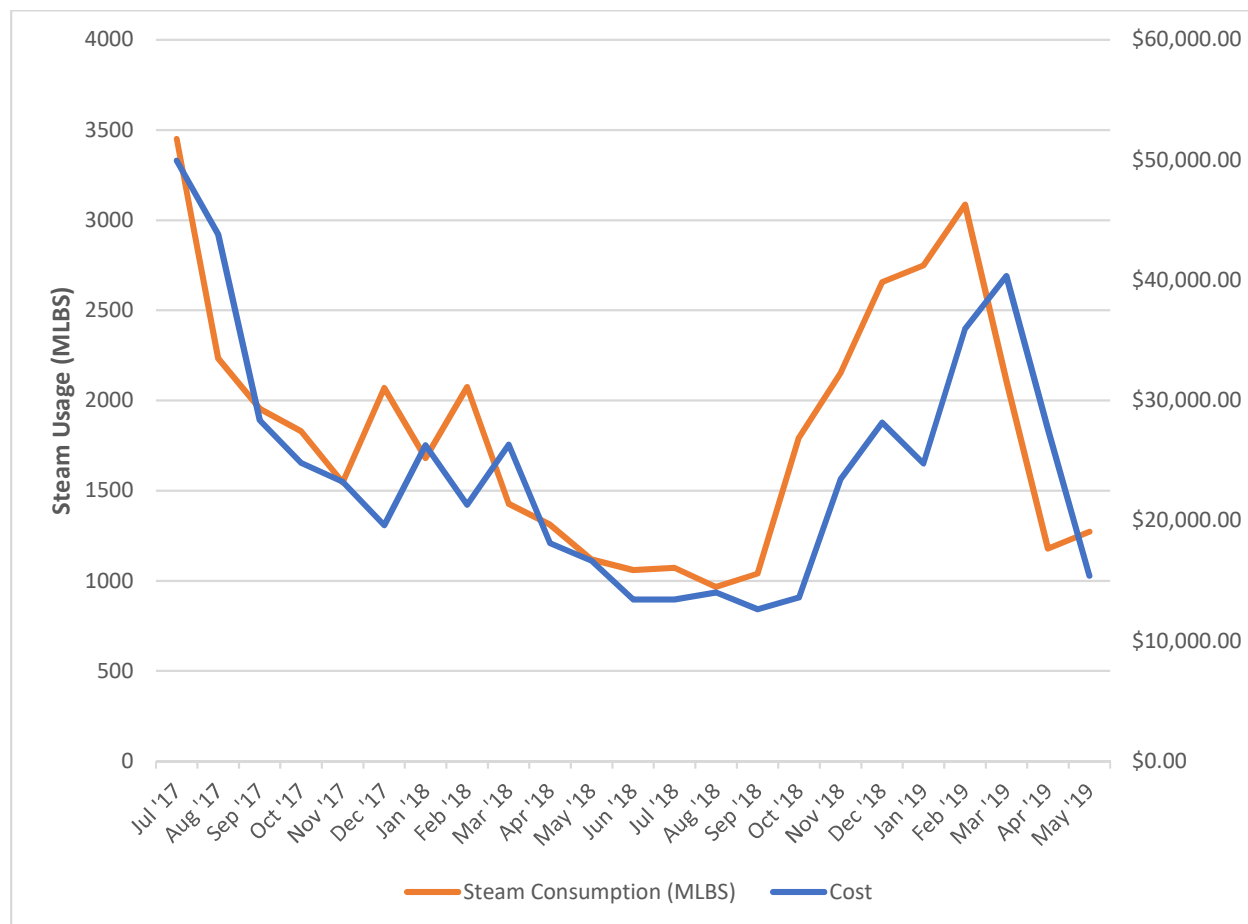


Figure 5 plots chilled water usage and spending each month for an entire year.

Figure 5: Monthly Chilled Water Usage and Cost – Research II Building

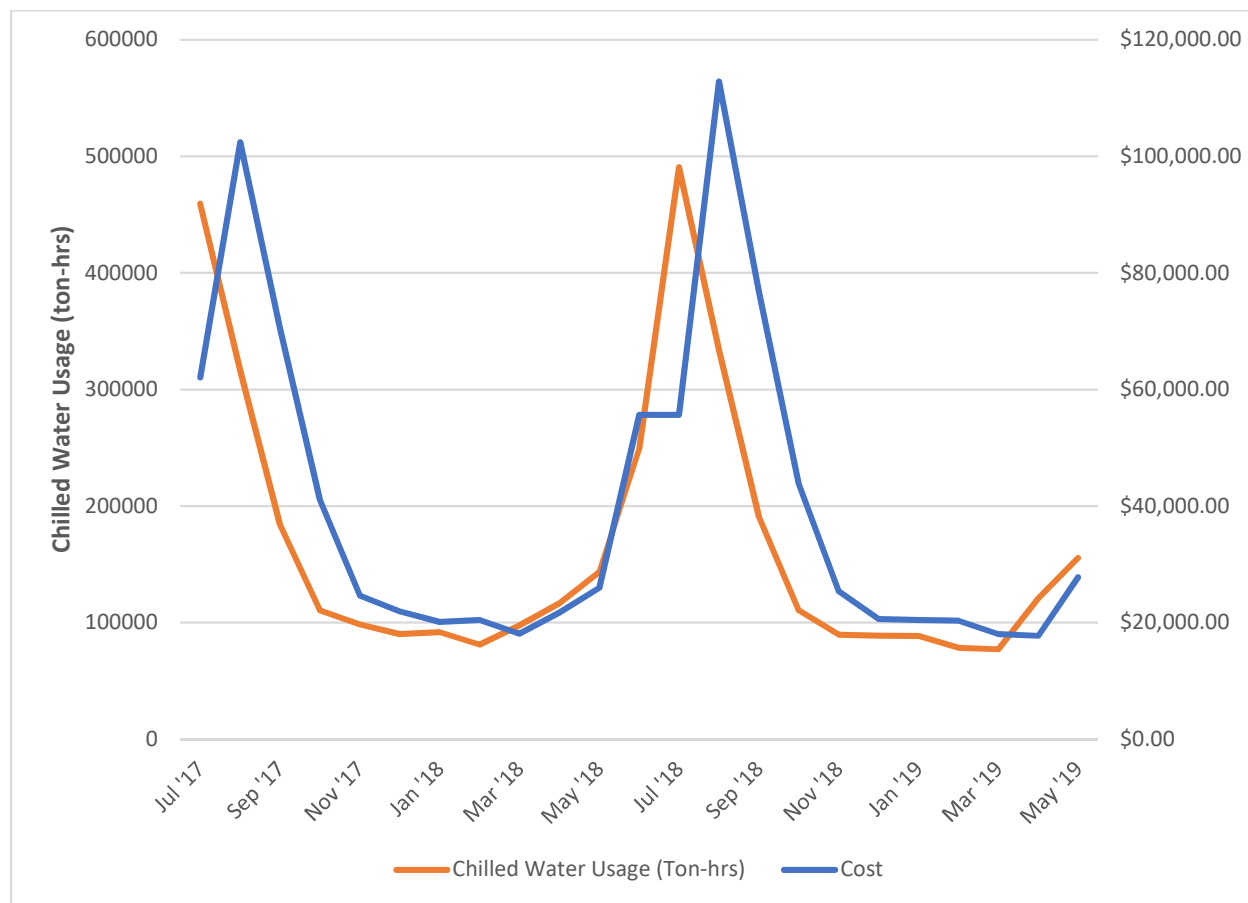
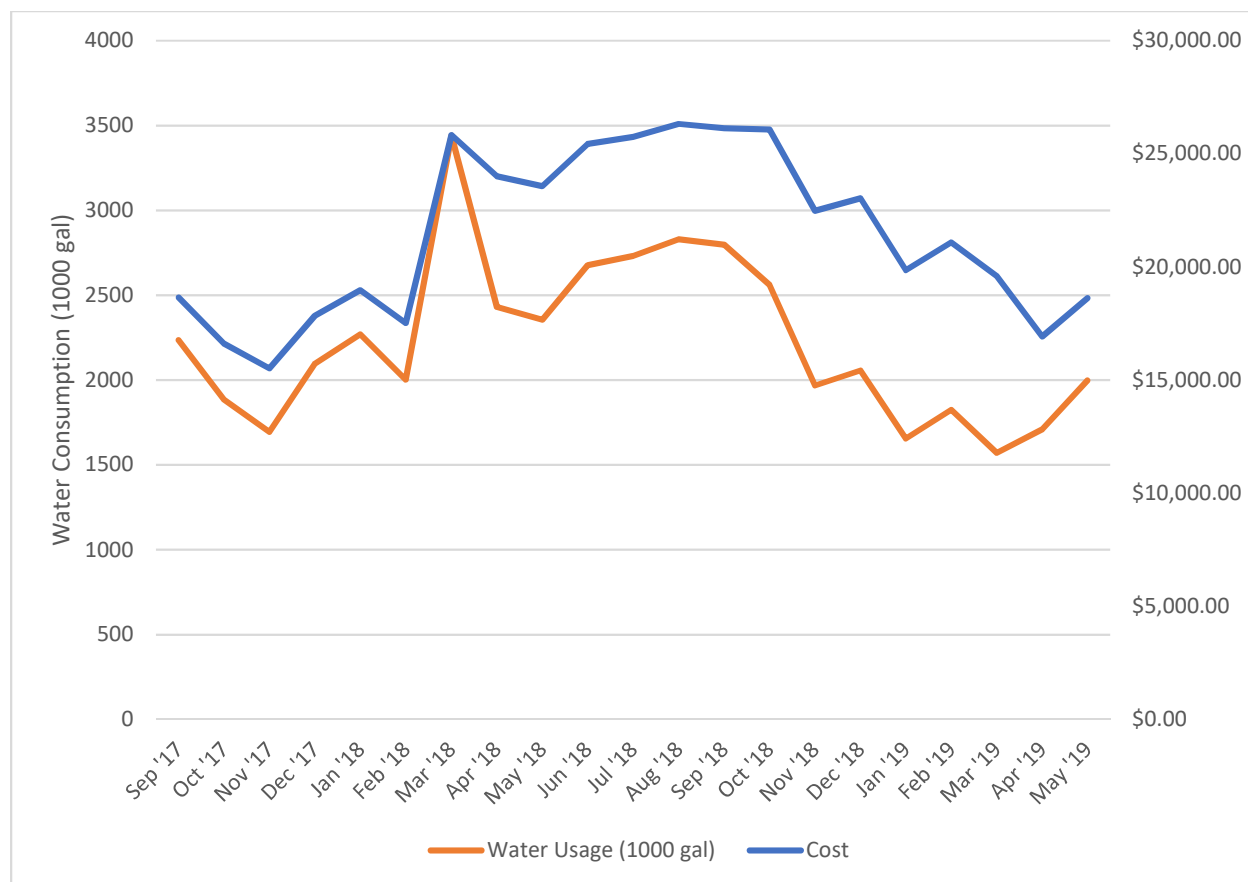


Figure 6 plots domestic water usage and spending each month for an entire year.

Figure 6: Monthly Domestic Water Usage and Cost – Research II Building



5.0 Energy Allocation Analysis

5.1 Overview of Facility Energy Allocation

This energy allocation analysis estimates energy consumption for the Research II Building site end-uses as a fraction of its total annual energy consumption. The allocations provide an insight into the efficiency of the building systems and provide a basis for energy savings calculations for each potential ECM. Systems typically considered in the analysis include heating, ventilation, and air conditioning (HVAC), lighting, plug loads, process, and other energy-consuming systems. For this preliminary analysis, AECOM developed energy allocation estimates based on information gathered during the site visit, using building energy simulations, and from our experience at similar facilities.

Proprietary modeling software that utilizes the connected-load inputs of the mechanical equipment and lighting inventory were used to develop end-use consumption values specific to facility type and location. The following tables and graphs provide the end-use electric consumption for each building. Costs for this breakdown were developed using the blended utility rates from Section 4.

5.2 End-Use Component Breakdown – Research II Building

Table 5: Modeled Annual End-Use Electric Consumption – Research II Building

End-Use	Installed Capacity	Demand Intensity	Effective Full Load Hours	Consumption		Energy Cost
				Intensity	Absolute	
	kW	W/ft ²		kWh/ft ²	kWh	
Interior Lighting	716	1.5	4,890	7.3	3,499,125	\$241,167
Fans – Air Handling Units and Exhaust Fans	2,098	4.4	2,376	10.5	4,985,371	\$343,525
Pumps and Compressors	465	1.0	5,757	5.6	2,676,965	\$184,475
Equipment	2,322	4.9	3,182	15.5	7,387,362	\$509,022
Total	5,601	11.8		38.9	18,548,824	\$1,278,189

Table 6: Modeled Annual End-Use Steam Consumption – Research II Building

End-Use	Installed Capacity	Demand Intensity	Consumption		Energy Cost
			Intensity	Absolute	
	kBtu/h	Btu/ft ²	kBtu/ft ²	kBtu	
Heating*	49,559	104.0	45.0	21,462,324	\$256,732
DHW*	1,440	3.0	1.1	513,510	\$6,143
Total	50,999	107.0	46.1	21,975,834	\$262,875

* Steam and chilled water purchased from a central plant

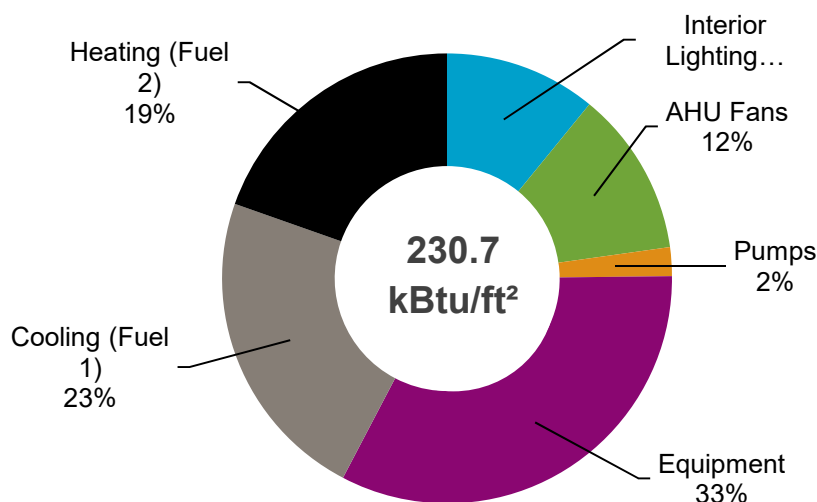
Table 7: Annual End-Use Chilled Water Consumption – Research II Building

End-Use	Installed Capacity	Demand Intensity	Consumption		Energy Cost
			Intensity	Absolute	
	kBtu/h	Btu/ft ²	kBtu/ft ²	kBtu	
Cooling*	11,630	24.4	52.2	24,870,603	\$494,927

* Steam and chilled water purchased from a central plant

Figure 11 shows the proportional breakdown of energy end-uses at the facility. The majority of energy is consumed by equipment. This is considered plug loads and non-facility conditioning equipment. The proportion of cooling and heating being purchased from the central plant are also identified as the next largest consumption values. The overall energy benchmark, which is energy consumed per area of facility space is provided in kBtu/ft².

Figure 11: Energy Consumption by End-Use Percentage for Research II



6.0 Energy Performance Benchmarking Comparison

The building has a calculated Energy Use Intensity (EUI) of **230.7 kBtu/sf** from data provided by the University. Commercial Buildings Energy Consumption Survey (CBECS) would predict and EUI of **115.3 kBtu/sf** for a building of similar size, usage, and climate zone. This difference is mainly due to the type of equipment being used in the facility and the extended operation hours of the facility.

7.0 Energy Conservation Measures

AECOM identified potentially viable ECMs and associated cost saving opportunities that will enable CU Anschutz to progress toward its resiliency and energy conservation goals. The ECMs provide intrinsic resiliency value as part of a holistic approach to improve overall resiliency by reducing energy consumption. In most cases, ECMs are associated with buildings and end-uses.

7.1 Low Cost/No Cost – O&M Measures

7.1.1 Reduce ACH for Unoccupied Areas

Table 8: Reduce ACH Savings

Building	Budgetary Costs	Annual Utility Savings			Annual Energy Cost Savings	Annual O&M Costs	Simple Payback	NPV	SIR
		Electricity (kWh)	Steam (MLBS)	Chilled Water (ton-hrs)	(\$)	(\$)	(years)	(\$)	
R2	\$	296,276	4,786	108	\$93,714	N	0.0		

Existing Condition

It is standard industry practice to provide a high ventilation rate in laboratory spaces to ensure the health and safety of building occupants. While prevailing codes and standards vary in the specific amount of ventilation that is required for each laboratory occupancy classification, the recommended range is 4 to 12 air changes per hour (ACH). At Research II, a rate of 6 ACH is always employed, including during unoccupied hours, resulting in excess energy being utilized to condition incoming outdoor air.

Recommendation

Utilizing the existing controls, reduce the ACH rate for unoccupied hours. This measure assumes the ventilation rate will be reduced to 4 ACH between 11:00 PM and 6:00 AM.

Implementation

This measure can be achieved using existing HVAC control infrastructure and can be executed by Facilities staff. The cost is conservatively estimating the time for CU staff to program the BAS and to check operation once implemented.

7.2 Recommended Measures

The following section provides the analysis results and description of measures that were evaluated for Research II Building that have a payback of less than 10 years.

7.2.1 Interior Lighting Efficiency

Table 9: Lighting Savings

Building	Budgetary Costs	Annual Utility Savings		Annual Energy Cost Savings	Annual O&M Costs	Simple Payback	NPV	SIR
		Electricity (kWh)	Demand (kW)	(\$)	(\$)	(years)	(\$)	
R2	\$	2,648,709	556	97,539	N/A	4.54	\$1,158,669	2.6

Existing Condition

The lighting that currently exists within the facility is the original lighting from construction in 2008. This consists of linear fluorescent and compact fluorescent lamps that are far less energy efficient than LED lamps that are currently available.

Recommendation

Replace the lamps in all existing linear fluorescent fixtures with LED equivalent luminaires. The new installation can be either a tubular LED lamp replacement or an LED retrofit kit. A tubular lamp replacement typically requires changing the electrical wiring, replacing the ballast with an external driver or altering the existing holders ("tombstones") to accommodate the new lamps. Newer technologies can offer magnetic luminaire strips with on-board drivers that can be directly wired to the existing electrical lead and connected to the existing metal trougher with magnets, leaving the existing tombstones in place for a quick and efficient replacement. A retrofit kit provides the required electrical components, optical element and light source in a prepackaged kit. This replacement option can bypass the ballast entirely and run directly from the line voltage at the installation and will be compatible with the reduced wattage, helping to keep installation costs down.



Implementation

Estimate includes the cost to furnish all lamps, including material and labor cost estimates using RSMeans data. In order to estimate savings, yearly runtime estimates were made for all existing fixtures based on operational/occupancy schedule(s) and control(s) collected during the audit. This measure will replace or modify existing lighting fixtures to LED technology. This measure will reduce electric consumption and peak demand, reduce labor for changing lamps, and reduce lamp replacement costs while improving lighting quality. Overall, this measure contributes to achieving overall efficiency that will help increase reliability and resiliency at the site.

7.2.2 Interior Lighting Controls – Occupancy Controls/Occupancy Setback

Table 10: Interior Lighting Controls Savings

Building	Budgetary Costs	Annual Utility Savings			Annual Energy Cost Savings	Annual O&M Costs	Simple Payback	NPV	SIR
		Electricity (kWh)	Electricity (kW)	Natural Gas (therms)	(\$)	(\$)	(years)	(\$)	
R2	\$	274,223	0	N/A	\$10,098	N/A		\$	1.8

Existing Condition

The existing lighting controls are typically manual S1 switches with few rooms controlled by occupancy sensors or dimmers. There is no central lighting control system currently installed in the facility. It was observed during the audit that the majority of lighting was on past 9pm on several nights while the facility was minimally occupied.

Recommendation

It is recommended that the University install a lighting control system, such as Siemens Encelium, as well as occupancy sensors throughout the facility in order to reduce lighting runtime based on an efficiency setback of occupancy or daylight harvesting.

Implementation

Estimate includes the cost to furnish all control hardware and software, including material and labor cost estimates using RSMeans data. In order to estimate savings, yearly runtime estimates were made for all existing fixtures based on operational/occupancy schedule(s) and control(s) collected during the audit. This measure will replace or modify existing manual lighting controls with occupancy sensors. This measure will reduce electric consumption and utility costs. Overall, this measure contributes to achieving overall efficiency that will help increase reliability and resiliency at the site.

7.2.3 Continuous Commissioning and Building Optimization

Table 11: ECM 7.2a - Building Optimization Combined Savings

Building	Chilled Water Savings (ton-hrs/yr)	Steam Savings (Mlbs/yr)	Electricity Savings (kWh/yr)	Water Savings (kgal/yr)	Utility Cost Savings (\$/yr)	Estimated Implementation Cost (\$)	Simple Payback (yrs)
R2	389,688.0	4,949.0	101,300.0	0	\$139,857	\$72,000	0.51

Table 12: ECM 7.2b - Continuous Commissioning Savings

Building	Chilled Water Savings (ton-hrs/yr)	Steam Savings (Mlbs/yr)	Electricity Savings (kWh/yr)	Water Savings (kgal/yr)	Utility Cost Savings (\$/yr)	Estimated Implementation Cost (\$)	Simple Payback (yrs)
R2	221,637.0	2,225.0	502,278.0	0	\$85,718	\$	

Existing Condition

This measure deals mainly with the existing building automation system (BAS) and the use of the existing SkySpark data analytics platform for equipment diagnostic purposes. The existing control system is a Siemens Insight control system, that is currently being upgraded to the Siemens Desigo control system. The system was installed when the building was constructed in 2008 and has full digital control over all of the mechanical systems described in Section 3.0 of this report. In general, the systems are all operating in accordance with the original design sequence of operations document that was used by the construction team. The system is in good working order and fully capable of accepting modifications to the existing programming and control methods.

In addition to the Siemens Insight BAS, there is an instance of the SkySpark platform installed to monitor energy, natural gas, steam, and chilled water usage throughout the campus. SkySpark is a stand-alone software package that is capable of collecting data from a variety of sources and analyzing the data based on a customized set of rules that are developed for each application. For the Research 2 building, SkySpark is currently only used to monitor the utilities used by the building from both the electric grid and the central utility plant.

Recommendation

This recommendation is split into two sections: Optimization of the existing mechanical systems and continuous commissioning and diagnostics of systems and ECMs after they are implemented.

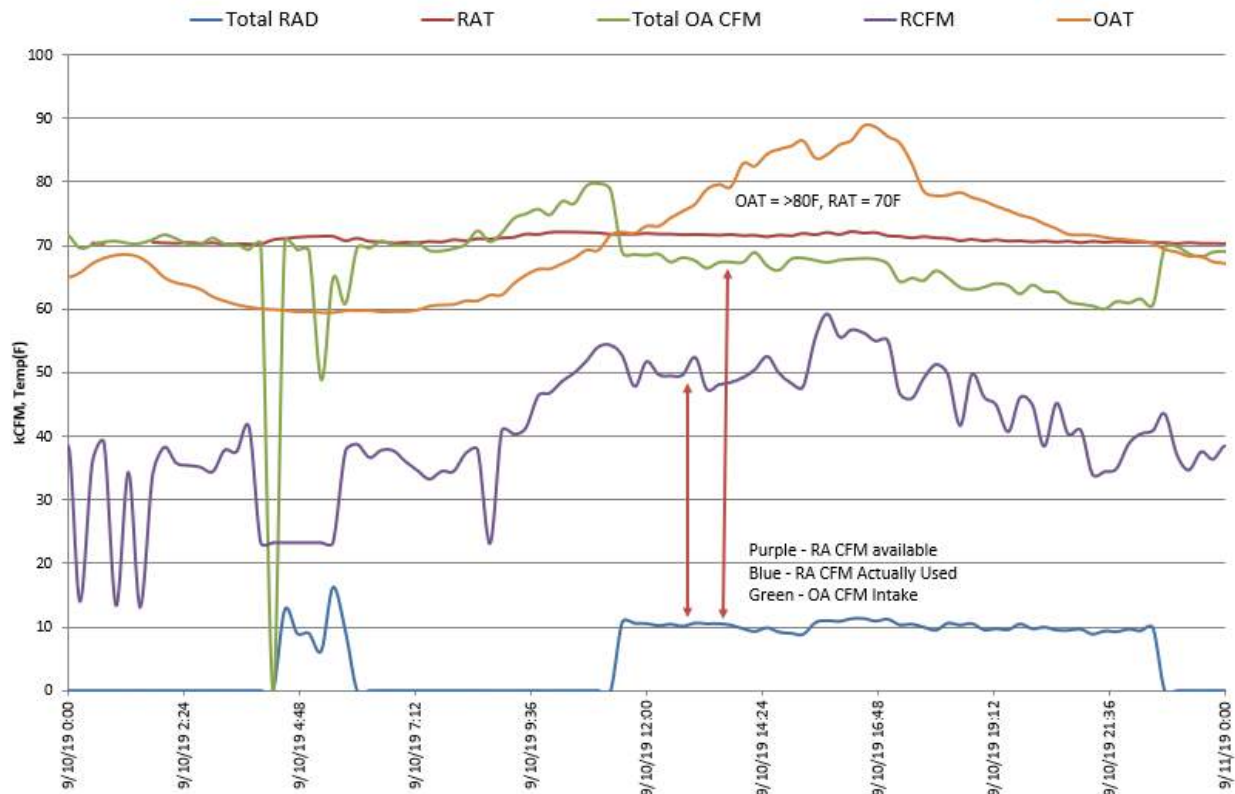
Optimization of Existing Mechanical Systems:

Operational data was collected from the BAS and a list of potential energy conservation measures was developed based on inefficiencies found in the building. The individual measures included in the savings calculations are listed below:

1. Minimize OA intake based on building pressurization and thermal demands: The goal of this measure is to minimize the outside air intake at the AHU OA intake dampers, which was observed to be in excess of the amount required to balance the building exhaust load and ventilation requirements. The following figure provides an example of an AHU system that is exhausting 40,000 CFM of conditioned air that could be recirculated and used to lower the overall cooling load of the building. This measure recommends adjusting the programming of the OA intake dampers so that the minimum flow setpoint is low enough that all available return air is recirculated. This will minimize the amount of total

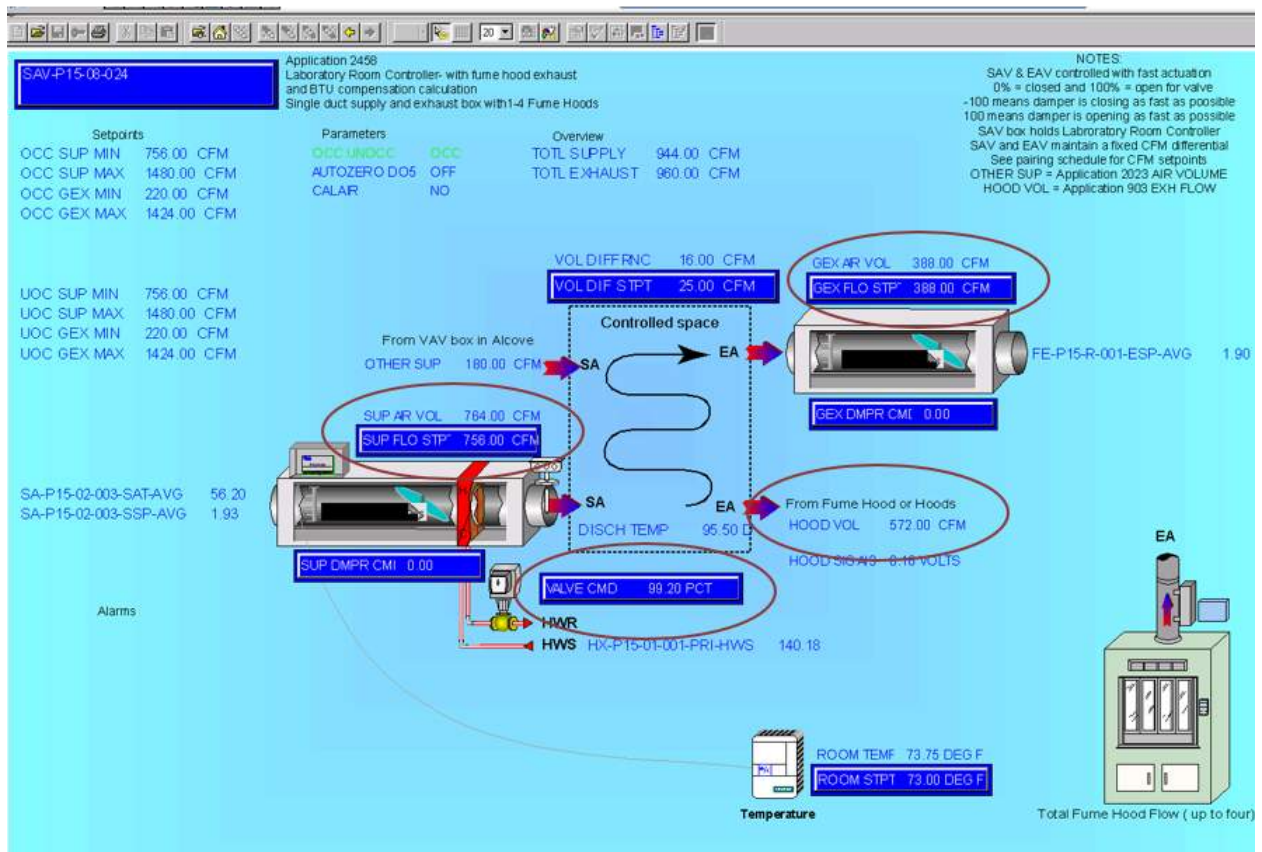
heating and cooling energy used by the building AHUs to meet the supply air temperature and CFM requirements.

Figure 12: AHU Operational Data Showing Unnecessary Ventilation



2. **Reduce Terminal Unit Minimum Flow Setpoints:** A large sample of terminal unit controls were inspected and it was observed that many areas have a high utilization of the reheat coils during both cold and warm weather. In many cases, the CFM setpoints determined in the design phase appear to oversupply air to the spaces, which leads to overcooling and additional mechanical heat usage. This measure recommends reducing the minimum CFM setpoints on terminal units, supply and exhaust where applicable, in areas where trends show consistent use of mechanical heat when the system should be cooling or idle. The following figure provides an example of a laboratory unit that is fully utilizing its reheat coil while still exhausting air through the general exhaust. In this example, both the supply and exhaust minimum CFM setpoints should be reduced so that the room is still properly balanced but simultaneous heating and cooling at the supply VAV is minimized.

Figure 13: Terminal Units in Laboratory Oversupplying Air



3. Install Occupancy Sensors with Fume Hoods – In laboratories, when occupied, ASHRAE recommends that there be a minimum face velocity across the opening of the fume hood as well as a minimum room air change rate based on the volume of the space. If occupancy is being monitored, and it is determined to be unoccupied, the requirements for air changes per hour in the room are reduced. This measure suggests installing occupancy sensors in the laboratory areas and adjusting airflow requirements to reduce the overall air delivered. This will reduce the overall energy used by the AHU fans and overall heating load in the building.
4. Reduce Night Mode CFM and Temperature Setpoints – For non-lab areas, this measure suggests adding an occupied schedule and turning off airflow to areas in night mode if temperature parameters are satisfied. This will reduce the overall load on the supply fans and heating systems when the building is at low occupancy.
5. DAT Reset on Return Air Units – Increasing the DAT during winter months will help to reduce the demand for steam for heating from the central utility plant. This measure suggests increasing the discharge air temperature automatically as outside air temperature decreases, which will minimize the amount of conditioned air that is exhausted during winter months.

6. Repair Static Pressure Control on Return Fans – several return fans in the building were operating in a “run-out” condition because setpoints could not be met and utilization was maximized. This measure suggests repairing the control of the static control on return fans so that setpoints can be achieved and fans are allowed to modulate.

Continuous Commissioning of Existing Systems and ECM Performance Monitoring:

This part of the recommendation was designed to serve two purposes: Expand the existing capabilities of SkySpark monitoring to include equipment diagnostics and troubleshooting, and also to monitor the performance of all implemented ECMs so that energy savings can be quantified and tracked to make sure payback periods are achieved. Monitoring of performance will allow developing issues to be caught early and energy losses to be minimized. The scope of this measure includes the following:

1. Develop written description of all rules included in the expansion of existing SkySpark software package.
2. Provide fault detection and diagnostic programs in Axon programming language that can be easily deployed as rules and KPIs to monitor equipment performance
3. Develop criteria for tracking energy conservation measure persistence and provide automated reports for quantifying project savings.
4. Use SkySpark to supplement the Measurement and Verification process of all new mechanical projects at the facility. The functional testing procedures developed in the M&V phase of each project will be codified and applied to a continuous commissioning plan that SkySpark will run to monitor overall project performance.
5. Provide a management dashboard for easy access to the results of the continuous commissioning program.

Implementation

The cost of implementation is estimation based on previous projects with similar scopes. The estimated costs for the optimization component of the ECM include \$30,000 to perform additional engineering design work and scope development that, once completed, can be handed off to the installation team. The estimated cost for the continuous commissioning component is the upfront costs to integrate additional data points, write and deploy SkySpark rules to monitor ECM performance, and setup the management dashboard. Additional maintenance will likely be required to tune rules as building parameters and usage changes. These costs are not included in the estimates.

7.2.4 Water Conservation Measures

Table 13: Optimizing Space Heating Savings

Building	Budgetary Costs	Annual Utility Savings	Annual Energy Cost Savings	Annual O&M Costs	Simple Payback	NPV	SIR
		Water (1000 gallons)	(\$)	(\$)	(years)	(\$)	
R2	931,344	13,466	120,183.67	N/A	7.75	\$856,676	0.1

Existing Condition

Currently the plumbing fixtures in the restrooms are 1.6 gal/flush for water closets and 1.0 gal/flush for urinals and no metering devices on lavatory fixtures.

Recommendation

Replacing the plumbing fixtures throughout the building in the main restrooms to low flow fixtures (1.1 gal/flush water closet, 0.125 gal/flush urinals, 0.5 gpm lavatory) and metering devices at the lavatories would significantly reduce the amount of water consumption for the building.

Implementation

Estimate includes the cost to replace all plumbing fixtures in the main restrooms on every level. In order to estimate savings, similar buildings with low-flow fixtures were analyzed and given a gal/sf consumption value. This value was averaged across multiple buildings and applied to Research II to estimate total yearly savings potential. Overall, while this is not an energy conservation measure it contributes to achieving overall water efficiency that will help make the site more sustainable while conserving natural resources.

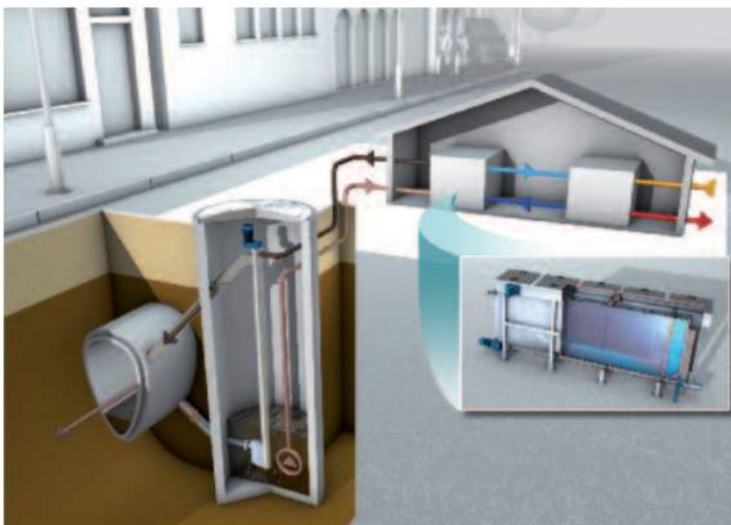
7.3 Evaluated Measures That Are Not Recommended

The following are measures that were evaluated for Research II Building that have a payback of more than 20 years and are not recommended for implementation. These measures were initially identified as opportunities for energy conservation but due to poor financial viability, would not be recommended for implementation.

7.3.1 Waste Heat Recovery from Sewer

Sewer heat exits each of the buildings through sanitary sewer piping. The flow rate is relatively stable, with a residual temperature between 75 and 80 deg F. The intent of this ECM is energy recovery; to capture heat from the wastewater flow existing the building which would otherwise be lost and utilize it.

The image below shows a typical sewer heat recovery schematic, intercepting the sewer line with a well; pumping the intercepted wastewater to and from the heat exchanger in a closed-loop, and exchanging the heat within the building for domestic water heating.



A system from Sharc Energy Systems called the 'Piranha' is a self-contained, thermal energy recovery system specifically designed to pre-heat domestic hot water by re-using energy contained in wastewater that would otherwise be lost down the drain. To offset – or reduce – the amount of steam used at the buildings to make domestic hot water, a series of Piranha's would be installed. The capacity limit of the Piranha systems is 300,000 BTU/h. Large buildings, similar to Research 2, which have a large domestic hot water load require multiple systems, equating to a substantial amount of equipment and floor space to be able to significantly offset the steam usage currently heating the domestic water. In exchange for the steam consumption reduction, the recovery system requires electrical power to operate; there is a heat pump which transfers the heat, and auxiliary pumps to circulate the wastewater to and from the sewer connection point – a wet well.

The simple payback exceeded the upper limit required for additional study. The total cost of constructing the wet well, installing the circulation pumping system, piping and equipment exceeded the cost savings from steam utility savings. Therefore, the ECM is not recommended for inclusion as part of the bundled energy project.

Future consideration can be applied on new construction or major renovations where buildings are located near large capacity sewer mains (12-inches diameter or larger), where steady wastewater flow is present. The sewer main can be used as a heat sink or source for cooling or heating applications using heat pumps. The relatively constant temperatures of the wastewater year-round provide a better source for heating and sink for cooling than a conventional geothermal system.

7.3.2 Regenerative Braking for Elevators

The potential to add regenerative drive control to the existing worm-drive machines that currently operate the elevators in the facility. This measure would return power to the system during regenerative operation. It was evaluated that the cost of implementing the regenerative drives would not have a payback within a sufficient period to recommend as a viable measure. The amount of potential energy returned is minimized by the typical operation of these elevators and the efficiency losses in the worm-drive.

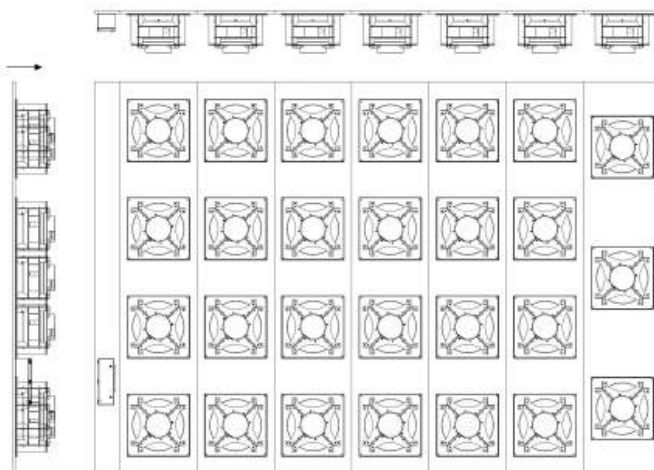
7.3.3 Freezer Standardization

This ECM attempted to look at the feasibility to standardize the ultra-low temperature freezers between various lab groups so the most efficient type could be used and reduce overall energy consumption. A particular model on the market uses 70-75% less energy than standard compressor-based systems and significantly reduced heat output and HVAC costs. The cost of the unit is sometimes nearly twice the cost of a standard ultra-low temperature freezer and with limited budgets between the research groups it would be difficult to mandate a particular style freezer. If an incentive strategy could be implemented to assist in the cost of the freezers it may be possible to standardize the freezers across the different labs.

7.3.4 Fan Wall System

This ECM explored the energy savings possibilities of replacing existing supply air fans with a fan wall or fan array. The existing air handlers have a single 200 hp supply fan motor providing 80,000 CFM at 8.25" of total static pressure. The fan array would provide multiple (27 in this case) smaller fans that are quieter, produce less vibration, and would be simpler to install and replace if needed.

The thought would be they would have a better efficiency than the larger fan, but the brake horsepower of the large fan and the sum of the smaller ones were very similar, so we didn't see as big of an efficiency gain as we originally thought. For a replacement situation, should an existing fan go down and need to be completely replaced, we would strongly recommend a fan wall or array option just for the ease of installation alone.



7.3.5 Physical Shading

This ECM explored the option to provide a physical shade on South, East and West building exposures. This shading would help reduce chilled water usage by reducing the heat load on the building. It was discovered, in an initial meeting to discuss these measures, that a design review board approval would be required for any exterior modifications which would cost around \$40,000 for the entire process. This significantly reduced the savings and made the return on investment much greater than anticipated.

7.3.6 Roof Exhaust Velocity Decrease

The intent of this ECM is to reduce the roof exhaust fan speeds when the chemical concentrations were low and allow the discharge velocities to be reduced and ultimately conserve energy. The issue with this ECM arises because the nature of a lot of these buildings are research, there is no way to measure just a single concentration of any particular chemical, you would have to measure multiple different chemicals at varying concentrations and it because a very expensive chemical sensor and while one concentration may be low another may be high so the odds of all chemical concentrations being below acceptable levels would be rare.

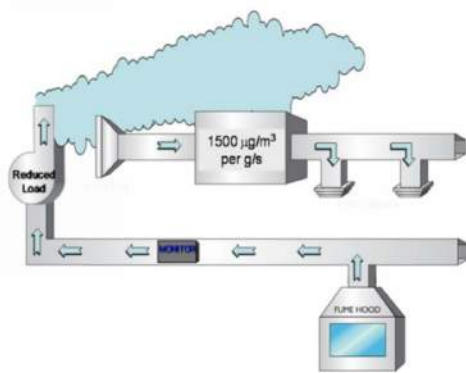


Figure 8. Higher intake concentrations are allowable when the exhaust stream is essentially "clean."

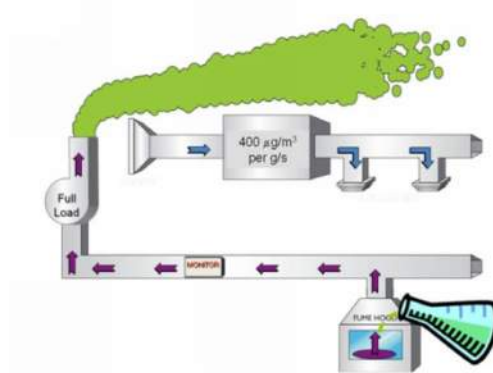


Figure 9. When chemical concentrations are detected in the exhaust stream, the exhaust volume flow rate is increased, reducing downwind intake concentrations.

Appendix B ASHRAE Audit Pharmacy Building

ASHRAE Level II Energy Audit Report

University of Colorado – Anschutz
Pharmacy Facility

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1.0 Executive Summary

This section provides the findings and analysis from AECOMs energy audit and initial assessment of potential energy conservation measures (ECMs) at Pharmacy Building, one of the relevant sites identified by the Anschutz Medical Campus team. The audit was performed in accordance with ASHRAE Level II requirements for energy auditing and reporting. Level II requirements both identify opportunities for energy savings and also project financials which become actionable information items for future projects to be based upon.

The comprehensive energy audit consisted of 1 building identified in Table 1. The facility was audited the week of August 12th, 2019.

Table 1: CU Anschutz Medical Campus

Building Number	Building Name	Functional Use	Area (SF)	Year Built
V20	Pharmacy	Laboratory	171,000	2011

1.1 Key Audit Findings

For Research II Building, the audit process identified a potential annual cost savings of \$133,492 through 6 separate ECMs that have the potential of providing a reduction of:

- 793,239 kilowatt hours (kWh) of electricity, annually
- 5,128 MLBS of steam, annually
- 115,273 Ton-hrs. of chilled water, annually

Table 2 lists all identified ECMs with paybacks less than 10 years and their associated implementation cost and savings metrics. A detailed description of each ECM is included in Section 7 of this report.

Table 2: Summary of Recommended Energy Conservation Measures

ECM No.	ECM Desc.	Annual Utility Savings			Est. Annual Cost Savings	Investment	Simple Payback	20yr NPV	SIR
		(kWh/yr)	(MLBS/yr)	(Ton-hrs/ yr)	(\$/yr)				
1	Interior Lighting Efficiency	271,995	0	0					0.2
2	Interior Lighting Controls - Occupancy Setback	57,894	0	0					2.1
3	Continuous-Commissioning - Existing System RCx	136,939	76,761	76,761					1.1
4	Continuous Commissioning - Continuous Commissioning of existing systems and ECM performance monitoring.	124,309	38,234	38,234					0.5
5	Reduce ACH by for unoccupied areas	199,849	35	35					34.6
6	Replace door seals for EVR's	2,253	243	243					3.1
Total		793,239	5,128	115,273					0.8

2.0 Audit Methodology & Scope

2.1 ASHRAE Level II Guidelines

Figure 1 provides the auditing and reporting requirements for ASHRAE Level I, II and III commercial building energy audits. This auditing report provides and surpasses the requirements of ASHRAE Level II, as whole-building energy models were developed to determine ECM savings interactions.

PROCESS	AUDIT LEVEL		
	I	II	III
Conduct Preliminary Energy-Use Analysis (PEA)	•	•	•
Conduct walk-through survey	•	•	•
Identify low-cost/no-cost recommendations	•	•	•
Identify Capital improvements	•	•	•
Review mechanical and electrical (M&E) design and conditions and O&M practices		•	•
Analyze capital measures (savings and cost, including interactions)		•	•
Meet with owner/operators to review recommendations		•	•
Conduct additional testing/monitoring			•
Perform detailed system modeling			•
Provide schematic layouts for recommendations			•
REPORT	AUDIT LEVEL		
	I	II	III
Estimate savings from utility rate change	•	•	•
Compare EUI to EUI of similar sites	•	•	•
Summarize utility data	•	•	•
Estimate savings if EUI were to meet target	•	•	•
Calculate detailed end-use breakdown		•	•
Estimate Capital Project costs and savings		•	•
Complete building description and equipment inventory		•	•
Document general description of considered measures		•	•
Recommend measurement and verification (M&V) method		•	•
Perform financial analysis of recommended EEMs		•	•
Write detailed description of recommended measures			•
Compile detailed EEM cost estimates			•

Figure 1: ASHRAE – Procedures for Commercial Building Energy Audits, Second Edition

2.2 Audit Process

Site inspections were carried out the week of August 12th, 2019 to determine the physical and operational condition of the building systems. Interviews with maintenance personnel were conducted during the site visits to understand the facility operation, details of any recent upgrades

and/or modifications to the systems, plans for upcoming capital upgrades, and to identify current operational concerns.

The mechanical systems, including heating system, cooling system, and the domestic hot water were examined during the site visit. All equipment from these categories were inspected and inventoried. Data collection included the system-specific end-use, capacity, run time, equipment age, and all equipment nameplate information (where available). Operational notes that would help identify potential ECMs were taken for all equipment. Lighting systems were inspected with inventorying that includes all lighting types, capacities, location, operational hours and quantities. Lighting controls were evaluated and potential ECMs were noted.

2.3 ECM Identification

The identification and development of the ECMs presented in this report consisted of the following general evaluation stages:

- Existing system components were modeled through a whole-building energy model that utilized connected loads developed through the equipment inventorying process and calibrated to facility energy consumption data.
- ECMs identified from the facility inspections were modeled against component systems energy consumption in order to evaluate energy and cost savings.
- Implementation costs associated with the prescribed ECMs were developed using known contractor pricing and RSMeans cost data.
- Cost/benefit analyses were developed, including payback calculations for the proposed energy conservation opportunities.

Equipment and system costing values are estimates, based on industry standards and RSMeans costing database public weather data to determine the energy savings associated with proposed measures.

2.4 Financial Analysis – Methodologies & Assumptions

All financial analyses included in this report were developed using the National Institute of Standards and Technology (NIST) Handbook 135 Life-Cycle Cost (LCC) Analysis and the May 2017 Energy Price Indices and Discount Factors Annual Supplement. For this audit, the NIST Life-Cycle Cost methodology was used to perform an analysis of each ECM. Using the initial project cost, annual savings, life of the equipment, and the equipment's replacement cost, the LCC develops a variety of useful financial and energy savings metrics.

The LCC methodology uses the following assumptions to estimate the potential energy and financial savings:

- **Maintenance Escalation** – This variable represents the annual increase in maintenance costs. In the calculator, it is assumed that these costs will increase by 2.2 percent each year.

- **Discount Rate** – Also known as the rate of interest, this variable is used to convert or discount future cash flows to a common time. The industry standard value of 3 percent was used.
- **Time Period** – Savings for each project are calculated over a period of 20 years.
- **Utility Escalation Rate** – This variable represents the annual increase in utilities cost. Energy commodity escalation projections developed by the U.S. Energy Information Administration were used. Based on this data, it is assumed these costs will increase by 1.5 percent each year.
- **Utility Rates** – A rate structure analysis is provided in Section 4 of this report, which identifies rates with which savings were developed.

The cost calculation reports three different metrics to determine the financial effectiveness of each project. These are:

- **20-Year Net Present Value (NPV)** – Current total value of all annual savings and one-time costs, minus the initial cost. If a net present value is less than zero (0), it is due to either the annual savings costs being less than annual O&M or less than the amortized capital cost.
- **Savings to Investment Ratio (SIR)** – Twenty (20) year net present value divided by the initial investment. This is a unit-less measure of performance where if the SIR is greater than one, the project is cost effective. If greater than one (1), this means that for each extra dollar spent, the amount saved will be greater. If the SIR is less than one (1), for each extra dollar spent, the amount saved will be less.
- **Simple Payback** – The number of years after ECM construction that the aggregate annual savings would equal the cost of implementation.

3.0 Facility Descriptions

3.1 Pharmacy Building

3.1.1 Facility Overview

Pharmacy is a 4-story, 159,042 square-foot building at the University of Colorado Anschutz medical campus. It was constructed in 2011. The primary building use is laboratory/research space, including a vivarium in at the basement level. The remaining building spaces are typically offices and common space. The facility is constructed of structural steel and reinforced concrete with a brick veneer and glass exterior surrounding the main building and a glass curtain wall exterior on the east-facing extension. Heating and cooling are supplied from a central plant at CU Anschutz that provides the campus with steam and chilled water. The facility is open 24 hours a day, 7 days a week.

Building Envelope

Walls

Brick veneer with internal foil faced semi-rigid insulation surrounding the main building. A glass curtain and aluminum ladder exterior on the east extension. Wall assemblies have minimum U-value of 0.079 (R-12.6)

Windows

Insulated Low-E glass units.

U-value Winter = 0.29

U-value Summer = 0.28

Shading Coefficient = 0.44

Solar Heat Gain Coefficient = 0.38

Roof

Concrete deck with built up insulation. Roof assemblies have minimum U-value of 0.50 (R-20).

Mechanical Systems

Cooling Systems

Central plant on site provides chilled water to the building where chilled water pumps distribute the chilled water to built up air handlers or to a heat exchanger for a process cooling water loop.

Heating Systems

Central plant on site provides steam to the building where steam to water heat exchangers provide heating hot water and pumps distribute the heating hot water throughout the building. Large built up air handlers use steam for heating and humidification as well.

Air Distribution & Ventilation Systems

There are 4 large air handlers, roughly 80,000 CFM each, where the supply air ducts manifold together and are routed up shafts to service all floors. All units are 100% outside air units and

multiple exhaust fans are manifolded together to exhaust the lab areas and maintain building pressurization.

Domestic Hot Water Systems

Central plant on site provides steam to the building where steam to water generators are used to provide domestic hot water throughout the building.

Electrical Systems

Lighting

The majority of the lighting fixtures of the Pharmacy building are T5 28-Watt linear fluorescent lamps of 4 ft length, recess mounted into the drop ceiling of each floor of the building. The remainder of the lighting fixtures throughout the building are either T8 32-Watt linear fluorescents, Type A or 4-pin compact fluorescents and LED lights.

The lighting is controlled by a Siemens Encelium lighting controls system. The system is currently not scheduled for any efficiency setback. The majority of lighting circuits throughout the building are connected to occupancy sensors while there are manual switches in a small number of rooms.

Transformers

Three (3) 225kVA dry-type transformers are located in the electrical room of the facility. All were installed during construction of the building in 2011. There are a number of smaller transformers serving other electrical demands throughout the facility.

Energy Management System

The Pharmacy building is currently operated using the Siemens Insight Building Automation System. This system is currently being upgraded to the Desigo BAS.

Miscellaneous Systems

Compressors

There is a single Quincy 2-stage compressor that provides compressed air for actuating control dampers in the mechanical space.

Elevators

There are 2 traction passenger elevators and 2 traction freight elevators located in the facility. The elevators are operated with Thyssenkrupp controllers that were original to the building construction.

Lab Hoods

There are approximately 26 lab hoods on each floor of laboratory space within Pharmacy. These lab hoods are connected to the roof exhaust system.

EVR Rooms

The Pharmacy building operates 3 Environmental Rooms (EVRs) or walk-in freezers. One on each of the research floors of the facility. Each EVR has it's own compressor for DX cooling.

Ultra-Low Temperature Freezers

Each floor of laboratory space within the facility has approximately 85 Ultra Low Temperature (ULT) freezers that provide cooling down to -80°F. Many of these freezers are of different manufacturers, different ages and different energy standards.

Autoclaves

There are autoclaves on each floor of the Pharmacy building. Each is served by a 60 kW electric steam generator.

3.2 Controls Strategy

Table 3: Research II Building Operational Schedule

Operational Condition	Days	Start time	End Time	Heating Set point Temperature (°F)	Cooling Set point Temperature (°F)
Occupied	Mon-Sun	6am	9pm	72-76	76-76
Night Setback	Mon-Sun	9pm	6am	66	80
Unoccupied	N/A	N/A		N/A	N/A

4.0 Utility Analysis

The site utilities include electricity, steam, chilled water and water. AECOM analyzed the site utilities in order to evaluate utility consumption, costs, and rates, which yields a deeper understanding of the baseline utility consumption and savings potential. The baseline profile for energy consumption was developed using utility data from the past two years. It is important to note that the cost of consumption values in this utility analysis section reflect the past two years rate structure. Meanwhile, the cost savings calculations for all ECMs were developed using real costs from calendar year 2019 utility bill analyses in order to most accurately reflect expected cost savings.

Table 4: Baseline Utility Consumption and Blended Rates

Commodity	Consumption	Cost	Actual \$/unit	Demand Rate (\$/kW)
Electricity	4,602,836	\$321,176	\$0.07	N/A
Steam	10,571	\$129,837	\$12.28	N/A
Chilled Water	360,330	\$86,460	\$0.24	N/A
Water	4,316	\$36,291	\$8.42	N/A
Total		\$573,764		

4.1 Utility Data – Pharmacy Building

Figure 2 illustrates utility spending each month for an entire year for Pharmacy Building electricity, steam, chilled water and water consumption.

Figure 2: Monthly Utility Cost Breakdown – Pharmacy Building

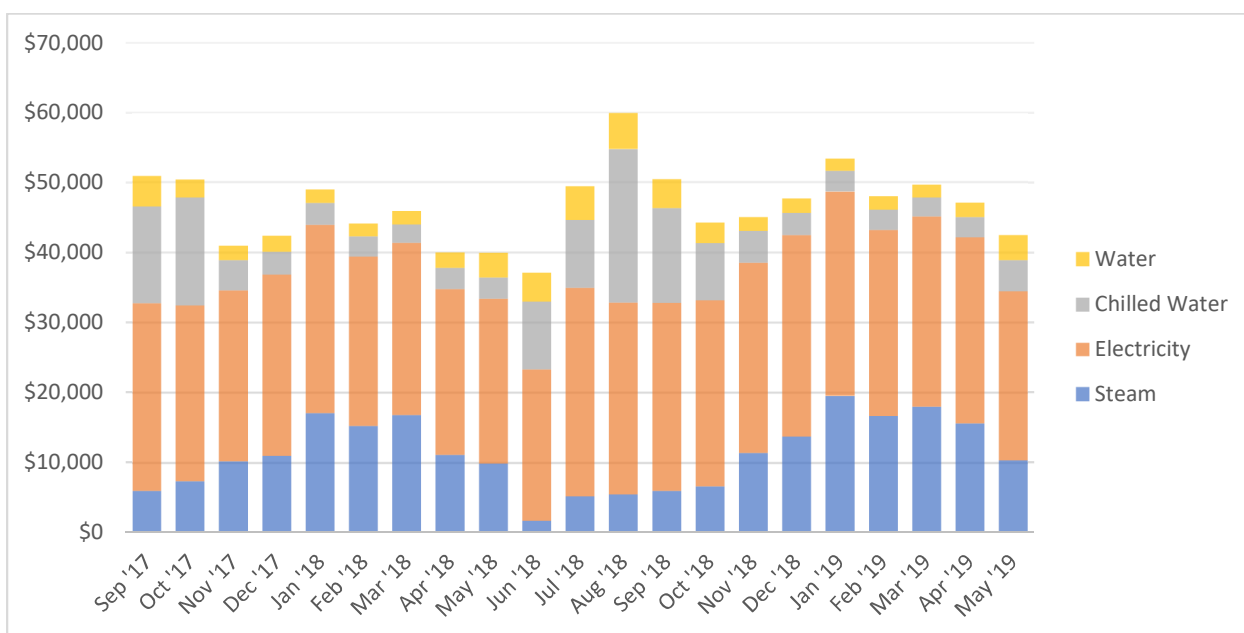


Figure 3 plots electricity consumption and spending each month for an entire year.

Figure 3: Monthly Electricity Usage and Cost – Pharmacy Building

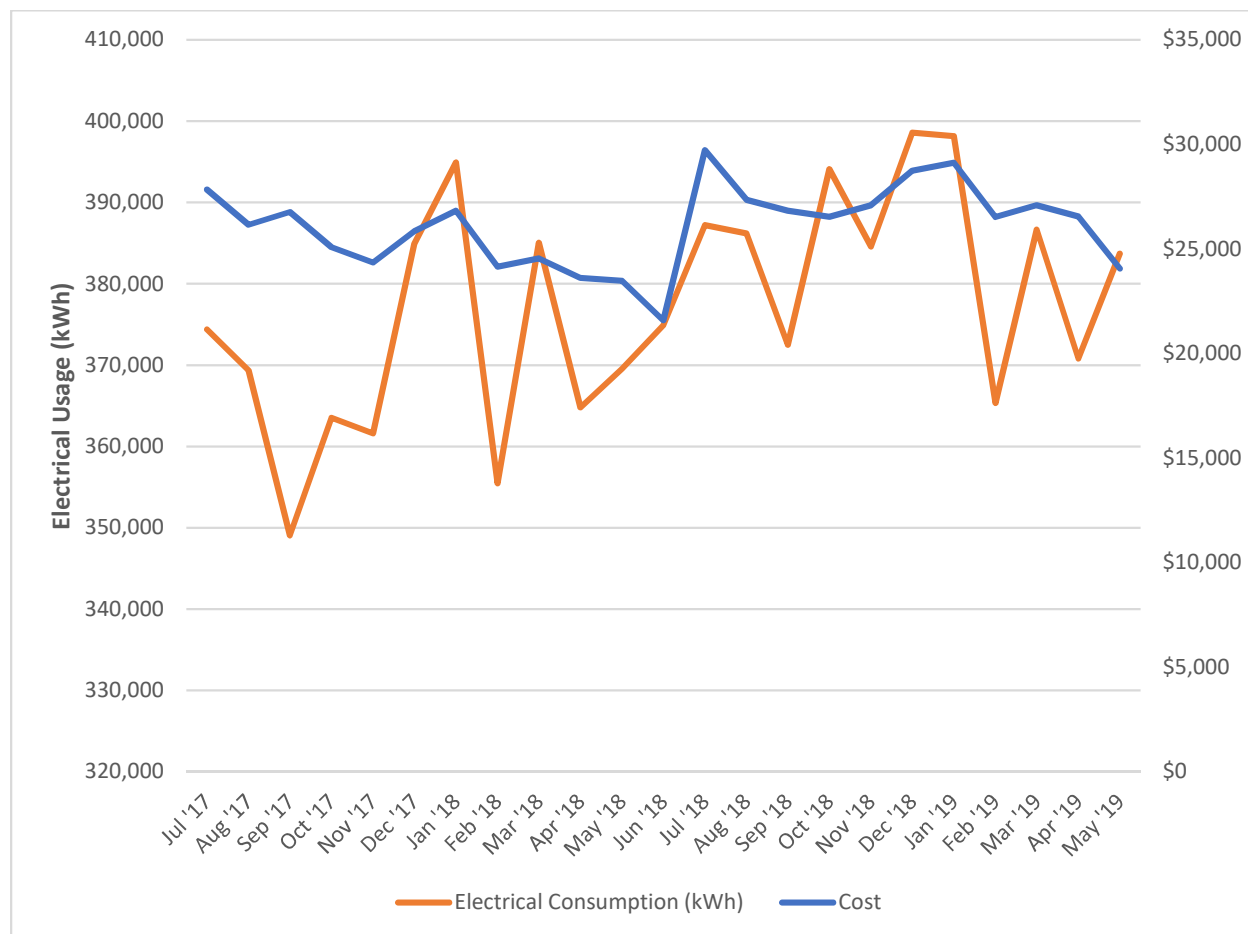


Figure 4 plots steam consumption and spending each month for an entire year.

Figure 4: Monthly Steam Usage and Cost – Pharmacy Building



Figure 5 plots chilled water usage and spending each month for an entire year.

Figure 5: Monthly Chilled Water Usage and Cost – Pharmacy Building

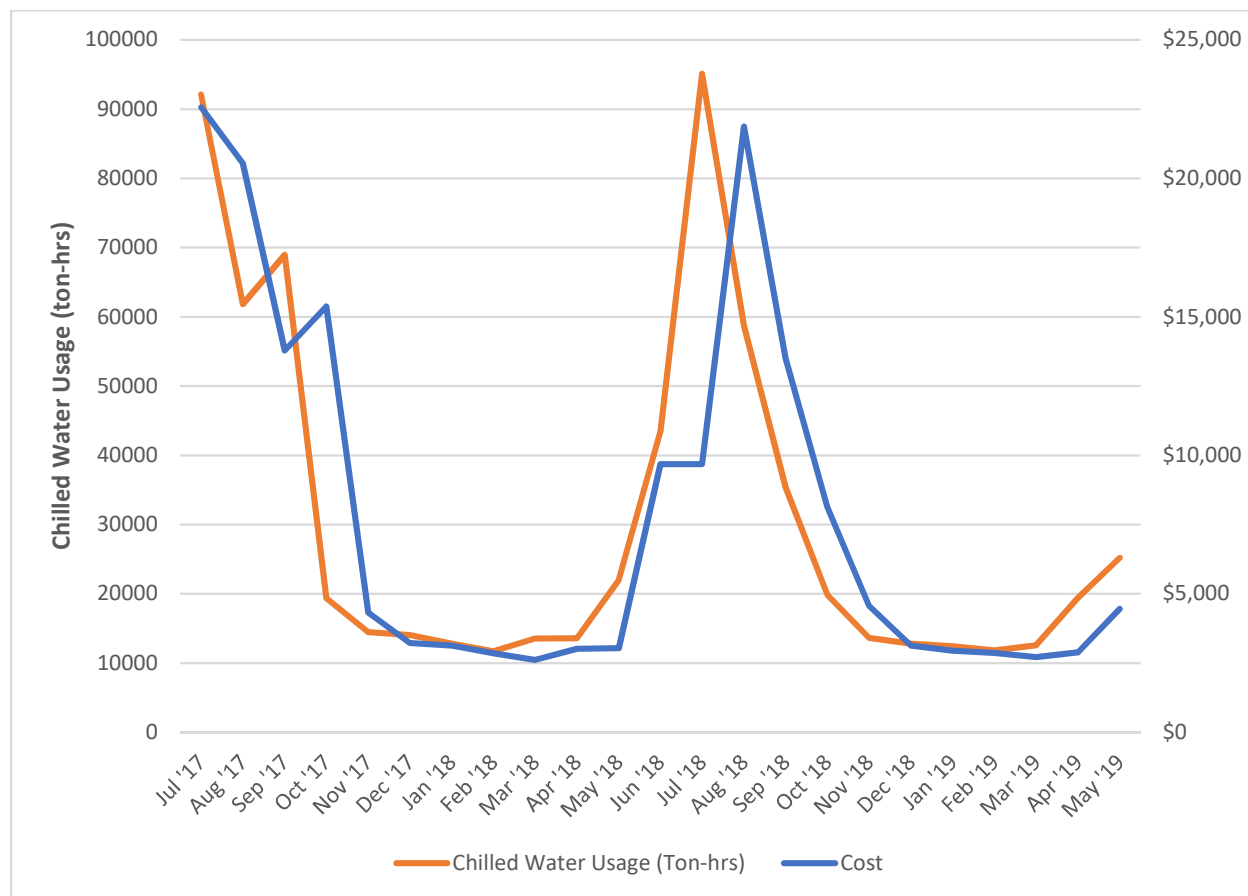
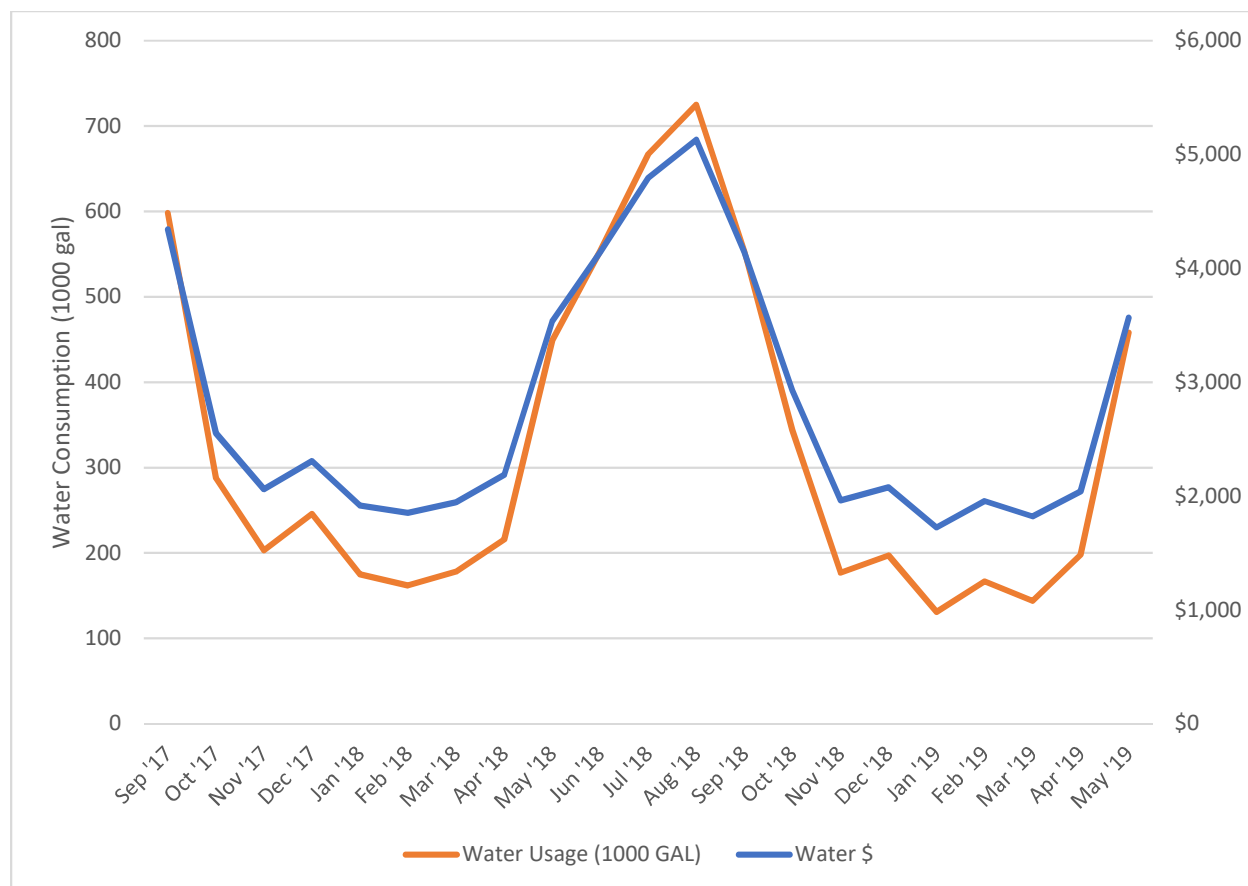


Figure 6 plots domestic water usage and spending each month for an entire year.

Figure 6: Monthly Domestic Water Usage and Cost – Pharmacy Building



5.0 Energy Allocation Analysis

5.1 Overview of Facility Energy Allocation

This energy allocation analysis estimates energy consumption for the Pharmacy Building site end-uses as a fraction of its total annual energy consumption. The allocations provide an insight into the efficiency of the building systems and provide a basis for energy savings calculations for each potential ECM. Systems typically considered in the analysis include heating, ventilation, and air conditioning (HVAC), lighting, plug loads, process, and other energy-consuming systems. For this preliminary analysis, AECOM developed energy allocation estimates based on information gathered during the site visit, using building energy simulations, and from our experience at similar facilities.

Proprietary modeling software that utilizes the connected-load inputs of the mechanical equipment and lighting inventory were used to develop end-use consumption values specific to facility type and location. The following tables and graphs provide the end-use electric consumption for each building. Costs for this breakdown were developed using the blended utility rates from Section 4.

5.2 End-Use Component Breakdown – Pharmacy Building

Table 5: Modeled Annual End-Use Electric Consumption – Pharmacy Building

End-Use	Installed Capacity kW	Demand Intensity W/ft ²	Effective Full Load Hours	Consumption		Energy Cost
				Intensity kWh/ft ²	Absolute kWh	
Interior Lighting	239	1.5	4,259	6.4	1,016,952	\$71,078
Fans – Air Handling Units and Exhaust Fans	596	5.8	1,796	10.4	1,659,212	\$115,330
Pumps and Compressors	233	1.5	3,359	4.9	782,600	\$54,931
Equipment	537	3.4	2,129	7.2	1,144,071	\$79,836
Total	1,933	12.2	11,542	28.9	4,602,836	\$321,175

Table 6: Modeled Annual End-Use Steam Consumption – Pharmacy Building

End-Use	Installed Capacity kBtu/h	Demand Intensity Btu/ft ²	Consumption		Energy Cost
			Intensity kBtu/ft ²	Absolute kBtu	
Heating*	26,125	164.3	62.2	9,890,997	\$117,504
DHW*	5,600	35.2	6.9	1,098,999	\$12,333
Total	31,725	199.5	69.1	10,989,996	\$129,837

* Steam and chilled water purchased from a central plant

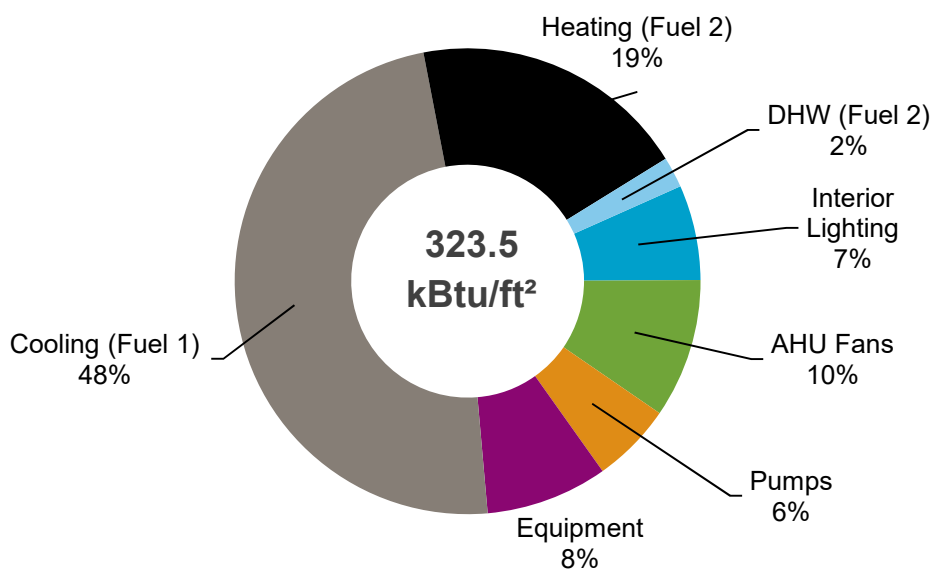
Table 7: Annual End-Use Chilled Water Consumption – Pharmacy Building

End-Use	Installed Capacity	Demand Intensity	Consumption		Energy Cost
			Intensity	Absolute	
	kBtu/h	Btu/ft ²	kBtu/ft ²	kBtu	
Cooling*	5,049	24.4	52.2	24,870,603	\$86,460

* Steam and chilled water purchased from a central plant

Figure 11 shows the proportional breakdown of energy end-uses at the facility. The majority of energy is consumed by equipment. This is considered plug loads and non-facility conditioning equipment. The proportion of cooling and heating being purchased from the central plant are also identified as the next largest consumption values. The overall energy benchmark, which is energy consumed per area of facility space is provided in kBtu/ft².

Figure 11: Energy Consumption by End-Use Percentage for Pharmacy Building



6.0 Energy Performance Benchmarking Comparison

The building has a calculated Energy Use Intensity (EUI) of **323.5 kBtu/sf** from data provided by the University. Commercial Buildings Energy Consumption Survey (CBECS) would predict and EUI of **115.3 kBtu/sf** for a building of similar size, usage, and climate zone. This difference is mainly due to the type of equipment being used in the facility and the extended operation hours of the facility.

7.0 Energy Conservation Measures

AECOM identified potentially viable ECMs and associated cost saving opportunities that will enable CU Anschutz to progress toward its resiliency and energy conservation goals. The ECMs provide intrinsic resiliency value as part of a holistic approach to improve overall resiliency by reducing energy consumption. In most cases, ECMs are associated with buildings and end-uses.

7.1 Low Cost/No Cost – O&M Measures

7.1.1 Reduce ACH for Unoccupied Areas

Table 8: Reduce ACH Savings

Building	Budgetary Costs \$	Annual Utility Savings			Annual Energy Cost Savings (\$)	Annual O&M Costs (\$)	Simple Payback (years)	NPV (\$)	SIR
		Electricity (kWh)	Steam (MLBS)	Chilled Water (ton-hrs)					
V20		199,879	1,573	35	\$	N/A	0.0	\$	34.6

Existing Condition

It is standard industry practice to provide a high ventilation rate in laboratory spaces to ensure the health and safety of building occupants. While prevailing codes and standards vary in the specific amount of ventilation that is required for each laboratory occupancy classification, the recommended range is 4 to 12 air changes per hour (ACH). At the Pharmacy building, a rate of 6 ACH is always employed, including during unoccupied hours, resulting in excess energy being utilized to condition incoming outdoor air.

Recommendation

Utilizing the existing controls, reduce the ACH rate for unoccupied hours. This measure assumes the ventilation rate will be reduced to 4 ACH between 11:00 PM and 6:00 AM.

Implementation

This measure can be achieved through the use of existing infrastructure and can be executed by Facilities staff. The cost is conservatively estimating the time for CU staff to program the BAS and to check operation once implemented.

7.1.2 Interior Lighting Controls – Occupancy Setback

Table 9: Interior Lighting Controls Savings

Building	Budgetary Costs	Annual Utility Savings			Annual Energy Cost Savings (\$)	Annual O&M Costs (\$)	Simple Payback (years)	NPV (\$)	SIR
		Electricity (kWh)	Electricity (kWh)	Natural Gas (therms)					
V20	\$1,000	57,894	0	N/A	\$2,132	N/A	0.5	\$30,718	2.1

Existing Condition

The Pharmacy building has the Siemens Encelium lighting management system installed but is not currently scheduled for any type of setback or daylight harvesting. The Encelium system is capable of running the lights with an efficiency setback during unoccupied hours or hours with daylight.

Recommendation

It is recommended that the University program the existing lighting controls to reduce lighting runtime based on an unoccupied setback and daylight scheduling.

Implementation

This measure can be achieved through the use of existing infrastructure and can be executed by Facilities staff. The cost is conservatively estimating the time for CU staff to program the BAS and to check operation once implemented.

7.1.3 Replace EVR Door Seals

Table 10: EVR Door Seals

Building	Budgetary Costs	Annual Utility Savings			Annual Energy Cost Savings	Annual O&M Costs	Simple Payback	NPV	SIR
		Electricity (kWh)	Steam (MLBS)	Chilled Water (ton-hrs)	(\$)	(\$)	(years)	(\$)	
V20	\$	2,253	0.034	243.5		0	0.3		3.1

Existing Condition

The Environmental Rooms (EVRs) each had access doors that were not sealing properly when closed. It was observed during the site visit that a significant volume of air was escaping through the door seals due to the positive pressure of the space and the inadequate door seals.

Recommendation

It is recommended to replace the door seals to each of the EVRs to reduce the loss of conditioned air and reduce energy consumption of the dedicated DX unit for the EVR.

Implementation

This is a simple repair that can be done by maintenance or by a refrigeration specialist. Costs include the door seal material and labor for a refrigeration specialist.

7.2 Recommended Measures

The following section provides the analysis results and description of measures that were evaluated for Pharmacy Building that have a payback of less than 10 years.

7.2.1 Interior Lighting Efficiency

Table 11: Lighting Savings

Building	Budgetary Costs	Annual Utility Savings		Annual Energy Cost Savings	Annual O&M Costs	Simple Payback	NPV	SIR
		Electricity (kWh)	Demand (kW)	(\$)	(\$)	(years)	(\$)	
V20	\$	271,995	49	\$10,16	N/A			0.2

Existing Condition

The lighting that currently exists within the facility is the original lighting from construction in 2008. This consists of linear fluorescent and compact fluorescent lamps that are far less energy efficient than LED lamps that are currently available.

Recommendation

Replace the lamps in all existing compact or linear fluorescent fixtures with LED equivalent luminaires. The new installation can be either a tubular LED lamp replacement or an LED retrofit kit. A tubular lamp replacement typically requires changing the electrical wiring, replacing the ballast with an external driver or altering the existing holders ("tombstones") to accommodate the new lamps. Newer technologies can offer magnetic luminaire strips with on-board drivers that can be directly wired to the existing electrical lead and connected to the existing metal trougher with magnets, leaving the existing tombstones in place for a quick and efficient replacement. A retrofit kit provides the required electrical components, optical element and light source in a prepackaged kit. This replacement option can bypass the ballast entirely and run directly from the line voltage at the installation and will be compatible with the reduced wattage, helping to keep installation costs down.



Implementation

Estimate includes the cost to furnish all lamps, including material and labor cost estimates using RSMeans 2017 data. In order to estimate savings, yearly runtime estimates were made for all existing fixtures based on operational/occupancy schedule(s) and control(s) collected during the audit. This measure will replace or modify existing lighting fixtures to LED technology. This measure will reduce electric consumption and peak demand, reduce labor for changing lamps, and reduce lamp replacement costs while improving lighting quality. Overall, this measure contributes to achieving overall efficiency that will help increase reliability and resiliency at the site.

7.2.2 Continuous Commissioning and Building Optimization

Table 12: ECM 7.3a - Building Optimization Combined Savings

Building	Chilled Water Savings (ton-hrs/yr)	Steam Savings (Mlbs/yr)	Electricity Savings (kWh/yr)	Water Savings (kgal/yr)	Utility Cost Savings (\$/yr)	Estimated Implementation Cost (\$)	Simple Payback (yrs)
V20	76,761	2,439	136,939	0	\$		0.9

Table 13: ECM 7.3b - Continuous Commissioning Savings

Building	Chilled Water Savings (ton-hrs/yr)	Steam Savings (Mlbs/yr)	Electricity Savings (kWh/yr)	Water Savings (kgal/yr)	Utility Cost Savings (\$/yr)	Estimated Implementation Cost (\$)	Simple Payback (yrs)
V20	38,234	1,116	124,309	0			

Existing Condition

This measure deals mainly with the existing building automation system (BAS) and the use of the existing SkySpark data analytics platform for equipment diagnostic purposes. The existing control system is a Siemens Insight control system, that is currently being upgraded to the Siemens Desigo control system. The system was installed when the building was constructed in 2008 and has full digital control over all of the mechanical systems described in Section 3.0 of this report. In general, the systems are all operating in accordance with the original design sequence of operations document that was used by the construction team. The system is in good working order and fully capable of accepting modifications to the existing programming and control methods.

In addition to the Siemens Insight BAS, there is an instance of the SkySpark platform installed to monitor energy, natural gas, steam, and chilled water usage throughout the campus. SkySpark is a stand-alone software package that is capable of collecting data from a variety of sources and analyzing the data based on a customized set of rules that are developed for each application. For the Research 2 building, SkySpark is currently only used to monitor the utilities used by the building from both the electric grid and the central utility plant.

Recommendation

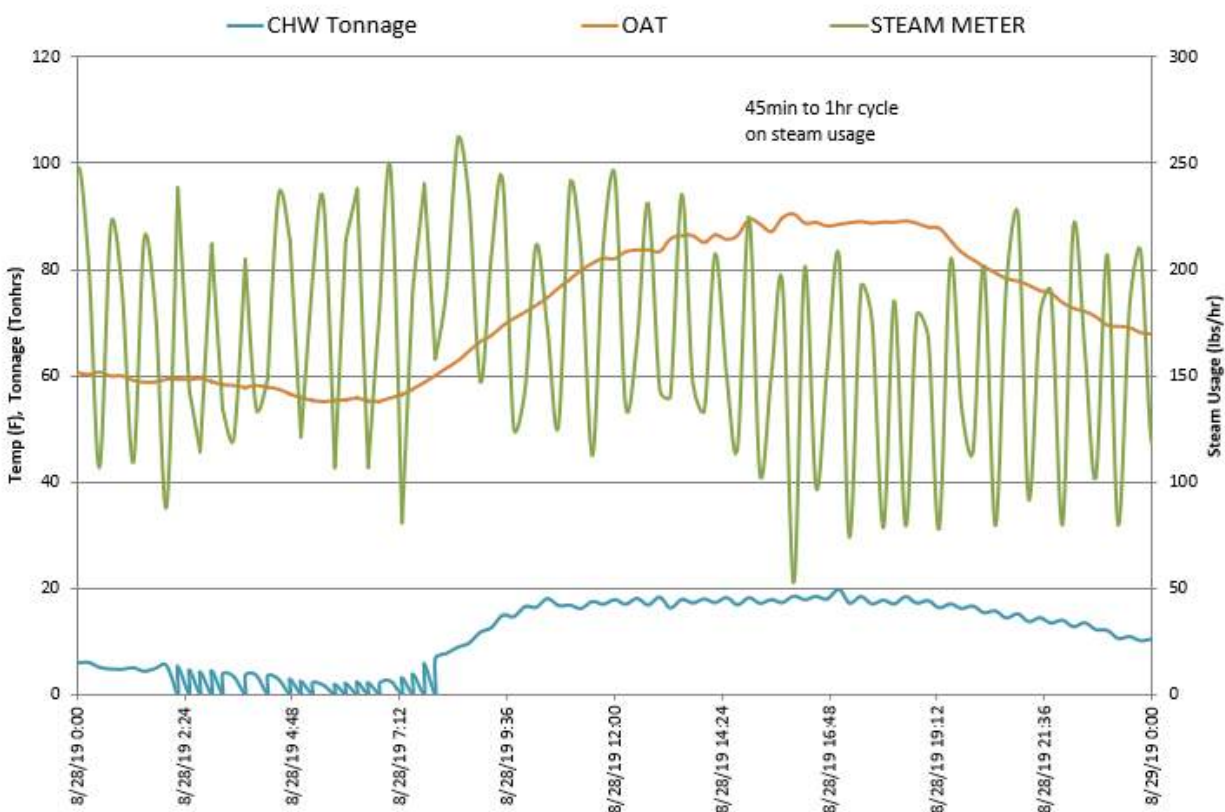
This recommendation is split into two sections: Optimization of the existing mechanical systems and continuous commissioning and diagnostics of systems and ECMs after they are implemented.

Optimization of Existing Mechanical Systems:

Operational data was collected from the BAS and a list of potential energy conservation measures was developed based on inefficiencies found in the building. The individual measures included in the savings calculations are listed below:

1. Tune Reheat Coil and Heating Coil Operations: The total building heating load has been monitored and shows very inconsistent usage. This pattern is common in heating systems that require controls tuning, typically from cycling too fast between heating and cooling modes at the AHUs or terminal units. This measure recommends increasing the integral component of the PID loops for both the terminal unit dampers and the reheat coil valves. This will slow down the response of the systems and allow

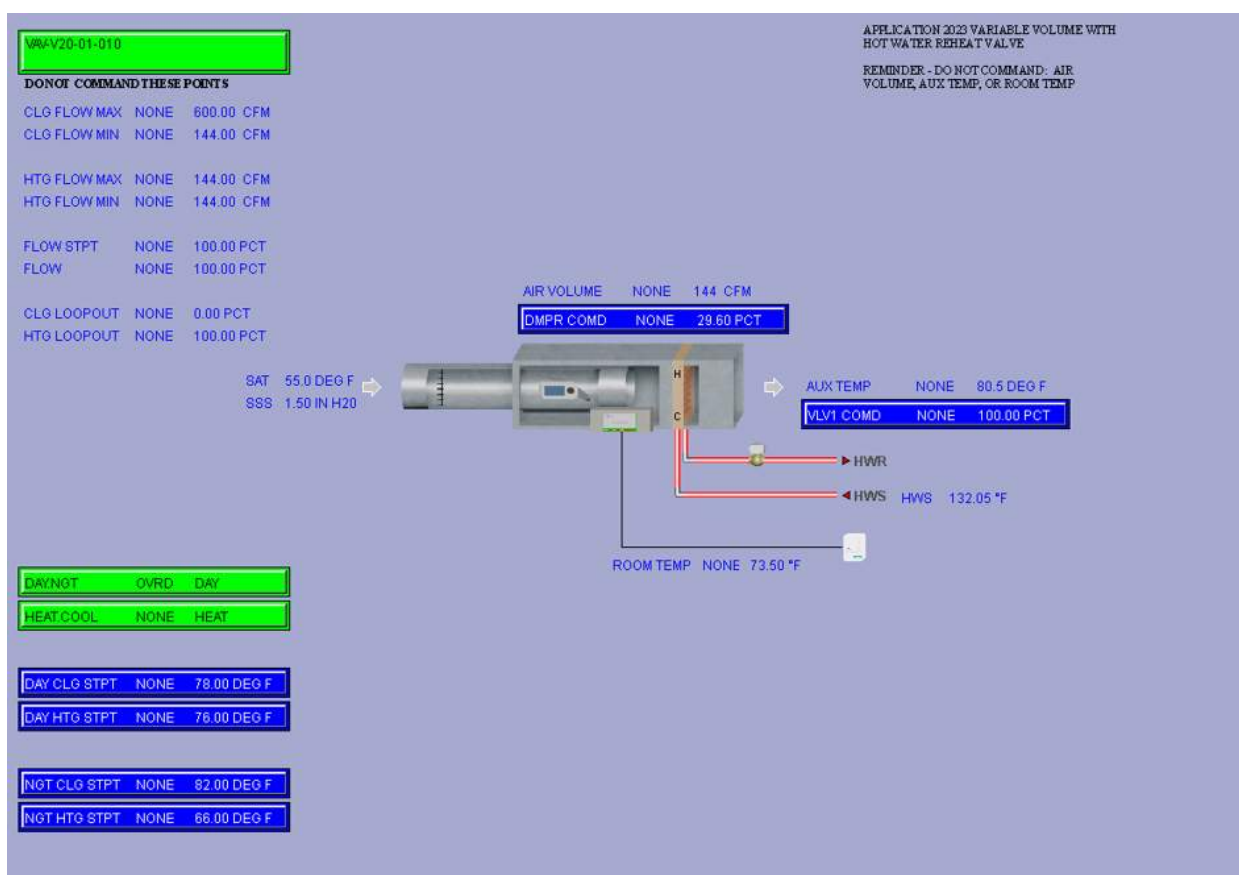
Figure 12: Total building heating load showing nearly 100% increase in demand cycling every 45 minutes.



2. Minimize OA intake based on building pressurization and thermal demands: The goal of this measure is to minimize the outside air intake at the AHU OA intake dampers, which was observed to be in excess of the amount required to balance the building exhaust load and ventilation requirements. This measure recommends adjusting the programming of the OA intake dampers so that the minimum flow setpoint is low enough that all available return air is recirculated. This will minimize the amount of total heating and cooling energy used by the building AHUs to meet the supply air temperature and CFM requirements.

3. **Reduce Terminal Unit Minimum Flow Setpoints:** A large sample of terminal unit controls were inspected and it was observed that many areas have a high utilization of the reheat coils during both cold and warm weather. In many cases, the CFM setpoints determined in the design phase appear to oversupply air to the spaces, which leads to overcooling and additional mechanical heat usage. This measure recommends reducing the minimum CFM setpoints on terminal units, supply and exhaust where applicable, in areas where trends show consistent use of mechanical heat when the system should be cooling or idle. The following figure provides an example of a terminal unit that is 100% utilized in heating mode and overridden to DAY mode so it is not allowed to set back.

Figure 14: Terminal Units In fully Heating on 86F OAT day, Overridden to DAY mode.



4. **Install Occupancy Sensors with Fume Hoods –** In laboratories, when occupied, ASHRAE recommends that there be a minimum face velocity across the opening of the fume hood as well as a minimum room air change rate based on the volume of the space. If occupancy is being monitored, and it is determined to be unoccupied, the requirements for air changes per hour in the room are reduced. This measure suggests installing occupancy sensors in the laboratory areas and adjusting airflow requirements to reduce

the overall air delivered. This will reduce the overall energy used by the AHU fans and overall heating load in the building.

5. Reduce Night Mode CFM and Temperature Setpoints – For non-lab areas, this measure suggests adding an occupied schedule and turning off airflow to areas in night mode if temperature parameters are satisfied. This will reduce the overall load on the supply fans and heating systems when the building is at low occupancy.
6. DAT Reset on Return Air Units – Increasing the DAT during winter months will help to reduce the demand for steam for heating from the central utility plant. This measure suggests increasing the discharge air temperature automatically as outside air temperature decreases, which will minimize the amount of conditioned air that is exhausted during winter months.
7. Repair Static Pressure Control on Return Fans – several return fans in the building were operating in a “run-out” condition because setpoints could not be met and utilization was maximized. This measure suggests repairing the control of the static control on return fans so that setpoints can be achieved and fans are allowed to modulate.

Continuous Commissioning of Existing Systems and ECM Performance Monitoring:

This part of the recommendation was designed to serve two purposes: Expand the existing capabilities of SkySpark monitoring to include equipment diagnostics and troubleshooting, and also to monitor the performance of all implemented ECMs so that energy savings can be quantified and tracked to make sure payback periods are achieved. Monitoring of performance will allow developing issues to be caught early and energy losses to be minimized. The scope of this measure includes the following:

1. Develop written description of all rules included in the expansion of existing SkySpark software package.
2. Provide fault detection and diagnostic programs in Axon programming language that can be easily deployed as rules and KPIs to monitor equipment performance
3. Develop criteria for tracking energy conservation measure persistence and provide automated reports for quantifying project savings.
4. Use SkySpark to supplement the Measurement and Verification process of all new mechanical projects at the facility. The functional testing procedures developed in the M&V phase of each project will be codified and applied to a continuous commissioning plan that SkySpark will run to monitor overall project performance.
5. Provide a management dashboard for easy access to the results of the continuous commissioning program.

Implementation

The cost of implementation is estimation based on previous projects with similar scopes. The estimated costs for the optimization component of the ECM include \$25,000 to perform additional engineering design work and scope development that, once completed, can be handed off to the installation team. The estimated cost for the continuous commissioning component is the upfront costs to integrate additional data points, write and deploy SkySpark rules to monitor ECM

performance, and setup the management dashboard. Additional maintenance will likely be required to tune rules as building parameters and usage changes. These costs are not included in the estimates.

7.3 Evaluated Measures That Are Not Recommended

The following are measures that were evaluated for Pharmacy Building that have a payback of more than 20 years and are not recommended for implementation. These measures were initially identified as opportunities for energy conservation but due to poor financial viability, would not be recommended for implementation.

7.3.1 Regenerative Braking for Elevators

The potential to add regenerative drive control to the existing worm-drive machines that currently operate the elevators in the facility. This measure would return power to the system during regenerative operation. It was evaluated that the cost of implementing the regenerative drives would not have a payback within a sufficient period to recommend as a viable measure. The amount of potential energy returned is minimized by the typical operation of these elevators and the efficiency losses in the worm-drive.

7.3.2 Convert Autoclaves to Steam

This measure involves replacing the existing garage doors that open to the exterior. It was observed that these doors take approximately 30 seconds to open-close which causes infiltration of cold air and thus increasing the heating load. By replacing them with high performance, high speed doors, which take about 1/3 of the time of typical overhead doors to open-close, we can reduce the heat loss and therefore the heating load in these facilities. These doors also have better insulation than the existing doors.

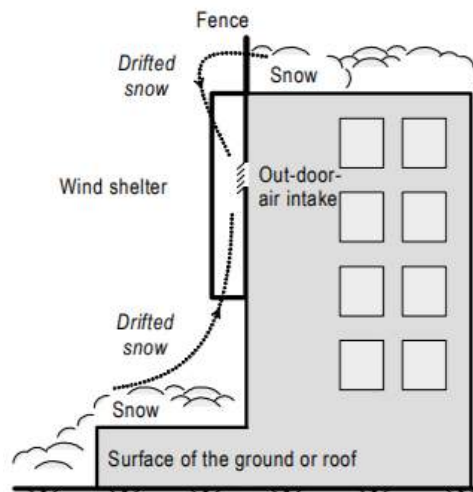
7.3.3 Freezer Standardization

This ECM attempted to look at the feasibility to standardize the ultra-low temperature freezers between various lab groups so the most efficient type could be used and reduce overall energy consumption. A particular model on the market uses 70-75% less energy than standard compressor-based systems and significantly reduced heat output and HVAC costs. The cost of the unit is sometimes nearly twice the cost of a standard ultra-low temperature freezer and with limited budgets between the research groups it would be difficult to mandate a particular style freezer. If an incentive strategy could be implemented to assist in the cost of the freezers it may be possible to standardize the freezers across the different labs.

7.3.4 Snowmelt System Upgrade

This ECM was to review alternatives to using electric heaters to melt incoming snow from entering the air handlers. All four air handlers at Pharmacy building are located in a penthouse with their outside air intakes through louvers almost right up against the units. This caused snow to get into the units and block up the filters. A mesh with a heater was added to melt any snow that would get into the units prior to reaching the coils. These heaters are roughly 28.5 kW each and consume a lot of electricity when operated. We looked at extending hoods, changing to different louver

types, and other elaborate types of intake configurations to prevent snow entrainment but none were cost effective enough to offset the cost of operating the heaters. The heaters only operate at select times during the year when it was sensing a low temperature and moisture, so the operating hours were not significant enough to incur the added costs of other options.



7.3.5 Physical Shading

This ECM explored the option to provide a physical shade on South, East and West building exposures. This shading would help reduce chilled water usage by reducing the heat load on the building. It was discovered, in an initial meeting to discuss these measures, that a design review board approval would be required for any exterior modifications which would cost around \$40,000 for the entire process. This significantly reduced the savings and made the return on investment much greater than anticipated.

7.3.6 Roof Exhaust Velocity Decrease

The intent of this ECM is to reduce the roof exhaust fan speeds when the chemical concentrations were low and allow the discharge velocities to be reduced and ultimately conserve energy. The issue with this ECM arises because the nature of a lot of these buildings are research, there is no way to measure just a single concentration of any particular chemical, you would have to measure multiple different chemicals at varying concentrations and it because a very expensive chemical sensor and while one concentration may be low another may be high so the odds of all chemical concentrations being below acceptable levels would be rare.

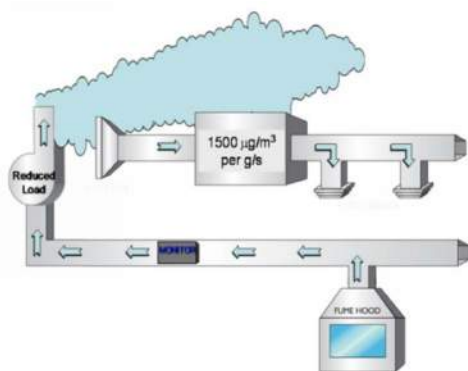


Figure 8. Higher intake concentrations are allowable when the exhaust stream is essentially "clean."

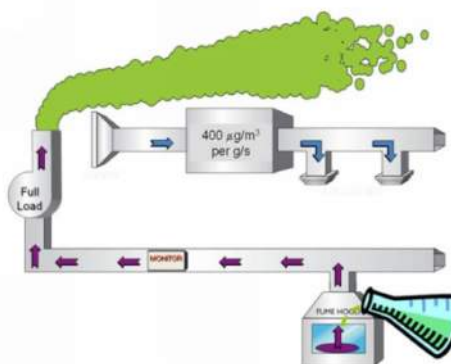


Figure 9. When chemical concentrations are detected in the exhaust stream, the exhaust volume flow rate is increased, reducing downwind intake concentrations.

Appendix C Cost Estimate Updates

University of Colorado Anschutz Medical Campus

Energy Studies Cost Estimates Education 2 Facility

Contents:

Updated cost estimates of ECMs based on the Feb. 18, 2013,
energy study report by Cator, Ruma & Associates, Co.

Scope of Estimate:

In 2013, Cator, Ruma and Associates developed an energy study for Education 2 building at the CU Anschutz campus (included in Appendix D). Through their study, they identified 8 ECMs of which 1 was implemented and 4 more have been reviewed by AECOM, with cost estimates conducted to update previous estimates to current market values.

ECM 3 - Community Room Return Air Additions:

The air handlers serving community room areas are 100% outside air units with all the air supplied into the rooms being exhausted out. These units are large energy consuming units and anytime you can return clean air back to the unit to mix with outside air it's the preferred method. So, this ECM is recommended to be implemented as part of the bundled energy project.

ECM 4 - Lighting Replacement in Large Auditorium:

The large auditorium space consists of high wattage quartz pendants and down-lights. At the time of the study, LED lighting was at a premium price point, so the payback wasn't realized, and the ECM was not pursued further. Now that LED lights are more common and typically the first choice in newer buildings, prices have come down significantly and would make this ECM more conceivable. This ECM is not recommended to be implemented as part of the bundled energy project.

ECM 6 - Occupancy Sensor Additions – Lighting Only:

Lighting control in spaces that are not always occupied such as offices, file rooms, and storage rooms should have sensors to shut the lights off when no one is in those spaces. This ECM proposed adding occupancy sensors to these areas to conserve lighting energy at times when the spaces are unoccupied. It is recommended that this ECM be implemented as part of the bundled energy project.

ECM 8 - Daylighting:

The west facing fourth floor corridor and second floor bridge have significant amount of exposure to natural light making them ideal candidates for daylighting sensors. For this ECM the daylighting sensors would detect when there are high levels of natural lighting available, the electrical lighting system can be dimmed or turned off completely conserving energy. It is a simple and effective way to conserve lighting energy and is recommended to be implemented as part of the bundled energy project.

Summary: As common practice across the campus, if clean air can be returned it should be. LED lighting should be used to the extent possible as well with occupancy sensors and daylighting controls as building spaces permit.

ECM No.	ECM Description	Annual Utility Savings			Estimated Annual Cost Savings (\$/yr)	Investment (\$)	Simple Payback (years)
		Electricity (kWh/yr)	Chilled Water (ton/hrs)	Steam (MLBS/hr)			
3	Community Room Return	370,127	157,362	3,911	105,388	273,416	2.6
4	Lighting Replacement	27,381	2,707	(29.5)	9,469	169,289	17.8
6	Occupancy Sensors	129,062	13,180	(110.6)	11,990	115,087	9.6
8	Daylighting	63,331	9,572	26.9	10,374	19,776	1.9



AECOM
Bldg
xxx Street
Denver, CO xxxxxx

Project: University of Colorado Denver
Location: Denver, CO
Client: University of Colorado Denver
Job #: 60599515 Task 2

9/30/2019

By: SM

Chkd: JL

Energy Studies - Education 2

Division	Description	% of Costs		Total
1	General Conditions			
2	Existing Conditions			
3	Concrete			
4	Masonry			
5	Metals			
6	Wood, Lumber, and Composites			
7	Thermal and Moisture Protection			
8	Openings			
9	Finishes			
10	Specialties			
11	Equipment			
12	Furnishings			
13	Special Construction			
14	Conveying Systems			
21	Fire Suppression			
22	Plumbing			
23	Heating, Ventilating, and Air Conditioning			
26	Electrical			
	ECM -3 Community Room Return Air Additions	47.34%		\$ (273,417)
	ECM -4 Lighting Replacement in Large Auditorium	29.31%		\$ (169,290)
	ECM -6 Occupancy Sensor Additions – Lighting Only	19.93%		\$ (115,087)
	ECM -8 Daylight Sensors	3.42%		\$ (19,766)
27	Communications			
28	Electronic Safety and Security			
31	Earthwork			
32	Exterior Improvements			
33	Utilities			
Subtotal				\$ (577,560)
General Conditions				10.00% \$ (57,756)
Security Allowance				3.00% \$ (17,327)
Phasing Requirements				0.00% \$ -
Subtotal				\$ (652,643)
Mid Project Escalation				2.50% \$ (16,316)
Subtotal				\$ (668,959)
General Contractor Overhead				10.00% \$ (66,896)
General Contractor Profit				8.00% \$ (53,517)
Subtotal				\$ (789,371)
Bonds and Insurance				1.00% \$ (7,894)
Subtotal				\$ (797,265)
Estimate Contingency				0.00% \$ -
Bidding Contingency				0.00% \$ -
Total Construction Costs				\$ (797,265)



AECOM University of Colorado Denver
848g Location: Denver, CO
xxx Street Client: University of Colorado Denver
Denver, CO xxxxxx Job#: 60999515 Task 2

Estimate Date: Monday, September 30, 2019
Type: Concept

Item #	Description	Quantity	UCM	MH/Unit	Crew	\$/MH	Material	Other	Other Total	Unit Cost	Subtotal	Sub Markups	Total Cost
023 HVAC													
ECM -3 Community Room Return Air Additions													
1 Add: Add return air ducting and grilles to each Student Community room.													
Currently, 34,975 cfm of supply air is continuously being provided to the Student Community rooms during operating hours. Each Student Community room is also 100% exhausted, with no return air.													
Notes:													
2 Add: Add exhaust air systems to be modified to provide 200 cfm of exhaust in each Student Community room, located directly above the kitchen/microwave area.													
Modify exhaust air devices for lower cfm flow													
	13 EA	3.00 Q5		\$ 65.00	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 195.00	\$ 2,535.00	0.00%	\$2,535.00
3 This return duct will save an estimated 34,480 cfm of exhaust air during light loads.													
Consequently, the supply air to each Student Community room can be reduced during non-use or light use. A schedule of the cfm quantities is listed below:													
	Install return air ducting for N108	743 LBS	0.08 Q5	\$ 65.00	\$ 1.25	\$ -	\$ -	\$ -	\$ 6.45	\$ 4,789.13	0.00%	\$4,789.13	
	Install return air ducting for N109	689 LBS	0.08 Q5	\$ 65.00	\$ 1.25	\$ -	\$ -	\$ -	\$ 6.45	\$ 4,440.83	0.00%	\$4,440.83	
	Install return air ducting for N110	891 LBS	0.08 Q5	\$ 65.00	\$ 1.25	\$ -	\$ -	\$ -	\$ 6.45	\$ 5,746.95	0.00%	\$5,746.95	
	Install return air ducting for N209	540 LBS	0.08 Q5	\$ 65.00	\$ 1.25	\$ -	\$ -	\$ -	\$ 6.45	\$ 3,483.00	0.00%	\$3,483.00	
	Install return air ducting for N212	594 LBS	0.08 Q5	\$ 65.00	\$ 1.25	\$ -	\$ -	\$ -	\$ 6.45	\$ 3,831.30	0.00%	\$3,831.30	
	Install return air ducting for N216	590 LBS	0.08 Q5	\$ 65.00	\$ 1.25	\$ -	\$ -	\$ -	\$ 6.45	\$ 3,802.28	0.00%	\$3,802.28	
	Install return air ducting for N229	864 LBS	0.08 Q5	\$ 65.00	\$ 1.25	\$ -	\$ -	\$ -	\$ 6.45	\$ 5,572.80	0.00%	\$5,572.80	
	Install return air ducting for S111	729 LBS	0.08 Q5	\$ 65.00	\$ 1.25	\$ -	\$ -	\$ -	\$ 6.45	\$ 4,702.05	0.00%	\$4,702.05	
	Install return air ducting for N216	810 LBS	0.08 Q5	\$ 65.00	\$ 1.25	\$ -	\$ -	\$ -	\$ 6.45	\$ 5,224.50	0.00%	\$5,224.50	
	Install return air ducting for N217	891 LBS	0.08 Q5	\$ 65.00	\$ 1.25	\$ -	\$ -	\$ -	\$ 6.45	\$ 5,746.95	0.00%	\$5,746.95	
	Install return air ducting for N218	810 LBS	0.08 Q5	\$ 65.00	\$ 1.25	\$ -	\$ -	\$ -	\$ 6.45	\$ 5,224.50	0.00%	\$5,224.50	
	Install return air ducting for N219	648 LBS	0.08 Q5	\$ 65.00	\$ 1.25	\$ -	\$ -	\$ -	\$ 6.45	\$ 4,179.60	0.00%	\$4,179.60	
	Install return air ducting for N220	648 LBS	0.08 Q5	\$ 65.00	\$ 1.25	\$ -	\$ -	\$ -	\$ 6.45	\$ 4,179.60	0.00%	\$4,179.60	
	Install return air devices for N208	8 EA	0.85 Q5	\$ 65.00	\$ 65.00	\$ -	\$ -	\$ -	\$ 120.25	\$ 944.82	0.00%	\$944.82	
	Install return air devices for N209	7 EA	0.85 Q5	\$ 65.00	\$ 65.00	\$ -	\$ -	\$ -	\$ 120.25	\$ 876.11	0.00%	\$876.11	
	Install return air devices for N210	9 EA	0.85 Q5	\$ 65.00	\$ 65.00	\$ -	\$ -	\$ -	\$ 120.25	\$ 1,133.79	0.00%	\$1,133.79	
	Install return air devices for N209	6 EA	0.85 Q5	\$ 65.00	\$ 65.00	\$ -	\$ -	\$ -	\$ 120.25	\$ 687.14	0.00%	\$687.14	
	Install return air devices for N212	6 EA	0.85 Q5	\$ 65.00	\$ 65.00	\$ -	\$ -	\$ -	\$ 120.25	\$ 755.86	0.00%	\$755.86	
	Install return air devices for N216	6 EA	0.85 Q5	\$ 65.00	\$ 65.00	\$ -	\$ -	\$ -	\$ 120.25	\$ 747.27	0.00%	\$747.27	
	Install return air devices for N229	9 EA	0.85 Q5	\$ 65.00	\$ 65.00	\$ -	\$ -	\$ -	\$ 120.25	\$ 1,099.43	0.00%	\$1,099.43	
	Install return air devices for S111	8 EA	0.85 Q5	\$ 65.00	\$ 65.00	\$ -	\$ -	\$ -	\$ 120.25	\$ 927.64	0.00%	\$927.64	
	Install return air devices for N216	9 EA	0.85 Q5	\$ 65.00	\$ 65.00	\$ -	\$ -	\$ -	\$ 120.25	\$ 1,030.71	0.00%	\$1,030.71	
	Install return air devices for N217	9 EA	0.85 Q5	\$ 65.00	\$ 65.00	\$ -	\$ -	\$ -	\$ 120.25	\$ 1,133.79	0.00%	\$1,133.79	
	Install return air devices for N218	9 EA	0.85 Q5	\$ 65.00	\$ 65.00	\$ -	\$ -	\$ -	\$ 120.25	\$ 1,030.71	0.00%	\$1,030.71	
	Install return air devices for N219	7 EA	0.85 Q5	\$ 65.00	\$ 65.00	\$ -	\$ -	\$ -	\$ 120.25	\$ 824.57	0.00%	\$824.57	
	Install return air devices for N220	7 EA	0.85 Q5	\$ 65.00	\$ 65.00	\$ -	\$ -	\$ -	\$ 120.25	\$ 824.57	0.00%	\$824.57	
4 This reduction of supply air duct will save an estimated 24,480 cfm of exhaust air during light loads. (-3,673lbs)													
Consequently, the supply air to each Student Community room can be reduced during non-use or light use. A listing of the demo poundage quantities are listed below:													
	Reduce supply air ducting for N108	289 LBS	0.10 Q5	\$ 65.00	\$ 1.25	\$ -	\$ -	\$ -	\$ 7.75	\$ 2,239.75	0.00%	\$2,239.75	
	Reduce supply air ducting for N109	268 LBS	0.10 Q5	\$ 65.00	\$ 1.25	\$ -	\$ -	\$ -	\$ 7.75	\$ 2,077.00	0.00%	\$2,077.00	
	Reduce supply air ducting for N110	347 LBS	0.10 Q5	\$ 65.00	\$ 1.25	\$ -	\$ -	\$ -	\$ 7.75	\$ 2,689.25	0.00%	\$2,689.25	
	Reduce supply air ducting for N209	210 LBS	0.10 Q5	\$ 65.00	\$ 1.25	\$ -	\$ -	\$ -	\$ 7.75	\$ 1,627.50	0.00%	\$1,627.50	
	Reduce supply air ducting for N212	231 LBS	0.10 Q5	\$ 65.00	\$ 1.25	\$ -	\$ -	\$ -	\$ 7.75	\$ 1,790.25	0.00%	\$1,790.25	
	Reduce supply air ducting for N216	229 LBS	0.10 Q5	\$ 65.00	\$ 1.25	\$ -	\$ -	\$ -	\$ 7.75	\$ 1,774.75	0.00%	\$1,774.75	
	Reduce supply air ducting for N229	336 LBS	0.10 Q5	\$ 65.00	\$ 1.25	\$ -	\$ -	\$ -	\$ 7.75	\$ 2,604.00	0.00%	\$2,604.00	
	Reduce supply air ducting for S111	284 LBS	0.10 Q5	\$ 65.00	\$ 1.25	\$ -	\$ -	\$ -	\$ 7.75	\$ 2,201.00	0.00%	\$2,201.00	
	Reduce supply air ducting for N116	315 LBS	0.10 Q5	\$ 65.00	\$ 1.25	\$ -	\$ -	\$ -	\$ 7.75	\$ 2,441.25	0.00%	\$2,441.25	
	Reduce supply air ducting for N117	347 LBS	0.10 Q5	\$ 65.00	\$ 1.25	\$ -	\$ -	\$ -	\$ 7.75	\$ 2,689.25	0.00%	\$2,689.25	
	Reduce supply air ducting for N118	315 LBS	0.10 Q5	\$ 65.00	\$ 1.25	\$ -	\$ -	\$ -	\$ 7.75	\$ 2,441.25	0.00%	\$2,441.25	
	Reduce supply air ducting for N119	252 LBS	0.10 Q5	\$ 65.00	\$ 1.25	\$ -	\$ -	\$ -	\$ 7.75	\$ 1,953.00	0.00%	\$1,953.00	
	Reduce supply air ducting for N120	252 LBS	0.10 Q5	\$ 65.00	\$ 1.25	\$ -	\$ -	\$ -	\$ 7.75	\$ 1,953.00	0.00%	\$1,953.00	
	Reduce supply air insulation	2,066 SF	0.02 Q5	\$ 65.00	\$ 3.50	\$ -	\$ -	\$ -	\$ 4.80	\$ 9,916.80	0.00%	\$9,916.80	
	Reconnect supply air duct to existing devices	110 EA	2.00 Q5	\$ 65.00	\$ 15.00	\$ -	\$ -	\$ -	\$ 145.00	\$ 15,950.00	0.00%	\$15,950.00	
5 The Student Community rooms and adjacent corridor/rooms in most cases will need to be closed off for construction.													
The return air mains are quite a distance from the affected rooms in some instances, (this) so several other areas will be affected.													
	Allowance for main duct connections	1 LS	84.00 Q5	\$ 65.00	\$ 10,000.00	\$ -	\$ -	\$ -	\$ 15,460.00	\$ 15,460.00	0.00%	\$15,460.00	
	Allowance for ceiling space work disruptions	798 LS	1.00 Q5	\$ 65.00	\$ -	\$ -	\$ -	\$ -	\$ 65.00	\$ 51,870.00	0.00%	\$51,870.00	
6 No additional maintenance will be required once the system is installed. (But testing, adjusting and balancing will be required.)													
	TAB of AHU NPD1,04	2 EA	24.00 Q5	\$ 65.00	\$ -	\$ -	\$ -	\$ -	\$ 1,560.00	\$ 3,120.00	0.00%	\$3,120.00	
	TAB of AHU NPD2,NPD3,SPD2,SPD3	4 EA	24.00 Q5	\$ 65.00	\$ -	\$ -	\$ -	\$ -	\$ 1,560.00	\$ 6,240.00	0.00%	\$6,240.00	
	TAB of AHU SPD1,04	2 EA	24.00 Q5	\$ 65.00	\$ -	\$ -	\$ -	\$ -	\$ 1,560.00	\$ 3,120.00	0.00%	\$3,120.00	
	Sub-contractor General Conditions & Provisions @ 5%	1 LS	0.00 Q5	\$ 65.00	\$ -	\$ -	\$ -	\$ -	\$ 209,632.94	\$209,632.94	5.00%	\$10,481.65	
	Sub-contractor Overhead & Profit @ 15%	1 LS	0.00 Q5	\$ 65.00	\$ -	\$ -	\$ -	\$ -	\$ 220,114.58	\$220,114.58	15.00%	\$33,017.19	
	Engineering Fees	1 LS	0.00 Q5	\$ 65.00	\$ -	\$ -	\$ -	\$ -	\$ 20,285.00	\$ 20,285.00	0.00%	\$20,285.00	
Total 2019 Cost for ECM -3 Community Room Return Air Additions													(\$279,416.77)
Savings in 2019 for ECM -3 Community Room Return Air Additions													\$ 129,548.76
Net Savings in 2019 for ECM -3 Community Room Return Air Additions													(\$149,868.01)
Total 2020 Cost for ECM -3 Community Room Return Air Additions													(\$143,868.01)
Savings in 2020 for ECM -3 Community Room Return Air Additions													\$ 134,062.97
Net Savings in 2020 for ECM -3 Community Room Return Air Additions													(\$9,765.04)
Total 2020 Cost for ECM -3 Community Room Return Air Additions													(\$9,765.04)
Savings in 2020 for ECM -3 Community Room Return Air Additions													\$ 138,775.87
Net Savings in 2020 for ECM -3 Community Room Return Air Additions													\$128,990.83
ECM -4 Lighting Replacement in Large Auditorium													
1 Demo: Remove existing incandescent Lighting Fixtures													
	300w Quartz pendants	24 EA	0.75 ELEC	\$ 65.00	\$ -	\$ -	\$ -	\$ -	\$ 48.75	\$ 1,170.00	0.00%	\$1,170.00	
	250w Quartz pendants	11 EA	0.75 ELEC	\$ 65.00	\$ -	\$ -	\$ -	\$ -	\$ 48.75	\$ 536.25	0.00%	\$536.25	
	250w Quartz downlights	44 EA	1.00 ELEC	\$ 65.00	\$ -	\$ -	\$ -	\$ -	\$ 65.00	\$ 2,860.00	0.00%	\$2,860.00	
2 Add: New LED Lighting Fixtures													
	300w Quartz pendants	24 EA	2.00 ELEC	\$ 65.00	\$ 1,250.00	\$ -	\$ -	\$ -	\$ 1,380.00	\$ 33,120.00	0.00%	\$33,120.00	
	250w Quartz pendants	11 EA	2.00 ELEC	\$ 65.00	\$ 950.00	\$ -	\$ -	\$ -	\$ 1,060.00	\$ 11,860.00	0.00%	\$11,860.00	
	250w Quartz downlights	44 EA	3.00 ELEC	\$ 65.00	\$ 675.00	\$ -	\$ -	\$ -	\$ 870.00	\$ 38,280.00	0.00%	\$38,280.00	
	Allowance for dimming wiring control modifications	79 EA	2.00 ELEC	\$ 65.00	\$ 32.00	\$ -	\$ -	\$ -	\$ 162.00	\$ 12,798.00	0.00%	\$12,798.00	
	Allowance for scissors lift	60 Days	0.00 ELEC	\$ 65.00	\$ 150.00	\$ -	\$ -	\$ -	\$ 150.00	\$ 9,000.00	0.00%	\$9,000.00	
	Allowance for auditorium space disruptions	1 LS	84.00 ELEC	\$ 65.00	\$ -	\$ -	\$ -	\$ -	\$ 5,460.00	\$ 5,460.00	0.00%	\$5,460.00	
	Allowance for patching/repairs/misc connections in auditorium	1 LS	200.00 ELEC	\$ 65.00	\$ 500.00	\$ -	\$ -	\$ -	\$ 13,500.00	\$ 13,500.00	0.00%	\$13,500.00	
	Sub-contractor General Conditions & Provisions @ 5%	1 LS	0.00 ELEC	\$ 65.00	\$ -	\$ -	\$ -	\$ -	\$ 128,664.25	\$128,664.25	5.00%	\$6,433.21	
	Sub-contractor Overhead & Profit @ 15%	1 LS	0.00 ELEC	\$ 65.00	\$ -	\$ -	\$ -	\$ -	\$ 135,034.46	\$135,034.46	15.00%	\$20,255.17	
	Engineering Fees	1 LS	0.00 ELEC	\$ 65.00	\$ -	\$ -	\$ -	\$ -	\$ 14,000.00	\$ 14,000.00	0.00%	\$14,000.00	
Total 2019 Cost for ECM -4 Lighting Replacement in Large Auditorium													(\$169,289.63)
Savings in 2019 for ECM -4 Lighting Replacement in Large Auditorium													



AECOM University of Colorado Denver
848 Location: Denver, CO
xxx Street Client: University of Colorado Denver
Denver, CO xxxxxx Job#: 60599515 Task 2

Estimate Date: Monday, September 30, 2019
Type: Concept

Item #	Description	Quantity	UCM	MH/Unit	Crew	\$/MH	Material	Other	Other Total	Unit Cost	Subtotal	Sub Markups	Total Cost
Total 2020 Cost for ECM -8: Occupancy Sensor Additions – Lighting Only													
NOT A PAYBACK YEAR													
Savings in 2020 for ECM -8: Occupancy Sensor Additions – Lighting Only													\$ (5100,348.58)
Net Savings in 2020 for ECM -8: Occupancy Sensor Additions – Lighting Only													\$ (585,293.95)
ECM -8 Daylight Sensors													
1 Add: Daylight Sensors													
	Daylight Sensor - Ceiling mounted	7	EA	0.85	ELEC	\$ 65.00	\$ 125.00	\$ -	\$ -	\$ 180.25	\$ 1,261.75	0.00%	\$1,261.75
	Occupancy Sensor - Ceiling Dual Tech	7	EA	1.20	ELEC	\$ 65.00	\$ 200.00	\$ -	\$ -	\$ 278.00	\$ 1,946.00	0.00%	\$1,946.00
	Allowance for scissors lift	30	Days	0.00	ELEC	\$ 65.00	\$ 150.00	\$ -	\$ -	\$ 150.00	\$ 4,500.00	0.00%	\$4,500.00
	Allowance for wiring	1,050	LF	0.04	ELEC	\$ 65.00	\$ 3.50	\$ -	\$ -	\$ 6.10	\$ 6,405.00	0.00%	\$6,405.00
	Allowance for ceiling space disruptions	1	LS	16.91	ELEC	\$ 65.00	\$ -	\$ -	\$ -	\$ 1,098.83	\$ 1,098.83	0.00%	\$1,098.83
	Sub-contractor General Conditions & Provisions @ 5%	1	LS	0.00	ELEC	\$ 65.00	\$ -	\$ -	\$ -	\$ 13,949.83	\$13,949.83	5.00%	\$697.49
	Sub-contractor Overhead & Profit @ 15%	1	LS	0.00	ELEC	\$ 65.00	\$ -	\$ -	\$ -	\$ 14,647.32	\$14,647.32	15.00%	\$2,197.10
	Engineering Fees	1	LS	0.00	ELEC	\$ 65.00	\$ 1,660.00	\$ 1,660.00	\$ 1,660.00	\$ 1,660.00	\$ 1,660.00	0.00%	\$1,660.00
Total 2019 Cost for ECM -8: Daylight Sensors													\$ (519,746.36)
Savings in 2019 for ECM -8: Daylight Sensors													\$ 12,752.29
Net Savings in 2019 for ECM -8: Daylight Sensors													\$ (57,013.87)
Total 2020 Cost for ECM -8: Daylight Sensors													\$ (57,013.87)
Savings in 2020 for ECM -8: Daylight Sensors													\$ 13,198.63
Net Savings in 2020 for ECM -8: Daylight Sensors													\$ 66,184.76
PAYBACK YEAR													

University of Colorado Anschutz Medical Campus

Energy Studies Cost Estimates Barbara Davis Building

Contents:

Updated cost estimates of ECMs based on the
Sep. 7, 2017 report generated by BCER Engineering, Inc.

Scope of Estimate:

In 2017, BCER developed an energy study for the Barbara Davis building at the CU Anschutz campus (included in Appendix D). Through their study, 16 ECMs were identified and 10 are to be reviewed by AECOM, with cost estimates conducted to update previous estimates to current market values.

It is recommended that the building systems be retro-commissioned to a point that would indicate all systems are operating as originally intended.

ECM 2 - Direct Evaporative Cooling (Atomizing):

Given Denver's relatively dry climate during cooling months, it's always good to have direct evaporative cooling as a first stage of cooling. It is an inexpensive way to provide cooling without using chilled water but does add humidity to the space so humidity sensors should provide feedback to the BMS if spaces are getting over humidified to switch over to mechanical cooling. High-pressure atomizing nozzles can also be piped to provide different stages of cooling by sequencing different nozzle arrangements adding capacity control during low loads. This ECM has been successfully implemented at other locations on the CU Anschutz campus and it is recommended to be implemented as part of the bundled energy project.

Indirect Evaporative Cooling (Atomizing): This strategy would add an atomizing evaporative cooling section prior to the heat recovery coils to reduce the temperature of the exhaust air stream. The reduced temperature of the exhaust air would then come in contact with the run-around coil and transfer that additional energy to pre-cool the incoming outside air at the make-up air handlers. This would further reduce the cooling consumption required for the building. It is recommended that this ECM be implemented as part of the bundled energy project.

ECM 4 - Duct Static Pressure Optimization:

The intent of this measure is to reduce the fan power on MAU-1, MAU-2 and EHU-1 by reducing the static pressure required to maintain airflow to the critical zone. It is a balancing and controls exercise which will attempt to reduce the static pressure setpoint of the units to the lowest value possible that still maintains the required airflow to the zone with the highest anticipated static pressure. Multiple critical zones will have to be identified as the critical zone may shift as other zone demands change. This building was completed in 2005 so a rebalancing exercise, that could potentially reduce fan power energy, should be considered. It is recommended that this ECM be implemented as part of the bundled energy project.

AHU-1 Ventilation Optimization and Demand Control Ventilation (DCV): ASHRAE Standard 62.1 provides guidelines on how to calculate the volumetric flow rate of outside air required to maintain acceptable indoor quality for the building. It has a cfm/person component as well as a cfm/square foot component to the flow rate calculations. When the assumed people are not occupying a high-density space, such as a conference room, the amount of outside air provided can be reduced. A way to determine when high-density spaces are occupied are by using CO2 sensors connected to the BMS to make decisions on whether the outside air damper needs to be opened more to provide additional ventilation or if it can be reduced during those low occupancy periods. It is recommended that this ECM be implemented as part of the bundled energy project.

ECM 6 - HVAC Integration with Lighting Occupancy Sensors:

This ECM would require supplemental controls to signal the BMS, when a lighting occupancy sensor doesn't detect any occupants and turns the lights off, to reduce the airflow to that space down to its minimum level. This would reduce the amount of heating or cooling energy required. It currently has a payback greater than 20 years but with newer technology such as wireless sensors, installation costs could be reduced and make it a more viable option. At this point it is recommended not to pursue this ECM until further costing analysis and benefits could be realized.

ECM 8 - Lab Air Change Rate Reduction:

Laboratory spaces on the 3rd and 4th floors are currently ventilated at a constant 8 air changes per hour (ACH). If EH&S personnel could agree that during periods where the lab is unoccupied, the air change rate can be reduced down to 5 ACH, heating and cooling energy savings could be realized due to the reduced airflow. It is recommended that this ECM be implemented as part of the bundled energy project.

ECM 11 - Flooded High Pressure Steam Heat Exchanger:

The CU Anschutz campus currently delivers 125 psi steam to each building. The buildings then have pressure reducing stations to bring the pressure down to usable levels in equipment. The pressure reducing stations required to bring the steam pressure down take up a lot of space and reject heat to the space they are in. Energy is also lost at steam traps which tend to leak live steam rather than just relieving condensed steam. Using a flooded high-pressure heat exchanger eliminates the need for a pressure reducing station and live steam cannot be lost due to the inherit nature of the capacity control. Steam energy is transferred to the heating hot water loop to provide space heating with minimal losses. It is not recommended that this ECM be implemented as part of the bundled energy project.

ECM 12 - Variable Flow Vacuum Pump:

The vacuum pumps are currently constant speed and have two 40 horsepower pumps. They are also cooled using chilled water. Given the vacuum pumps are in need of replacement, they should be replaced with variable speed vacuum pumps to reduce pump cycling, improve motor life, and reduce energy consumption during lower flow requirements in addition to the chilled water savings at the lower flows. It is recommended that this ECM be implemented as part of the bundled energy project.

ECM 14 - Variable Flow Exhaust Fan Control (Option 2):

The three Strobic fans that exhaust the laboratory area are currently exhausting with an outlet velocity at 5400 fpm. The minimum outlet velocity for typically lab applications is 3000 fpm. By adding variable frequency drives and controls to the fans to reduce the discharge plume outlet velocity by 1400 fpm and allowing the fans to modulate based on indoor exhaust requirements, fan energy can be reduced. At this point, it is recommended not to pursue this ECM until wind analysis can be performed to see what effect lowering the outlet velocity will have on surrounding buildings.

ECM 16 - LED Luminaires with Daylight Controls:

This ECM would require the replacement of all the existing fluorescent lighting with new LED light fixtures with daylighting controls. LED lighting consume less energy and with the daylighting controls would allow lighting to be dimmed or turned off when high levels of natural light are present. It is not recommended that this ECM be implemented as part of the bundled energy project.

ECM No.	ECM Description	Annual Utility Savings			Estimated Annual Cost Savings (\$/yr)	Investment (\$)	Simple Payback (years)
		Electricity (kWh/yr)	Chilled Water (dth)	Steam (dth)			
2	Direct Evap. Cooling	(30,293)	2,484.8	0	42,355	102,212	2.4
4	Indirect Evap. Cooling	(48,182)	1,299	(265)	17,536	115,819	6.6
6	Duct Static Pres. Optimization	91,232	70.2	(13.5)	7,197	22,290	3.1
8	AHU-1 Vent. Optimization and DCV	0	35.6	168	2,793	35,027	12.5
9	HVAC Integration w/ Occ. Sens.	8,944	54.8	282.4	5,590	125,882	22.5
10	Lab ACH Reduction	325,191	783.4	1,385.9	44,698	10,071	0.2
11	Flooded High-Pressure HX	0	467.8	340.8	13,078	242,901	18.5
12	Variable Flow Vacuum Pump	19,120	32.6	0	6,591	14,442	2.2
14	Variable Flow Exhaust Op 2	158,622	0	0	6,086	30,465	5.0
16	LED Upgrade w/ Daylight	201,672	152.8	(363.3)	21,465	386,572	18.0



AECOM
Bldg
xxx Street
Denver, CO xxxxxx

Project: University of Colorado Denver
Location: Denver, CO
Client: University of Colorado Denver
Job #: 60599515 Task 2

9/30/2019

Energy Studies - Barbara Davis Facility

By: SM

Chkd: JL

Division	Description	% of Costs	Total
1	General Conditions		
2	Existing Conditions		
3	Concrete		
4	Masonry		
5	Metals		
6	Wood, Lumber, and Composites		
7	Thermal and Moisture Protection		
8	Openings		
9	Finishes		
10	Specialties		
11	Equipment		
12	Furnishings		
13	Special Construction		
14	Conveying Systems		
21	Fire Suppression		
22	Plumbing		
23	Heating, Ventilating, and Air Conditioning		
26	Electrical		
	ECM -2 Direct Evaporative Cooling (via atomizing)	9.41%	\$ (102,212)
	ECM -4 Indirect Evaporative Cooling (via atomizing)	10.67%	\$ (115,819)
	ECM-6 Supply air and exhaust air duct pressure optimization	2.05%	\$ (22,290)
	ECM-8 AHU- Ventilation optimization and DCV	3.23%	\$ (35,027)
	ECM-9 HVAC integration with lighting occupancy sensors	11.59%	\$ (125,882)
	ECM-10 Lab air change rate reduction	0.93%	\$ (10,071)
	ECM-11 Flooded high pressure steam heat exchanger	22.37%	\$ (242,901)
	ECM-12 Variable flow vacuum pump	1.33%	\$ (14,442)
	ECM-14 Variable flow exhaust fan (controls option #2)	2.81%	\$ (30,465)
	ECM-16 LED luminaires with daylight responsive controls	35.61%	\$ (386,572)
27	Communications		
28	Electronic Safety and Security		
31	Earthwork		
32	Exterior Improvements		
33	Utilities		
Subtotal			\$ (1,085,680)
General Conditions			10.00% \$ (108,568)
Security Allowance			3.00% \$ (32,570)
Phasing Requirements			0.00% \$ -
Subtotal			\$ (1,226,818)
Mid Project Escalation			2.50% \$ (30,670)
Subtotal			\$ (1,257,489)
General Contractor Overhead			10.00% \$ (125,749)
General Contractor Profit			8.00% \$ (100,599)
Subtotal			\$ (1,483,837)
Bonds and Insurance			1.00% \$ (14,838)
Subtotal			\$ (1,498,675)
Estimate Contingency			0.00% \$ -
Bidding Contingency			0.00% \$ -
Total Construction Costs			\$ (1,498,675)



AECOM University of Colorado Denver
8080 Location: Denver, CO
xxx Street Client: University of Colorado Denver
Denver, CO xxxxxx Job#: 60999515 Task 2

Estimate Date: Monday, September 30, 2019
Type: Concept

Item #	Description	Quantity	UOM	MH/Unit	Crew	\$/MH	Material	Other	Other Total	Unit Cost	Subtotal	Sub Markups	Total Cost
929 HVAC													
ECM - 2 Direct Evaporative Cooling (via atomizing)													
1 Add: Add indirect evaporative equipment cooling section: New high pressure atomizer unit (installed downstream of primary heating coil in makeup air handling units assume at 30,000 cfm ea)													
Cut into unit and prepare supports for high pressure atomizer nozzle manifold rows													
	New plate/ frame heat exchangers (feeding high pressure atomizer nozzles)	2	EA	12.00	QS	\$ 65.00	0.00	\$ -	\$ -	\$ 780.00	\$ 1,560.00	0.00%	\$1,560.00
	New high pressure atomizer units (installed downstream of primary heating coil) assume 30,000 cfm capacity each for make up air units	2	EA	8.00	QS	\$ 65.00	6000.00	\$ -	\$ -	\$ 6,520.00	\$ 13,040.00	0.00%	\$13,040.00
	2 Add: New domestic water and sanitary for new atomizing nozzles	2	EA	12.00	QS	\$ 65.00	15000.00	\$ -	\$ -	\$ 15,780.00	\$ 31,560.00	0.00%	\$31,560.00
	Install 2" Copper "1/2" BS / S soldered water piping/ insulation /valves, allow 80' ea	160	LF	0.26	QS	\$ 65.00	15.00	\$ -	\$ -	\$ 31.90	\$ 5,104.00	0.00%	\$5,104.00
	Install 2" SWCI no-hub sanitary piping (from base of condensate pan in unit to floor drain not included)	160	LF	0.38	QS	\$ 65.00	10.00	\$ -	\$ -	\$ 34.70	\$ 5,552.00	0.00%	\$5,552.00
	3 Add: New controls for the new nozzle A/C operation												
	Provide additional control point connections/ manifold to existing DDC control panel for unit (12 pts ea)	24	PTS	4.50	QS	\$ 65.00	750.00	\$ -	\$ -	\$ 1,042.50	\$ 25,020.00	0.00%	\$25,020.00
	4 Add: Power for the new evaporative nozzle operations												
	Provide electrical connections	2	EA	8.00	QS	\$ 65.00	500.00	\$ -	\$ -	\$ 1,020.00	\$ 2,040.00	0.00%	\$2,040.00
	5 Installation phasing due to shut downs for installation												
	Provide on-site requirements for work laydown/ storage over time periods	2	EA	8.00	QS	\$ 65.00	0.00	\$ -	\$ -	\$ 520.00	\$ 1,040.00	0.00%	\$1,040.00
	Sub-contractor General Conditions & Provisions @ 5%	1	LS	0.00	QS	\$ 65.00	\$ -	\$ -	\$ -	\$ 43,356.00	\$83,356.00	5.00%	\$4,167.80
	Sub contractor Overhead & Profit @ 15%	1	LS	0.00	QS	\$ 65.00	\$ -	\$ -	\$ -	\$ 87,523.80	\$87,523.80	15.00%	\$13,128.57
	Total 2019 Cost for ECM - 2 Indirect Evaporative Cooling (via atomizing)												(\$102,212.37)
	Savings in 2019 for ECM - 4 Indirect Evaporative Cooling (via atomizing)												\$ 45,571.72
	Net Savings in 2019 for ECM - 4 Indirect Evaporative Cooling (via atomizing)												(\$56,640.64)
	Total 2020 Cost for ECM - 4 Indirect Evaporative Cooling (via atomizing)												(\$56,640.64)
	Savings in 2020 for ECM - 4 Indirect Evaporative Cooling (via atomizing)												\$ 46,959.75
	Net Savings in 2020 for ECM - 4 Indirect Evaporative Cooling (via atomizing)												(\$5,680.89)
	Total 2021 Cost for ECM - 4 Indirect Evaporative Cooling (via atomizing)												(\$5,680.89)
	Savings in 2021 for ECM - 4 Indirect Evaporative Cooling (via atomizing)												\$ 46,601.14
	Net Savings in 2021 for ECM - 4 Indirect Evaporative Cooling (via atomizing)												\$38,722.45
ECM - 4 Indirect Evaporative Cooling (via atomizing)													
1 Add: Add indirect evaporative equipment cooling section: New high pressure atomizer unit (installed downstream of filter rack in exhaust heat recovery units for Lab Exhaust Fans assume at 30,000 cfm ea)													
	New plate/ frame heat exchangers (feeding high pressure atomizer nozzles)	2	EA	12.00	QS	\$ 65.00	8500.00	\$ -	\$ -	\$ 9,280.00	\$ 18,560.00	0.00%	\$18,560.00
	New EHU high pressure atomizer units (installed downstream of filter rack in exhaust heat recovery unit) assume 30,000 cfm capacity each for lab fan	2	EA	24.00	QS	\$ 65.00	13500.00	\$ -	\$ -	\$ 15,060.00	\$ 30,120.00	0.00%	\$30,120.00
	2 Add: Reconfigure access door to nozzles, if required												
	Remove existing access door on ERC unit	2	EA	4.00	QS	\$ 65.00	0.00	\$ -	\$ -	\$ 260.00	\$ 520.00	0.00%	\$520.00
	Install new access door, enlarged, to provide access to atomizing nozzles	2	EA	12.00	QS	\$ 65.00	2500.00	\$ -	\$ -	\$ 3,280.00	\$ 6,560.00	0.00%	\$6,560.00
	3 Add: New domestic water and sanitary for new atomizing nozzles												
	Install 2" Copper "1/2" BS / S soldered water piping/ insulation /valves, allow 80' ea	160	LF	0.26	QS	\$ 65.00	15.00	\$ -	\$ -	\$ 31.90	\$ 5,104.00	0.00%	\$5,104.00
	Install 2" SWCI no-hub sanitary piping (from base of condensate pan in unit to floor drain not included)	160	LF	0.38	QS	\$ 65.00	10.00	\$ -	\$ -	\$ 34.70	\$ 5,552.00	0.00%	\$5,552.00
	4 Add: New controls for the new nozzle A/C operation												
	Provide additional control point connections/ manifold to existing DDC control panel for unit (12 pts ea)	24	PTS	4.50	QS	\$ 65.00	750.00	\$ -	\$ -	\$ 1,042.50	\$ 25,020.00	0.00%	\$25,020.00
	5 Add: Power for the new evaporative nozzle operations												
	Provide electrical connections	2	EA	8.00	ELEC	\$ 65.00	1200.00	\$ -	\$ -	\$ 1,720.00	\$ 3,440.00	0.00%	\$3,440.00
	6 Installation phasing due to shut downs for installation												
	Provide on-site requirements for work laydown/ storage over time periods	2	EA	8.00	QS	\$ 65.00	0.00	\$ -	\$ -	\$ 520.00	\$ 1,040.00	0.00%	\$1,040.00
	Sub-contractor General Conditions & Provisions @ 5%	1	LS	0.00	QS	\$ 65.00	\$ -	\$ -	\$ -	\$ 95,916.00	\$95,916.00	5.00%	\$4,795.80
	Sub contractor Overhead & Profit @ 15%	1	LS	0.00	QS	\$ 65.00	\$ -	\$ -	\$ -	\$ 100,711.80	\$100,711.80	15.00%	\$15,106.77
	Total 2019 Cost for ECM - 4 Indirect Evaporative Cooling (via atomizing)												(\$115,818.57)
	Savings in 2019 for ECM - 4 Indirect Evaporative Cooling (via atomizing)												\$ 18,785.07
	Net Savings in 2019 for ECM - 4 Indirect Evaporative Cooling (via atomizing)												(\$97,033.57)
	Total 2020 Cost for ECM - 4 Indirect Evaporative Cooling (via atomizing)												(\$97,033.57)
	Savings in 2020 for ECM - 4 Indirect Evaporative Cooling (via atomizing)												\$ 19,442.48
	Net Savings in 2020 for ECM - 4 Indirect Evaporative Cooling (via atomizing)												(\$77,591.09)
	Total 2021 Cost for ECM - 4 Indirect Evaporative Cooling (via atomizing)												(\$77,591.09)
	Savings in 2021 for ECM - 4 Indirect Evaporative Cooling (via atomizing)												\$ 20,122.86
	Net Savings in 2021 for ECM - 4 Indirect Evaporative Cooling (via atomizing)												(\$57,468.13)
	Total 2022 Cost for ECM - 4 Indirect Evaporative Cooling (via atomizing)												(\$57,468.13)
	Savings in 2022 for ECM - 4 Indirect Evaporative Cooling (via atomizing)												\$ 20,827.27
	Net Savings in 2022 for ECM - 4 Indirect Evaporative Cooling (via atomizing)												(\$36,640.86)
ECM - 6 Supply air and exhaust air duct pressure optimization													
1 Add: Measuring air flow													
	Perform initial measurements of static air pressures as low as required to balance to all VAV zones	84	Hours	1.00	QS	\$ 65.00	\$ -	\$ -	\$ -	\$ 65.00	\$ 5,460.00	0.00%	\$5,460.00
	2 Add: Adjusting and Rebalancing VAVs, dampers												
	Rebalance air flows to a minimum at the VAVs	100	EA	2.00	QS	\$ 65.00	\$ -	\$ -	\$ -	\$ 130.00	\$ 13,000.00	0.00%	\$13,000.00
	Sub-contractor General Conditions & Provisions @ 5%	1	LS	0.00	QS	\$ 65.00	\$ -	\$ -	\$ -	\$ 18,460.00	\$18,460.00	5.00%	\$923.00
	Sub contractor Overhead & Profit @ 15%	1	LS	0.00	QS	\$ 65.00	\$ -	\$ -	\$ -	\$ 19,383.00	\$19,383.00	15.00%	\$2,907.45
	Total 2019 Cost for ECM-6 Supply air and exhaust air duct pressure optimization												(\$22,290.45)
	Savings in 2019 for ECM-6 Supply air and exhaust air duct pressure optimization												\$ 7,709.61
	Net Savings in 2019 for ECM-6 Supply air and exhaust air duct pressure optimization												(\$14,580.84)
	Total 2020 Cost for ECM-6 Supply air and exhaust air duct pressure optimization												(\$14,580.84)
	Savings in 2020 for ECM-6 Supply air and exhaust air duct pressure optimization												\$ 6,770.64
	Net Savings in 2020 for ECM-6 Supply air and exhaust air duct pressure optimization												(\$6,601.40)
	Total 2021 Cost for ECM-6 Supply air and exhaust air duct pressure optimization												(\$6,601.40)
	Savings in 2021 for ECM-6 Supply air and exhaust air duct pressure optimization												\$ 8,258.72
	Net Savings in 2021 for ECM-6 Supply air and exhaust air duct pressure optimization												\$1,657.32
ECM - 8 AHU- Ventilation optimization and DCV													
1 Add: CO2 sensors													
	Add: CO2 sensors to high occupancy areas such as conference rooms, allow	12	EA	2.50	QS	\$ 65.00	\$ 200.00	\$ -	\$ -	\$ 362.50	\$ 4,350.00	0.00%	\$4,350.00
	2 Add: AMS												
	Add: AMS 26 SF (30000 to 30000 cfm) Air flow measuring station at AHU-1 (vav unit) of the outdoor air intake, assume	1	EA	16.00	ELEC	\$ 65.00	\$ 2,200.00	\$ -	\$ -	\$ 3,240.00	\$ 3,240.00	0.00%	\$3,240.00
	4 Add: New controls for the sensors												
	Provide control point connections to existing DDC control panel for CO2 sensors (2 pt ea)	24	PTS	4.50	QS	\$ 65.00	750.00	\$ -	\$ -	\$ 1,042.50	\$ 25,020.00	0.00%	\$25,020.00
	Sub-contractor General Conditions & Provisions @ 5%	1	LS	0.00	QS	\$ 65.00	\$ -	\$ -	\$ -	\$ 23,610.00	\$33,610.00	5.00%	\$1,630.50
	Sub contractor Overhead & Profit @ 15%	1	LS	0.00	QS	\$ 65.00	\$ -	\$ -	\$ -	\$ 34,240.50	\$34,240.50	15.00%	\$5,136.08
	Total 2019 Cost for ECM-8 AHU- Ventilation optimization and DCV												(\$39,026.58)
	Savings in 2019 for ECM-8 AHU- Ventilation optimization and DCV												\$ 2,091.93
	Net Savings in 2019 for ECM-8 AHU- Ventilation optimization and DCV												(\$36,934.64)
	Total 2020 Cost for ECM-8 AHU- Ventilation optimization and DCV												(\$36,934.64)
	Savings in 2020 for ECM-8 AHU- Ventilation optimization and DCV												\$ 3,096.65
	Net Savings in 2020 for ECM-8 AHU- Ventilation optimization and DCV												(\$33,837.99)
	Total 2021 Cost for ECM-8 AHU- Ventilation optimization and DCV												(\$33,837.99)
	Savings in 2021 for ECM-8 AHU- Ventilation optimization and DCV												\$ 2,205.69
	Net Savings in 2021 for ECM-8 AHU- Ventilation optimization and DCV												(\$31,632.30)
ECM - 9 HVAC integration with lighting occupancy sensors													
	Provide control point connections to existing DDC control panel for occupancy sensors - assume 30 rooms (12 pt ea)	100	PTS	4.50	QS	\$ 65.00	750.00	\$ -	\$ -	\$ 1,042.50	\$ 104,250.00	0.00%	\$104,250.00
	Sub-contractor General Conditions & Provisions @ 5%	1	LS	0.00	QS	\$ 65.00	\$ -	\$ -	\$ -	\$ 104,250.00	\$104,250.00	5.00%	\$5,212.50
	Sub contractor Overhead & Profit @ 15%	1	LS	0.00	QS	\$ 65.00	\$ -	\$ -	\$ -	\$ 109,462.50	\$109,462.50	15.00%	\$16,413.88
	Total 2019 Cost for ECM-9 HVAC integration with lighting occupancy sensors												(\$125,866.38)
	Savings in 2019 for ECM-9 HVAC integration with lighting occupancy sensors												\$ 5,988.15
	Net Savings in 2019 for ECM-9 HVAC integration with lighting occupancy sensors												(\$119,878.23)
	Total 2020 Cost for ECM-9 HVAC integration with lighting occupancy sensors												(\$119,878.23)
	Savings in 2020 for ECM-9 HVAC integration with lighting occupancy sensors												\$ 6,197.73
	Net Savings in 2020 for ECM-9 HVAC integration with lighting occupancy sensors												(\$113,680.50)
	Total 2021 Cost for ECM-9 HVAC integration with lighting occupancy sensors												(\$113,680.50)
	Savings in 2021 for ECM-9 HVAC integration with lighting occupancy sensors												\$ 6,414.65
	Net Savings in 2021 for ECM-9 HVAC integration with lighting occupancy sensors												(\$107,265.84)
ECM - 10 Lab air change rate reduction													
	Provide MUA-12 control modifications to existing DDC control panel for programming air changes flow monitoring												
	1 allow 4 points ea	8	PTS	4.50	QS	\$ 65.00	750.00	\$ -	\$ -	\$ 1,042.50	\$ 8,340.00	0.00%	\$8,340.00
	Sub-contractor General Conditions & Provisions @ 5%	1	LS	0.00	QS	\$ 65.00	\$ -	\$ -	\$ -	\$ 8,340.00	\$8,340.00	5.00%	\$417.00
	Sub contractor Overhead & Profit @ 15%	1	LS	0.00	QS	\$ 65.00	\$ -	\$ -	\$				



AECOM University of Colorado Denver
808 Location: Denver, CO
xxx Street Client: University of Colorado Denver
Denver, CO xxxxxx Job#: 60599515 Task 2

Estimate Date: Monday, September 30, 2019
Type: Concept

Item #	Description	Quantity	UOM	MH/Unit	Crew	\$/MH	Material	Other	Other Total	Unit Cost	Subtotal	Sub Markups	Total Cost
	Equipment modification: Allow high pressure steam to be utilized in a condensate flooded (shell) Tube heat exchanger thereby eliminating the use of HPS-LPS PRVs, except at the trap. A lowering overall of heat transfer loss will result in the equipment area cooling load to decrease, but that cost is not captured here.												
	Allow for shutdowns, disconnections and reconnections	1	LS	84.00	Q5	\$ 65.00	\$ 48,000.00	\$ -	\$ -	\$ 53,460.00	\$ 53,460.00	0.00%	\$53,460.00
	Remove existing PRV/SPRs to heat exchanger steam system Removal allowance of existing steam/condensate piping/valves	1	LS	60.00	Q5	\$ 65.00	\$ -	\$ -	\$ -	\$ 3,900.00	\$ 3,900.00	0.00%	\$3,900.00
		1	LS	200.00	Q5	\$ 65.00	\$ -	\$ -	\$ -	\$ 13,000.00	\$ 13,000.00	0.00%	\$13,000.00
		1	EA	48.00	Q5	\$ 65.00	\$ -	\$ -	\$ -	\$ 3,120.00	\$ 3,120.00	0.00%	\$3,120.00
	Remove existing horizontal HPS- LPS heat exchanger												
	Remove existing steam condensate trap	1	EA	12.00	Q5	\$ 65.00	\$ -	\$ -	\$ -	\$ 780.00	\$ 780.00	0.00%	\$780.00
	New vertical HPS flooded HK	1	EA	60.00	Q5	\$ 65.00	\$ 75,000.00	\$ -	\$ -	\$ 78,900.00	\$ 78,900.00	0.00%	\$78,900.00
	Install new 2" condensate high pressure/ low pressure PRV with new condensate trap	1	EA	60.00	Q5	\$ 65.00	\$ 8,500.00	\$ -	\$ -	\$ 12,400.00	\$ 12,400.00	0.00%	\$12,400.00
	Install new piping for steam/condensate piping for high pressure and low pressure	1	EA	240.00	Q5	\$ 65.00	\$ 20,000.00	\$ -	\$ -	\$ 35,600.00	\$ 35,600.00	0.00%	\$35,600.00
	Sub-contractor General Conditions & Provisions @ 5%	1	LS	0.00	Q5	\$ 65.00	\$ -	\$ -	\$ -	\$ 201,160.00	\$201,160.00	5.00%	\$10,058.00
	Sub contractor Overhead & Profit @ 15%	1	LS	0.00	Q5	\$ 65.00	\$ -	\$ -	\$ -	\$ 211,218.00	\$211,218.00	15.00%	\$31,682.70
	Total 2019 Cost for ECM-11 Flooded high pressure steam heat exchanger												(\$242,900.70)
	Savings in 2019 for ECM-11 Flooded high pressure steam heat exchanger												\$ 14,009.48
	Net Savings in 2019 for ECM-11 Flooded high pressure steam heat exchanger												(\$228,891.22)
	Total 2020 Cost for ECM-11 Flooded high pressure steam heat exchanger												(\$228,891.22)
	Savings in 2020 for ECM-11 Flooded high pressure steam heat exchanger												\$ 14,499.81
	Net Savings in 2020 for ECM-11 Flooded high pressure steam heat exchanger												(\$214,391.41)
	Total 2021 Cost for ECM-11 Flooded high pressure steam heat exchanger												(\$214,391.41)
	Savings in 2021 for ECM-11 Flooded high pressure steam heat exchanger												\$ 16,001.31
	Net Savings in 2021 for ECM-11 Flooded high pressure steam heat exchanger												(\$199,384.10)
	NOT A PAYBACK YEAR												
ECM-12	Variable flow vacuum pump												
1	New vacuum pump VFDs at 40 hp	2	EA	10.00	Q5	\$ 65.00	\$ 4,500.00	\$ -	\$ -	\$ 5,150.00	\$ 10,300.00	0.00%	\$10,300.00
	Power for VFDs	2	EA	2.00	ELEC	\$ 65.00	\$ 700.00	\$ -	\$ -	\$ 830.00	\$ 1,660.00	0.00%	\$1,660.00
	Sub-contractor General Conditions & Provisions @ 5%	1	LS	0.00	Q5	\$ 65.00	\$ -	\$ -	\$ -	\$ 11,960.00	\$11,960.00	5.00%	\$598.00
	Sub contractor Overhead & Profit @ 15%	1	LS	0.00	Q5	\$ 65.00	\$ -	\$ -	\$ -	\$ 12,558.00	\$12,558.00	15.00%	\$1,883.70
	Total 2019 Cost for ECM-12 Variable flow vacuum pump												(\$16,443.70)
	Savings in 2019 for ECM-12 Variable flow vacuum pump												\$ 7,061.44
	Net Savings in 2019 for ECM-12 Variable flow vacuum pump												(\$7,381.26)
	Total 2020 Cost for ECM-12 Variable flow vacuum pump												(\$7,381.26)
	Savings in 2020 for ECM-12 Variable flow vacuum pump												\$ 2,809.56
	Net Savings in 2020 for ECM-12 Variable flow vacuum pump												(\$73.70)
	Total 2021 Cost for ECM-12 Variable flow vacuum pump												\$7,307.56
	Savings in 2021 for ECM-12 Variable flow vacuum pump												\$ 7,561.32
	Net Savings in 2021 for ECM-12 Variable flow vacuum pump												\$14,870.88
	PAYBACK YEAR												
ECM-14	Variable flow exhaust fan (controls option #2)												
1	New lab exhaust fan VFDs - assumed at 60-75 hp	3	EA	12.00	Q5	\$ 65.00	\$ 6,800.00	\$ -	\$ -	\$ 7,580.00	\$ 22,740.00	0.00%	\$22,740.00
	Power for VFDs	3	EA	2.00	ELEC	\$ 65.00	\$ 700.00	\$ -	\$ -	\$ 830.00	\$ 2,490.00	0.00%	\$2,490.00
	Sub-contractor General Conditions & Provisions @ 5%	1	LS	0.00	Q5	\$ 65.00	\$ -	\$ -	\$ -	\$ 9,230.00	\$9,230.00	5.00%	\$4,615.50
	Sub contractor Overhead & Profit @ 15%	1	LS	0.00	Q5	\$ 65.00	\$ -	\$ -	\$ -	\$ 26,491.50	\$26,491.50	15.00%	\$3,973.73
	Total 2019 Cost for ECM-14 Variable flow exhaust fan (controls option #2)												(\$38,469.23)
	Savings in 2019 for ECM-14 Variable flow exhaust fan (controls option #2)												\$ 6,519.48
	Net Savings in 2019 for ECM-14 Variable flow exhaust fan (controls option #2)												(\$21,949.75)
	Total 2020 Cost for ECM-14 Variable flow exhaust fan (controls option #2)												(\$21,949.75)
	Savings in 2020 for ECM-14 Variable flow exhaust fan (controls option #2)												\$ 6,747.66
	Net Savings in 2020 for ECM-14 Variable flow exhaust fan (controls option #2)												(\$17,202.09)
ECM-16	LED luminaires with daylight responsive controls												
1	Day-lighting controls for 50% fixtures	116,000	SF	0.01	Q5	\$ 65.00	\$ 0.35	\$ -	\$ -	\$ 1.00	\$ 116,000.00	0.00%	\$116,000.00
	Remove existing fluorescent fixtures (17300sf)	387	EA	1.00	Q5	\$ 65.00	\$ -	\$ -	\$ -	\$ 65.00	\$ 25,155.00	0.00%	\$25,155.00
	New LED fixtures	387	EA	2.50	Q5	\$ 65.00	\$ 300.00	\$ -	\$ -	\$ 462.50	\$ 178,987.50	0.00%	\$178,987.50
	Sub-contractor General Conditions & Provisions @ 5%	1	LS	0.00	Q5	\$ 65.00	\$ -	\$ -	\$ -	\$ 320,142.50	\$320,142.50	5.00%	\$16,007.13
	Sub contractor Overhead & Profit @ 15%	1	LS	0.00	Q5	\$ 65.00	\$ -	\$ -	\$ -	\$ 336,149.63	\$336,149.63	15.00%	\$50,422.44
	Total 2019 Cost for ECM-16 LED luminaires with daylight responsive controls												(\$386,575.07)
	Savings in 2019 for ECM-16 LED luminaires with daylight responsive controls												\$ 22,993.84
	Net Savings in 2019 for ECM-16 LED luminaires with daylight responsive controls												(\$363,581.22)
	Total 2020 Cost for ECM-16 LED luminaires with daylight responsive controls												(\$363,581.22)
	Savings in 2020 for ECM-16 LED luminaires with daylight responsive controls												\$ 23,798.63
	Net Savings in 2020 for ECM-16 LED luminaires with daylight responsive controls												(\$339,782.59)
	NOT A PAYBACK YEAR												

University of Colorado Anschutz Medical Campus

Energy Studies Cost Estimates E, H & S Building

Contents:

Updated cost estimates of ECMs based on the
Aug. 18, 2017 report generated by BCER Engineering, Inc.

Scope of Estimate:

In 2017, BCER developed an energy study for the Environmental Health & Safety building at the CU Anschutz campus (included in Appendix D). Through their study, 10 ECMs were identified and 6 are to be reviewed by AECOM, with cost estimates conducted to update previous estimates to current market values.

It is recommended that the building systems be retro-commissioned to a point that would indicate all systems are operating as originally intended.

ECM 1 - Exhaust Air Heat Recovery:

The units serving the EH&S building are 100% outside air units which tend to consume a lot of energy. By providing run-around coils between the exhaust air streams and the outside air intakes, the units can capture some energy and pre-heat or pre-cool incoming outside air into the units. This will reduce the heating consumption or cooling consumption required for the building. Most other buildings on the campus employ a similar strategy and have been found to be effective. This ECM is recommended to be implemented as part of the bundled energy project.

ECM 3 - Indirect Evaporative Cooling:

This strategy would add an atomizing evaporative cooling section prior to the heat recovery coils to reduce the temperature of the exhaust air stream. The reduced temperature of the exhaust air would then come in contact with the run-around coil and transfer that additional energy to pre-cool the incoming outside air at the air handlers. This would further reduce the cooling consumption required for the building. If the Exhaust Air Heat Recovery run-around coil ECM is implemented, this ECM should be implemented as well. This ECM cannot be incorporated without the Exhaust Air Heat Recovery ECM.

ECM 4 - Variable Exhaust/Make-up:

The intent of this ECM is to reduce the amount of exhaust air required which in turn reduces the amount of make-up air required which reduces energy consumption. Exhaust air is currently drawn through ducts at each storage drum location. Full exhaust airflow is provided whether a drum exists in that location or not. This ECM would install proximity sensors on the drums and when a drum is sensed, full airflow will be extracted. When no drum is sensed, the exhaust air valve can go to a minimum position reducing the amount of make-up air required. It is recommended that this ECM be implemented as part of the bundled energy project.

ECM 7 - Flooded High Pressure Heat Exchanger:

The CU Anschutz campus currently delivers 125 psi steam to each building. The buildings then have pressure reducing stations to bring the pressure down to usable levels in equipment. The pressure reducing stations required to bring the steam pressure down take up a lot of space and reject heat to the space they are in. Energy is also lost at steam traps which tend to leak live steam rather than just relieving condensed steam. Using a flooded high-pressure heat exchanger eliminates the need for a pressure reducing station and live steam cannot be lost due to the inherent nature of the capacity control. Steam energy is transferred to the heating hot water loop to provide space heating with minimal losses. It is not recommended that this ECM be implemented as part of the bundled energy project.

ECM 8 - HID Lighting Upgrade:

The EH&S building currently has a lot of metal halide high bay and low bay fixtures. These fixtures are very power intensive and Phase I of the building has an estimated watts per square foot of 2.5 which is very high for today's standards. Replacing the high and low bay metal halide fixtures with LED light fixtures would significantly reduce the lighting power consumption. It is not recommended that this ECM be implemented as part of the bundled energy project.

ECM 9 - LED Lighting with Occupancy Sensors:

The intent of this ECM is to add occupancy sensors that would tie into the lighting system to be able to automatically turn off the lights in areas that have been unoccupied for a period of time. This measure is successfully applied all over the CU Anschutz campus and would be straightforward to implement at this building. It is recommended that this ECM be implemented as part of the bundled energy project.

Summary:

There is some caution that should be exercised with the first four ECMs dealing with exhaust energy recovery, indirect evaporative cooling, variable exhaust/make-up and the flooded high-pressure heat exchanger. It is assumed that the additional static pressure drop caused by adding an energy recovery coil and an indirect evaporative cooling section at the exhaust fan plenum can be handled by the same exhaust fans and just increasing their speed. Additional research is required on those fans to ensure they can handle that increased pressure. Also, by varying the exhaust airflow rates you will negate some of the energy you can ultimately recover from the energy recovery loop. There would have to be a minimum airflow where the energy not recovered vs. the energy conserved by reducing the make-up air would render the system ineffective. Lastly, there was concern expressed when installing and cold starting up of the flooded high-pressure heat exchangers that they would crack and must be replaced. Lessons learned from that failed installation should be carried through to the installation of any future flooded high-pressure heat exchangers on CU Anschutz campus.

ECM No.	ECM Description	Annual Utility Savings			Estimated Annual Cost Savings (\$/yr)	Investment (\$)	Simple Payback (years)
		Electricity (kWh/yr)	Chilled Water (dth)	Steam (dth)			
1	Exhaust Air Heat Recovery	(177,889)	146.3	3,088.3	31,210	150,401	4.8
3	Indirect Evap. Cooling	(177,595)	264.7	3,088.3	33,443	161,954	4.8
4	Variable Exhaust/Make-up	90,499	50.5	1,073.7	20,057	112,048	5.6
7	Flooded High-pressure HX	0	0	304.2	3,851	129,818	33.7
8	HID Lighting Upgrade	62,346	46.7	(147.7)	2,761	191,418	69.3
9	LED Lighting w/ Occ Sensor	103,900	72.3	(253.6)	4,398	24,777	5.6



AECOM
Bldg
xxx Street
Denver, CO xxxxxx

Project: University of Colorado Denver
Location: Denver, CO
Client: University of Colorado Denver
Job #: 60599515 Task 2

9/30/2019

Energy Studies - EH&S Building

By: SM

Chkd: JL

Division	Description	% of Costs	Total
1	General Conditions		
2	Existing Conditions		
3	Concrete		
4	Masonry		
5	Metals		
6	Wood, Lumber, and Composites		
7	Thermal and Moisture Protection		
8	Openings		
9	Finishes		
10	Specialties		
11	Equipment		
12	Furnishings		
13	Special Construction		
14	Conveying Systems		
21	Fire Suppression		
22	Plumbing		
23	Heating, Ventilating, and Air Conditioning		
26	Electrical		
	ECM-1 Exhaust air heat recovery	19.52%	\$ (150,401)
	ECM -3 Indirect Evaporative Cooling (via atomizing)	21.02%	\$ (161,955)
	ECM-4 Variable exhaust air / makeup air (fans)	14.54%	\$ (112,048)
	ECM-7 Flooded high pressure steam heat exchanger	16.85%	\$ (129,818)
	ECM-8 HID lighting change to LED	24.85%	\$ (191,419)
	ECM-9 LED lighting with occupancy sensors	3.22%	\$ (24,778)
27	Communications		
28	Electronic Safety and Security		
31	Earthwork		
32	Exterior Improvements		
33	Utilities		
Subtotal			\$ (770,419)
	General Conditions	10.00%	\$ (77,042)
	Security Allowance	3.00%	\$ (23,113)
	Phasing Requirements	Not Required	0.00% \$ -
Subtotal			\$ (870,574)
	Mid Project Escalation	2.50%	\$ (21,764)
Subtotal			\$ (892,338)
	General Contractor Overhead	10.00%	\$ (89,234)
	General Contractor Profit	8.00%	\$ (71,387)
Subtotal			\$ (1,052,959)
	Bonds and Insurance	1.00%	\$ (10,530)
Subtotal			\$ (1,063,488)
	Estimate Contingency	Not Required	0.00% \$ -
	Bidding Contingency	Not Required	0.00% \$ -
Total Construction Costs			\$ (1,063,488)



AECOM University of Colorado Denver
848g Location: Denver, CO
xxx Street Client: University of Colorado Denver
Denver, CO xxxxxx Job#: 60999515 Task 2

Estimate Date: Monday, September 30, 2019
Type: Concept

Item #	Description	Quantity	UOM	MH/Unit	Crew	\$/MH	Material	Other	Other Total	Unit Cost	Subtotal	Sub Markups	Total Cost
023 HVAC													
ECM-1 Exhaust air heat recovery													
1 Add: Remove air unit existing steam pre-heat coil sections for new heat recovery coils													
	Allowance for demolition of AHU-1 and AHU-P-3 former existing steam pre-heat coil sections	2	EA	18.00	Q5	\$	65.00	\$	-	\$	1,170.00	2,340.00	\$2,340.00
2 Add: Add 30% physical run-around piping loops to AHU-1 heat recovery coil (in the space of former existing steam pre-heat coil section removed)													
	Allowance for AHU-1/EF EIRC coils and piping loop system in-between	1	LS	0.00	Q5	\$	65.00	\$	53,827.89	\$	53,827.89	\$	\$53,827.89
	Allowance for heating hot water and condensate supplemental piping, insulation, valves and connections to EIRC coil	1	LS	0.00	Q5	\$	65.00	\$	6,500.00	\$	6,500.00	\$	\$6,500.00
3 Add: Add 30% physical run-around piping loops to AHU-P-3 heat recovery coil (in the space of former existing steam pre-heat coil section removed)													
	Allowance for AHU-P-3/EF EIRC coils and piping loop system in-between	1	LS	0.00	Q5	\$	65.00	\$	53,827.89	\$	53,827.89	\$	\$53,827.89
	Allowance for heating hot water and condensate supplemental piping, insulation, valves and connections to EIRC coil	1	LS	0.00	Q5	\$	65.00	\$	6,500.00	\$	6,500.00	\$	\$6,500.00
4 Add: Add allowance for shut down and re-start of air systems													
	Allowance	2	EA	12.00	Q5	\$	65.00	\$	-	\$	780.00	1,560.00	\$1,560.00
	Sub-contractor General Conditions & Provisions @ 5%	1	LS	0.00	Q5	\$	65.00	\$	-	\$	124,555.79	\$124,555.79	\$5,000.00
	Sub-contractor Overhead & Profit @ 15%	1	LS	0.00	Q5	\$	65.00	\$	-	\$	130,783.58	\$130,783.58	\$15,000.00
	Total 2019 Cost for ECM-1 Exhaust air heat recovery												\$150,403.13
	Savings in 2019 for ECM-1 Exhaust air heat recovery												\$3,432.93
	Net Savings in 2019 for ECM-1 Exhaust air heat recovery												(\$116,968.18)
	Total 2020 Cost for ECM-1 Exhaust air heat recovery												(\$116,968.18)
	Savings in 2020 for ECM-1 Exhaust air heat recovery												\$4,603.08
	Net Savings in 2020 for ECM-1 Exhaust air heat recovery												(\$82,365.10)
ECM-3 Indirect Evaporative Cooling (via atomizing)													
1 Add: Add indirect evaporative equipment cooling sections to AHU-1 & AHU-P-3: New high pressure atomizer unit installed downstream of filter rack in exhaust heat recovery units for Lab Exhaust Fans assume at 30,000 cfm ea)													
	New plate/ frame heat exchangers (feeding high pressure atomizer nozzles)	3	EA	12.00	Q5	\$	65.00	\$	7500.00	\$	8,280.00	24,840.00	\$24,840.00
	New EIRC high pressure atomizer units (installed downstream of filter rack in exhaust heat recovery unit) assume 15,000 cfm capacity each for Lab fans	3	EA	24.00	Q5	\$	65.00	\$	11250.00	\$	12,810.00	38,430.00	\$38,430.00
	2 Add: Reconfigure access door to nozzles, if required	3	EA	4.00	Q5	\$	65.00	\$	0.00	\$	260.00	780.00	\$780.00
	Remove existing access door on EIRC unit	3	EA	4.00	Q5	\$	65.00	\$	0.00	\$	260.00	780.00	\$780.00
	Install new access door, enlarged, to provide access to atomizing nozzles	3	EA	12.00	Q5	\$	65.00	\$	2500.00	\$	3,280.00	9,840.00	\$9,840.00
3 Add: New domestic water and sanitary for new atomizing nozzles													
	Install 2" Copper "L", 95 / 5 soldered water piping/ insulation (valves, allow 80' ea)	240	LF	0.26	Q5	\$	65.00	\$	15.00	\$	31.90	7,656.00	\$7,656.00
	Install 3" SWCI no-hub sanitary piping (from base of condensate pan in unit to floor drain not included)	240	LF	0.38	Q5	\$	65.00	\$	10.00	\$	34.70	8,328.00	\$8,328.00
4 Add: New controls for the remote EDC operation													
	Provide additional control point connections/ manifold to existing DDC control panel for units (12 pts ea)	36	PTS	4.50	Q5	\$	65.00	\$	750.00	\$	1,042.50	37,530.00	\$37,530.00
5 Add: Power for the atomizing nozzles operations													
	Provide electrical connections	3	EA	8.00	ELEC	\$	65.00	\$	1,200.00	\$	1,720.00	5,160.00	\$5,160.00
6 Installation phasing due to shut downs for installation													
	Provide on-site requirements for work laydown/ storage over time periods	3	EA	8.00	Q5	\$	65.00	\$	0.00	\$	520.00	1,560.00	\$1,560.00
	Sub-contractor General Conditions & Provisions @ 5%	1	LS	0.00	Q5	\$	65.00	\$	-	\$	134,124.00	\$134,124.00	\$5,000.00
	Sub-contractor Overhead & Profit @ 15%	1	LS	0.00	Q5	\$	65.00	\$	-	\$	140,830.20	\$140,830.20	\$15,000.00
	Total 2019 Cost for ECM-3 Indirect Evaporative Cooling (via atomizing)												\$343,464.73
	Savings in 2019 for ECM-3 Indirect Evaporative Cooling (via atomizing)												\$35,824.98
	Net Savings in 2019 for ECM-3 Indirect Evaporative Cooling (via atomizing)												(\$126,129.75)
	Total 2020 Cost for ECM-3 Indirect Evaporative Cooling (via atomizing)												(\$126,129.75)
	Savings in 2020 for ECM-3 Indirect Evaporative Cooling (via atomizing)												\$7,078.45
	Net Savings in 2020 for ECM-3 Indirect Evaporative Cooling (via atomizing)												(\$89,050.90)
	Total 2021 Cost for ECM-3 Indirect Evaporative Cooling (via atomizing)												(\$89,050.90)
	Savings in 2021 for ECM-3 Indirect Evaporative Cooling (via atomizing)												\$38,376.61
	Net Savings in 2021 for ECM-3 Indirect Evaporative Cooling (via atomizing)												(\$50,674.29)
	Total 2022 Cost for ECM-3 Indirect Evaporative Cooling (via atomizing)												(\$50,674.29)
	Savings in 2022 for ECM-3 Indirect Evaporative Cooling (via atomizing)												\$8,735.79
	Net Savings in 2022 for ECM-3 Indirect Evaporative Cooling (via atomizing)												(\$10,954.50)
ECM-4 Variable exhaust air / makeup air (fans)													
24 valves assumed													
1 Add: Add variable precision VAV terminal exhaust boxes for drum exhaust hazardous storage stations													
	Disconnect & remove existing exhaust valves	24	EA	2.00	Q5	\$	65.00	\$	-	\$	130.00	3,120.00	\$3,120.00
	New Lab grade Phoenix Variable Exhaust Valve 1200 cfm (active)	24	EA	1.85	Q5	\$	65.00	\$	1,275.00	\$	1,395.25	3,486.00	\$3,486.00
	Sensors for air valves	24	EA	0.50	Q5	\$	65.00	\$	250.00	\$	282.50	6,780.00	\$6,780.00
	New Lab grade Phoenix Variable Exhaust Valve 1200 cfm (passive)	10	EA	1.75	Q5	\$	65.00	\$	975.00	\$	1,088.75	10,887.50	\$10,887.50
	Misc for valve electrical disconnection/ re-connection	24	EA	2.00	Elec	\$	65.00	\$	150.00	\$	280.00	6,720.00	\$6,720.00
2 Add: Add variable frequency drive upgrades to exhaust fan													
	Perform air flow measurements for existing fan capacity	3	EA	2.00	Q5	\$	65.00	\$	-	\$	130.00	390.00	\$390.00
	Remove EF VFDs assume at 25 hp	3	EA	8.00	Q5	\$	65.00	\$	-	\$	520.00	1,560.00	\$1,560.00
	New EF VFD assume 45 hp for full room exhaust	3	EA	0.00	Q5	\$	65.00	\$	-	\$	-	-	\$0.00
	Misc for opening/ closing fans	3	EA	4.00	Q5	\$	65.00	\$	250.00	\$	510.00	1,530.00	\$1,530.00
3 Add: Add variable frequency drive upgrades to makeup air supply fan													
	Remove SF VFDs assume at 45 hp	3	EA	8.00	Q5	\$	65.00	\$	-	\$	520.00	1,560.00	\$1,560.00
	New SF VFD assume 65 hp	3	EA	14.00	Q5	\$	65.00	\$	7,500.00	\$	8,420.00	25,230.00	\$25,230.00
	Misc for opening/ closing fans	3	EA	4.00	Q5	\$	65.00	\$	250.00	\$	510.00	1,530.00	\$1,530.00
	Sub-contractor General Conditions & Provisions @ 5%	1	LS	0.00	Q5	\$	65.00	\$	-	\$	92,793.50	\$92,793.50	\$5,000.00
	Sub-contractor Overhead & Profit @ 15%	1	LS	0.00	Q5	\$	65.00	\$	-	\$	97,433.18	\$97,433.18	\$15,000.00
	Total 2019 Cost for ECM-4 Variable exhaust air / makeup air (fans)												\$112,046.18
	Savings in 2019 for ECM-4 Indirect Evaporative Cooling (via atomizing)												\$21,699.80
	Net Savings in 2019 for ECM-4 Indirect Evaporative Cooling (via atomizing)												(\$90,346.35)
	Total 2020 Cost for ECM-4 Indirect Evaporative Cooling (via atomizing)												(\$90,346.35)
	Savings in 2020 for ECM-4 Indirect Evaporative Cooling (via atomizing)												\$2,459.30
	Net Savings in 2020 for ECM-4 Indirect Evaporative Cooling (via atomizing)												(\$67,889.05)
	Total 2021 Cost for ECM-4 Indirect Evaporative Cooling (via atomizing)												(\$67,889.05)
	Savings in 2021 for ECM-4 Indirect Evaporative Cooling (via atomizing)												\$2,245.37
	Net Savings in 2021 for ECM-4 Indirect Evaporative Cooling (via atomizing)												(\$44,643.68)
	Total 2022 Cost for ECM-4 Indirect Evaporative Cooling (via atomizing)												(\$44,643.68)
	Savings in 2022 for ECM-4 Indirect Evaporative Cooling (via atomizing)												\$4,058.66
	Net Savings in 2022 for ECM-4 Indirect Evaporative Cooling (via atomizing)												(\$20,584.71)
ECM-7 Flooded high pressure steam heat exchanger													
1 Add: Replace existing heat exchanger system													
	Equipment modification: Allow high pressure steam to be utilized in a condensate-flooded Shell/ Tube heat exchanger thereby eliminating the use of HPS-UPS PRVs, except at the trap.												
	A lowering overall of heat transfer loss will result in the equipment area cooling load to decrease, but that cost is not captured here.												
	Allow for shutdowns, disconnections and reconnections	1	LS	84.00	Q5	\$	65.00	\$	30,000.00	\$	35,460.00	35,460.00	\$35,460.00
	Remove existing PRV/ SRVs to heat exchanger steam system	1	LS	60.00	Q5	\$	65.00	\$	-	\$	3,900.00	3,900.00	\$3,900.00
	Removal allowance of existing steam/ condensate piping/ valves	1	LS	200.00	Q5	\$	65.00	\$	-	\$	13,000.00	13,000.00	\$13,000.00
	1 EA	48.00	Q5	\$	65.00	\$	-	\$	-	\$	3,120.00	3,120.00	\$3,120.00
	Remove existing horizontal HPS- UPS heat exchanger												
	Remove existing steam condensate trap	1	EA	12.00	Q5	\$	65.00	\$	-	\$	780.00	780.00	\$780.00
	New vertical HPS flooded HX	1	EA	60.00	Q5	\$	65.00	\$	18,750.00	\$	22,650.00	22,650.00	\$22,650.00
	Install new 4" condensate high pressure/ low pressure PRV with new condensate trap	1	EA	60.00	Q5	\$	65.00	\$	2,600.00	\$	6,500.00	6,500.00	\$6,500.00
	Install new piping for steam/condensate piping for high pressure and low pressure	1	EA	240.00	Q5	\$	65.00	\$	6,500.00	\$	22,100.00	22,100.00	\$22,100.00
	Sub-contractor General Conditions & Provisions @ 5%	1	LS	0.00	Q5	\$	65.00	\$	-	\$	107,510.00	\$107,510.00	\$5,000.00
	Sub-contractor Overhead & Profit @ 15%	1	LS	0.00	Q5	\$	65.00	\$	-	\$	112,865.50	\$112,865.50	\$16,932.83
	Total 2019 Cost for ECM-7 Flooded high pressure steam heat exchanger												(\$129,818.33)
	Savings in 2019 for ECM-7 Flooded high pressure steam heat exchanger												\$1,225.29
	Net Savings in 2019 for ECM-7 Flooded high pressure steam heat exchanger												(\$128,593.04)
	Total 2020 Cost for ECM-7 Flooded high pressure steam heat exchanger												(\$128,593.04)
	Savings in 2020 for ECM-7 Flooded high pressure steam heat exchanger												\$2,265.67
	Net Savings in 2020 for ECM-7 Flooded high pressure steam heat exchanger												(\$121,421.36)
	Total 2021 Cost for ECM-7 Flooded high pressure steam heat exchanger												(\$121,421.36)
	Savings in 2021 for ECM-7 Flooded high pressure steam heat exchanger												\$4,418.11
	Net Savings in 2021 for ECM-7 Flooded high pressure steam heat exchanger												(\$117,204.25)
ECM-8 HD lighting change to LED													
1 Add: Replace existing halide light fixtures with LED													
	Demo: 250 W - TXK Z50M PAJ2C TB, Lithonia - Metal halide	63	EA	1.00	ELEC	\$	65.00	\$	-	\$	65.00	4,095.00	\$4,095.00
	Return to be replaced with LED fixtures												
	Demo: 250 W - TXK Z50M A23 TB, Lumark/ Lithonia - Metal halide fixtures to be replaced with LED fixtures	19	EA	1.00	ELEC	\$	65.00	\$	-	\$	65.00	1,235.00	\$1,235.00
	Demo: 100 W - LEC L10M TRW TB, 27° Lithonia - Recessed metal halide fixture to be replaced with LED	11	EA	1.00	ELEC	\$	65.00	\$	-	\$	65.00	715.00	\$715.00



AECOM University of Colorado Denver
848 Location: Denver, CO
xxx Street Client: University of Colorado Denver
Denver, CO xxxxxx Job#: 60599515 Task 2

Estimate Date: Monday, September 30, 2019
Type: Concept

Item #	Description	Quantity	UCM	MH/Unit	Crew	\$/MH	Material	Other	Other Total	Unit Cost	Subtotal	Sub Markups	Total Cost
	Demo: 250 W – SXP 25H 04-GG-P/5K250-CL Rig-A-Lite - Metal halide fixtures to be replaced with LED fixtures	12 EA		1.00	ELEC	\$ 65.00	\$ -	\$ -	\$ -	\$ 65.00	\$ 780.00	0.00%	\$780.00
	Demo: 250 W – KACM 250M FP TB DWHG KACV/L, Lithonia - Metal halide fixtures to be replaced with LED fixtures	6 EA		1.00	ELEC	\$ 65.00	\$ -	\$ -	\$ -	\$ 65.00	\$ 390.00	0.00%	\$390.00
	Allowance for disconnections	111 EA		0.15	ELEC	\$ 65.00	\$ 15.00	\$ -	\$ -	\$ 24.75	\$ 2,747.25	0.00%	\$2,747.25
	New: 250 W – TXR 250M PA22C TB, Lithonia LED fixtures	63 EA		4.00	ELEC	\$ 65.00	\$ 375.00	\$ -	\$ -	\$ 635.00	\$ 40,005.00	0.00%	\$40,005.00
	New: 250 W – TXC 250M A23 TB, Lumark/Lithonia LED fixtures	19 EA		4.00	ELEC	\$ 65.00	\$ 400.00	\$ -	\$ -	\$ 660.00	\$ 12,540.00	0.00%	\$12,540.00
	New: 100 W – LGH 100M 78W FFL 277, Lithonia LED fixtures	11 EA		4.00	ELEC	\$ 65.00	\$ 320.00	\$ -	\$ -	\$ 580.00	\$ 6,380.00	0.00%	\$6,380.00
	New: 250 W – SXP 25H 04-GG-P/5K250-CL Rig-A-Lite LED fixtures	12 EA		4.00	ELEC	\$ 65.00	\$ 275.00	\$ -	\$ -	\$ 535.00	\$ 6,420.00	0.00%	\$6,420.00
	New: 250 W – KACM 250M FP TB DWHG KACV/L, Lithonia LED fixtures	6 EA		4.00	ELEC	\$ 65.00	\$ 450.00	\$ -	\$ -	\$ 710.00	\$ 4,260.00	0.00%	\$4,260.00
	Allowance for re-wiring and connections	111 EA		6.00	ELEC	\$ 65.00	\$ 300.00	\$ -	\$ -	\$ 690.00	\$ 76,590.00	0.00%	\$76,590.00
	Functional Testing allowance	111 EA		0.50	ELEC	\$ 65.00	\$ -	\$ -	\$ -	\$ 32.50	\$ 3,607.50	0.00%	\$3,607.50
	Sub-contractor General Conditions & Provisions @ 5%	1 LS		0.00	QS	\$ 65.00	\$ -	\$ -	\$ -	\$ 152,549.75	\$152,549.75	5.00%	\$7,627.49
	Sub contractor Overhead & Profit @ 15%	1 LS		0.00	QS	\$ 65.00	\$ -	\$ -	\$ -	\$ 160,177.24	\$160,177.24	15.00%	\$24,026.59
	Total 2019 Cost for ECM-8 HID lighting change to LED												\$ (519,418.82)
	Savings in 2019 for ECM-8 HID lighting change to LED												\$ 2,957.65
	Net Savings in 2019 for ECM-8 HID lighting change to LED												\$ (518,461.17)
	Total 2020 Cost for ECM-8 HID lighting change to LED												\$ (518,461.17)
	Savings in 2020 for ECM-7 Flooded high pressure steam heat exchanger												\$ 3,061.17
	Net Savings in 2020 for ECM-7 Flooded high pressure steam heat exchanger												\$ (518,400.00)
	Total 2021 Cost for ECM-7 Flooded high pressure steam heat exchanger												\$ (518,400.00)
	Savings in 2021 for ECM-7 Flooded high pressure steam heat exchanger												\$ 1,168.31
	Net Savings in 2021 for ECM-7 Flooded high pressure steam heat exchanger												\$ (518,231.69)
	ECM-9 LED lighting with occupancy sensors												
	Allowance for sensors	18,000 SF		0.002	ELEC	\$ 65.00	\$ 0.95	\$ -	\$ -	\$ 1.08	\$ 20,520.00	0.00%	\$20,520.00
	Sub-contractor General Conditions & Provisions @ 5%	1 LS		0.00	QS	\$ 65.00	\$ -	\$ -	\$ -	\$ 20,520.00	\$20,520.00	5.00%	\$1,026.00
	Sub contractor Overhead & Profit @ 15%	1 LS		0.00	QS	\$ 65.00	\$ -	\$ -	\$ -	\$ 21,546.00	\$21,546.00	15.00%	\$3,231.90
	Total 2019 Cost for												\$24,777.90
	Savings in 2019 for ECM-7 Flooded high pressure steam heat exchanger												\$ 5,767.48
	Net Savings in 2019 for ECM-7 Flooded high pressure steam heat exchanger												\$ (510,010.42)
	Total 2020 Cost for ECM-7 Flooded high pressure steam heat exchanger												\$ (510,010.42)
	Savings in 2020 for ECM-7 Flooded high pressure steam heat exchanger												\$ 5,385.24
	Net Savings in 2020 for ECM-7 Flooded high pressure steam heat exchanger												\$ (513,041.09)
	Total 2021 Cost for ECM-7 Flooded high pressure steam heat exchanger												\$ (513,041.09)
	Savings in 2021 for ECM-7 Flooded high pressure steam heat exchanger												\$ 6,178.26
	Net Savings in 2021 for ECM-7 Flooded high pressure steam heat exchanger												\$ (506,862.82)

University of Colorado Anschutz Medical Campus

Energy Studies Cost Estimates Perinatal Research Facility

Contents:

Updated cost estimates of ECMs based on the
Nov. 26, 2013 report generated by AMERESCO

Scope of Estimate:

In 2013, Ameresco developed an energy study for the Perinatal Research Facility building at the CU Anschutz campus (included in Appendix D). Through their study, 17 ECMs were identified and 11 are to be reviewed by AECOM, with cost estimates conducted to update previous estimates to current market values.

It is recommended that the building systems be retro-commissioned to a point that would indicate all systems are operating as originally intended.

ECM 1 - Variable Speed HW Pumps:

Currently there are two hot water pumps that are constant volume pumps. This ECM would provide variable frequency drives on HWP1 and HWP2.

ECM 4 - PH1 – Control and RTU at Front Office:

This ECM would require a separate roof top unit be provided to condition the front office area while the existing PH1 would be provided with alternative control strategies such as night set-back and supply air temperature reset.

ECM 5 - Reduce Duct Static Pressure:

This ECM would look to reduce the duct static pressure in the existing system by removing an attenuator and adding a dynamic air filter. By reducing the duct static pressure, you reduce the work the fan needs to produce to move air through the system and therefore save energy.

ECM 6 - PH1 – VVT/DDC Conversion:

This would replace all pneumatic controllers and actuators with direct digital controls and electronic actuators.

Summary: Apart from the original analysis from AMERESCO, it is recommended to provide direct (atomizing) evaporative cooling as a first stage of cooling for PH1 and PH2 units.

ECM No.	ECM Description	Annual Utility Savings			Estimated Annual Cost Savings (\$/yr)	Investment (\$)	Simple Payback (years)
		Electricity (kWh/yr)	Chilled Water (ton/hrs)	Steam (MLBS/yr)			
1	Variable Speed HW Pumping				1,904	10,312	5.5
4	PH1 – Control and RTU at front office				22,840	21,179	1.0
5	Reduce Duct Static Pressure				8,728	16,325	1.9
6	PH1 – VVT/DDC Conversion				8,515	250,725	29.5



AECOM
Bldg
xxx Street
Denver, CO xxxxxx

Project: University of Colorado Denver
Location: Denver, CO
Client: University of Colorado Denver
Job #: 60599515 Task 2

9/30/2019

Energy Studies Design #4

By: SM

Chkd: JL

Division	Description	% of Costs		Total
1	General Conditions			
2	Existing Conditions			
3	Concrete			
4	Masonry			
5	Metals			
6	Wood, Lumber, and Composites			
7	Thermal and Moisture Protection			
8	Openings			
9	Finishes			
10	Specialties			
11	Equipment			
12	Furnishings			
13	Special Construction			
14	Conveying Systems			
21	Fire Suppression			
22	Plumbing			
23	Heating, Ventilating, and Air Conditioning			
26	Electrical			
	ECM #1 Variable Speed HW Pumping Modification	1.55%		\$ 10,312
	ECM #3 Lighting	55.22%		\$ 368,118
	ECM #4 AHU1 - Control + RTU at front office	3.18%		\$ 21,180
	ECM #5 Reduce Duct Static Pressure	2.45%		\$ 16,325
	ECM #6 PH1 - VVT/DDC Conversion	37.61%		\$ 250,725
27	Communications			
28	Electronic Safety and Security			
31	Earthwork			
32	Exterior Improvements			
33	Utilities			
Subtotal				\$ 666,660
General Conditions				10.00% \$ 66,666
Security Allowance				3.00% \$ 20,000
Phasing Requirements				0.00% \$ -
Subtotal				\$ 753,326
Mid Project Escalation				2.50% \$ 18,833
Subtotal				\$ 772,159
General Contractor Overhead				10.00% \$ 77,216
General Contractor Profit				8.00% \$ 61,773
Subtotal				\$ 911,148
Bonds and Insurance				1.00% \$ 9,111
Subtotal				\$ 920,259
Estimate Contingency				0.00% \$ -
Bidding Contingency				0.00% \$ -
Total Construction Costs				\$ 920.259



Estimate Date: Monday, September 30, 2019

Type: Concept

C - 22

Appendix D Existing Studies

University of Colorado
Anschutz Medical Campus

Education 2 - Energy Study

February 18, 2013

Prepared by:

CATOR, RUMA & ASSOCIATES, CO.
CONSULTING MECHANICAL/ELECTRICAL ENGINEERS

896 Tabor Street
Lakewood, CO 80401
303.232.6200

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 - 2. ECM-2 – Energy recovery.
 - 3. ECM-3 – Return air in Community Rooms.
 - 4. ECM-4 – Lighting replacement in large Auditorium.
 - 5. ECM-5 – CO2 sensors.
 - 6. ECM-6 – Occupancy sensors.
 - 7. ECM-7 – Light switches.
 - 8. ECM-8 – Daylight sensors.
 - 9. Note: Each of the ECM's above will include the following (as applicable):
 - a. ECM Description
 - b. Non-Energy Project Impacts
 - c. Measurement of Energy
 - d. Energy Estimate
 - e. Financial Analysis

A. Executive Summary

1. Cator, Ruma & Associates (CRA) was hired by University of Colorado Denver (UCD) and Xcel Energy to perform an energy study of the existing Education 2 building. Eight different Energy Conservation Measures were studied.
2. A brief description of each Energy Conservation Measure (ECM) studied is provided below. Also included are the estimated construction costs, yearly savings and simple payback for each ECM. More detailed descriptions, cost opinions and financial analyses are included at the end of this report.

ECM # (Energy Conservation Measure)	Description	Estimated Construction Costs	Net Yearly Savings (Including O&M Costs)	Simple Payback
ECM-1	Evaporative Cooling Additions	\$580,319	\$34,244	16.9 Years
ECM-2	Energy Recovery Loop Additions	\$2,500,000	\$30,275	82.6 Years
ECM-3	Community Room Return Air Additions	\$223,132	\$105,388	2.1 Years
ECM-4	Lighting Replacement in Large Auditorium	\$153,986	\$9,469	16.3 Years
ECM-5	CO2 Sensor Additions	\$212,298	\$12,256	17.3 Years
ECM-6	Occupancy Sensor Additions – Lighting Only	\$101,074	\$11,990	8.4 Years
ECM-7	Light Switch Additions	\$13,072	\$267	48.6 Years
ECM-8	Daylighting	\$18,261	\$10,374	1.8 Years

B. Introduction

1. Project Details
 - a. Building – Education 2 North and South, Anschutz Medical Campus
 - b. Address (N. Bldg.) – 13120 E 19th Ave, Aurora, CO 80045
 - c. Address (S. Bldg.) – 13121 E 17th Ave, Aurora, CO 80045
 - d. Gross area of both buildings = 275,376 sq. ft. (5 stories each)
 - e. Building use:
 - 1) 1st & 2nd floors are generally classroom & study areas.

- 2) 3rd, 4th & 5th floors are typical office use.
2. Project Owner
 - a. University of Colorado Denver – Anschutz Medical Campus
 - b. Project Manager – Mike Vigil – 303-724-1141 – mike.vigil@ucdenver.edu
3. Building Services Description
 - a. Building cooling is provided through the campus chilled water system. The chilled water is pumped up to (8) main air handling units located on the roof. A few other chilled water fan coil units are used for spot cooling in certain areas. The chiller plant efficiency of 0.7 kW/ton was used in this study and obtained from the facilities engineering staff.
 - b. Building heat and domestic water heat are provided through the campus steam system. Heat exchangers convert the steam to heating hot water and domestic hot water. The heating water is pumped up to (8) main air handling units located on the roof and to reheat coils in the VAV boxes.
 - c. The north and south buildings are served from separate electrical service. The services have demand meters and are connected to the BAS system for load and energy usage trending.

C. Study Summary

1. The base energy model was based on information obtained from meetings with UCD personnel, building construction submittals and site visits to the Education 2 building. UCD provided actual monthly energy consumption values from July 2007 through June 2011 for chilled water, steam and electrical. UCD also provided classroom and office schedules for the building. CRA utilized this information to generate the base model, and then compared it to actual monthly energy consumption values to verify that the model was as accurate as possible.
2. Energy simulation software utilized: Trane Trace 700, version 6.2.8.3.
3. Refer to the attached Energy Conservation Opportunities Form for a breakdown of each ECM studied.
4. It was found during the energy simulations that all of the large air handling units have significant capacity for future growth. This was confirmed by studying some trend data for each AHU, provided by the Owner. A rough summary of the peak supply airflows, taken from the trend data, is shown below:
 - a. AHU-NP01 actual max supply airflow = ~65% of original design airflow.

- b. AHU-NP02 actual max supply airflow = ~71% of original design airflow.
 - c. AHU-NP03 actual max supply airflow = ~68% of original design airflow.
 - d. AHU-NP04 actual max supply airflow = ~54% of original design airflow.
 - e. AHU-SP01 actual max supply airflow = ~62% of original design airflow.
 - f. AHU-SP02 actual max supply airflow = ~60% of original design airflow.
 - g. AHU-SP03 actual max supply airflow = ~78% of original design airflow.
 - h. AHU-SP04 actual max supply airflow = ~56% of original design airflow.
- 5. There are several smaller air handling units and fan coil units that do not have airside economizer capability. Therefore, chilled water is used year-round.
 - 6. Please note: The payback numbers shown in Xcel's "Energy Conservation Opportunities Form" do not include savings/costs from natural gas usage, since Xcel is not the provider of natural gas to UCD. The payback numbers shown in the table above do account for the natural gas savings/costs.

D. Conclusions and Recommendations

- 1. Based on a simple payback of less than 15 years, ECM's 1, 3, 6 and 8 all appear to be feasible measures. We recommend that UCD evaluate the budget(s) they have available to determine which ECM's they would like to pursue. If required, CRA can combine the chosen ECM's to determine an overall cost and payback period.
- 2. ECM's 2, 4, 5 and 7 have payback periods over 15 years. At this point, we do not recommend pursuing these any further.

E. Project Team

- 1. Bruce Appel, P.E. Principal in Charge
- 2. Sean Convery, P.E. Principal
- 3. Neal Wondel, P.E. Sr. Electrical Engineer
- 4. Corey Huck Energy Modeler
- 5. Mark Schoenheider Xcel Energy Account Manager

F. Energy Conservation Measures (see attached)

- 1. ECM-1 – Evaporative Cooling

2. ECM-2 – Energy Recovery
3. ECM-3 – Return Air in Community Rooms
4. ECM-4 – Lighting Replacement in Large Auditorium
5. ECM-5 – CO₂ Sensors
6. ECM-6 – Occupancy Sensors
7. ECM-7 – Light Switches
8. ECM-8 – Daylighting

G. Xcel Energy Disclaimer

The estimated costs shown for each opportunity are based on previous experience with comparable cost reduction plans in other facilities. While the energy conservation and load management measures contained in this report have been reviewed for technical accuracy, Xcel Energy and Cator, Ruma & Associates do not guarantee the cost savings or reduction in total energy requirements presented in the recommendations. Xcel Energy and Cator, Ruma & Associates shall, in no event, be liable to University of Colorado Denver in the event that the potential energy savings are not achieved.

The recommendations are based on an analysis of conditions observed at the time of the survey, information provided by Xcel Energy and costs based upon Cator, Ruma & Associates experience on similar projects. Estimated savings are computed on the basis of research by government agencies product literature, and engineering associations. Actual savings will depend on many factors including: conservation measures implemented, seasonal weather variations, fuel price increases and specific energy use practices of the facility's occupants and workers. Performance guidelines provided in the report are for informational purposes only and are not to be construed as a design document. This report is written for energy saving purposes only and should not be used for bid specifications.

Xcel Energy will not benefit in any way from your decision to select a particular contractor or Cator, Ruma & Associates to supply or install the products and measures recommended by Cator, Ruma & Associates. You are encouraged to ask for the option of contractors or suppliers you have worked with in the past for further information on the suggested measures.

Disturbance, removal or replacement of building material, insulation system, high intensity discharge and fluorescent lamps, lamp ballasts, power factor correction capacitors, starting and running capacitors of motors and other potentially hazardous components that contain asbestos, mercury or PCB's will require proper handling and disposal in accordance with applicable federal and state laws and regulations. It is the University of Colorado Denver's responsibility to ensure that the contractor follows such guidelines in implementing the recommendations of this report.

Xcel Energy advises that University of Colorado Denver check with their Xcel Energy sales representative to determine the estimated value of their rebate and to verify that the equipment qualifies for Xcel Energy programs prior to implementing any conservation measure. Some measures identified in this report may qualify for an Xcel Energy Custom Efficiency rebate. Custom Efficiency projects require pre-approval prior to purchase and installation. The University of Colorado Denver is responsible for submitting project information to their Xcel Energy sales representative to obtain pre-approval for Custom Efficiency projects and to determine the eligible custom rebate amount.

FOR REFERENCE ONLY

STC/NCWef
P:\CU\UCD\2011-237 Education 2 Energy Study\Sup\Docs\Reports\UCD Education 2 Energy Study.doc

University of Colorado Anschutz Medical Campus
Education 2 - Energy Study

February 18, 2013

Energy Conservation Measure ECM-1 – Evaporative Cooling Addition

ECM Description:

- A. Add new 95% efficient direct evaporative cooling coils to the (8) existing rooftop air handling units.
 - 1. AHU-NP01 – 75,000 cfm
 - 2. AHU-NP02 – 65,000 cfm
 - 3. AHU-NP03 – 65,000 cfm
 - 4. AHU-NP04 – 75,000 cfm
 - 5. AHU-SP01 – 40,000 cfm
 - 6. AHU-SP02 – 65,000 cfm
 - 7. AHU-SP03 – 65,000 cfm
 - 8. AHU-SP04 – 40,000 cfm
- B. Existing final filter section will be relocated within each AHU, to be directly downstream of the pre-filter section. The new evaporative coils will take the place of the final filters, just before the supply air discharge of each unit.
- C. Controls will be added to operate the evaporative cooling during hot and dry conditions. The controls will also switch the cooling to the chilled water coil when conditions are humid or if a particular space served by that AHU is not satisfied.
- D. Domestic water and sanitary sewer lines will need to be extended to each evaporative cooling section.

Non-Energy Project Impacts:

- A. Each AHU will need to be shut down for a period of time (estimated at 2 to 3 weeks per AHU) to install the evaporative coils and relocate the final filters.
- B. Additional maintenance will be required to keep the evaporative coil in good working order.

Measurement of Energy:

- A. UCD already has procedures in place to measure the electrical, chilled water and steam energy consumption for the Education 2 building, on a monthly basis.
- B. No additional costs are anticipated to verify the energy use, since these procedures are already in place.

Energy Estimate:

- A. Refer to the attached Energy Cost Budget for total energy and cost savings estimated per year. **Please note:** The numbers reflected in the attached reports do not take into account the energy savings from adding direct evaporative cooling coils to AHU-SP02 and AHU-SP04. A glitch in the Trane Trace program did not allow us to properly model those AHU's with evap cooling. Additional calculations shown below are used to estimate the additional savings that should occur if the program were to model it correctly.
- B. Refer to the attached Monthly Energy Consumption and Monthly Utility Costs for a monthly breakdown of the energy usage and costs. See note above regarding additional calculations.
- C. Note: An additional 0.25" w.g. was added to the supply fan static in the model for each AHU. This was to account for the pressure drop of the new evaporative coil.
- D. It was found during the energy simulations that all of the large air handling units have significant capacity for future growth. This was confirmed by studying some trend data for each AHU, provided by the Owner. A rough summary of the peak supply airflows, taken from the trend data, is shown below:
 - a. AHU-NP01 actual max supply airflow = ~65% of original design airflow.
 - b. AHU-NP02 actual max supply airflow = ~71% of original design airflow.
 - c. AHU-NP03 actual max supply airflow = ~68% of original design airflow.
 - d. AHU-NP04 actual max supply airflow = ~54% of original design airflow.
 - e. AHU-SP01 actual max supply airflow = ~62% of original design airflow.
 - f. AHU-SP02 actual max supply airflow = ~60% of original design airflow.
 - g. AHU-SP03 actual max supply airflow = ~78% of original design airflow.
 - h. AHU-SP04 actual max supply airflow = ~56% of original design airflow.

Financial Analysis:

- A. Estimated construction costs = \$ 580,319 (Refer to the attached Opinion of Probable Construction Costs for ECM-1 for a further breakdown).
- B. Energy cost savings = \$ 35,646 per year (per the attached Excel spreadsheet)
- C. Adjusted cost savings (based on \$/cfm) = $[(200,424 \text{ cfm total}) / (161,477 \text{ cfm without AHU-SP02 \& 04})] * (\$ 35,646/\text{yr}) = \$ 44,244 \text{ per year}$

- D. Estimated maintenance costs = \$ 10,000 per year
- E. Total net operating and maintenance cost savings = \$ 34,244 per year
- F. Estimated simple payback = 16.9 years

FOR REFERENCE ONLY

ECM-1

UCD Ed 2 Base

	January	February	March	April	May	June	July	August	September	October	November	December	FY total
Electric													
On-Peak Cons. (kWh)	266,022	239,840	273,006	261,934	277,578	286,383	285,612	292,840	270,540	269,980	266,436	262,022	3,246,193 kWh
On-Peak Demand (kW)	710	713	757	774	790	823	818	813	805	776	758	732	823 kW
Purchased Steam													
On-Peak Cons. (therms)	15,856	14,520	10,198	11,070	3,643	2,400	2,505	2,569	3,009	7,640	14,013	14,821	102,244 therms
On-Peak Demand (therms/hr)	95	97	122	81	47	10	12	33	65	88	93		97 therms/hr
Purchased CHW													
On-Peak Cons. (therms)	2,180	1,926	2,888	3,335	9,041	18,090	17,647	17,379	12,949	4,742	2,287	2,283	93,747 therms
On-Peak Demand (therms/hr)	16	20	28	33	53	73	70	73	64	48	24	24	73 therms/hr
On-Peak Demand (kW)	93	117	163	192	309	426	408	426	373	280	140	140	
Xcel Bill Calculation													
Service & Facility Charge	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	
On-Peak Cons. (June-Sept)													
Off-Peak Cons. (Oct-May)	\$0.02832	\$0.02832	\$0.02832	\$0.02832	\$0.02832	\$0.02832	\$0.02832	\$0.02832	\$0.02832	\$0.02832	\$0.02832	\$0.02832	
On-Peak Demand (June-Sept)													
Off-Peak Demand (Oct-May)	\$15.43	\$15.43	\$15.43	\$15.43	\$15.43	\$18.93	\$18.93	\$18.93	\$18.93	\$15.43	\$15.43	\$15.43	
Consumption	\$9,348.09	\$8,390.80	\$10,128.50	\$10,102.94	\$15,364.81	\$30,620.50	\$30,104.72	\$30,081.24	\$23,387.25	\$11,581.57	\$9,273.70	\$9,315.29	
Demand	\$12,395.43	\$12,807.78	\$14,007.73	\$14,913.08	\$16,960.11	\$23,640.37	\$23,214.45	\$23,451.07	\$22,305.81	\$16,294.06	\$13,856.13	\$13,454.95	\$409,440.04
Total Monthly Xcel Bill (no steam)	\$20,743.52	\$21,198.58	\$24,136.23	\$25,016.02	\$32,324.92	\$54,260.87	\$53,299.17	\$53,532.31	\$45,693.66	\$27,875.63	\$23,729.83	\$22,770.24	\$131,291.52
Total Steam Bill	\$20,360.69	\$18,645.13	\$13,095.25	\$14,214.99	\$4,677.98	\$3,081.64	\$3,216.67	\$3,298.85	\$3,863.86	\$9,810.52	\$17,994.09	\$19,031.65	
CHW Portion - Consumption	\$360.13	\$318.17	\$477.09	\$534.42	\$1,493.56	\$3,957.16	\$3,860.26	\$3,801.63	\$2,635.70	\$783.37	\$377.81	\$377.15	\$18,974.48
CHW Portion - Demand	\$1,440.13	\$1,800.16	\$2,520.22	\$2,970.26	\$4,770.41	\$8,060.98	\$7,729.71	\$8,060.98	\$7,067.16	\$4,320.38	\$2,160.19	\$2,160.19	\$53,060.75
CHW Portion - Total Bill	\$2,155.07	\$2,473.14	\$3,352.12	\$3,852.12	\$6,618.79	\$12,372.95	\$11,944.78	\$12,217.42	\$10,057.67	\$5,458.56	\$2,892.81	\$2,892.15	\$76,294.95

UCD Ed 2 - Evap Cooling

	January	February	March	April	May	June	July	August	September	October	November	December	FY total
Electric													
On-Peak Cons. (kWh)	269,000	242,521	276,231	265,022	281,413	289,920	289,726	296,943	274,111	273,317	263,317	264,870	3,286,401 kWh
On-Peak Demand (kW)	721	723	763	781	796	831	828	826	814	787	757	735	831 kW
Purchased Steam													
On-Peak Cons. (therms)	15,829	14,468	10,128	10,982	3,351	2,217	2,363	2,369	2,702	7,527	14,005	14,856	100,797 therms
On-Peak Demand (therms/hr)	95	97	72	81	47	10	12	11	33	65	88	91	97 therms/hr
Purchased CHW													
On-Peak Cons. (therms)	1,897	1,665	1,451	1,756	4,895	13,201	14,611	13,563	6,468	2,301	1,780	1,919	65,707 therms
On-Peak Demand (therms/hr)	10	11	10	15	49	63	64	70	59	31	10	10	72 therms/hr
On-Peak Demand (kW)	58	64	58	87	286	367	373	408	344	181	58	58	
Xcel Bill Calculation													
Service & Facility Charge	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	
On-Peak Cons. (June-Sept)													
Off-Peak Cons. (Oct-May)	\$0.02832	\$0.02832	\$0.02832	\$0.02832	\$0.02832	\$0.02832	\$0.02832	\$0.02832	\$0.02832	\$0.02832	\$0.02832	\$0.02832	
On-Peak Demand (June-Sept)													
Off-Peak Demand (Oct-May)	\$15.43	\$15.43	\$15.43	\$15.43	\$15.43	\$18.93	\$18.93	\$18.93	\$18.93	\$15.43	\$15.43	\$15.43	
Consumption	\$9,192.54	\$8,250.10	\$9,193.15	\$8,962.86	\$12,032.34	\$25,380.06	\$26,922.77	\$26,041.27	\$17,387.58	\$9,650.11	\$8,934.49	\$9,093.84	
Demand	\$12,025.11	\$12,145.98	\$12,673.17	\$13,400.95	\$16,692.66	\$22,687.57	\$22,741.20	\$23,365.89	\$21,924.06	\$14,933.65	\$12,580.59	\$12,241.13	\$372,710.77
Total Monthly Xcel Bill (no steam)	\$21,572.46	\$20,750.89	\$22,221.13	\$22,718.62	\$29,079.81	\$48,422.44	\$50,018.78	\$49,761.96	\$39,666.44	\$24,938.57	\$21,869.89	\$21,689.78	\$129,433.43
Total Steam Bill	\$20,326.02	\$18,578.36	\$13,005.36	\$14,101.99	\$4,303.02	\$2,846.85	\$3,034.33	\$3,042.03	\$3,469.64	\$9,665.42	\$17,983.82	\$19,076.59	
Total Add'l Water Bill @ 3.22 gal/ton-hr @ 3 cycles of concentration	\$29.69	\$27.38	\$129.76	\$155.14	\$434.89	\$512.83	\$318.46	\$400.28	\$685.42	\$256.05	\$53.18	\$38.18	\$2,941.26
Energy Savings: (incl. AHU-SP02 & 04)													\$35,646.11 per year
Energy Savings: (incl. AHU-SP02 & 04)													\$44,243.67 per year
Maintenance													-\$10,000.00 per year
Total Savings:													\$34,243.67 per year
Estimated Construction Costs													\$580,319.00
Estimated Simple Payback													16.9 years

Total Peak Demand Savings (kW)

24

42

99

98

17

50

25

4

20

88

83

79

CATOR, RUMA & ASSOCIATES, CO.					DATE PREPARED: 02/18/13		SHEET 1 OF 1	
OPINION OF PROBABLE CONSTRUCTION COSTS								
PROJECT: UCD Education 2 ECM-1 - Evaporative Cooling Addition							BASIS: <input checked="" type="checkbox"/> No Design <input type="checkbox"/> Prelim. Design <input type="checkbox"/> Final Design <input type="checkbox"/> Other _____	
LOCATION: Aurora, CO				PREPARED BY: JAW				
REFERENCE DRAWING NO.:				CHECKED BY:				
SUMMARY		QUANTITY		MATERIAL		LABOR		TOTAL COST
	NO. UNITS	UNIT	PER UNIT	TOTAL	PER UNIT	TOTAL		
New:								
Evap. Cooling install & piping (75K cfm AHU)	2	ea	\$31,600.00	\$63,200.00	\$7,875.00	\$15,750.00		\$78,950.00
Evap. Cooling install & piping (65K cfm AHU)	4	ea	\$27,400.00	\$109,600.00	\$6,825.00	\$27,300.00		\$136,900.00
Evap. Cooling install & piping (40K cfm AHU)	2	ea	\$16,900.00	\$33,800.00	\$4,200.00	\$8,400.00		\$42,200.00
DDC Controls (12 pts per unit)	96	ea	\$200.00	\$19,200.00	\$1,300.00	\$124,800.00		\$144,000.00
Electrical	8	ea	\$500.00	\$4,000.00	\$2,000.00	\$16,000.00		\$20,000.00
Subtotal								\$422,050.00
Tools, safety, trash, trucks, etc.								\$42,205.00
Contractor O&P/Mark-up								\$63,307.50
Subtotal								\$527,562.50
Engineering Fees								\$52,756.25
Grand Total:								\$580,318.75

Energy Conservation Measure ECM-2 – Energy Recovery Addition

ECM Description:

- A. Add new energy recovery loops and coils in each of the (8) existing rooftop air handling units and the associated building exhaust fans.
- B. Due to the financial analysis (see below), this ECM was not pursued any further.

Energy Estimate:

- A. Refer to the attached Energy Cost Budget for total energy and cost savings estimated per year.
- B. Refer to the attached Monthly Energy Consumption and Monthly Utility Costs for a monthly breakdown of the energy usage and costs.

Financial Analysis:

- A. Estimated construction costs = \$ 2,500,000 to \$ 3,000,000. This quick estimate was formulated from a previous energy recovery project recently performed on the Research I facility at UCD. A detailed Opinion of Probable Construction Costs for ECM-2 was not performed due to the extensive payback period.
- B. Energy cost savings = \$ 40,275 per year
- C. Estimated maintenance costs = \$ 10,000 per year
- D. Estimated simple payback = 82.6 years

ECM-2															
UDC Ed 2 Base															
Electric	On-Peak Cons. (kWh)	284,739	256,746	290,936	278,799	292,165	298,944	298,461	300,332	284,304	286,824	278,488	280,681	FY total	3,437,419 kWh 844 kW
	On-Peak Demand (kW)	752	750	784	803	815	844	841	837	828	802	785	760		
Purchased Steam	On-Peak Cons. (therms)	17,324	16,016	11,252	12,024	3,994	2,557	2,676	2,754	3,286	8,267	15,348	16,295	111,793 therms	106 therms/hr
Purchased CHW	On-Peak Demand (therms/hr)	106	106	81	85	51	11	13	14	35	68	92	98	96,957 therms	80 therms/hr
	On-Peak Cons. (therms)	2,351	2,103	3,024	3,401	9,248	18,646	18,112	17,891	12,397	4,859	2,463	2,462	96,957 therms	80 therms/hr
Xcel Bill Calculation	On-Peak Demand (therms/hr)	99	122	175	192	321	467	420	432	379	297	146	140		
	On-Peak Demand (kW)														
Service & Facility Charge		\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	
	On-Peak Cons. (June-Sept)	\$0.02832	\$0.02832	\$0.02832	\$0.02832	\$0.02832	\$0.03750	\$0.03750	\$0.03750	\$0.03750	\$0.02832	\$0.02832	\$0.02832	\$0.02832	
Off-Peak Cons. (Oct-May)		\$15.43	\$15.43	\$15.43	\$15.43	\$15.43	\$18.93	\$18.93	\$18.93	\$18.93	\$15.43	\$15.43	\$15.43	\$15.43	
	On-Peak Demand (June-Sept)														
Off-Peak Demand (Oct-May)															
	Consumption Demand	\$10,015.08	\$9,016.48	\$10,749.15	\$10,718.33	\$15,949.71	\$31,702.59	\$31,097.60	\$31,149.88	\$24,285.86	\$12,155.70	\$9,931.01	\$9,982.28		
Total Monthly Xcel Bill (no steam)		\$13,133.49	\$13,462.66	\$14,797.35	\$15,340.55	\$17,525.88	\$24,810.87	\$23,870.68	\$24,015.81	\$22,851.63	\$16,985.26	\$14,362.75	\$13,886.99	\$426,065.32	
	Total Steam Bill	\$22,245.75	\$20,566.19	\$14,448.69	\$15,440.02	\$5,128.70	\$3,283.44	\$3,436.23	\$3,536.41	\$4,219.59	\$10,616.65	\$19,708.37	\$20,924.41	\$143,553.59	
UDC Ed 2 - Energy Recovery															
Electric	On-Peak Cons. (kWh)	270,584	243,940	276,725	265,284	278,167	285,552	284,990	292,270	270,947	272,784	264,755	266,695	3,272,693 kWh	812 kW
	On-Peak Demand (kW)	724	722	756	776	787	812	812	809	801	775	757	732	94,665 therms	73 therms/hr
Purchased Steam	On-Peak Cons. (therms)	14,007	12,659	9,578	10,285	3,737	2,523	2,650	2,717	3,168	7,405	12,641	13,295	93,707 therms	67 therms/hr
	On-Peak Demand (therms/hr)	73	72	67	66	41	11	14	14	28	55	73	71		
Purchased CHW	On-Peak Cons. (therms)	2,210	1,946	3,008	3,364	9,151	17,770	17,464	17,191	12,003	4,851	2,373	2,376	96,957 therms	80 therms/hr
	On-Peak Demand (therms/hr)	17	21	30	33	52	66	65	67	60	49	25	24	96,957 therms	80 therms/hr
Xcel Bill Calculation	On-Peak Demand (therms/hr)	99	122	175	192	303	385	379	391	350	286	146	140		
	On-Peak Demand (kW)														
Service & Facility Charge		\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	
	On-Peak Cons. (June-Sept)	\$0.02832	\$0.02832	\$0.02832	\$0.02832	\$0.02832	\$0.03750	\$0.03750	\$0.03750	\$0.03750	\$0.02832	\$0.02832	\$0.02832	\$0.02832	
Off-Peak Cons. (Oct-May)		\$15.43	\$15.43	\$15.43	\$15.43	\$15.43	\$18.93	\$18.93	\$18.93	\$18.93	\$15.43	\$15.43	\$15.43	\$15.43	
	On-Peak Demand (June-Sept)														
Off-Peak Demand (Oct-May)															
	Consumption Demand	\$9,497.18	\$8,232.51	\$10,333.41	\$10,304.88	\$15,472.78	\$30,237.65	\$29,880.28	\$29,863.25	\$23,351.96	\$11,751.45	\$9,467.39	\$9,524.82		
Total Monthly Xcel Bill (no steam)		\$12,701.45	\$13,030.62	\$14,365.31	\$14,943.94	\$16,623.82	\$22,659.17	\$22,548.74	\$22,712.80	\$21,786.39	\$16,366.63	\$13,930.71	\$13,454.95	\$407,784.83	
	Total Steam Bill	\$17,986.39	\$16,255.42	\$12,299.11	\$13,206.97	\$4,798.68	\$3,239.78	\$3,402.87	\$3,488.90	\$4,068.03	\$9,508.76	\$16,232.31	\$17,072.11	\$121,559.33	
Energy Savings:													\$40,274.56 per year		
Maintenance													-\$10,000.00 per year		
Total Savings:													\$30,274.56 per year		
Estimated Construction Costs													\$2,500,000.00		
Estimated Simple Payback													82.6 years		

Energy Conservation Measure ECM-3 – Community Room Return Air Addition

ECM Description:

- A. Add return air ducting and grilles to each Student Community room. Currently, 34,975 cfm of supply air is continuously being provided to the Student Community rooms during operating hours. Each Student Community room is also 100% exhausted, with no return air.
- B. Exhaust air systems will be modified to provide 200 cfm of exhaust in each Student Community room, located directly above the kitchen/microwave area.
- C. Return air ducting and grilles will be added to allow the VAV boxes to modulate down to a 30% minimum during light loads.
- D. This will save an estimated 24,480 cfm of exhaust air during light loads. Consequently, the supply air to each Student Community room can be reduced during non-use or light use. A schedule of the cfm quantities is listed below:

Terminal Box #	Original Minimum CFM	New Minimum CFM
N108	2750	825
N109	2550	765
N110	3300	990
N209	2000	600
N212	2200	660
N216	2175	655
N229	3200	960
S111	2700	810
S113	3000	900
S203	3300	990
S206	3000	900
S215	2400	720
S216	2400	720
Totals:	34,975	10,495
Total supply air saved at minimum loads: ~24,480 cfm		

Non-Energy Project Impacts:

- A. Student Community rooms and adjacent corridor/rooms in most cases will need to be closed off for construction. The return air mains are quite a distance from the affected rooms in some instances, so several other areas will be affected.
- B. No additional maintenance will be required once the system is installed.

Measurement of Energy:

- A. UCD already has procedures in place to measure the electrical, chilled water and steam energy consumption for the Education 2 building, on a monthly basis.
- B. No additional costs are anticipated to verify the energy use, since these procedures are already in place.

Energy Estimate:

- A. Refer to the attached Energy Cost Budget for total energy and cost savings estimated per year.
- B. Refer to the attached Monthly Energy Consumption and Monthly Utility Costs for a monthly breakdown of the energy usage and costs.

Financial Analysis:

- A. Estimated construction costs = \$ 223,132 (Refer to the attached Opinion of Probable Construction Costs for ECM-3 for a further breakdown).
- B. Energy cost savings = \$ 105,388 per year
- C. Estimated maintenance costs = \$ 0 per year
- D. Total net operating and maintenance cost savings = \$ 105,388 per year
- E. Estimated simple payback = 2.1 years

ECM-3

UCD Ed 2 Base

	January	February	March	April	May	June	July	August	September	October	November	December	FY total
Electric													
On-Peak Cons. (kWh)	265,942	239,797	273,036	261,930	277,782	286,595	285,825	293,059	270,746	270,086	260,397	261,987	3,247,182 kWh
On-Peak Demand (kW)	711	713	758	774	790	824	818	813	805	777	759	733	824 kW
Purchased Steam													
On-Peak Cons. (therms)	15,812	14,486	10,172	11,038	3,641	2,400	2,505	2,569	3,009	7,624	13,974	14,787	102,017 therms
On-Peak Demand (therms/hr)	95	97	72	81	47	10	12	12	33	65	88	93	97 therms/hr
Purchased CHW													
On-Peak Cons. (therms)	2,179	1,926	2,888	3,235	9,041	18,090	17,647	17,379	12,049	4,742	2,286	2,283	93,745 therms
On-Peak Demand (therms/hr)	16	20	28	33	53	73	70	73	64	48	24	24	73 therms/hr
On-Peak Demand (kW)	93	117	163	192	309	426	408	426	373	280	140	140	
Xcel Bill Calculation													
Service & Facility Charge	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	
On-Peak Cons. (June-Sept)													
Off-Peak Cons. (Oct-May)	\$0.02832	\$0.02832	\$0.02832	\$0.02832	\$0.02832	\$0.03750	\$0.03750	\$0.03750	\$0.03750	\$0.02832	\$0.02832	\$0.02832	
On-Peak Demand (June-Sept)	\$15.43	\$15.43	\$15.43	\$15.43	\$15.43	\$18.93	\$18.93	\$18.93	\$18.93	\$15.43	\$15.43	\$15.43	
Off-Peak Demand (Oct-May)													
Consumption	\$9,339.99	\$8,389.58	\$10,129.35	\$10,102.82	\$15,370.58	\$30,628.45	\$30,112.71	\$30,089.45	\$23,394.98	\$11,584.57	\$9,271.76	\$9,314.30	
Demand	\$12,410.86	\$12,801.75	\$14,216.16	\$14,913.08	\$16,960.11	\$23,659.30	\$23,214.45	\$23,461.07	\$22,305.81	\$16,309.49	\$13,871.56	\$13,470.38	
Total Monthly Xcel Bill (no steam)	\$22,105.66	\$21,546.14	\$24,700.31	\$25,370.71	\$32,685.51	\$54,642.56	\$53,681.97	\$53,895.33	\$46,055.60	\$28,488.87	\$23,498.13	\$23,139.49	\$409,570.27
Total Steam Bill	\$20,304.19	\$18,601.47	\$13,061.87	\$14,173.90	\$4,675.41	\$3,081.84	\$3,216.67	\$3,298.85	\$3,863.86	\$9,789.98	\$17,944.01	\$18,987.99	\$131,000.03

UCD Ed 2 - Comm. Rm. R/A

	January	February	March	April	May	June	July	August	September	October	November	December	FY total
Electric													
On-Peak Cons. (kWh)	233,979	210,861	241,280	231,781	246,857	256,386	255,163	261,514	240,801	238,806	229,248	230,379	2,877,055 kWh
On-Peak Demand (kW)	645	642	702	708	724	765	754	744	750	724	693	664	765 kW
Purchased Steam													
On-Peak Cons. (therms)	10,592	9,475	6,386	7,341	1,361	459	500	520	952	4,559	9,402	9,794	61,341 therms
On-Peak Demand (therms/hr)	73	73	54	64	37	4	6	7	24	50	68	70	73 therms/hr
Purchased CHW													
On-Peak Cons. (therms)	1,646	1,469	2,326	2,601	7,327	14,460	14,096	13,860	9,698	3,834	1,800	1,740	74,857 therms
On-Peak Demand (therms/hr)	13	16	23	27	42	59	58	59	53	43	18	18	59 therms/hr
On-Peak Demand (kW)	76	93	134	157	245	344	338	344	309	251	105	105	
Xcel Bill Calculation													
Service & Facility Charge	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	
On-Peak Cons. (June-Sept)													
Off-Peak Cons. (Oct-May)	\$0.02832	\$0.02832	\$0.02832	\$0.02832	\$0.02832	\$0.03750	\$0.03750	\$0.03750	\$0.03750	\$0.02832	\$0.02832	\$0.02832	
On-Peak Demand (June-Sept)	\$15.43	\$15.43	\$15.43	\$15.43	\$15.43	\$18.93	\$18.93	\$18.93	\$18.93	\$15.43	\$15.43	\$15.43	
Off-Peak Demand (Oct-May)													
Consumption	\$7,992.42	\$7,190.82	\$8,765.57	\$8,722.80	\$13,072.21	\$25,506.20	\$25,060.29	\$25,039.09	\$19,688.26	\$9,945.11	\$7,986.26	\$7,968.49	
Demand	\$11,122.45	\$11,346.19	\$12,902.04	\$13,354.65	\$14,951.65	\$20,996.49	\$20,677.83	\$20,598.96	\$20,049.99	\$15,041.66	\$12,313.13	\$11,865.66	
Total Monthly Xcel Bill (no steam)	\$19,469.68	\$18,891.81	\$22,020.42	\$22,432.26	\$28,378.67	\$46,857.49	\$45,992.86	\$45,992.86	\$40,093.06	\$25,341.57	\$20,654.20	\$20,188.96	\$356,413.92
Total Steam Bill	\$13,601.19	\$12,166.85	\$8,200.26	\$9,426.58	\$1,747.66	\$589.40	\$642.05	\$667.73	\$1,222.46	\$5,854.21	\$12,073.11	\$12,576.48	\$78,767.98
Energy Savings:													\$105,388.40 per year
Maintenance													\$0.00 per year
Total Savings:													\$105,388.40 per year
Estimated Construction Costs													\$223,132.00
Estimated Simple Payback													2.1 years

CATOR, RUMA & ASSOCIATES, CO.				DATE PREPARED: 02/18/13		SHEET 1 OF 1	
OPINION OF PROBABLE CONSTRUCTION COSTS							
PROJECT: UCD Education 2 ECM-3 - Community Room Return Air Addition						BASIS: <input checked="" type="checkbox"/> No Design <input type="checkbox"/> Prelim. Design <input type="checkbox"/> Final Design <input type="checkbox"/> Other _____	
LOCATION: Aurora, CO				PREPARED BY: JAW			
REFERENCE DRAWING NO.:				CHECKED BY:			
SUMMARY	QUANTITY		MATERIAL		LABOR		TOTAL COST
	NO. UNITS	UNIT	PER UNIT	TOTAL	PER UNIT	TOTAL	
Demolition:							
Existing duct	2000	lbs		\$0.00	\$0.75	\$1,500.00	\$1,500.00
New:							
Ductwork	13500	lbs	\$0.62	\$8,370.00	\$4.55	\$61,425.00	\$69,795.00
Insulation	6750	sf	\$0.77	\$5,197.50	\$4.50	\$30,375.00	\$35,572.50
50% Labor add for working above existing ceiling.							\$46,650.00
Test & Balance	lump	sum					\$5,000.00
General Conditions (ceiling removal & replacement, etc.)	4000	sf		\$0.00	\$0.94	\$3,760.00	\$3,760.00
Subtotal							\$162,277.50
Tools, safety, trash, trucks, etc.							\$16,227.75
Contractor O&P/Mark-up							\$24,341.63
Subtotal							\$202,846.88
Engineering Fees							\$20,284.69
Grand Total:							\$223,131.56

Energy Conservation Measure ECM-4 – Lighting Replacement In Large Auditorium

ECM Description:

- A. Replace the incandescent lighting in the large auditorium with LED luminaires:
 - 1. (24) 500 watt quartz pendants
 - 2. (11) 250 watt quartz pendants
 - 3. (44) 250 watt quartz downlights
- B. The dimming panel will require alterations to control low voltage dimming to the LED luminaires and additional control wiring may be required between the luminaires and the dimming panels.
- C. Assumptions:
 - 1. The luminaires will be replaced at the existing location and not relocated or re-circuited.

Non-Energy Project Impacts:

- A. The auditorium will need to be closed off and seats may need to be removed to accommodate a lift to replace the lights and install control wiring.
- B. The LED luminaires (over 100,000 hrs based on maintaining 70% of light output) are rated to last approximately 57.5 times longer than the incandescent luminaires (2000 hrs).

Measurement of Energy:

- A. UCD already has procedures in place to measure the electrical, chilled water and steam energy consumption for the Education 2 building, on a monthly basis.

Energy Estimate:

- A. Refer to the attached Energy Cost Budget for total energy and cost savings estimated per year.
- B. Refer to the attached Monthly Energy Consumption and Monthly Utility Costs for a monthly breakdown of the energy usage and costs.

Financial Analysis:

- A. Estimated construction costs = \$ 153,986 (Refer to the attached Opinion of Probable Construction Costs for ECM-4 for a further breakdown).
- B. Energy cost savings = \$ 4,319 per year
- C. Estimated maintenance costs savings = \$ 5150 every 1 year for lamp replacement of incandescent lamps. \$0 for the maintenance of LED luminaires over the payback period.
- D. Total net operating and maintenance cost savings = \$ 9,469 per year
- E. Estimated simple payback = 16.3 years

Peak Demand reduction example calculation:

Existing lighting load = 25,750W

New lighting load = 6,450W

Removed lighting load = 19,300 W = 19.3 KW

The energy model predicted a savings of 14 KW; therefore 5.3 KW of the lighting savings may not be realized because the room's usage schedule combined with the effects to the mechanical system.

Energy Cost savings example calculation:

19.3 KW x 1290 hrs/year = 24,900 KWh

The energy model predicted an electrical savings of 27,400 KWh; therefore 2,500 KWh reflects the reductions for mechanical cooling systems.

ECM-4

UCD Ed 2 Base

Electric	January	February	March	April	May	June	July	August	September	October	November	December	FY total
On-Peak Cons. (kWh)	284,739	256,746	290,936	278,799	292,165	298,944	298,461	306,332	284,304	286,824	278,488	280,681	3,437,419 kWh
On-Peak Demand (kW)	752	750	784	803	815	844	841	837	828	802	785	760	844 kW
Purchased Steam													
On-Peak Cons. (therms)	17,324	16,016	11,252	12,024	3,994	2,557	2,676	2,754	3,286	8,267	15,348	16,295	111,793 therms
On-Peak Demand (therms/hr)	106	106	81	85	51	11	13	14	35	68	92	98	106 therms/hr
Purchased CHW													
On-Peak Cons. (therms)	2,351	2,103	3,024	3,401	9,248	18,646	18,112	17,891	12,397	4,859	2,463	2,462	96,957 therms
On-Peak Demand (therms/hr)	17	21	30	33	55	80	72	74	65	51	25	24	80 therms/hr
On-Peak Demand (kW)	99	122	175	192	321	467	420	432	379	297	146	140	
Xcel Bill Calculation													
Service & Facility Charge	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	
On-Peak Cons. (June-Sept)						\$0.03750	\$0.03750	\$0.03750	\$0.03750				
Off-Peak Cons. (Oct-May)	\$0.02832	\$0.02832	\$0.02832	\$0.02832	\$0.02832					\$0.02832	\$0.02832	\$0.02832	
On-Peak Demand (June-Sept)	\$15.43	\$15.43	\$15.43	\$15.43	\$15.43	\$18.93	\$18.93	\$18.93	\$18.93	\$15.43	\$15.43	\$15.43	
Off-Peak Demand (Oct-May)													
Consumption	\$10,015.08	\$9,016.48	\$10,749.15	\$10,718.33	\$15,949.71	\$31,702.59	\$31,097.60	\$31,149.88	\$24,285.86	\$12,155.70	\$9,931.01	\$9,992.28	
Demand	\$13,133.49	\$13,462.66	\$14,797.35	\$15,360.55	\$17,152.88	\$24,810.87	\$23,870.68	\$24,015.81	\$22,851.62	\$16,965.28	\$14,362.75	\$13,886.99	
Total Monthly Xcel Bill (no steam)	\$23,503.38	\$22,833.96	\$25,901.31	\$26,433.69	\$33,830.40	\$56,868.27	\$55,323.10	\$55,520.51	\$47,492.29	\$29,751.77	\$24,648.56	\$24,234.08	\$426,065.32
Total Steam Bill	\$22,245.75	\$20,566.15	\$14,448.69	\$15,440.02	\$5,128.70	\$3,283.44	\$3,436.25	\$3,536.41	\$4,219.55	\$10,615.65	\$19,708.37	\$20,924.41	\$143,553.39

UCD Ed 2 - LED

Electric	January	February	March	April	May	June	July	August	September	October	November	December	FY total
On-Peak Cons. (kWh)	282,589	254,753	288,530	276,540	289,882	296,583	295,905	304,016	282,069	284,536	276,225	278,410	3,410,038 kWh
On-Peak Demand (kW)	737	737	770	788	801	830	828	823	813	788	771	746	830 kW
Purchased Steam													
On-Peak Cons. (therms)	17,369	16,062	11,289	12,069	4,002	2,557	2,677	2,754	3,289	8,295	15,395	16,342	112,100 therms
On-Peak Demand (therms/hr)	107	106	81	85	51	11	13	14	35	68	92	98	107 therms/hr
Purchased CHW													
On-Peak Cons. (therms)	2,351	2,106	3,011	3,395	9,203	18,881	18,041	17,833	12,348	4,841	2,462	2,460	96,632 therms
On-Peak Demand (therms/hr)	16	21	28	33	55	80	70	74	63	51	25	24	80 therms/hr
On-Peak Demand (kW)	93	122	163	192	321	467	408	432	367	297	146	140	
Xcel Bill Calculation													
Service & Facility Charge	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	
On-Peak Cons. (June-Sept)						\$0.03750	\$0.03750	\$0.03750	\$0.03750				
Off-Peak Cons. (Oct-May)	\$0.02832	\$0.02832	\$0.02832	\$0.02832	\$0.02832					\$0.02832	\$0.02832	\$0.02832	
On-Peak Demand (June-Sept)	\$15.43	\$15.43	\$15.43	\$15.43	\$15.43	\$18.93	\$18.93	\$18.93	\$18.93	\$15.43	\$15.43	\$15.43	
Off-Peak Demand (Oct-May)													
Consumption	\$9,954.19	\$8,962.53	\$10,670.22	\$10,649.38	\$15,847.71	\$31,542.61	\$30,923.72	\$30,999.29	\$24,148.19	\$12,075.96	\$9,866.09	\$9,926.31	
Demand	\$12,812.04	\$13,262.07	\$14,401.32	\$15,129.10	\$17,309.86	\$24,545.85	\$23,403.75	\$23,750.79	\$22,346.83	\$16,749.24	\$14,146.73	\$13,670.97	
Total Monthly Xcel Bill (no steam)	\$23,121.04	\$22,579.41	\$25,426.35	\$26,133.28	\$33,512.38	\$56,443.27	\$54,682.28	\$55,104.89	\$46,849.83	\$29,180.01	\$24,367.62	\$23,952.09	\$421,352.46
Total Steam Bill	\$22,303.53	\$20,625.21	\$14,496.20	\$15,497.80	\$5,138.97	\$3,283.44	\$3,436.41	\$4,223.40	\$10,615.61	\$19,768.72	\$20,984.76		\$143,947.61
Energy Savings:													\$4,318.64 per year
Maintenance													\$5,150.00 per year
Total Savings:													\$9,468.64 per year
Estimated Construction Costs													\$153,986.00
Estimated Simple Payback													16.3 years

CATOR, RUMA & ASSOCIATES, CO.				DATE PREPARED: 02/18/13		SHEET 1 OF 1	
OPINION OF PROBABLE CONSTRUCTION COSTS							
PROJECT: UCD Education 2 ECM-4 - Lighting Replacement In Large Auditorium						BASIS: <input checked="" type="checkbox"/> No Design <input type="checkbox"/> Prelim. Design <input type="checkbox"/> Final Design <input type="checkbox"/> Other _____	
LOCATION: Aurora, CO				PREPARED BY: NCW			
REFERENCE DRAWING NO.:				CHECKED BY:			
SUMMARY	QUANTITY		MATERIAL		LABOR		TOTAL COST
	NO. UNITS	UNIT	PER UNIT	TOTAL	PER UNIT	TOTAL	
New:							
500W Quartz pendant replacement	24	ea	\$1,000.00	\$24,000.00	\$100.00	\$2,400.00	\$26,400.00
250W Quartz pendant replacement	11	ea	\$850.00	\$9,350.00	\$100.00	\$1,100.00	\$10,450.00
250W Quartz downlight replacement	44	ea	\$550.00	\$24,200.00	\$200.00	\$8,800.00	\$33,000.00
0-10V dimming control wiring	79	ea	\$20.00	\$1,580.00	\$100.00	\$7,900.00	\$9,480.00
Lift rental	2	month	\$3,200.00	\$6,400.00			\$6,400.00
30% Labor add for working in existing space.							\$6,060.00
General Conditions (wall patch, proj. super., etc.)	200	hrs		\$200.00	\$100.00	\$20,000.00	\$20,200.00
Subtotal							\$111,990.00
Tools, safety, trash, trucks, etc.							\$11,199.00
Contractor O&P/Mark-up							\$16,798.50
Subtotal							\$139,987.50
Engineering Fees							\$13,998.75
Grand Total:							\$153,986.25

Energy Conservation Measure ECM-5 – CO2 Sensors in High Occupancy Areas

ECM Description:

- A. Add CO2 sensors in the following rooms:
 - 1. 60 seat classrooms
 - 2. 30 seat classrooms
 - 3. Student Community rooms
 - 4. Small Group Learning rooms
 - 5. Conference rooms
- B. If all of the above areas are included, a total of (93) CO2 sensors will need to be added.
- C. The CO2 sensors can be utilized to open VAV box valves, if high CO2 levels are detected.

Non-Energy Project Impacts:

- A. The rooms listed above and adjacent corridors/rooms will need to be closed off for sensor and wiring installation.
- B. Re-calibration of each sensor will be required every 3 to 5 years, depending on the manufacturer.

Measurement of Energy:

- A. UCD already has procedures in place to measure the electrical, chilled water and steam energy consumption for the Education 2 building, on a monthly basis.
- B. No additional costs are anticipated to verify the energy use, since these procedures are already in place.

Energy Estimate:

- A. Please note that the base model had to be changed in order to properly evaluate this ECM. In all of the other base models, the outside air is calculated based on 2003 International Mechanical Code, which is what the building design was based on. In order for the Trace program to allow the addition of CO2 sensors, the base model had to be based on ASHRAE 62.1-2007. This slightly changed the amount of outside air, thereby changing the base energy usage. This base model change allowed us to properly compare the energy savings provided by adding CO2 sensors.

- B. Refer to the attached Energy Cost Budget for total energy and cost savings estimated per year.
- C. Refer to the attached Monthly Energy Consumption and Monthly Utility Costs for a monthly breakdown of the energy usage and costs.

Financial Analysis:

- A. Estimated construction costs = \$ 212,298 (Refer to the attached Opinion of Probable Construction Costs for ECM-3 for a further breakdown).
- B. Energy cost savings = \$ 13,456 per year
- C. Estimated maintenance costs = \$ 1200 per year
- D. Total net operating and maintenance cost savings = \$ 12,256 per year
- E. Estimated simple payback = 17.3 years

ECM-5

UCD Ed 2 Base

Electric	January	February	March	April	May	June	July	August	September	October	November	December	FY total
On-Peak Cons. (kWh)	280,171	252,265	286,485	275,343	289,991	297,612	297,072	304,749	282,314	283,350	274,031	275,931	3,399,314 kWh
On-Peak Demand (kW)	737	739	780	798	819	841	841	836	830	803	776	753	841 kW
Purchased Steam													
On-Peak Cons. (therms)	16,872	15,604	10,968	11,779	3,901	2,513	2,631	2,710	3,206	8,088	14,991	15,857	109,120 therms
On-Peak Demand (therms/hr)	104	103	80	84	50	11	13	13	33	66	91	96	104 therms/hr
Purchased CHW													
On-Peak Cons. (therms)	2,316	2,097	2,992	3,362	9,160	18,524	17,982	17,767	12,294	4,810	2,430	2,435	96,169 therms
On-Peak Demand (therms/hr)	16	21	28	33	54	80	72	74	65	50	25	24	80 therms/hr
On-Peak Demand (kW)	93	122	163	192	315	467	420	432	379	292	146	140	
Xcel Bill Calculation													
Service & Facility Charge	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	
On-Peak Cons. (June-Sept)													
Off-Peak Cons. (Oct-May)	\$0.02832	\$0.02832	\$0.02832	\$0.02832	\$0.02832	\$0.03750	\$0.03750	\$0.03750	\$0.03750	\$0.02832	\$0.02832	\$0.02832	
On-Peak Demand (June-Sept)													
Off-Peak Demand (Oct-May)	\$15.43	\$15.43	\$15.43	\$15.43	\$15.43	\$18.93	\$18.93	\$18.93	\$18.93	\$15.43	\$15.43	\$15.43	
Consumption	\$9,856.66	\$8,884.60	\$10,596.54	\$10,588.09	\$15,815.11	\$31,518.56	\$30,902.64	\$30,954.24	\$24,098.03	\$12,016.65	\$9,777.40	\$9,835.35	
Demand	\$12,812.04	\$13,292.93	\$14,555.62	\$15,288.40	\$17,497.59	\$24,754.08	\$23,996.88	\$22,889.48	\$16,890.68	\$14,223.88	\$13,778.98		
Total Monthly Xcel Bill (no steam)	\$23,023.51	\$22,532.34	\$25,506.97	\$26,226.30	\$33,667.51	\$56,627.45	\$55,128.14	\$55,305.94	\$47,332.33	\$29,627.14	\$24,356.08	\$23,969.14	\$422,947.84
Total Steam Bill	\$21,665.34	\$20,037.10	\$14,084.01	\$15,125.41	\$5,009.27	\$3,226.94	\$3,378.47	\$3,479.91	\$4,116.62	\$10,385.80	\$19,249.94	\$20,361.97	\$140,120.99

UCD Ed 2 - CO2 Sensors

Electric	January	February	March	April	May	June	July	August	September	October	November	December	FY total
On-Peak Cons. (kWh)	274,126	246,574	280,987	270,171	286,213	294,384	293,834	301,368	278,774	278,397	268,118	269,803	3,342,749 kWh
On-Peak Demand (kW)	726	728	773	792	813	834	834	829	824	805	768	744	834 kW
Purchased Steam													
On-Peak Cons. (therms)	15,874	14,547	10,218	11,089	3,727	2,444	2,548	2,627	3,068	7,660	14,106	14,883	102,791 therms
On-Peak Demand (therms/hr)	97	96	74	79	48	10	13	12	32	62	87	90	97 therms/hr
Purchased CHW													
On-Peak Cons. (therms)	2,184	1,951	2,845	3,258	9,087	18,266	17,728	17,516	12,123	4,750	2,329	2,316	94,353 therms
On-Peak Demand (therms/hr)	16	17	29	34	53	78	75	73	64	50	24	24	78 therms/hr
On-Peak Demand (kW)	93	99	169	198	309	455	437	426	373	292	140	140	
Xcel Bill Calculation													
Service & Facility Charge	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	
On-Peak Cons. (June-Sept)													
Off-Peak Cons. (Oct-May)	\$0.02832	\$0.02832	\$0.02832	\$0.02832	\$0.02832	\$0.03750	\$0.03750	\$0.03750	\$0.03750	\$0.02832	\$0.02832	\$0.02832	
On-Peak Demand (June-Sept)													
Off-Peak Demand (Oct-May)	\$15.43	\$15.43	\$15.43	\$15.43	\$15.43	\$18.93	\$18.93	\$18.93	\$18.93	\$15.43	\$15.43	\$15.43	
Consumption	\$9,575.91	\$8,602.26	\$10,318.83	\$10,355.30	\$15,647.53	\$31,113.96	\$30,502.07	\$30,551.60	\$23,777.35	\$11,826.58	\$9,526.11	\$9,563.04	
Demand	\$12,642.31	\$12,763.17	\$14,537.62	\$15,280.83	\$17,315.00	\$24,400.72	\$24,069.45	\$23,753.95	\$22,665.48	\$16,921.54	\$14,010.43	\$13,640.11	
Total Monthly Xcel Bill (no steam)	\$22,573.03	\$21,720.24	\$25,211.26	\$25,990.93	\$33,317.34	\$55,869.49	\$54,926.33	\$54,660.36	\$46,797.64	\$29,102.93	\$23,891.35	\$23,557.96	\$417,618.86
Total Steam Bill	\$20,383.80	\$18,679.80	\$13,120.93	\$14,239.38	\$4,785.84	\$3,138.34	\$3,271.89	\$3,373.33	\$3,939.62	\$9,836.21	\$18,113.51	\$19,111.26	\$131,993.92
Energy Savings:													\$13,456.04 per year
Maintenance													-\$1,200.00 per year
Total Savings:													\$12,256.04 per year
Estimated Construction Costs													\$212,298.00
Estimated Simple Payback													17.3 years

Total Peak Demand Savings (kW)

11 34 1 0 12 19 -10 13 12 -2 14 9

CATOR, RUMA & ASSOCIATES, CO.				DATE PREPARED: 02/18/13		SHEET 1 OF 1	
OPINION OF PROBABLE CONSTRUCTION COSTS							
PROJECT: UCD Education 2 ECM-5 - CO2 Sensor Addition						BASIS:	
						<input checked="" type="checkbox"/> No Design	
						<input type="checkbox"/> Prelim. Design	
						<input type="checkbox"/> Final Design	
						<input type="checkbox"/> Other _____	
LOCATION: Aurora, CO				PREPARED BY: JAW			
REFERENCE DRAWING NO.:				CHECKED BY:			
SUMMARY		QUANTITY		MATERIAL		LABOR	
	NO. UNITS	UNIT	PER UNIT	TOTAL	PER UNIT	TOTAL	TOTAL COST
New:							
CO2 Sensors	93	ea	\$500.00	\$46,500.00	\$60.00	\$5,580.00	\$52,080.00
Wiring/conduit (avg. of 100' per sensor)	93	ea		\$0.00	\$330.00	\$30,690.00	\$30,690.00
Engineering/Calibration/Start-up	93	ea	\$0.00	\$0.00	\$253.00	\$23,529.00	\$23,529.00
50% Labor add for working in existing space and short runs.							\$29,899.50
General Conditions (wall patch, proj. super., etc.)	180	hrs		\$200.00	\$100.00	\$18,000.00	\$18,200.00
Subtotal							\$154,398.50
Tools, safety, trash, trucks, etc.							\$15,439.85
Contractor O&P/Mark-up							\$23,159.78
Subtotal							\$192,998.13
Engineering Fees							\$19,299.81
Grand Total:							\$212,297.94

Energy Conservation Measure ECM-6 – Occupancy Sensors

ECM Description:

- A. Add occupancy sensors to control lighting in offices, file rooms, and storage rooms and various other spaces that do not currently have sensors.
- B. Connection of the sensors to the BAS system for control of the HVAC system in certain areas was evaluated as well. It was determined that the number of offices served by a single VAV box (up to 14 offices per box) was too great to realize any savings. The likelihood of all offices being unoccupied at the same time to pinch back the VAV is small. With the additional costs to wire all of the sensors to the BAS, it was determined that the payback was well over 100 years.
- C. For larger spaces, add sensors in the ceilings and relay packs to switch the lighting circuit in each space.
- D. For smaller spaces, add wall box sensors to switch the lighting circuit in each space.
- E. Assumptions:
 - 1. The lighting control system consists of stand alone devices and the sensors have extra contacts for a signal output to the BAS system.
 - 2. Wall box sensors will be infrared, and ceiling mounted sensors are dual-technology.

Non-Energy Project Impacts:

- A. Rooms will need to be closed off to install the sensors, relay packs and control wiring.

Measurement of Energy:

- A. UCD already has procedures in place to measure the electrical, chilled water and steam energy consumption for the Education 2 building, on a monthly basis.

Energy Estimate:

- A. Refer to the attached Energy Cost Budget for total energy and cost savings estimated per year.
- B. Refer to the attached Monthly Energy Consumption and Monthly Utility Costs for a monthly breakdown of the energy usage and costs.

Financial Analysis:

- A. Estimated construction costs = \$ 101,074 (Refer to the attached Opinion of Probable Construction Costs for ECM-6 for a further breakdown).
- B. The reduction in energy is variable based upon the occupants and use of the spaces. ASHRAE 90.1 appendix G recommends a 15% reduction for spaces 5000sf and less and a 10% reduction for spaces greater than 5000sf.
- C. Electrical energy cost savings = \$ 11,219 per year
- D. Estimated maintenance costs savings = \$ 771 per year for lamp replacement.
- E. Total net operating and maintenance cost savings = \$ 11,990 per year
- F. Estimated simple payback = 8.4 years

Energy Cost savings example calculation:

Assumption: ASHRAE 90.1 appendix G recommends a 15% reduction for spaces 5000sf and less and a 10% reduction for spaces greater than 5000sf. All areas considered for occupancy sensors are less than 5000sf.

$288 \text{ KW} \times 2917 \text{ hrs/year} = 840,100 \text{ KWh}$ energy used for lighting

$15\% \times 840,100 \text{ KWh} = 126,000 \text{ KWh}$

The energy model predicted an electrical savings of 129,100 KWh; therefore 3,100 KWh reflects the reductions for mechanical cooling systems.

ECM-6

UCD Ed 2 Base

	January	February	March	April	May	June	July	August	September	October	November	December	FY total
Electric													
On-Peak Cons. (kWh)	285,074	257,061	291,273	279,147	292,568	299,398	298,909	306,778	284,633	287,211	278,878	280,998	3,441,928 kWh
On-Peak Demand (kW)	752	751	783	804	816	845	843	838	829	810	786	761	845 kW
Purchased Steam													
On-Peak Cons. (therms)	17,211	16,008	11,202	12,016	4,016	2,569	2,680	2,767	3,277	8,302	15,361	16,305	111,714 therms
On-Peak Demand (therms/hr)	106	106	81	85	50	11	14	13	35	68	93	96	106 therms/hr
Purchased CHW													
On-Peak Cons. (therms)	2,277	2,104	3,000	3,403	9,281	18,679	18,143	17,926	12,401	4,889	2,463	2,481	97,047 therms
On-Peak Demand (therms/hr)	17	18	28	33	54	80	72	76	65	49	25	25	80 therms/hr
On-Peak Demand (kW)	99	105	163	192	315	467	420	443	379	286	146	146	
Xcel Bill Calculation													
Service & Facility Charge	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	
On-Peak Cons. (June-Sept)													
Off-Peak Cons. (Oct-May)	\$0.02832	\$0.02832	\$0.02832	\$0.02832	\$0.02832	\$0.03750	\$0.03750	\$0.03750	\$0.03750	\$0.02832	\$0.02832	\$0.02832	
On-Peak Demand (June-Sept)													
Off-Peak Demand (Oct-May)	\$15.43	\$15.43	\$15.43	\$15.43	\$15.43	\$18.93	\$18.93	\$18.93	\$18.93	\$15.43	\$15.43	\$15.43	
Consumption	\$9,963.15	\$9,026.23	\$10,738.77	\$10,729.85	\$15,988.52	\$31,755.88	\$31,148.47	\$31,205.07	\$24,302.59	\$12,191.56	\$9,942.05	\$10,017.03	
Demand	\$13,133.49	\$13,208.07	\$14,601.91	\$15,375.98	\$17,451.30	\$24,829.80	\$23,908.54	\$24,255.59	\$22,870.55	\$16,908.68	\$14,378.18	\$13,992.43	
Total Monthly Xcel Bill (no steam)	\$23,451.45	\$22,559.11	\$25,695.49	\$26,466.63	\$33,794.63	\$56,940.49	\$55,411.83	\$55,815.48	\$47,527.96	\$29,555.05	\$24,675.04	\$24,364.26	\$426,181.42
Total Steam Bill	\$22,100.65	\$20,555.87	\$14,384.49	\$15,429.75	\$5,156.95	\$3,298.85	\$3,441.39	\$3,553.10	\$4,208.00	\$10,460.60	\$19,725.06	\$20,937.25	\$143,451.95

UCD Ed 2 - Occ. Sensors

	January	February	March	April	May	June	July	August	September	October	November	December	FY total
Electric													
On-Peak Cons. (kWh)	274,864	247,804	280,421	268,958	281,081	287,811	287,419	294,883	273,597	276,248	268,760	271,020	3,312,866 kWh
On-Peak Demand (kW)	723	721	754	772	784	813	811	805	797	777	755	731	813 kW
Purchased Steam													
On-Peak Cons. (therms)	17,503	16,147	11,354	12,163	4,029	2,543	2,665	2,748	3,282	8,451	15,518	16,462	112,865 therms
On-Peak Demand (therms/hr)	103	106	79	87	54	12	14	14	36	70	95	99	106 therms/hr
Purchased CHW													
On-Peak Cons. (therms)	2,363	2,110	2,992	3,361	9,076	18,299	17,762	17,547	12,138	4,838	2,479	2,500	95,465 therms
On-Peak Demand (therms/hr)	13	20	28	33	53	78	74	74	64	49	25	24	78 therms/hr
On-Peak Demand (kW)	76	117	163	192	309	455	432	432	373	286	146	140	
Xcel Bill Calculation													
Service & Facility Charge	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	
On-Peak Cons. (June-Sept)													
Off-Peak Cons. (Oct-May)	\$0.02832	\$0.02832	\$0.02832	\$0.02832	\$0.02832	\$0.03750	\$0.03750	\$0.03750	\$0.03750	\$0.02832	\$0.02832	\$0.02832	
On-Peak Demand (June-Sept)													
Off-Peak Demand (Oct-May)	\$15.43	\$15.43	\$15.43	\$15.43	\$15.43	\$18.93	\$18.93	\$18.93	\$18.93	\$15.43	\$15.43	\$15.43	
Consumption	\$9,745.38	\$8,769.05	\$10,424.81	\$10,406.43	\$15,493.06	\$30,903.74	\$30,298.87	\$30,342.48	\$23,599.70	\$11,838.76	\$9,668.79	\$9,750.22	
Demand	\$12,325.99	\$12,925.19	\$14,154.44	\$14,882.22	\$16,867.53	\$24,003.19	\$23,523.63	\$23,410.05	\$22,154.37	\$16,399.49	\$13,899.85	\$13,439.52	\$413,484.50
Total Monthly Xcel Bill (no steam)	\$22,426.18	\$22,049.05	\$24,934.05	\$25,643.46	\$32,715.40	\$55,261.74	\$54,177.32	\$54,107.35	\$46,108.88	\$28,593.06	\$23,923.44	\$23,544.55	\$144,929.95
Total Steam Bill	\$22,475.60	\$20,734.36	\$14,579.67	\$15,618.51	\$5,173.64	\$3,265.47	\$3,422.13	\$3,528.71	\$4,214.42	\$10,851.93	\$19,926.66	\$21,138.85	

Based on ASHRAE 90.1 App G (15% savings)

Energy Savings:
Maintenance
Total Savings:

\$11,218.92 per year
\$771.00 per year
\$11,989.92 per year

Estimated Construction Costs
\$101,074.00

Estimated Simple Payback
8.4 years

33 31 36

Total Peak Demand Savings (kW)

52

18

29

32

38

44

20

45

38

33

31

36

CATOR, RUMA & ASSOCIATES, CO.				DATE PREPARED: 02/18/13		SHEET 1 OF 1	
OPINION OF PROBABLE CONSTRUCTION COSTS							
PROJECT: UCD Education 2 ECM-6 - Occupancy Sensor Addition (Lighting Only)						BASIS:	
						<input checked="" type="checkbox"/> No Design	
						<input type="checkbox"/> Prelim. Design	
						<input type="checkbox"/> Final Design	
						<input type="checkbox"/> Other _____	
LOCATION: Aurora, CO				PREPARED BY: NCW			
REFERENCE DRAWING NO.:				CHECKED BY:			
SUMMARY	QUANTITY		MATERIAL		LABOR		TOTAL COST
	NO. UNITS	UNIT	PER UNIT	TOTAL	PER UNIT	TOTAL	
New:							
Occupancy Sensor, Wall IR	397	ea	\$65.50	\$26,003.50	\$17.20	\$6,828.40	\$32,831.90
Occupancy Sensor, Ceiling Dual Tech	76	ea	\$177.00	\$13,452.00	\$63.50	\$4,826.00	\$18,278.00
Remote Power Pack	76	ea	\$36.50	\$2,774.00	\$60.00	\$4,560.00	\$7,334.00
30% Labor add for working in existing space.							\$4,864.32
General Conditions (wall patch, proj. super., etc.)	100	hrs		\$200.00	\$100.00	\$10,000.00	\$10,200.00
Subtotal							\$73,508.22
Tools, safety, trash, trucks, etc.							\$7,350.82
Contractor O&P/Mark-up							\$11,026.23
Subtotal							\$91,885.28
Engineering Fees							\$9,188.53
Grand Total:							\$101,073.80

Energy Conservation Measure ECM-7 – Light Switches

ECM Description:

- A. Remove 3-way lighting control in the Small Group Learning rooms and provide separate control for each side.
 - 1. Remove 3-way switches
 - 2. Add standard toggle switches
 - 3. Re-circuit to provide separate control for each side
- B. Assumptions:
 - 1. The raceways and boxes can be reused and are accessible to pull new wiring

Non-Energy Project Impacts:

- A. The Small Group Learning rooms will need to be closed off to allow re-circuiting.

Measurement of Energy:

- A. UCD already has procedures in place to measure the electrical, chilled water and steam energy consumption for the Education 2 building, on a monthly basis.

Energy Estimate:

- A. Refer to the attached Energy Cost Budget for total energy and cost savings estimated per year.
- B. Refer to the attached Monthly Energy Consumption and Monthly Utility Costs for a monthly breakdown of the energy usage and costs.

Financial Analysis:

- A. Estimated construction costs = \$ 13,072 (Refer to the attached Opinion of Probable Construction Costs for ECM-7 for a further breakdown).
- B. Electrical energy cost savings = \$ 203 per year
- C. Estimated maintenance costs savings = \$ 66 per year for lamp replacement.
- D. Total net operating and maintenance cost savings = \$ 267 per year
- E. Estimated simple payback = 48.6 years

Energy Cost savings example calculation:

Assumption: 50% of the lights will remain off 50% of the time the rooms are used.

$5.5 \text{ KW} \times 2917 \text{ hrs/year} = 16,000 \text{ KWh}$ energy used for lighting

$50\% \times 50\% \times 16,000 \text{ KWh} = 4,000 \text{ KWh}$

The energy model predicted an electrical savings of 6,400 KWh; therefore 2,400 KWh reflects the reductions for mechanical cooling systems.

FOR REVIEW ONLY

ECM-7

UCD Ed 2 Base

Electric	January	February	March	April	May	June	July	August	September	October	November	December	FY total
On-Peak Cons. (kWh)	284,739	256,746	290,936	278,799	292,165	298,944	298,461	306,332	284,304	286,824	278,488	280,681	3,437,419 kWh
Service & Facility Charge	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	
On-Peak Cons. (June-Sept)													
Off-Peak Cons. (Oct-May)	\$0.02832	\$0.02832	\$0.02832	\$0.02832	\$0.02832	\$0.03750	\$0.03750	\$0.03750	\$0.03750	\$0.02832	\$0.02832	\$0.02832	
Consumption	\$8,063.84	\$7,271.08	\$8,239.34	\$7,895.62	\$8,274.14	\$11,210.44	\$11,192.33	\$11,487.49	\$10,661.44	\$8,122.88	\$7,886.81	\$7,948.91	
Total Monthly Xcel Bill (no steam)	\$8,418.65	\$7,625.89	\$8,594.15	\$8,250.43	\$8,628.95	\$11,565.25	\$11,547.14	\$11,842.30	\$11,016.25	\$8,477.69	\$8,241.62	\$8,303.72	\$112,512.02

UCD Ed 2 - Light Switch

Electric	January	February	March	April	May	June	July	August	September	October	November	December	FY total
On-Peak Cons. (kWh)	284,242	256,265	290,372	278,294	291,585	298,338	297,935	305,772	283,748	286,268	278,013	280,160	3,430,982 kWh
Service & Facility Charge	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	
On-Peak Cons. (June-Sept)													
Off-Peak Cons. (Oct-May)	\$0.02832	\$0.02832	\$0.02832	\$0.02832	\$0.02832	\$0.03750	\$0.03750	\$0.03750	\$0.03750	\$0.02832	\$0.02832	\$0.02832	
Consumption	\$8,049.76	\$7,257.17	\$8,223.36	\$7,881.31	\$8,257.72	\$11,187.71	\$11,172.60	\$11,466.49	\$10,640.59	\$8,107.14	\$7,873.36	\$7,934.16	
Total Monthly Xcel Bill (no steam)	\$8,404.57	\$7,611.98	\$8,578.17	\$8,236.12	\$8,612.53	\$11,542.52	\$11,527.41	\$11,821.30	\$10,995.40	\$8,461.95	\$8,228.17	\$8,288.97	\$112,309.09

Energy Savings: \$202.93 per year
Maintenance: \$66.00 per year
Total Savings: \$268.93 per year

Estimated Construction Costs: \$13,072.00
Estimated Simple Payback: 48.6 years

CATOR, RUMA & ASSOCIATES, CO.				DATE PREPARED: 02/18/13		SHEET 1 OF 1	
OPINION OF PROBABLE CONSTRUCTION COSTS							
PROJECT: UCD Education 2 ECM-7 - Light Switch Addition						BASIS: <input checked="" type="checkbox"/> No Design <input type="checkbox"/> Prelim. Design <input type="checkbox"/> Final Design <input type="checkbox"/> Other _____	
LOCATION: Aurora, CO				PREPARED BY: NCW			
REFERENCE DRAWING NO.:				CHECKED BY:			
SUMMARY	QUANTITY		MATERIAL		LABOR		TOTAL COST
	NO. UNITS	UNIT	PER UNIT	TOTAL	PER UNIT	TOTAL	
New:							
Wall Switch	36	ea	\$7.60	\$273.60	\$15.25	\$549.00	\$822.60
Re-circuiting to add switch-leg	18	ea	\$45.00	\$810.00	\$200.00	\$3,600.00	\$4,410.00
50% Labor add for working in existing space and short runs.							\$2,074.50
General Conditions (wall patch, proj. super., etc.)	20	hrs		\$200.00	\$100.00	\$2,000.00	\$2,200.00
Subtotal							\$9,507.10
Tools, safety, trash, trucks, etc.							\$950.71
Contractor O&P/Mark-up							\$1,426.07
Subtotal							\$11,883.88
Engineering Fees							\$1,188.39
Grand Total:							\$13,072.26

Energy Conservation Measure ECM-8 – Daylight Sensors

ECM Description:

- A. Add daylight sensors in the west facing fourth floor corridors and the second floor bridge.
- B. Assumptions:
 - 1. The daylight dimming system consists of stand alone devices that are installed locally in each separate area.

Non-Energy Project Impacts:

- A. Hallways will need to be closed off to install the sensors, relay packs and control wiring.

Measurement of Energy:

- A. UCD already has procedures in place to measure the electrical, chilled water and steam energy consumption for the Education 2 building, on a monthly basis.

Energy Estimate:

- A. Refer to the attached Energy Cost Budget for total energy and cost savings estimated per year.
- B. Refer to the attached Monthly Energy Consumption and Monthly Utility Costs for a monthly breakdown of the energy usage and costs.

Financial Analysis:

- A. Estimated construction costs = \$ 18,261 (Refer to the attached Opinion of Probable Construction Costs for ECM-8 for a further breakdown).
- B. Energy cost savings = \$ 7335 per year
- C. Estimated maintenance costs savings = \$ 3039 every year for lamp replacement.
- D. Total net operating and maintenance cost savings = \$ 10,374 per year
- E. Estimated simple payback = 1.8 years

Energy Cost savings example calculation:

Assumption: An average of 8 hours a day (33%) the lights will remain off.

$21.8 \text{ KW} \times 8760 \text{ hrs/year} = 191,000 \text{ KWh}$ energy used for lighting

$33\% \times 191,000 \text{ KWh} = 63,700 \text{ KWh}$

The energy model predicted an electrical savings of 63,300 KWh.

FOR REFERENCE ONLY

ECM-8

UCD Ed 2 Base

	January	February	March	April	May	June	July	August	September	October	November	December	FY total
Electric													
On-Peak Cons. (kWh)	284,739	256,746	290,936	278,799	292,165	298,944	298,461	306,332	284,304	286,824	278,488	280,681	3,437,419 kWh
On-Peak Demand (kW)	752	750	784	803	815	844	841	837	828	802	785	760	844 kW
Purchased Steam													
On-Peak Cons. (therms)	17,324	16,016	11,252	12,024	3,994	2,557	2,676	2,754	3,286	8,267	15,348	16,295	111,793 therms
On-Peak Demand (therms/hr)	106	106	81	85	51	11	13	14	35	68	92	98	106 therms/hr
Purchased CHW													
On-Peak Cons. (therms)	2,351	2,103	3,024	3,401	9,248	18,646	18,112	17,891	12,397	4,859	2,463	2,462	96,957 therms
On-Peak Demand (therms/hr)	17	21	30	33	55	80	72	74	65	51	25	24	80 therms/hr
On-Peak Demand (kW)	99	122	175	192	321	467	420	432	379	297	146	140	
Xcel Bill Calculation													
Service & Facility Charge	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	
On-Peak Cons. (June-Sept)													
Off-Peak Cons. (Oct-May)	\$0.02832	\$0.02832	\$0.02832	\$0.02832	\$0.02832	\$0.03750	\$0.03750	\$0.03750	\$0.03750	\$0.02832	\$0.02832	\$0.02832	
On-Peak Demand (June-Sept)	\$15.43	\$15.43	\$15.43	\$15.43	\$15.43	\$18.93	\$18.93	\$18.93	\$18.93	\$15.43	\$15.43	\$15.43	
Off-Peak Demand (Oct-May)													
Consumption	\$10,015.08	\$9,016.48	\$10,749.15	\$10,718.33	\$15,949.71	\$31,702.59	\$31,097.60	\$31,149.88	\$24,285.86	\$12,155.70	\$9,931.01	\$9,992.28	
Demand	\$13,133.49	\$13,462.66	\$14,797.35	\$15,360.55	\$17,525.88	\$24,810.87	\$23,870.68	\$24,015.81	\$22,861.62	\$16,965.26	\$14,362.75	\$13,886.99	
Total Monthly Xcel Bill (no steam)	\$23,503.38	\$22,883.96	\$25,901.31	\$26,433.69	\$33,830.40	\$56,868.27	\$55,323.10	\$55,520.51	\$47,492.29	\$29,757.77	\$24,648.56	\$24,234.08	\$426,065.32
Total Steam Bill	\$22,245.75	\$20,566.15	\$14,448.69	\$15,440.02	\$5,128.70	\$3,283.44	\$3,436.25	\$3,536.41	\$4,219.55	\$10,615.65	\$19,708.37	\$20,924.41	\$143,553.39

UCD Ed 2 - Daylighting

	January	February	March	April	May	June	July	August	September	October	November	December	FY total
Electric													
On-Peak Cons. (kWh)	280,605	252,603	285,358	273,448	285,602	292,150	291,616	300,096	278,896	282,117	274,682	276,915	3,374,088 kWh
On-Peak Demand (kW)	740	742	766	785	796	826	823	818	809	784	768	745	826 kW
Purchased Steam													
On-Peak Cons. (therms)	17,251	15,986	11,223	12,044	3,985	2,556	2,677	2,752	3,275	8,243	15,302	16,219	111,513 therms
On-Peak Demand (therms/hr)	107	106	81	85	50	11	13	14	35	70	92	98	107 therms/hr
Purchased CHW													
On-Peak Cons. (therms)	2,319	2,072	2,973	3,355	9,122	18,443	17,912	17,707	12,254	4,790	2,428	2,433	95,808 therms
On-Peak Demand (therms/hr)	16	20	30	33	54	80	71	74	65	50	25	24	80 therms/hr
On-Peak Demand (kW)	93	117	175	192	315	467	414	432	379	292	146	140	
Xcel Bill Calculation													
Service & Facility Charge	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	\$354.81	
On-Peak Cons. (June-Sept)													
Off-Peak Cons. (Oct-May)	\$0.02832	\$0.02832	\$0.02832	\$0.02832	\$0.02832	\$0.03750	\$0.03750	\$0.03750	\$0.03750	\$0.02832	\$0.02832	\$0.02832	
On-Peak Demand (June-Sept)	\$15.43	\$15.43	\$15.43	\$15.43	\$15.43	\$18.93	\$18.93	\$18.93	\$18.93	\$15.43	\$15.43	\$15.43	
Off-Peak Demand (Oct-May)													
Consumption	\$9,871.44	\$8,873.42	\$10,548.85	\$10,528.61	\$15,659.27	\$31,224.71	\$30,621.11	\$30,713.81	\$23,925.90	\$11,965.13	\$9,794.17	\$9,861.56	
Demand	\$12,858.33	\$13,249.22	\$14,519.61	\$15,082.81	\$17,142.70	\$24,470.13	\$23,419.52	\$23,656.14	\$22,491.95	\$16,597.51	\$14,100.44	\$13,655.54	
Total Monthly Xcel Bill (no steam)	\$23,084.58	\$22,477.45	\$25,423.28	\$25,966.23	\$33,156.79	\$56,049.65	\$54,395.44	\$54,724.77	\$46,772.66	\$28,917.45	\$24,249.42	\$23,871.91	\$419,089.62
Total Steam Bill	\$22,152.01	\$20,527.62	\$14,411.45	\$15,465.70	\$5,117.14	\$3,282.16	\$3,437.54	\$3,533.84	\$4,205.43	\$10,584.84	\$19,649.30	\$20,826.82	\$143,193.84
Energy Savings:													\$7,335.24 per year
Maintenance Savings:													\$3,039.00 per year
Total Savings:													\$10,374.24 per year
Estimated Construction Costs													\$18,261.00
Estimated Simple Payback													1.8 years

CATOR, RUMA & ASSOCIATES, CO.				DATE PREPARED: 02/18/13		SHEET 1 OF 1	
OPINION OF PROBABLE CONSTRUCTION COSTS							
PROJECT: UCD Education 2 ECM-8 - Daylight Sensor Addition						BASIS:	
						<input checked="" type="checkbox"/> No Design	
						<input type="checkbox"/> Prelim. Design	
						<input type="checkbox"/> Final Design	
						<input type="checkbox"/> Other _____	
LOCATION: Aurora, CO				PREPARED BY: NCW			
REFERENCE DRAWING NO.:				CHECKED BY:			
SUMMARY	QUANTITY		MATERIAL		LABOR		TOTAL COST
	NO. UNITS	UNIT	PER UNIT	TOTAL	PER UNIT	TOTAL	
New:							
Daylight Sensor, ceiling mount	7	ea	\$111.00	\$777.00	\$59.00	\$413.00	\$1,190.00
Remote Power Packs	7	ea	\$177.00	\$1,239.00	\$63.50	\$444.50	\$1,683.50
Lift rental	1	month	\$3,200.00	\$3,200.00			\$3,200.00
Re-circuit corridors	5	ea	\$300.00	\$1,500.00	\$500.00	\$2,500.00	\$4,000.00
30% Labor add for working in existing space.							\$1,007.25
General Conditions (wall patch, proj. super., etc.)	20	hrs		\$200.00	\$100.00	\$2,000.00	\$2,200.00
Subtotal							\$13,280.75
Tools, safety, trash, trucks, etc.							\$1,328.08
Contractor O&P/Mark-up							\$1,992.11
Subtotal							\$16,600.94
Engineering Fees							\$1,660.09
Grand Total:							\$18,261.03



Engineering Assistance Study, Energy Conservation Options

University of Colorado, Anschutz Medical Campus

Barbara Davis Building

Aurora, CO

September 7, 2017

Sean Beilman P.E.



Executive Summary

Purpose

Purpose of the study is to explore the viability of selected energy conservation opportunities for the Barbara Davis building on the University of Colorado, Anschutz Medical Campus. This includes estimated work required to implement the changes, the approximate construction cost, and the associated energy savings. Energy conservation opportunities will explore all potential energy savings measures that would impact all campus utilities including electricity, chilled water, and steam.

Existing Conditions

The Barbara Davis building is an existing 116,000 sf four story building with one below grade level on the Anschutz campus used for general patient exams, administrative support, and laboratory support. The building uses electricity, campus chilled water, and campus steam. The building is served by four (4) air handling units. Two (2) variable volume make up air units (MAU-1 and MAU-2) serve the laboratory spaces on the third and fourth floors. One (1) air handling unit (AHU-1) serves the general support spaces and exam spaces in the basement, first, and second floors. A fourth air handling unit (AHU-2) serves clean rooms on the third floor. The make up air units include hydronic heat recovery coils, hydronic preheat coils, hydronic heating coils, and hydronic cooling coils. The air handling unit includes hydronic heating coils, and hydronic cooling coils. The make up air units are 100% outdoor air and do not recirculate air. AHU-1 is a recirculating unit scheduled to provide approximately 30% outdoor air. The lab spaces on the third and fourth floor are exhausted by high plume exhaust fans with hydronic heat recovery. All air handling equipment is located on the roof of the building. The laboratory spaces typically include only general exhaust. The building includes nine (9) chemical fume hoods. The chemical fume hoods are constant exhaust flow and do not include sash position or occupancy control.

Interior lighting is provided by primarily fluorescent lamp luminaires. The laboratory spaces are equipped primarily with direct/indirect linear fixtures. Office and patient exam areas use primarily lay-in troffer type fluorescent lamp luminaires. Interior lighting is manually switched and includes occupancy sensors to automatically shut off lighting when lighting zones are unoccupied. Interior lighting does not currently include automatic daylight responsive control. The existing luminaires are not equipped with dimmable or stepped ballasts.

Study Summary

This study will explore the opportunities that exist to reduce the energy consumption of the Barbara Davis building. This includes reduction of steam, chilled water, and electricity. After review of the building design documents and performing site surveys the energy conservation options were narrowed down to those outlined in the following section.

Energy Conservation Options (ECOs)

- Direct evaporative cooling on MAU-1, MAU-2, and AHU-1
- Indirect evaporative cooling on MAU-1 and MAU-2
- AHU-1 supply air duct static pressure setpoint reset
- MAU-1, MAU-2, and EHU-1 duct static pressure setpoint optimization
- MAU-1, MAU-2, and AHU-1 supply air temperature setpoint reset
- AHU-1 ventilation optimization and demand control ventilation (DCV)
- Ventilation tied to lighting occupancy sensors
- Lab air change rate reduction
- Replace the low-pressure steam to hot water heat exchanger with a high pressure flooded heat exchanger
- Variable flow vacuum pump operation
- Variable flow Strobic exhaust fan operation
- Daylight responsive lighting controls on perimeter zones
- Daylight responsive controls with LED lighting fixtures

Project Description

Direct Evaporative Cooling

Direct evaporative cooling reduces cooling energy required by lowering the air dry bulb temperature through the evaporation of water. Typically, direct evaporative cooling is accomplished with an evaporative media similar to that shown in Figure 1. Water is pumped to the top of the media and washed over the media. Outdoor air flows through the media which promotes the evaporation of the water passing over the media. The excess water drains into a basin at the base of the media where it can be pumped over the media again. As the water evaporates, the basin is filled. This type of direct evaporative media is typically a very effective means of evaporative cooling and air saturation of 90-95% RH can be expected. As a result, the dry bulb temperature of the air leaving the evaporative media is typically within 2-3°F of the entering air wet bulb temperature. In Denver, CO the summer wet bulb temperature is frequently below 60°F which can provide significant cooling savings.

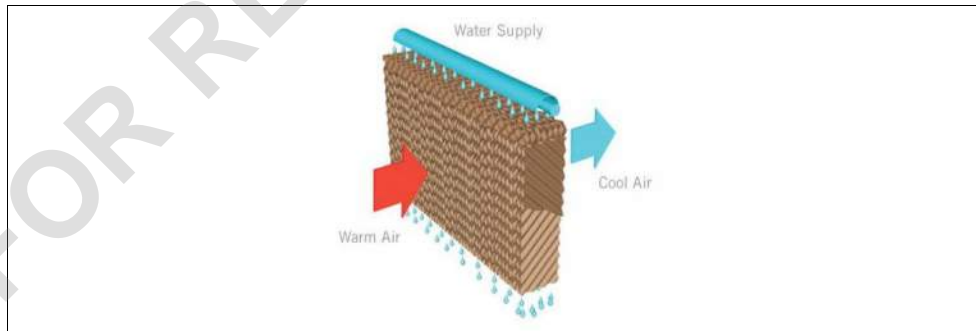


Figure 1 – Evaporative media diagram (courtesy Nature Cool)

Another form of evaporative cooling is high pressure atomization. This method of evaporative cooling is often used for humidification as well. Clean, high pressure water is atomized using nozzles. The small water particles then evaporate directly into the air. Unlike conventional direct evaporative cooling that uses media to evaporate the water, only the amount of water that can be effectively absorbed by the air is expelled from the nozzles. The high pressure nozzles are frequently located in air handling equipment, ductwork, or directly within the space being humidified.

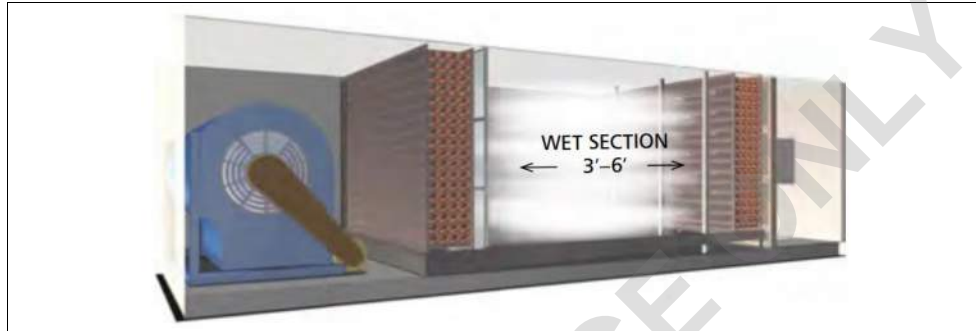


Figure 2 - High pressure atomizing humidifier/evaporative cooling (courtesy Mee Industries)

The primary obstacle to implementation of either method in the Barbara Davis facility is locating the evaporative equipment. The existing air handling equipment was not designed to accommodate the equipment necessary for these systems. Adding evaporative media requires the addition of a basin for the recirculation of the water which would require approximately 30" of length inside the air handling equipment. While the nozzles of a high pressure atomizing system are significantly smaller, this system requires at least 36" of unobstructed area downstream of the nozzles to allow for effective evaporation. Implementing the high pressure atomizing system without sufficient developed length downstream of the nozzles significantly reduces the effectiveness and eliminates the justification for the system.

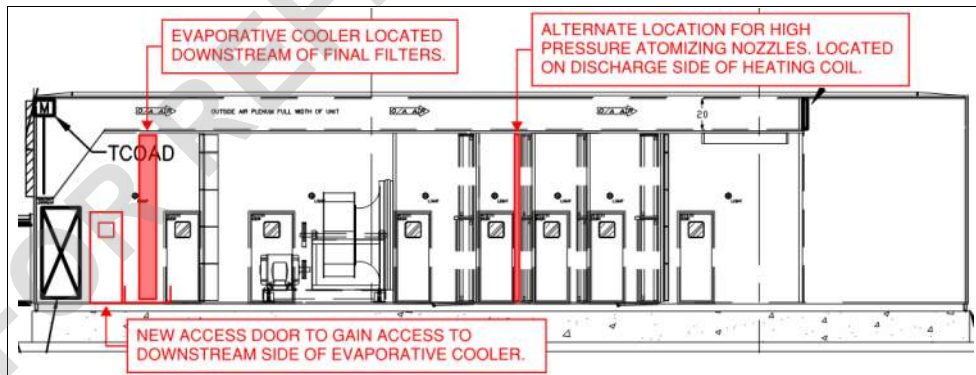


Figure 3 – Proposed MAU evaporative cooler and alternate high pressure atomizing nozzle location.

The supply air plenum downstream of the final filters is approximately long enough to accommodate a standard evaporative media section with a sump, Figure 3 and Figure 4. One limitation of installing standard evaporative media and sump in this location is access. The existing access door is directly downstream of the final filters. This means the evaporative media would need to be located downstream of the access door. If additional distance between the evaporative media and the ductwork connection is used, the existing access door can be relocated downstream of the evaporative media and the media can be located tight to the discharge of the final filters.

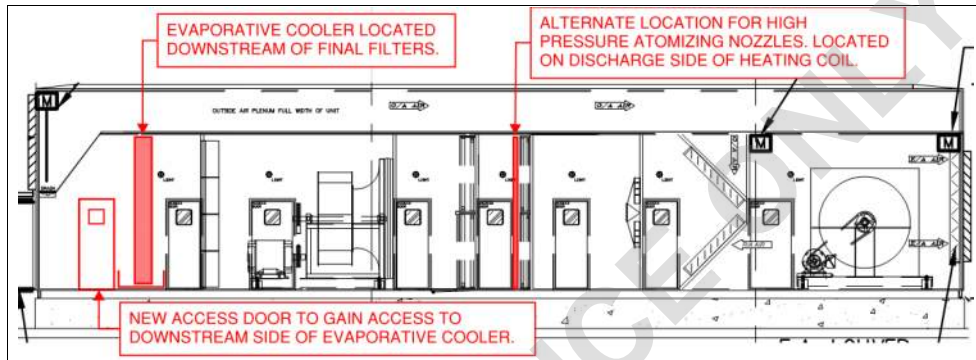


Figure 4 - Proposed AHU evaporative cooler and alternate high pressure atomizing nozzle location.

If high pressure atomizing nozzles are used the nozzles can be mounted to the discharge of the primary heating coil, Figure 3 and Figure 4. Using this location provides freeze protection and allows the cooling coil to collect any water particulates that have not evaporated into the airstream and divert them to the condensate pan. While the installation of the high pressure atomizing system requires fewer modifications to the air handling equipment relative to a standard evaporative cooler it carries a higher first cost. Also, the distance between the heating coil and the cooling coil is approximately 2'6" which is less than the optimal length and reduces the effectiveness of the atomizing system.

For the purpose of this study, standard evaporative media and high pressure atomizing nozzles have both been analyzed for a cost effectiveness comparison.

Indirect Evaporative Cooling

Similar to direct evaporative cooling, indirect evaporative cooling takes advantage of the low summer wet bulb temperatures experienced in the front range. In comparison to the direct evaporative cooling however, indirect evaporative cooling does not add humidity to the supply air or the occupied space. It uses evaporative cooling with the addition of a heat exchanger to conductively cool the supply air. This can be accomplished by adding direct evaporative cooling to "scavenger" air or "working" air that is taken from the outdoors and passed over an air to air heat exchanger to cool the supply air. In the Barbara Davis application the evaporative cooling would be added to the exhaust air to lower the dry bulb temperature of the exhaust air prior to passing over the run around loop heat recovery coil, Figure 5.

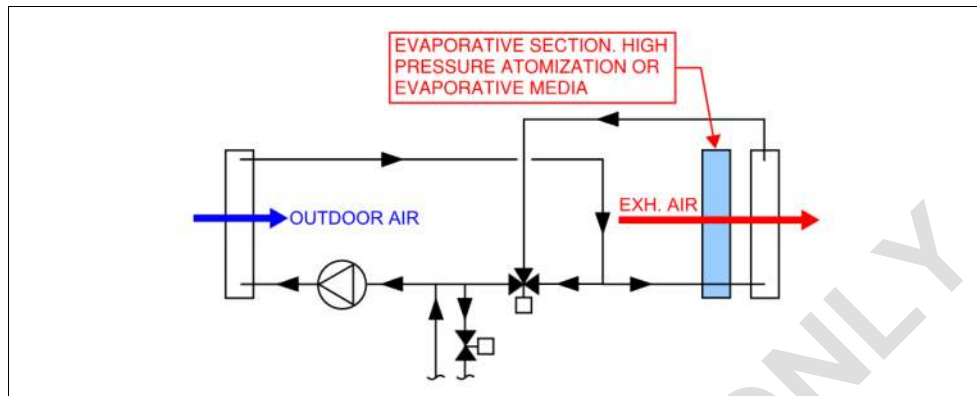


Figure 5 - Schematic of indirect evaporative cooling using a run around loop.

The existing exhaust air energy recovery unit includes sufficient space between the filter rack and the energy recovery coil to include evaporative cooling equipment, Figure 6. Only one access door currently exists for the filter access. Due to the location of the filter rack and the anticipated location of the evaporative cooler the access may need to be reconfigured to provide access to both the filter rack and both sides of the evaporative cooler. If high pressure atomizing is used, the access may not require reconfiguration but the arrangement of the nozzles must be arranged as to not block access to the filters. In this application, there is more length available which allows the atomizing system to approach air saturation levels similar to that of a standard evaporative media system. This reduces the advantage of the standard evaporative media in this application.

For the purpose of this study, standard evaporative media and high pressure atomizing nozzles have both been analyzed for a cost effectiveness comparison.

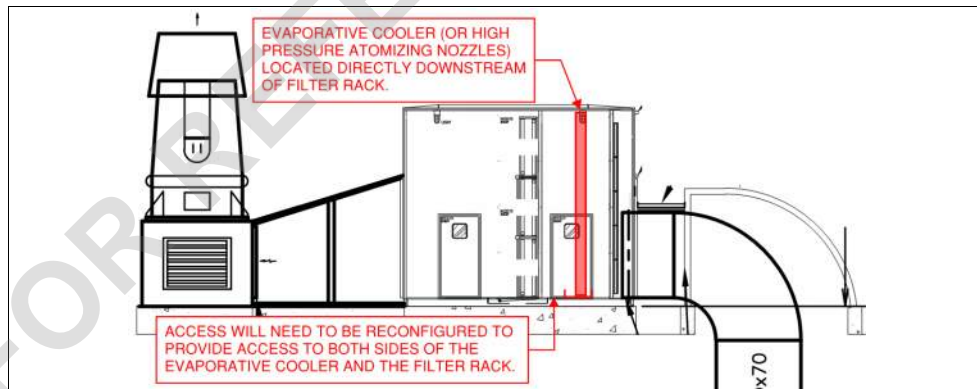


Figure 6 - Proposed EHU-1 evaporative cooler (or alternate high pressure atomizing nozzle) location.

Supply Air Duct Static Pressure Reset

Supply air duct static pressure reset is strictly an HVAC control strategy and will not require a hardware change. Supply air duct static pressure reset has the potential to significantly reduce fan power. As cooling demand from the zones decreases, the VAV boxes begin to close their dampers to reduce the airflow to the zones. When using a fixed supply air static pressure setpoint, when the cooling load reduces uniformly across the whole system all VAV box dampers must physically restrict the airflow by modulating the damper towards the closed position. When resetting the supply air duct static pressure, the AHU controller polls the VAV box damper positions. If all VAV box damper positions are less than some predefined percentage, e.g. 75% the duct static pressure is reset to a lower setpoint. The supply fan will slow in response to the lower setpoint and the VAV box dampers will open to maintain their respective flow. The total system air flow remains the same but the system static pressure is lowered and fan power is reduced. The static pressure would continue to be reset down until the VAV box with the highest cooling demand has a damper position close to wide open, e.g. 90%. If any box is wide open and the flow setpoint cannot be satisfied, the supply air duct static pressure setpoint is increased to maintain flow.

The duct static reset logic will include the ability to remove zones from the calculation where temperature control of the zone is not critical or the zone is malfunctioning and routinely preventing reset of the duct static pressure setpoint.

At Barbara Davis, the existing controls are DDC but use older technology. As such, there are limitations to implementation of more complex control strategies such as this. The primary concern is network traffic over the controls network. To minimize this, the frequency of polling the VAV boxes would be reduced as necessary to decrease network traffic. Ideally the supply air static pressure is reset at intervals no greater than 30 minutes.

Duct Static Pressure Optimization

This energy conservation measure is not appropriate for MAU-1, MAU-2, and EHU-1. These units use mechanically pressure independent air valves. As pressure changes in the MAU-1, MAU-2, and EHU-1 systems, the actuator positions do not change. There is a cone inside a venturi. As the inlet pressure increases, a spring inside the cone compresses to restrict free area and maintain the required flow. As the inlet pressure decreases, the spring expands to increase free area and maintain the required flow. This differs from AHU-1 where the VAV boxes are electronically (vs. mechanically) pressure independent. Because the actuator position on mechanically pressure independent air control valves does not indicate the position of the cone inside the air valve, it is not possible to determine if the inlet pressure is optimized for the required flow.

To reduce fan power on MAU-1, MAU-2, and EHU-1 it is recommended that balancing be performed to verify that the fixed static pressure setpoint is no higher than necessary to maintain flow to all zones. To do so, a balancing contractor and controls contractor would work together to reduce the duct static setpoint to the lowest value that still maintains the required air flow to the zone with the highest anticipated static pressure (the critical zone). It will be necessary to confirm the flow for multiple critical zones as the critical zone will shift as other zone demands change. For the purposes of this study, it is

estimated that the static pressure setpoint for MAU-1, MAU-2, and EHU-1 could each be reduced by 0.30"W.C. and maintain the required air flow.

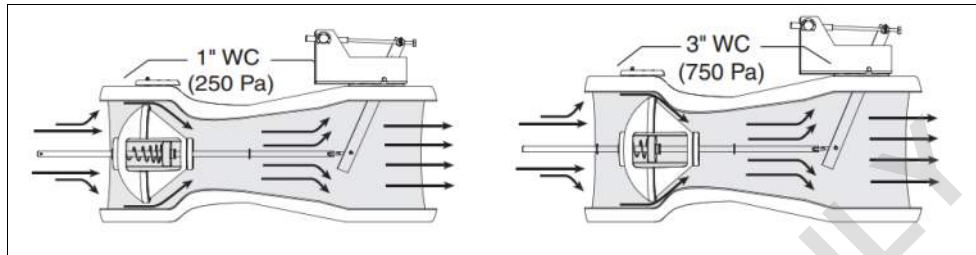


Figure 7 - Typical mechanically pressure independent air valve diagram illustrating constant flow at two different pressure differentials. Courtesy Phoenix Controls.

Supply Air Temperature Reset

Supply air temperature reset is strictly an HVAC control strategy and will not require a hardware change. VAV systems inherently provide simultaneous heating and cooling to satisfy the heating and cooling requirements of all spaces served by the system. By doing so, a VAV system can simultaneously provide heating to a perimeter zone and cooling to an interior zone. To accomplish this, it is necessary for the primary air temperature from the AHU to be low enough to meet the cooling load of the interior zone. If the primary air temperature is maintained at a constant 55°F, it will be able to provide cooling to any zone that requires it. However, this does not account for periods when 55°F supply air is not required to meet moderate cooling loads. This strategy reduces the amount of simultaneous heating by maintaining the highest supply air temperature possible which reduces return air cooling and primary air heating. The supply air temperature setpoint is maintained at the highest temperature that still satisfies the cooling load of the zone with the highest cooling demand. Because this strategy only relies on zone air temperature, it can be implemented into the sequence of operation for MAU-1, MAU-2, and AHU-1.

The supply air temperature reset logic will include the ability to remove zones from the calculation where temperature control of the zone is not critical or the zone is malfunctioning and routinely preventing reset of the supply air temperature setpoint.

As with supply duct static pressure reset, this strategy requires communication between the zone controllers and the AHU controllers. To minimize network traffic, the frequency of polling the zones would be reduced as necessary. Ideally the supply air temperature setpoint is reset at intervals no greater than 30 minutes. It may be necessary to implement proportional and integral (PI) control to improve the response time of the reset logic.

Ventilation Optimization and DCV

Currently AHU-1 does not modulate the outdoor air flow rate to the space during occupied periods. Reducing the outdoor air flow rate will reduce the amount of heating and cooling energy required for AHU-1. To reduce the outdoor air volume during occupied periods, CO₂ sensors would be added to high occupancy spaces and an air flow measurement station would be added to the AHU-1 outdoor air intake. The outdoor air flow rate of AHU-1 will be reduced based on the full occupancy of the low

density spaces and vacant high density spaces. When the CO₂ level of a high occupant density space increases, the supply air flow to that zone will increase. If the CO₂ setpoint cannot be satisfied at the maximum zone air flow, the AHU outdoor air flow rate will be increased until the CO₂ setpoints in all high occupant density zones are satisfied. If the CO₂ levels are all below the setpoint the outdoor air flow can be reduced. The outdoor air flow shall be increased beyond the setpoint if the AHU is in air economizer mode.

Ventilation Tied to Lighting Occupancy Sensors

An additional option for modulating outdoor airflow is to use lighting occupancy sensors to determine occupancy of a space. When sensors indicate a space is unoccupied, ventilation to the space would be reduced, thus reducing the amount of heating and cooling energy required.

Lighting occupancy sensors are installed in the building, but currently have no means to communicate with the building automation system (BAS). Therefore, supplemental controls must be installed to interpret the sensors' output and signal the BAS when rooms become occupied or unoccupied.

Lab Air Change Rate Reduction

Air changes are provided to the laboratory spaces on the third and fourth floor at a set rate to maintain a safe and comfortable environment. The current average air change rate provided to the third and fourth levels is approximately 8 air changes per hour (ACH). This ECO proposes reducing the air change rate during unoccupied hours to 5 ACH. This reduces the amount of outdoor air and the heating and cooling energy required by MAU-1 and MAU-2. This ECO would be implemented by updating the lab ventilation controls sequence.

Flooded High Pressure Steam Heat Exchanger

Currently the building uses pressure reducing valves (PRV) to reduce the incoming campus steam pressure, from 125 psi to 15 psi. The building includes a PRV station to reduce the pressure from 125 psi steam to 60 psi and another PRV to reduce the 60 psi steam to 15 psi. Each station includes a 1/3 PRV and a 2/3 PRV. Barbara Davis does not use 60 psi or 15 psi steam in the building for any uses other than generating hydronic heating water and domestic hot water. As such, campus steam does not serve any area of the Barbara Davis building outside of the mechanical room.

These PRVs occupy space within the mechanical room and reject heat, generating a significant cooling load. The low pressure steam is used for generating heating water and domestic hot water.

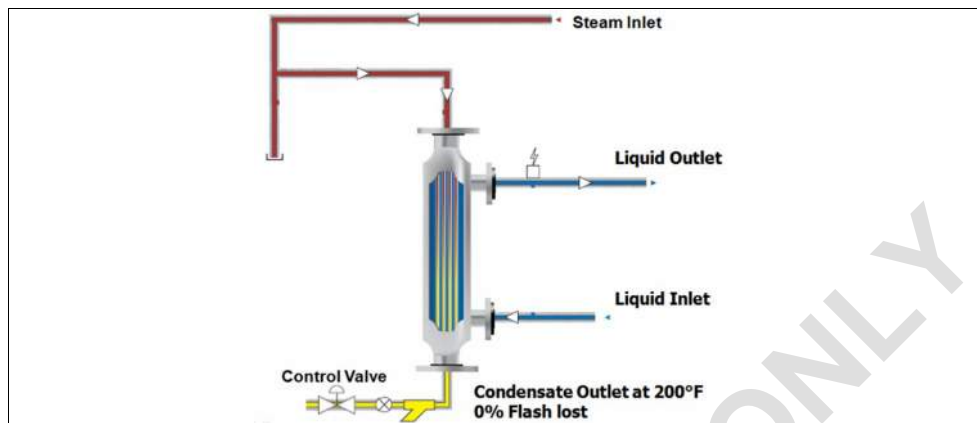


Figure 8- High pressure flooded type steam heat exchanger. Courtesy Maxi-therm.

Energy is often lost in steam systems through condensate traps. Ideally condensate traps relieve only condensed steam, but in practice traps frequently leak live steam. To reduce the amount of heat loss from the steam piping and through condensate traps, converting to a high pressure flooded type steam to heating water heat exchanger can accomplish both. A flooded heat exchanger controls the amount of heat transfer from the steam to the heating water by controlling the level of steam condensate within the heat exchanger. If more condensate is stored in the heat exchanger, there is less volume for steam. Less steam is exposed to the heat exchanger surface area and less heat is transferred. If more heat transfer is required, the condensate level is allowed to fall, increasing the heat exchanger surface area exposed to the steam. There are two primary advantages to this type of heat exchanger. First, live steam cannot escape from the heat exchanger due to the inherent nature of the capacity control. Second, the heat exchanger does not require low pressure steam but rather operates at high pressure and eliminates the need for PRVs. This results in space and energy savings relative to the current configuration.

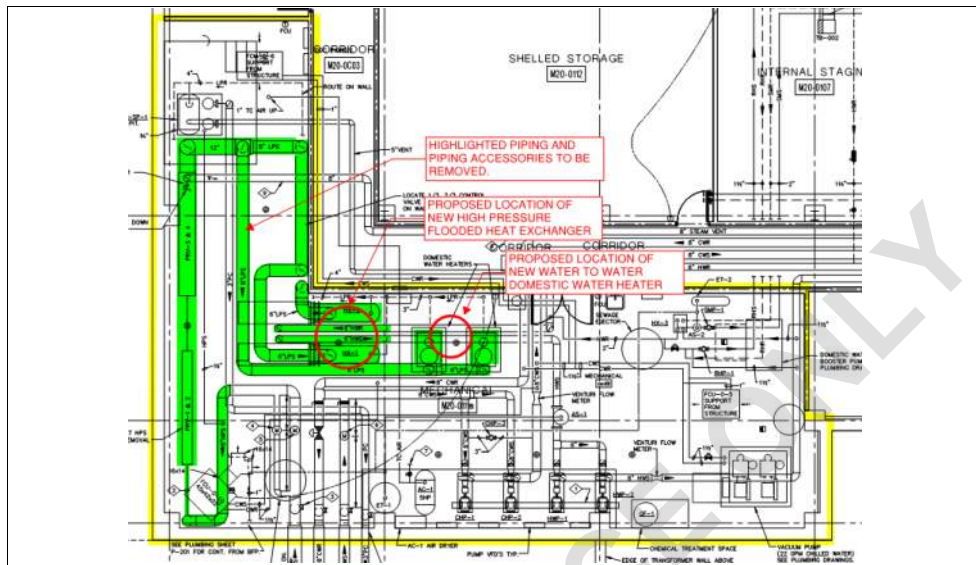


Figure 9 - Proposed location and modifications to the existing mechanical room.

Variable Flow Vacuum Pump Operation

The current vacuum pump does not include variable speed operation and includes two 40 HP pumps. The pumps cycle to maintain a vacuum in the accompanied receiver tank. The pumps also use 22 gpm of chilled water per pump to cool the vacuum pumps.

By adding variable speed operation to the vacuum pump, the peak electrical demand will be reduced and the part load efficiency will improve. Variable speed operation will also reduce pump cycling and improve motor life.

The vacuum pumps are currently in need of replacement. As such, the cost of adding variable speed vacuum pump operation is only the difference in cost between a constant speed pump system and a variable speed pump system. The cost differential between variable speed and constant speed is very low relative to the cost of the vacuum pump package.

Variable Flow Lab Exhaust Fan Operation

Three high plume Strobic fans exhaust the laboratory areas. The Strobic fans are scheduled to run at an outlet velocity of 5,400 fpm. The minimum velocity required for this application is 3,000 fpm, allowing the fans to decrease their outlet velocity by 1,400 fpm and still safely discharge exhaust air. In this ECO, variable frequency drives (VFDs) would be installed to turn the fan motors down to the speed (rpm) corresponding with 3,000 fpm outlet velocity. This ECO saves energy by not operating the fans at full speed when lab exhaust is less than full flow.

Currently the fans are staged and turn on or off based on the number of fans needed to meet the exhaust airflow. The corresponding fan curve is shown in Figure 10.

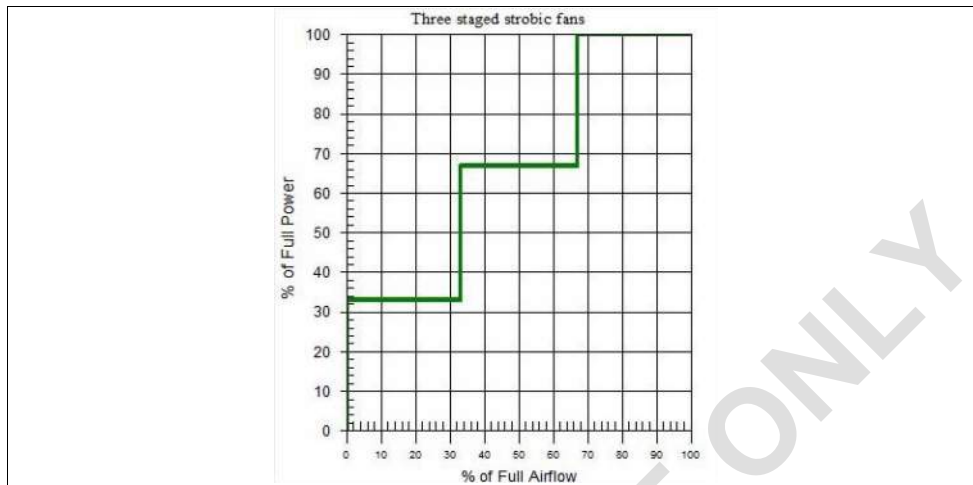


Figure 10 - Currently used (baseline) lab exhaust fan staging strategy.

There are two controls options to implement this ECO and add VFDs to the fans. The first option is: as exhaust flow decreases, reduce the speed of the motor on one fan until it reaches its minimum speed, then turn it off once flow drops below the capacity of two fans running at full speed. As flow drops further, the second fan would slow until it reached its minimum and turned off only once exhaust flow was within the capacity of a single fan. The last fan's speed may then be reduced to its minimum if flow decreases. The fan curve illustrating this option is shown in Figure 11.



Figure 11 - Use of varying individual lab exhaust fan speeds in conjunction with staging fans.

The second controls option is to turn all three fans down as flow decreases until all fans reach the minimum operating speed. At this point, fans may be staged off as flow drops further. The curve in Figure 12 illustrates this option.

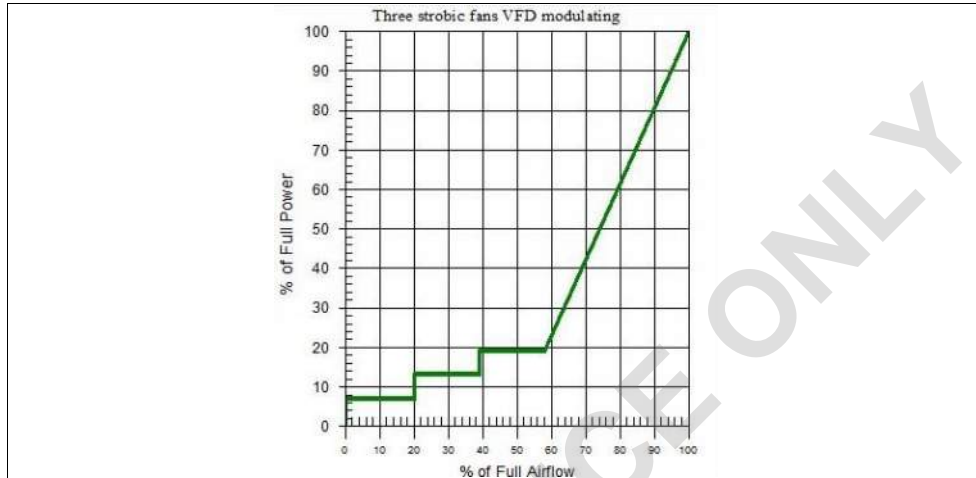


Figure 12 - Vary the speed of all lab exhaust fans in unison. Staging only occurs at minimum fan speed.

If this ECO is implemented, the second option is recommended for controlling the fans. The potential fan energy savings are much higher, since the corresponding fan power for all partial flows is lower than in controls option 1.

Daylight Responsive Controls

With this ECO, daylight responsive controls are used to reduce the lighting power in perimeter lighting control zones where sufficient natural light exists to meet the space lighting requirements.

This ECO reduces lighting energy by further reducing interior lighting energy consumption in perimeter lighting control zones during the day when natural light is available.

The daylight responsive controls and dimming ballasts are added to the existing luminaires. The first cost associated with replacement of the existing ballasts is included in the first cost of this ECO.

Daylight Responsive Controls with LED Lighting Fixtures

This ECO proposes implementing daylight responsive controls as explained in the previous section and replacing existing luminaires with LED lighting. Currently interior lighting is provided by primarily fluorescent lamp luminaires. This ECO replaces the fluorescent luminaires with LEDs, which consume less power and reduce lighting energy consumption. LED luminaires can support the integration of daylight responsive controls.

Financial Analysis

Energy Estimate

Energy conservation option savings were estimated using full year, 8760 hour energy analysis using Trane Trace 700 energy analysis software. The campus provides steam and chilled water at the following rates:

- Steam - \$12.70 per Mlb
- Chilled water - \$0.225 per ton-hr

Electricity rates were derived from Xcel Energy's 2016 rates for Primary General Service.

The results of the energy analysis provide anticipated utility energy and power usage of the building:

- electrical demand (kW and \$)
- electrical consumption (kWh and \$)
- chilled water consumption (dth and \$)
- steam consumption (dth and \$)

Each energy conservation option was run in a separate alternative to calculate the utility energy savings relative to the Baseline Building performance.

Utility Rates

Xcel utility rates from 2016 were used in the energy analysis of this study. The following rates were used for this study:

UTILITY RATES		
Electricity		
Summer Consumption	\$0.0368	per kWh
Winter Consumption	\$0.0392	per kWh
Summer Demand	\$18.32	per kW
Winter Demand	\$14.96	per kW
Chilled Water		
Consumption	\$1.874	per therm
Steam		
Consumption	\$1.266	per therm

Project Cost/Vendor Quotations

To develop simple paybacks, cost opinions were developed using a combination of 2017 RS Means data and budget pricing from vendors. The cost opinions include labor and materials of all anticipated work required to implement each ECO. The first cost included in the financial analysis includes anticipated credits for utility rebates.

Savings and Simple Payback

The following financial analysis table was developed using the first cost data from cost opinions and the results from the energy analysis. The result is a simple payback. Note that the utility cost savings (or

cost) does not include costs associated with changes in maintenance costs. For example, evaporative cooling will increase maintenance cost while the high pressure flooded steam heat exchanger will reduce maintenance cost. Other ECOs, such as controls changes will not have an impact on maintenance costs. This is further discussed in the non-energy impacts section below.

Energy Conservation Option	FINANCIAL ANALYSIS					
	Chilled Water Savings dth	Steam Savings dth	Electricity Savings kWh	Utility Cost Savings \$	Approximate 1 st Cost \$	Simple Payback yrs
Direct evaporative cooling (media)	2,712.7	(6.6)	(62,493)	\$44,984	\$104,800	2.3
Direct evaporative cooling (atomizing)	2,484.8	0.0	(30,293)	\$42,355	\$85,200	2.0
Indirect evaporative cooling (media)	1,443.8	(281.8)	(23,079)	\$21,835	\$42,900	2.0
Indirect evaporative cooling (atomizing)	1,299.0	(265.0)	(48,182)	\$17,536	\$39,300	2.2
Supply air duct static pressure reset	0.0	0.0	65,924	\$6,033	\$7,300	1.2
Supply and exh. duct pressure optimization	70.2	(13.5)	91,232	\$7,197	\$5,800	0.8
Supply air temperature reset	1,296.4	599.1	(15,396)	\$26,313	\$7,300	0.3
AHU-1 Ventilation optimization and DCV	35.6	168.0	0	\$2,793	\$32,100	11.5
HVAC integration with lighting occupancy sensors	54.8	282.4	8,944	\$5,590	\$112,700	20.2
Lab air change rate reduction	783.4	1,385.9	325,191	\$44,698	\$4,800	0.1
Flooded high pressure steam heat exchanger	467.8	340.8	0	\$13,078	\$232,700	17.8
Variable flow vacuum pump	32.6	0.0	19,120	\$6,591	\$3,000	0.5
Variable flow exhaust fan (controls option #1)	0.0	0.0	76,129	\$2,920	\$41,200	14.1
Variable flow exhaust fan (controls option #2)	0.0	0.0	158,622	\$6,086	\$41,200	6.8
Daylight responsive controls	117.5	(261.3)	148,446	\$17,579	\$163,300	10.4
LED luminaires with daylight responsive controls	152.8	(363.3)	201,672	\$21,465	\$312,900	14.6

Non-Energy Project Impacts

Direct evaporative cooling and indirect evaporative cooling will require additional scheduled maintenance associated with water replacement and freeze protection. Additional unscheduled maintenance will increase resulting from additional pumps, compressors (atomizing system only), and evaporative media replacement.

Supply air duct static pressure reset and supply air temperature reset will save energy but it may be at the cost of occupant comfort at times. It is possible that as the setpoints are reset, the building heating and cooling loads change faster than the setpoints reset. As a result, there may be periods where the supply air duct pressure is too low to maintain the desired airflow at the terminals or the supply air temperature is too high to satisfy the cooling load. For this reason, it is important that the building automation system accounts for the magnitude of zone temperature or air flow deviation from setpoint when calculating the reset values.

Replacing the low-pressure steam to hot water heat exchanger with a high pressure flooded heat exchanger will not change scheduled maintenance. It is anticipated to result in a slight reduction in unscheduled maintenance. It simplifies the steam system by removing multiple PRV stations, condensate traps, and steam to hot water heat exchangers. In their place will be a single high pressure heat exchanger with a high pressure control valve.

The addition of daylight responsive lighting controls will not increase scheduled maintenance but may slightly increase unscheduled maintenance associated with upkeep and adjustment of the controls sensors and logic.

Replacing the fluorescent luminaires with LEDs will reduce maintenance time associated with changing fluorescent lamps. The reduction in maintenance costs is not included in the simple payback calculation reported above, but it could make up for the difference in cost of the LED luminaires. This would decrease the payback time of the daylight responsive controls with LEDs to be comparable to integrating daylight responsive controls with the current lighting design.

Implementation

Based on the simple payback analysis, not all the ECOs explored by this study merit further investigation. BCER Engineering recommends proceeding with the following energy conservation options:

- Atomizing direct evaporative cooling
- Supply air duct static pressure reset
- Supply and exhaust air duct static pressure optimization
- Supply air temperature reset
- AHU-1 Ventilation optimization
- Lab air change rate reduction
- Variable flow vacuum pump
- Variable flow lab exhaust fan operation (Option #2)
- Daylight responsive lighting control with LED replacement

These energy conservation measures result in the shortest simple payback and result in the largest total energy savings.

Measurement of Energy

To verify the energy savings associated with each of the implemented ECOs energy metering is recommended. Note that the cost associated with this metering is not included in the first cost of the ECOs.

The following sensors and logic are required to quantify the energy saved by the direct evaporative cooling. Using the outdoor air enthalpy, supply air enthalpy (downstream of the hydronic cooling coil), and an air flow measurement station the actual change in enthalpy can be calculated relative to the theoretical enthalpy that would have been required to provide the same supply air dry bulb temperature without the evaporative cooling. Without direct evaporative cooling, the supply air enthalpy will be lower than that of the system that includes direct evaporative cooling. The difference between these two enthalpy values represents the cooling energy saved.

AHU-1 Supply air duct static pressure reset savings can be calculated by the BAS or an external analytics package. The actual fan power demand will be logged by the fan VFD (and the BAS) on 15 minute intervals for comparison to a calculated baseline fan power. The corresponding supply fan RPM, supply fan curve, and maximum duct static pressure setpoint can be used to calculate the fan power that would have been required had the static pressure setpoint not been reset. This can be compared for each data

point to compare the demand reduction and the consumption reduction from the static pressure reset logic.

The energy savings measurement strategy used for the supply air duct static reset logic can also be used for the MAU-1, MAU-2, and EHU-1 duct static pressure optimization. In lieu of using the maximum duct static reset setpoint, the previously implemented higher fixed duct static pressure setpoint would be used to calculate the baseline fan power for comparison to the actual measured fan power as measured by the fan VFD.

The energy savings associated with the supply air temperature reset is difficult to measure or calculate with the existing control system. This is because the amount of reheat that would have been required without the supply air temperature reset is unknown without the corresponding heating or cooling load of each respective space. While this could theoretically be calculated using the supply air temperature, each terminal discharge air temperature, and each terminal air flow rate, it is unlikely that the existing controls are capable of logging this data. If it were, this data could again be transferred to an analytics package for calculation of the energy savings relative to the calculated baseline performance without the supply air temperature reset.

The variable flow vacuum pump cost savings can be calculated by logging the electrical demand of the pumps at 15 minute intervals. Based on the energy consumed over time, a calculation could be used to estimate the equivalent energy that would have been consumed by a vacuum pump cycling at 100% power. This would calculate the demand and energy savings.

Energy measurement for the Strobic exhaust fans operating on VFD can be calculated by logging the electrical demand of the fans at 15 minute intervals. Based on the energy consumed over time, the equivalent energy that would have been consumed by the fans staging at 100% power can be calculated.

If simplistic lighting controls are used that do not include intelligent control, electrical energy meters shall be added to the lighting circuits to measure the total energy consumed by the lighting. Measuring the energy consumption of lighting circuits does not directly report the energy saved. To understand the total energy saved by the new lighting system, a baseline energy consumption must be established. This would require installation of the energy meters prior to implementation of the lighting control changes.



Engineering Assistance Study, Energy Conservation Options

University of Colorado, Anschutz Medical Campus

Environmental Health & Safety Building

Aurora, CO

August 18, 2017

Sean Beilman P.E.



Executive Summary

Purpose

Purpose of the study is to explore the viability of selected energy conservation opportunities for the Environmental Health & Safety (EH&S) building on the University of Colorado, Anschutz Medical Campus. This includes estimated work required to implement the changes, the approximate construction cost, and the associated energy savings. Energy conservation opportunities will explore all potential energy savings measures that would impact all campus utilities including electricity, chilled water, and steam.

Existing Conditions

The EH&S building is an existing 19,000 sf single story building on the Anschutz campus used for storage of radioactive material generated by other facilities on the campus. The building uses electricity, campus chilled water, and campus steam. The building was constructed in two phases, Figure 1. The building is served by three (3) air handling units. One constant volume recirculating unit serves the administrative area and two constant volume 100% outdoor air units serve the storage areas. The air handling units include steam preheat coils, hydronic heating coils, and hydronic cooling coils. Due to the type of material being stored within the facility, all heating and cooling air is once through. Exhaust fans are high plume units. Two sets of fans are installed in the building, one for the first phase and one for the second phase. The exhaust system on the first phase of the building includes inline duct filter boxes. The exhaust system on the second phase does not include filtration. Each exhaust fan system is paired to an associated air handling unit.



Figure 1 – Building overall floor plan.

Interior and exterior lighting is provided by a mixture of metal halide and fluorescent lamps. The office area is equipped primarily with indirect/direct linear fixtures. Tertiary office areas use lay-in fluorescent fixtures. The storage areas primarily use metal halide high bay fixtures. Interior lighting controls are

manual switching. No occupancy sensors or daylight responsive controls are present. Exterior lighting is automatically controlled.

Study Summary

This study will explore the opportunities that exist to reduce the energy consumption of the EH&S building. This includes reduction of steam, chilled water, and electricity. After review of the building design documents and performing site surveys the energy conservation options were narrowed down to those outlined in the following section.

Energy Conservation Options (ECOs)

- AHU-1 and AHU-P-3 (storage areas)
 - Exhaust air heat recovery
 - Variable flow exhaust/make-up
 - Direct evaporative cooling
 - Indirect evaporative cooling
- AHU-2 (administrative area)
 - Implement VAV operation
 - Implement demand controlled ventilation
- Replace the low-pressure steam to hot water heat exchanger with a high pressure flooded heat exchanger.
- Lighting
 - Replace metal halide HID lighting with LED lighting throughout.
 - Add occupancy sensors for lighting
 - Add daylight responsive controls for lighting

Project Description

Exhaust Air Heat Recovery

Because the air handling equipment serving the storage portion of the facility is 100% outdoor air, constant volume, and runs 24 hours per day/7 days per week exhaust air energy recovery presents a significant opportunity for energy savings by reclaiming heat from exhaust air that has already been heated by the HVAC system.

Multiple methods of exhaust air heat recovery exist but are not appropriate for this project. Common heat recovery methods are:

- Sensible heat wheel
- Air-to-air heat exchanger
- Heat pipe
- Hydronic run around loop

Of the exhaust air heat recovery methods listed above, only one is suitable for the application at EH&S due to the physical location of the exhaust air system relative to the make-up air system. Although it is

not the most effective means of exhaust air energy recovery, a hydronic run around loop is the only form of exhaust air energy recovery that can be used in situations where the exhaust and supply air streams are not adjacent (or very close) to one another. A schematic of the proposed run-around loop heat recovery method is provided in Figure 2. In this run around loop heat is reclaimed from the exhaust air and used to preheat the incoming outdoor air. During periods of extremely low outdoor air temperature, the heat reclaimed from the exhaust air stream is not enough to maintain the loop water temperature above freezing. To prevent the water from falling below freezing temperatures, multiple means of protection are to be provided.

- Glycol will be provided in the heating water loop and in the run around loop. 30%, consistent with the heating water loop in the building.
- The outdoor air coil is circulated with a constant volume pump.
- Backup heating in the form of hydronic heat is added to the outdoor coil.

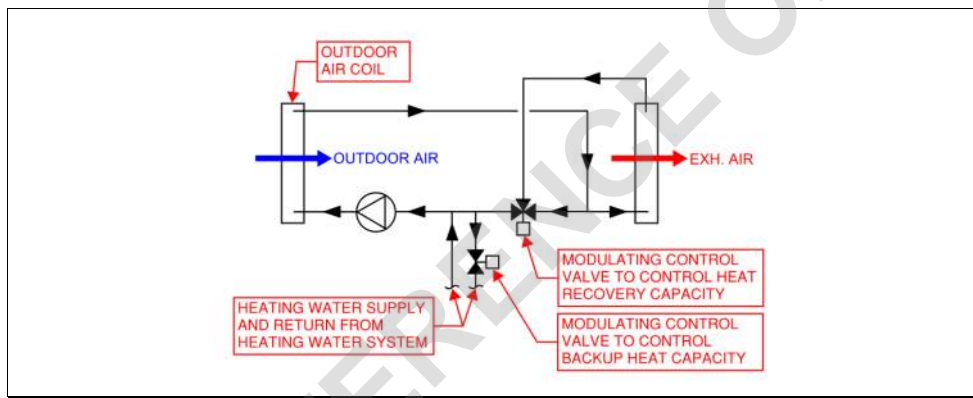


Figure 2 - Run-around loop schematic with backup hydronic heat.

The existing make-up air units were not designed with space for a future heat recovery coil. However, the units were originally provided with steam face and bypass preheat coils. If the steam preheat coil is removed in each make-up air unit, a heat recovery coil can be installed in its place. However, heat recovery alone will not provide enough heating capacity to offset the heating capacity of the steam coil it is replacing. To compensate, the heat recovery loop will be supplemented with heating water. Heating water is injected into the heating recovery loop to maintain the water temperature leaving the outdoor air coil above freezing. This condition applies to both AHU-1 and AHU-P-3 (Figure 3 and Figure 4 respectively).

The existing exhaust air system is comprised of three primary systems. In the first phase of the building, the exhaust air is separated into two separate systems. The larger of the two systems uses three high plume exhaust fans running in parallel to exhaust a common exhaust air plenum located on the underside of the roof structure. The high plume fans are located on the roof directly above the plenum. This system serves drum exhaust stations, chemical fume hoods, and general space exhaust. The second system is dedicated for hazardous exhaust from drum exhaust stations and uses a separate dedicated

high plume fan rated for such an application. This high plume fan is located on the roof adjacent to the other high plume fans.

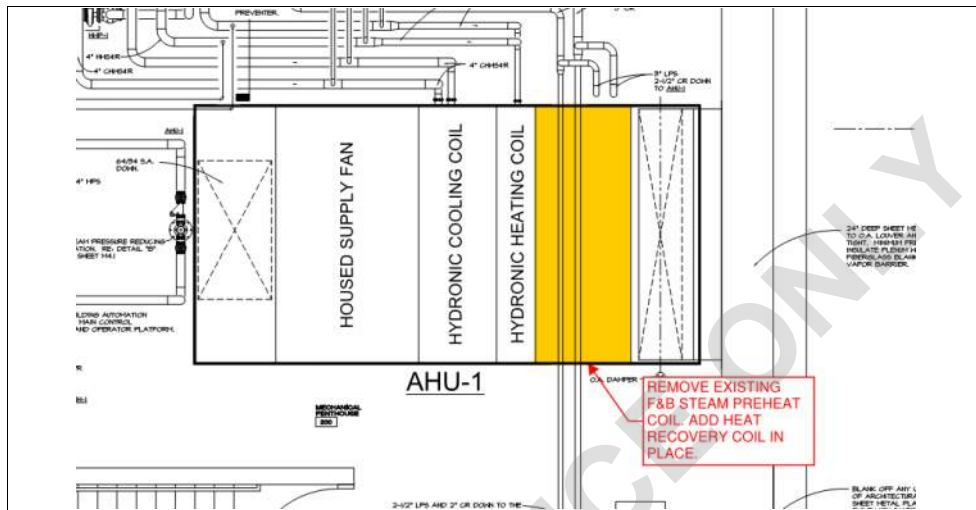


Figure 3 - Phase I building make-up air unit proposed heat recovery coil location.

In the second phase of the building the exhaust system provides general exhaust only and does not serve any drum exhaust stations or chemical fume hoods. Four high plume exhaust fans are provided on the roof in a central location. The general exhaust ductwork serving the space is ducted directly to each fan and is not ducted through an exhaust plenum as in the first phase.

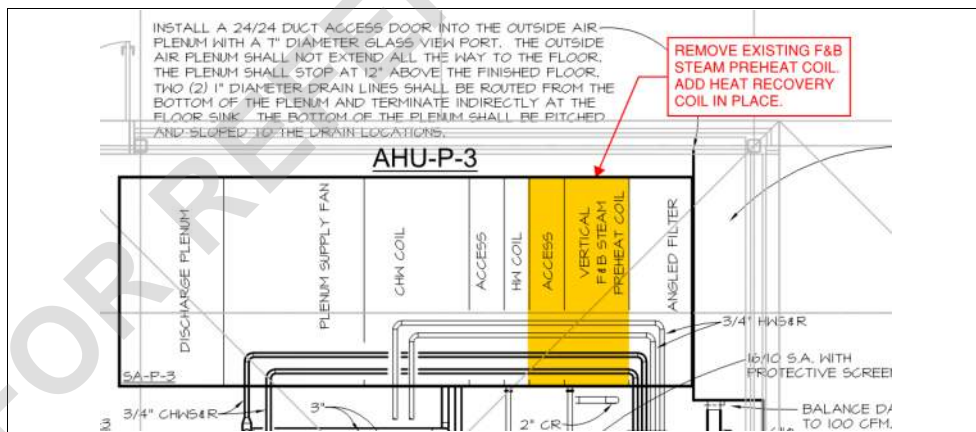


Figure 4 - Phase II building make-up air unit proposed heat recovery coil location.

To add a heat recovery coil to these exhaust systems two possible solutions exist:

1. Replace the high plume fan system on the roof with a system that includes a heat recovery coil.
2. Add a heat recovery coil to the existing ductwork inside the facility.

Replacing the high plume fan system on the roof was eliminated from this analysis for two reasons. Space on the roof is severely limited by CMU/brick screen walls and does not provide adequate space for the air handling enclosure that would be required for the heat recovery coil and fans. Also, this solution adds cost by requiring the replacement of the high plume exhaust fans.

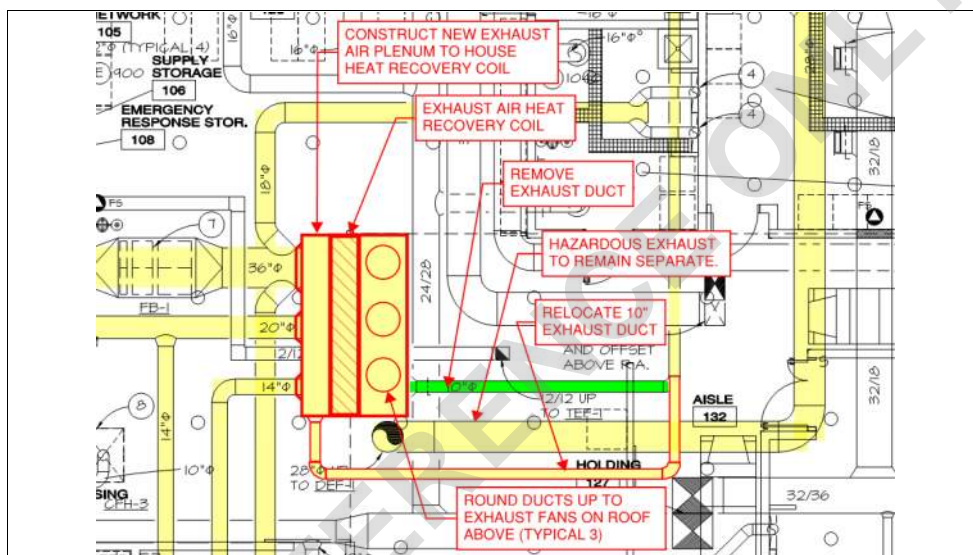


Figure 5 - Phase I building proposed exhaust air heat recovery coil locations.

This analysis is based on modifying the existing ductwork to add a heat recovery coil to the ductwork below the roof structure. In Phase 1, the addition of a heat recovery coil is proposed in the location of the existing exhaust air plenum. This will likely require the replacement of the plenum with new ductwork and support for the heat recovery coil. While portions of the Phase I exhaust system include filter boxes, not all exhaust air is filtered. Additional filtration must be provided to upstream of the heat recovery coil to protect it from particulate contamination. A sketch of the anticipated heat recovery coil configuration and ductwork revisions required for Phase I is shown in Figure 5.

In Phase II, the addition of a heat recovery coil is proposed inside the building just below the high plume fans on the roof. Currently the ductwork connected to these fans does not include a plenum. As part of the addition of a heat recovery coil, an exhaust air plenum would be added. The exhaust fans would run in parallel to exhaust this plenum. A filter rack would be required upstream of the heat recovery coil just as in the Phase I exhaust system. A sketch of the anticipated heat recovery coil configuration and ductwork revisions required for Phase II is shown in Figure 6.

Due to the cold temperatures of the heat recovery coils, condensate pans must be provided to collect condensate from the coils.

The addition of the heat recovery coils will add approximately 0.7"W.C. to 1.0"W.C. to the exhaust and supply air fans. For the supply air, there will be a credit however for the removal of the steam face and bypass preheat coil. For the purposes of this study, it is assumed that the existing exhaust fan speed can be increased to accommodate this additional static pressure. Prior to implementing the change, the capacity of the existing fans must be further investigated. This additional exhaust air resistance does not include the resistance associated with any other ECOs explored in this study.

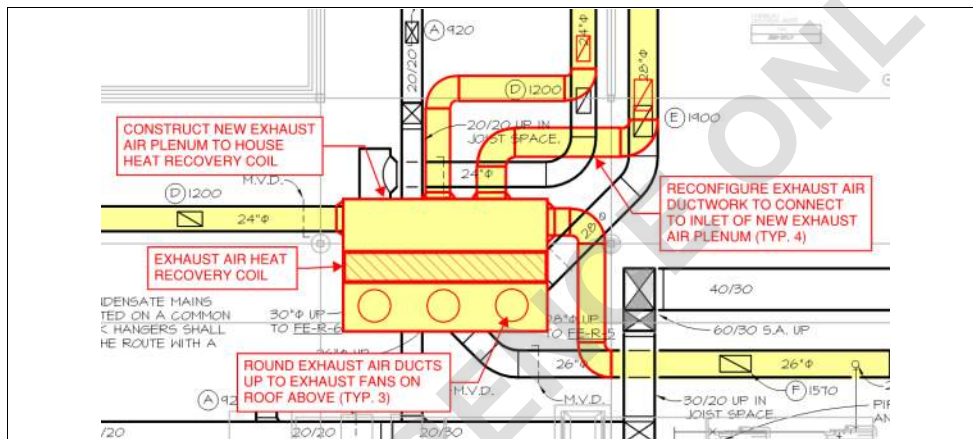


Figure 6 - Phase II building proposed exhaust air heat recovery coil locations.

Variable Exhaust/Make-up Air Flow

In Phase I of the building, drum exhaust stations account for approximately 65% of the total exhaust air flow. Monitoring the presence of drums at the station and adjusting the airflow of the station accordingly could further reduce airflow in the facility. With this ECO the drum exhaust stations would exhaust the full flow, 1300 CFM when a drum is present and reduce to 30% (adj.) flow when a drum is not present. To implement variable flow exhaust in Phase I the following measures must be taken:

1. Active pressure independent air valves must be added to the drum exhaust stations to actively control the air flow of the station based on the presence of a drum, Figure 7. A proximity sensor (or other monitoring device) must be provided to sense the presence of a drum. A visual indicator of the operation mode must be provided to indicate appropriate operation of the station.
2. The remainder of the exhaust system must be provided with passive pressure independent air valves to maintain the required airflow despite exhaust ductwork pressure variation resulting from active air valve operation, Figure 8.

- The high plume exhaust fan bypass dampers must be motorized to allow constant flow through the fans. This allows the required fan discharge air velocity to be maintained as the exhaust from the building reduces by increasing the bypass air flow.

While this system has the potential to significantly reduce the exhaust air rate, the savings are heavily dependent on the time drums occupy the stations. Further investigation is required to monitor the usage of the drum exhaust stations to better understand their usage and estimate the potential savings.

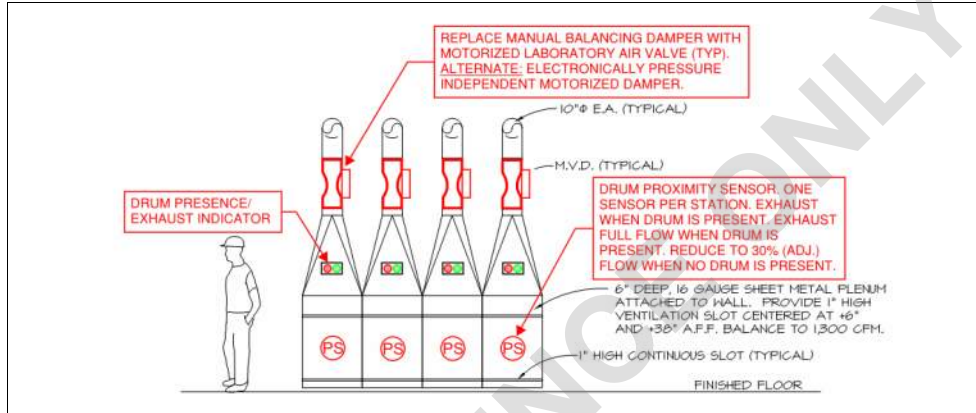


Figure 7 - Proposed drum exhaust station variable flow implementation.

Currently the air change rate for the entire facility is approximately 12 ACH of outdoor air. Per ASHRAE Standard 170 "Soiled workroom or soiled holding" areas and "Hazardous material storage" areas require a minimum of 10 ACH¹. If the vacant drum exhaust station air flow is 50% of the full flow, not all drum stations will be able to reduce to 50% and maintain the minimum allowable air change rate. At this percentage, no more than 50% of the drum exhaust stations may change to the vacant flow.

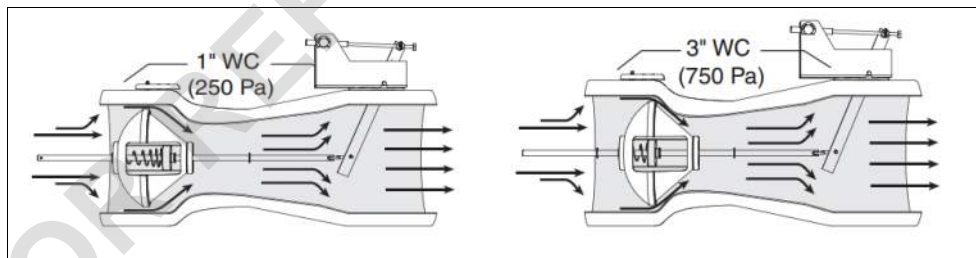


Figure 8 - Typical mechanically pressure independent air valve diagram illustrating constant flow at two different pressure differentials. Courtesy Phoenix Controls.

The addition of the exhaust valves will add between 0.3"W.C. and 0.6"W.C. to the exhaust air ductwork. For the purposes of this study, it is assumed that the existing exhaust fan speed can be increased to

¹ Room air may not be recirculated within the space and must be exhausted directly to the outdoors.

accommodate this additional static pressure. Prior to implementing the change, the capacity of the existing fans must be further investigated. This additional exhaust air resistance does not include the resistance associated with any other ECOs explored in this study.

Direct Evaporative Cooling

Direct evaporative cooling reduces cooling energy required by lowering the air dry bulb temperature through the evaporation of water. Typically, direct evaporative cooling is accomplished with an evaporative media similar to that shown in Figure 9. Water is pumped to the top of the media and washed over the media. Outdoor air flows through the media which promotes the evaporation of the water passing over the media. The excess water drains into a basin at the base of the media where it can be pumped over the media again. As the water evaporates, the basin is filled. This type of direct evaporative media is typically a very effective means of evaporative cooling and air saturation of 90-95% RH can be expected. As a result, the dry bulb temperature of the air leaving the evaporative media is typically within 2-3°F of the entering air wet bulb temperature. In Denver, CO the summer wet bulb temperature is frequently below 60°F which can provide significant cooling savings.

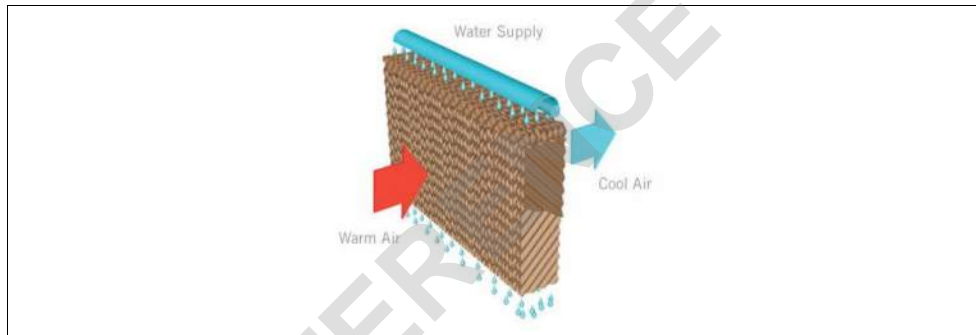


Figure 9 – Evaporative media diagram (courtesy Nature Cool)

Another form of evaporative cooling is high pressure atomization. This method of evaporative cooling is often used for humidification as well. Clean, high pressure water is atomized using nozzles. The small water particles then evaporate directly into the air. Unlike conventional direct evaporative cooling that uses media to evaporate the water, only the amount of water that can be effectively absorbed by the air is expelled from the nozzles. The high pressure nozzles are frequently located in air handling equipment, ductwork, or directly within the space being humidified.

The primary obstacle to implementation of either method in the EH&S facility is locating the evaporative equipment. The existing air handling equipment does not have excess free area or access space that can be used to house the equipment necessary for these systems. Adding evaporative media requires the addition of a basin for the recirculation of the water which would require approximately 30" of length inside the air handling equipment. While the nozzles of a high pressure atomizing system are significantly smaller, this system requires at least 36" of unobstructed area downstream of the nozzles to allow for effective evaporation. Implementing the high pressure atomizing system without sufficient

developed length downstream of the nozzles significantly reduces the effectiveness and eliminates the justification for the system.

This ECO assumes standard evaporative media will be used to maximize the effectiveness and savings of the system. To add standard evaporative media to this building, it is proposed that a separate evaporative AHU section be added outside the mechanical room on the roof adjacent to the existing outdoor air intake. To mask this new equipment a screen wall may be added. For the purposes of this study, the additional cost of the screen wall is not included in the approximate construction cost. Approximate anticipated configuration is illustrated in Figure 10 and Figure 11.

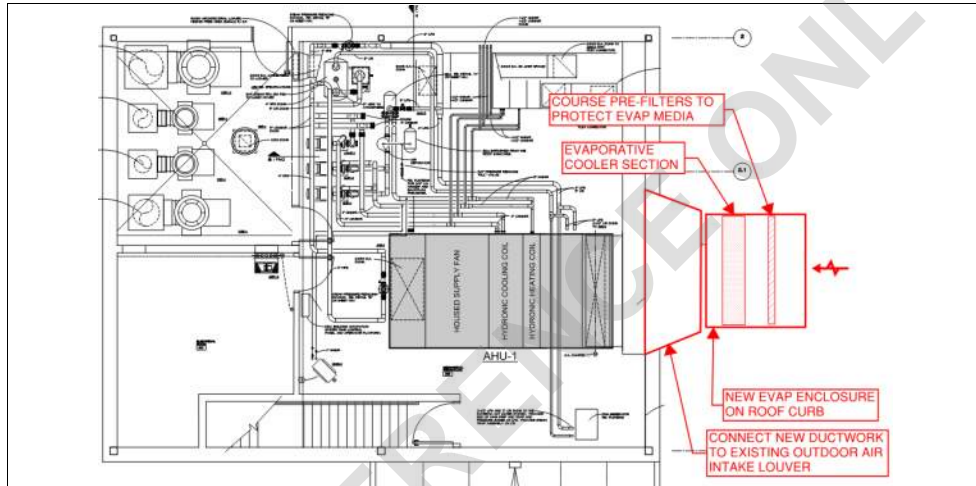


Figure 10 - Evaporative cooler addition to Phase I make up air unit.

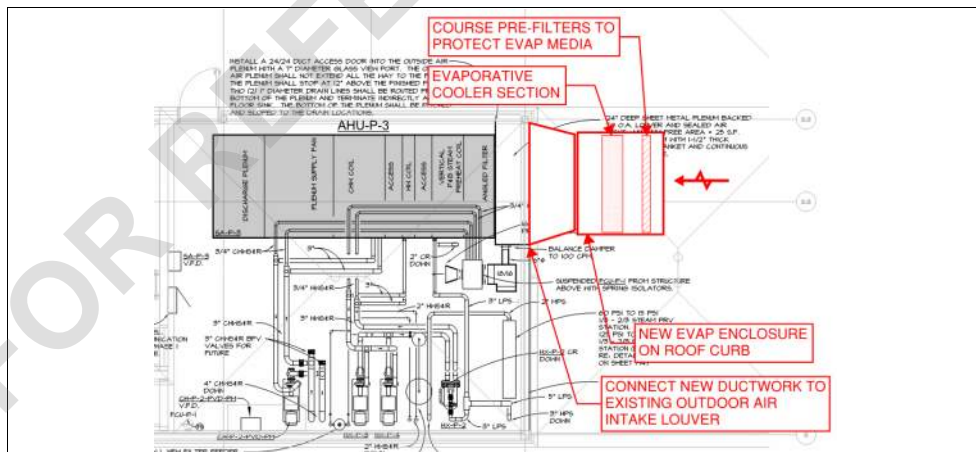


Figure 11 - Evaporative cooler addition to Phase II make up air unit.

Indirect Evaporative Cooling

Similar to direct evaporative cooling, indirect evaporative cooling takes advantage of the low summer wet bulb temperatures experienced in the front range. In comparison to the direct evaporative cooling however, indirect evaporative cooling does not add humidity to the supply air or the occupied space. It uses evaporative cooling with the addition of a heat exchanger to conductively cool the supply air. This can be accomplished by adding direct evaporative cooling to “scavenger” air or “working” air that is taken from the outdoors and passed over an air to air heat exchanger to cool the supply air. In the EH&S application the evaporative cooling would be added to the exhaust air duct to lower the dry bulb temperature of the exhaust air prior to passing over the run around loop heat recovery coil located in the exhaust air duct.

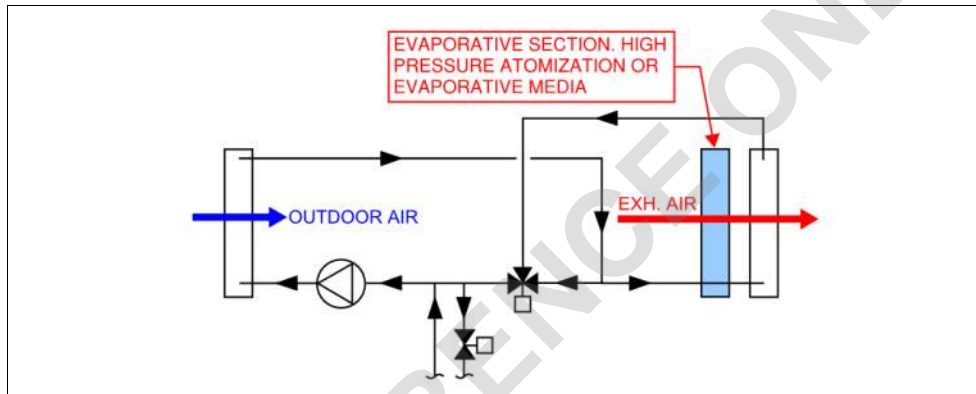


Figure 12 - Schematic of indirect evaporative cooling using a run around loop.

VAV Operation of AHU-2

AHU-2 is currently configured as a three-zone constant volume terminal reheat system. This costs significant reheat and fan energy. To reduce reheat and fan energy fan speed will be modulated and the supply air temperature from the AHU reset. Unlike true VAV systems though, this ECO only adds variable speed to the AHU, not each zone. While not adding VAV boxes to each zone will reduce the savings some, it reduces the cost of implementing the change while still saving energy. Additionally, there is not a significant variation in load or usage of the spaces served by this AHU, so the additional savings from adding VAV boxes to each zone would be limited.

To implement VAV operation, VFDs must be added to the supply and return fans. With the addition of these VFDs, the controls can monitor the space temperature setpoints and the discharge air temperatures. When any of the three zones reaches the cooling temperatures setpoint, the first stage of cooling shall be to reduce the supply air temperature. The second stage of cooling shall be to increase the supply air flow. The AHU shall run to meet the cooling load of the zone with the highest cooling demand. If all zone cooling temperature setpoints are satisfied, the fan shall be at minimum speed, 30% (adj.) and AHU supply air temperature shall be increased until one of the zones reaches its cooling temperature setpoint or the maximum supply air temperature, 70°F has been met.

At all times, the zone duct heating coil control valves shall modulate to maintain the space heating setpoint. The AHU return fan shall track with the supply air fan. The outdoor air flow would be fixed to satisfy the code minimum.

Demand Control Ventilation of AHU-2

Currently AHU-2 does not modulate the outdoor air flow rate to the space during occupied periods. To reduce the outdoor air volume during occupied periods, CO₂ sensors would be added to the occupied spaces. CO₂ sensors would be added to the open office area and the small conference room. The AHU outdoor air damper will maintain a minimum flow of 300 CFM during occupied mode if the CO₂ setpoints are satisfied. If either space reaches a CO₂ level of 1000 ppm, the AHU outdoor air flow will increase until the CO₂ setpoint is satisfied. If the CO₂ level falls below the setpoint the outdoor air flow can be reduced. The outdoor air flow may be increased past the setpoint if the AHU is in air economizer mode.

Reducing the outdoor air flow rate will reduce the amount of heating and cooling energy required for AHU-2.

Flooded High Pressure Steam Heat Exchanger

Currently the building uses pressure reducing valves (PRV) to reduce the incoming campus steam pressure, 125 psi to 15 psi. Phase I and Phase II each have their own set of PRVs. In each phase is a PRV station to reduce the pressure from 125 psi steam to 60 psi and another PRV to reduce the 60 psi steam to 15 psi. Each station includes a 1/3 PRV and a 2/3 PRV. These PRVs occupy space within the mechanical room and constantly reject heat to the room. The low pressure steam is used for steam preheat coils and for a steam to heating water heat exchanger.

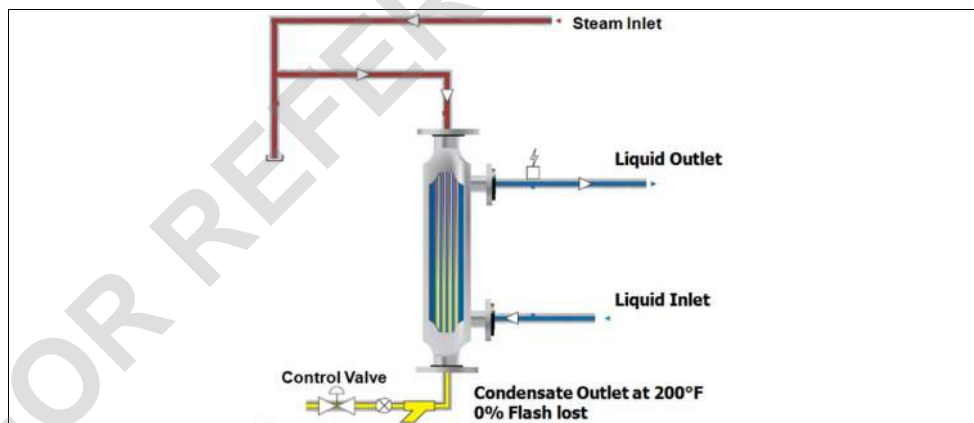


Figure 13- High pressure flooded type steam heat exchanger. Courtesy Maxi-therm.

Energy is often lost in steam systems through condensate traps. Ideally condensate traps relieve only condensed steam, but in practice traps frequently leak live steam. To reduce the amount of heat loss from the steam piping and through condensate traps, converting to a high pressure flooded type steam

to heating water heat exchanger can accomplish both. A flooded heat exchanger controls the amount of heat transfer from the steam to the heating water by controlling the level of steam condensate within the heat exchanger. If more condensate is stored in the heat exchanger, there is less volume for steam. Less steam is exposed to the heat exchanger surface area and less heat is transferred. If more heat transfer is required, the condensate level is allowed to fall, increasing the heat exchanger surface area exposed to the steam. There are two primary advantages to this type of heat exchanger. First, live steam cannot escape from the heat exchanger due to the inherent nature of the capacity control. Second, the heat exchanger does not require low pressure steam but rather operates at high pressure and eliminates the need for PRVs. This results in space and energy savings relative to the current configuration in the building.

Replace HID Lighting with LED

EH&S is currently equipped throughout with primarily HID (metal halide) high bay and low bay lighting. In the storage areas of the building, the lighting power density in Phase I and Phase II is 2.5 W/ft² and 0.98 W/ft² respectively. Replacing these luminaires with LED luminaires will lower the lighting power density by approximately 28% while maintaining a similar illuminance. A reduction in lighting power will reduce electricity demand and consumption. However, the primary benefit to replacing the HID luminaires with LED is to enable the implementation of automatic lighting controls. Currently the existing building does not include automatic lighting controls. This in part due to the limitations of HID lamps. HID lamps are not instant on and as such, automatic controls cannot be added to these luminaires. Using LED luminaires will allow the use of automatic lighting controls and dimming. When choosing to replace existing lighting technology, the advantages of LED lighting have made them the default choice in most new construction or replacement lighting applications. This includes lower power demand and improved controllability relative to fluorescent.

This ECO does not include replacement of the fluorescent luminaires in the office area as these luminaires are compatible with automatic lighting controls such as timers and occupancy sensors.

This ECO is required to implement the following two lighting control ECOs and further reduce lighting energy consumption.

LED Lighting with Occupancy Sensor Control

With this ECO occupancy sensors are added to interior lighting control zones. Each control zone would be equipped with at least one occupancy sensor to control the zone. Up to 50% of the lighting power in the control zone can be automatic on. The remaining lighting power must be manual on. The occupancy control will automatically turn the lighting off within 30 minutes of the last occupant vacating the control zone. This significantly reduces lighting energy consumption by reducing the amount of time the lighting is on.

Actual usage data of the building was not available to develop a lighting schedule to emulate the savings associated with the occupancy sensors. However, observed usage of the building during two separate site visits anecdotally indicated infrequent occupancy. For the purposes of this study and to gain a sense

of relative energy consumption with the addition of occupancy sensors, the lighting operation time was reduced by 25% in the storage areas and 10% in the office area.

As previously stated this ECO includes the previous ECO that replaces the HID luminaires with LED luminaires. In the office area, occupancy control are used with the existing luminaires and no additional first cost was added to replace those luminaires.

LED Lighting with Daylight Responsive Controls

With this ECO, daylight responsive controls are used to reduce the lighting power in perimeter lighting control zones where sufficient natural light exists to meet the space lighting requirements.

This ECO reduces lighting energy by further reducing interior lighting energy consumption in perimeter lighting control zones during the day when natural light is available.

As previously stated this ECO includes the previous ECO that replaces the HID luminaires with LED luminaires. In the office area, daylight responsive controls and dimming ballasts are added to the existing luminaires. The first cost associated with replacement of the existing ballasts is included in the first cost of this ECO.

Financial Analysis

Energy Estimate

Energy conservation option savings were estimated using full year, 8760 hour energy analysis using Trane Trace 700 energy analysis software. The campus provides steam and chilled water at the following rates:

- Steam - \$12.70 per Mlb
- Chilled water - \$0.225 per ton-hr

Electricity rates were derived from Xcel Energy's 2016 rates for Primary General Service.

The results of the energy analysis provide anticipated utility energy and power usage of the building:

- electrical demand (kW and \$)
- electrical consumption (kWh and \$)
- chilled water consumption (dth and \$)
- steam consumption (dth and \$)

Each energy conservation option was run in a separate alternative to calculate the utility energy savings relative to the Baseline Building performance. The exception to this methodology was for ECOs that required a previous ECO for implementation. For example, the indirect evaporative cooling ECO required the implementation of the run around loop ECO, so the energy analysis for this ECO included the run around loop as it was necessary for the implementation of the indirect evaporative cooling.

Utility Rates

Xcel utility rates from 2016 were used in the energy analysis of this study. The following rates were used for this study:

UTILITY RATES		
Electricity		
Summer Consumption	\$0.0368	per kWh
Winter Consumption	\$0.0392	per kWh
Summer Demand	\$18.32	per kW
Winter Demand	\$14.96	per kW
Chilled Water		
Consumption	\$1.874	per therm
Steam		
Consumption	\$1.266	per therm

Project Cost/Vendor Quotations

To develop simple paybacks, cost opinions were developed using a combination of 2017 RS Means data and budget pricing from vendors. The cost opinions include labor and materials of all anticipated work required to implement each ECO. The first cost included in the financial analysis includes anticipated credits for utility rebates.

Savings and Simple Payback

The following financial analysis table was developed using the first cost data from cost opinions and the results from the energy analysis. The result is a simple payback. Note that the utility cost savings (or cost) does not include costs associated with changes in maintenance costs. For example, evaporative cooling will increase maintenance cost while LED luminaires will reduce maintenance cost. Other ECOs, such as controls changes will not have an impact on maintenance costs. This is further discussed in the non-energy impacts section below.

Energy Conservation Option	FINANCIAL ANALYSIS					
	Chilled Water Savings dth	Steam Savings dth	Electricity Savings kWh	Utility Cost Savings \$	Approximate 1 st Cost \$	Simple Payback yrs
Exhaust air heat recovery	146.3	3,088.3	(177,889)	\$31,210	\$115,434	3.7
Direct evaporative cooling	639.8	95.8	(58,827)	\$9,605	\$150,585	16.1
Indirect evaporative cooling	264.7	3,088.3	(177,595)	\$33,443	\$154,941	4.5
Variable exhaust/make-up	50.5	1,073.7	90,499	\$20,057	\$89,112	4.4
VAV AHU-2 operation	0	8.8	2,757	\$329	\$10,285	31.3
VAV AHU-2 w/DCV	(12.7)	9.5	3,372	\$135	\$16,335	121.0
Flooded high pressure steam heat exchanger	0	304.2	0	\$3,851	\$115,895	30.1
HID lighting change to LED	46.7	(147.7)	62,346	\$2,761	\$68,849	24.9
LED lighting with occupancy sensors	72.3	(253.6)	103,900	\$4,398	\$81,736	18.6
LED lighting with daylight responsive controls	131.5	(247.7)	123,842	\$5,384	\$84,035	15.6

Non-Energy Project Impacts

Exhaust air heat recovery does not require scheduled preventative maintenance. It is anticipated that the water used for the run around loop will be shared with the heating water system. Scheduled water

treatment will not increase due to the addition of this system. Unscheduled maintenance will be slightly higher due to the additional pumps, control valves, and controls included in this system.

Variable flow exhaust/make-up does not require scheduled preventative maintenance. Unscheduled maintenance will be slightly higher due to the additional automatic air valves, manual air valves, variable exhaust, and controls included in this system.

Direct evaporative cooling and indirect evaporative cooling will require additional scheduled maintenance associated with water replacement and freeze protection. Additional unscheduled maintenance will increase resulting from additional pumps, compressors (atomizing system only), and evaporative media replacement.

AHU-2 VAV operation and demand controlled ventilation add controls and VFDs to the system. This does not add scheduled maintenance, but unscheduled maintenance associated with additional controls sensors and components will increase slightly.

Replacing the low-pressure steam to hot water heat exchanger with a high pressure flooded heat exchanger will not change scheduled maintenance. It is anticipated to result in a slight reduction in unscheduled maintenance. It simplifies the steam system by removing multiple PRV stations, condensate traps, and steam to hot water heat exchangers. In their place will be a single high pressure heat exchanger with a high pressure control valve.

Replacing the HID metal halide lighting with LED lighting will reduce scheduled maintenance by replacing consumable HID lamps with permanent LED.

The addition of occupancy sensors and daylight responsive lighting controls will not increase scheduled maintenance but may slightly increase unscheduled maintenance associated with upkeep and adjustment of the controls sensors and logic.

Implementation

Based on the simple payback analysis, not all the ECOs explored by this study merit further investigation. BCER Engineering recommends proceeding with the following energy conservation options:

- Exhaust air energy recovery
- Direct evaporative cooling
- Indirect evaporative cooling
- Variable exhaust/makeup
- HID replacement with LED and implementation of occupancy sensor control and daylight responsive controls

These energy conservation measures result in the shortest simple payback and result in the largest total energy savings. It should be noted however, that the exhaust air energy recovery and variable exhaust/makeup ECOs were each run alone and not together. While their first costs are additive, the associated energy savings is not additive. Implementing variable flow exhaust will reduce the amount of heat available for recovery by approximately 20%, lengthening the payback of the heat recovery ECO to approximately 5 yrs.

Measurement of Energy

To verify the energy savings associated with each of the implemented ECOs energy metering is recommended. Note that the cost associated with this metering is not included in the first cost of the ECOs.

To measure the heat reclaimed by the heat recovery run around loop, btu meters should be added to the heat recovery piping of the exhaust air heat recovery coil to quantify the total energy reclaimed by the heat recovery coil. An electric meter should be added to the run around loop pump to measure the amount of additional pump energy required to operate the heat reclaim loop. This energy consumption would be subtracted from the energy reclaimed by the heat recovery coil. The heat reclaim coils would add additional fan energy that would be difficult to accurately quantify. If desired, pressure differential sensors can be added to each heat recovery coil to measure the air flow resistance added to the fans. The associated additional fan power can be approximated from this pressure differential and the associated air flow.

Energy savings due to indirect evaporative cooling are difficult to measure separately from heat recovery. It is recommended that the same measurement technique for heat recovery be used for indirect evaporative cooling. Btu meters should be added to the heat recovery piping of the exhaust air heat recovery coil to quantify the total energy reclaimed. Although possible, it is difficult with this form of indirect evaporative cooling to separate the energy saved strictly by the indirect evaporative cooling from the energy reclaimed by the heat recovery system. To measure the energy saved strictly by the indirect evaporative cooling, an additional air flow measurement station would be required in the exhaust air stream and temperature sensors would be required before and after the evaporative cooling media. Additional software logic would calculate the sensible cooling achieved by the evaporative media and how much of the sensible cooling was applied to the outdoor air by the heat recovery system. It is unlikely that the additional metering required to break out the savings of the indirect evaporative cooling provides enough additional information to warrant the added cost.

The following sensors and logic are required to quantify the energy saved by the direct evaporative cooling. Using the outdoor air enthalpy, supply air enthalpy (downstream of the hydronic cooling coil), and an air flow measurement station the actual change in enthalpy can be calculated relative to the theoretical enthalpy that would have been required to provide the same supply air dry bulb temperature without the evaporative cooling. Without direct evaporative cooling, the supply air enthalpy will be lower than that of the system that includes direct evaporative cooling. The difference between these two enthalpy values represents the cooling energy saved.

To estimate the savings of the variable flow exhaust, no additional hardware is required. Only BAS programming logic is required. The air valves used to control the exhaust airflow act as air flow measurement stations. Using the airflow information from the exhaust control system in conjunction with the difference between the outdoor air temperature and the indoor air temperature, the amount of energy saved through reducing the makeup air flow can be calculated.

Multiple options exist to measure the energy savings associated with the change to LED lighting and the addition of automatic lighting controls. If an advance lighting control system is used to implement the automatic lighting controls, these systems frequently offer internal data logging capability which can quantify lighting power savings (with the addition of a workstation to store the data). This type of control can directly monitor the frequency and duration of occupancy sensor control and daylight responsive control which directly calculates the savings associated with these energy conservation measures. If more simplistic lighting controls are used that do not include this type of intelligent control, electrical energy meters can be added to the lighting circuits to measure the total energy consumed by the lighting. Measuring the energy consumption of lighting circuits does not directly convey the energy saved. To understand the total energy saved by the new lighting system, a baseline energy consumption must be established. This would require installation of the energy meters prior to implementation of the lighting control changes.

FOR REFERENCE ONLY

Perinatal Research Facility

Preliminary Work Session

November 26, 2013



University of Colorado
Denver



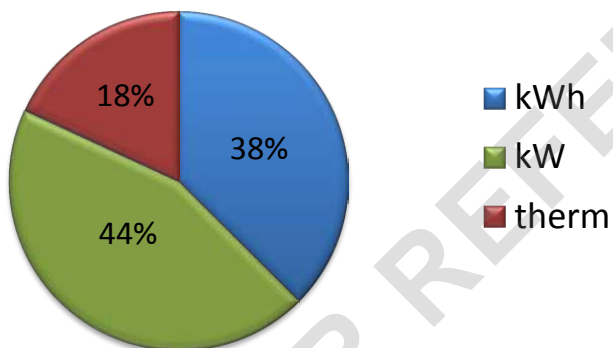
Agenda

- Utility Analysis
- Proposed Measures
- Cost/Benefit Review
- Additional Needs
- Next Steps

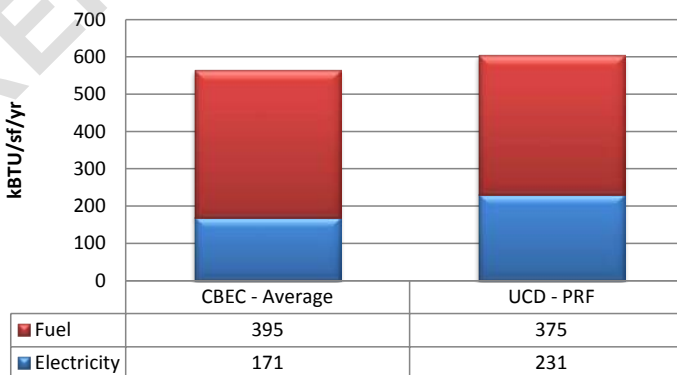
Utilities

Energy Costs					
Utilities	\$/kWh	\$ 0.04	Base Use	1535840 kWh	\$ 58,055 /yr
	\$/kW	\$ 19.78		3475 kW	\$ 68,736 /yr
	\$/therm	\$ 0.33		85000 therm	\$ 28,050 /yr

Energy Costs

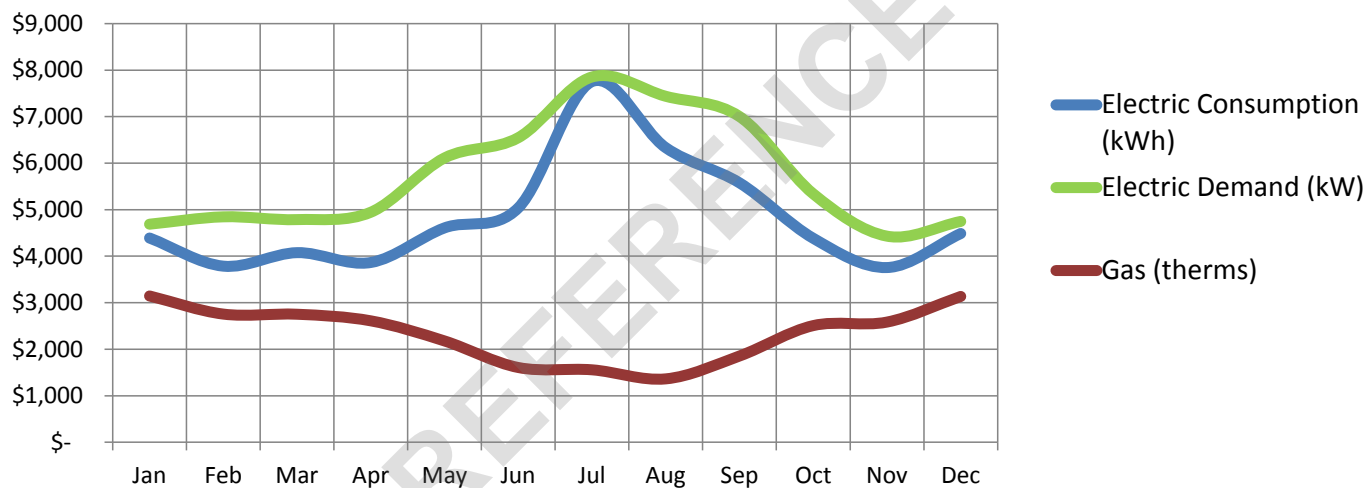


Energy Use Index

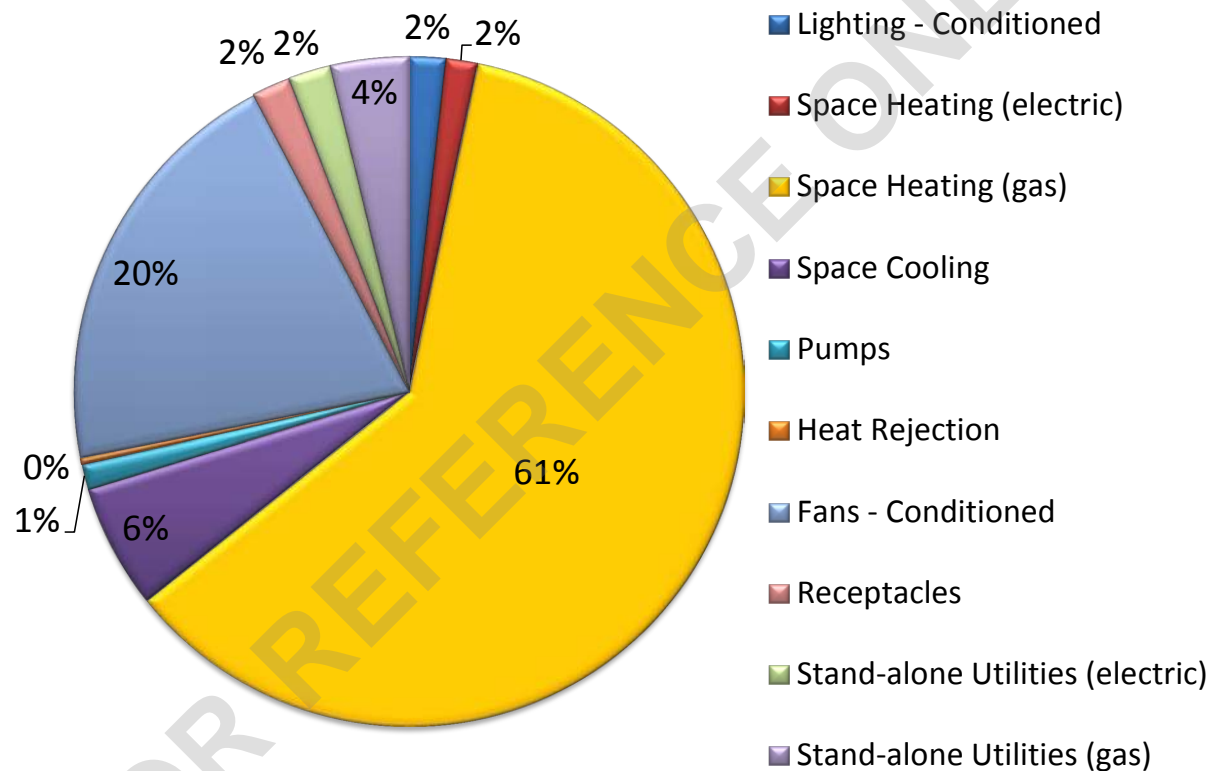


Measures

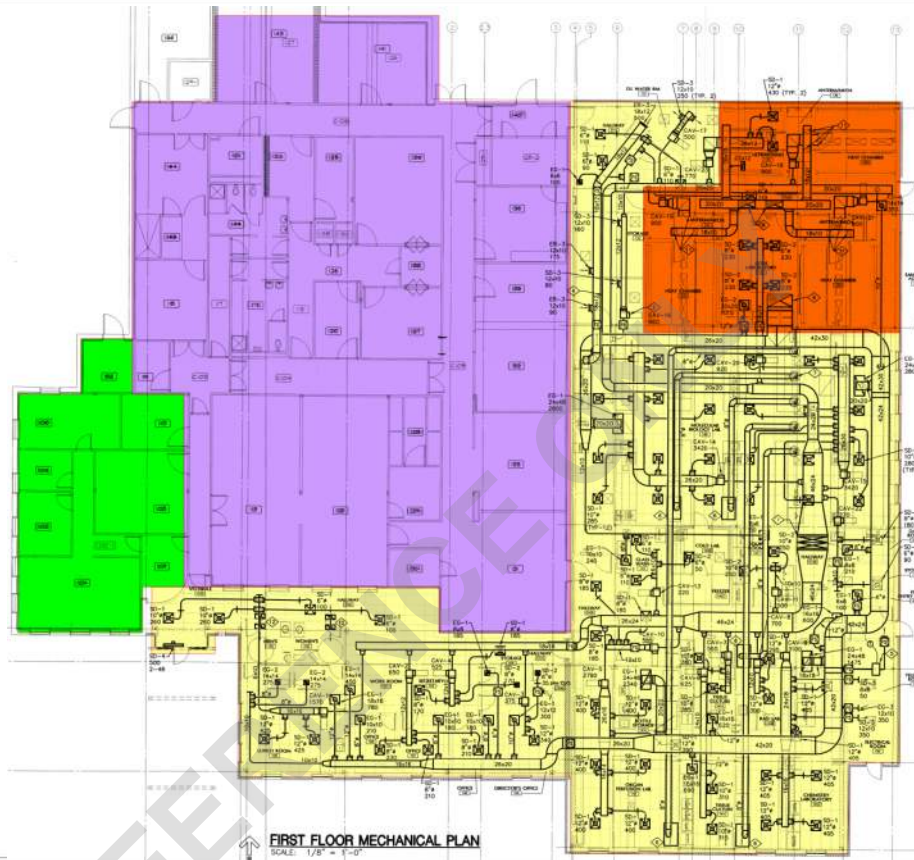
Monthly Utility Costs



Utilities - Energy By End Use



Perinatal Research Facility



Energy Conservation Measures

ECM#	ECM Name	Scope
1	Variable Speed HW Pumping	VFD for HWP1 and HWP2
2	Eliminate Steam System	Electric autoclave, ultrasonic humidifiers, gas HW
3	Exterior Lighting	LED Exterior Lighting
	Interior Lighting	Misc T12 and U Tube Replacements
4	AHU1 - Control + RTU at front office	Add night set back, SA reset, separate office zone with RTU
5	Reduce Duct Static Pressure	Remove attenuator, add dynamic air filter at AHU-1
6	PH1 - VVT/DDC Conversion	Add to DDC, replace pneum. Actuators, add reset schedule. Add ventilation night setback (PH-1), add temperature night setback (PH-2)
7	Heat Chamber Heat Recovery	Revise to dedicated ERV, SA Reset strategy, and reduced ventilation when not in use
8	Behavioral Changes / Greenlab	Increase freezer set point, consolidate autoclave loads, no incubators as refrigerator
9	Ground Source Heat Pump System	Replace air cooled chiller #2 with ground source heat pump system
10	Photovoltaics	15 kW - Roof Mounted
11	Photovoltaics	Parking Shade Structure with PV

Costs - Savings

ECM#	ECM Name	Guaranteed Energy Savings	Operational Savings	Total Estimated Savings	Estimated Cost Range		
1	Variable Speed HW Pumping	\$1,904	\$0	\$1,904	\$13,392	-	\$15,535
2	Eliminate Steam System	\$1,603	\$8,000	\$9,603	\$180,792	-	\$209,719
3	Lighting	\$556	\$720	\$1,276	\$13,091	-	\$15,185
4	AHU1 - Control + RTU at front office	\$22,760	\$80	\$22,840	\$133,920	-	\$155,347
5	Reduce Duct Static Pressure	\$4,528	\$4,200	\$8,728	\$120,193	-	\$139,424
6	PH1 - VVT/DDC Conversion	\$8,215	\$300	\$8,515	\$78,008	-	\$90,490
7	Heat Chamber Heat Recovery	\$1,619	\$0	\$1,619	\$31,471	-	\$36,507
8	Behavioral Changes / Greenlab	\$936	\$0	\$936	\$0	-	\$0
9	Ground Source Heat Pump System	\$20,919	\$400	\$21,319	\$828,630	-	\$961,211
10	Photovoltaics - Roof Mounted	\$1,437	\$0	\$1,437	\$61,380	-	\$71,201
11	Photovoltaics - Parking Structure	TBD	TBD	TBD	TBD	-	TBD

Measures Not Recommended

Reduce glycol percentage

High Efficiency Boilers

VAV Fume Hoods

AHU1 - VAV Control

LED Lab Lighting

Mechanical System Replacement - Chilled Beam

Next Steps

- Define scope
- Confirm pricing
- Final Working Session
- Final Investment Grade Audit Report

Appendix I

EXHIBIT A: CMGC DESIGNATED SERVICES AND METHOD OF PAYMENT

CONSTRUCTION MANAGER/GENERAL CONTRACTOR AGREEMENT
CMGC STANDARD FORMAT
(STATE FORM SC-6.4)

EXHIBIT A

CMGC DESIGNATED SERVICES AND METHOD OF PAYMENT

Exhibit A

Designated Services and Method of Payment
Clarifications

Exhibit A, Designated Services and Method of Payment, requests the CM/GC to include the following items in their estimates for the general conditions. This additional information/clarification is intended to augment the descriptions and requirements included within the actual matrix. Wherever the matrix includes more specific information or this document conflicts with the requirements noted in the matrix, the requirements included in the matrix govern.

1. A/E Trailer – (Temporary Facilities) - Will not be required.
2. Construction Manager's Payment & Performance Bonds – (Insurance and Bonds) - Base upon preliminary budget, will be adjusted if necessary.
3. General Liability, Automobile, Product Liability, and Excess Liability Insurance – (Insurance and Bonds) - Base upon preliminary budget, will be adjusted as necessary.
4. Builder's Risk Insurance – (Insurance and Bonds) - Base upon preliminary budget, will be adjusted as necessary. Costs begin when the construction starts.
5. Construction (Site) Fencing – (Temporary Facilities) - Assume fencing the entire site for the duration of the construction period.
6. Handrails & Toe Boards – (Temporary Facilities) - Provide allowance based on what would be reasonable for a project of this type and schedule.
7. Opening Protection – (Temporary Facilities) - Provide allowance based on what would be reasonable for a project of this type and schedule.
8. Temporary Stairs – (Temporary Facilities) - Provide allowance based on what would be reasonable for a project of this type and schedule.
9. Temporary Power Service – (On-Site Utilities and Services) - Provide allowance based on what would be reasonable for a project of this type and schedule.
10. Temporary Heating – (Temporary Heating) – The Temporary Heating Phase of Exhibit A contains and allocates many elements of anticipated reimbursable general conditions and direct costs. Provide appropriate allowances for these elements of reimbursable general conditions costs based upon what would be reasonable for a project of this type and schedule.
11. Field Inspector and trailer – (Quality Control) – The Quality Control Phase of Exhibit A contains and allocates many elements of anticipated reimbursable general conditions and direct costs. If the CM/GC submitting the proposal feels they will require Field Inspectors as part of their staff for managing the project, the appropriate costs should be reflected in the DPE for staff and reimbursable general condition expenses for transportation, office, and equipment. Please note and include as appropriate the other elements of general conditions cost included in Exhibit A's Quality Control Phase, project photographs, operator on-site training, and prepare operation/maintenance manuals.

Designated Services and Method of Payment

CONSTRUCTION MANAGEMENT SERVICES	REQUIRED OF CM/GC				REQUIRED OF ARCH	REQUIRED OF OWNER
	PRE- CONST SVCS FEE	CONST SVCS FEE	GEN CONDS.	DIRECT COST OF WORK		
PHASE: PRECONSTRUCTION						
ARCHITECTURAL SELECTION						X
STRUCTURAL, MECHANICAL AND ELECTRICAL (CONSULTANT)					1	2
SPECIAL CONSULTANT SELECTION						X
SURVEYOR SELECTION						X
SITE SELECTION RECOMMENDATIONS					2	1
REVIEW DESIGN CONCEPTS	X					
DEVELOP BID PACKAGES/SUB- CONTRACTING STRATEGY	1				2	
SITE USE RECOMMENDATIONS	2				1	
MATERIAL SELECTION RECOMMENDATIONS	2				1	
BUILDINGS SYSTEMS RECOMMENDATIONS	2				1	
BUILDING EQUIPMENT RECOMMENDATIONS (MOVEABLE)	2				2	1
BUILDING EQUIPMENT RECOMMENDATIONS (FIXED)	2	2			1	
CONSTRUCTION FEASIBILITY RECOMMENDATIONS	X					
PROJECT MASTER SCHEDULING	X					
BID PACKAGE RECOMMENDATIONS	1				2	
LIFE CYCLE COSTING ANALYSIS	2				1	
INFORMAL AND FORMAL VALUE ENGINEERING	X					
ENERGY USE ANALYSIS AND RECOMMENDATIONS	2				1	
PRELIMINARY TOTAL COST FEASIBILITY REVIEW	X					
LABOR AVAILABILITY REVIEW (SUBCONTRACTORS)	X					
MATERIAL EQUIPMENT AND CONTRACTOR AVAILABILITY	X					

Responsibility:

x = Total

1 = Primary

2 = Secondary

Designated Services and Method of Payment

CONSTRUCTION MANAGEMENT SERVICES	REQUIRED OF CM/GC				REQUIRED OF ARCH	REQUIRED OF OWNER
PHASE: PROJECT BUDGETING AND COST CONTROL	PRE- CONST SVCS FEE	CONST SVCS FEE	GEN CONDS.	DIRECT COST OF WORK		
TOTAL PROJECT COST BUDGET						X
CONSTRUCTION COST BUDGET	X					
CONSTRUCTION COST BUDGET ESTIMATES	X					
PRELIMINARY COST MODEL	X					
SCHEMATIC DESIGN PHASE ESTIMATES	X					
DESIGN DEVELOPMENT PHASE ESTIMATES	X					
BID PACKAGE/SUBCONTRACT ESTIMATES	X					
CASH FLOW PROJECTIONS	X					
PHASE FUNDING MODELING	X					
MATERIAL SURVEYS	X					
TRADE CONTRACTOR ESTIMATES	X					
CHANGE ORDER ESTIMATES			X			
SET-UP COST ACCOUNTING			X			
SET-UP REPORTING METHODS			X			
SET-UP PAYMENT PROCEDURES			2			1
SET-UP CHANGE ORDER PROCEDURES			1		2	1
CONTINUAL PROJECT COST MONITORING			1		2	1

Responsibility:

x = Total

1 = Primary

2 = Secondary

Designated Services and Method of Payment

CONSTRUCTION MANAGEMENT SERVICES	REQUIRED OF CM/GC				REQUIRED OF ARCH	REQUIRED OF OWNER
PHASE: SUB-CONTRACTING SELECTION AND PURCHASING	PRE- CONST SVCS FEE	CONST SVCS FEE	GEN CONDS.	DIRECT COST OF WORK		
SET PRE-QUALIFICATION CRITERIA	X					
RECOMMEND CONTRACTOR SELECTION METHODS	X					
RECOMMEND CONTRACTOR AWARD SELECTION METHODS	X					
DEVELOP CONTRACTOR INTEREST	X					
PREPARE BIDDING SCHEDULES	X					
CONDUCT PRE-BID CONFERENCE AND ISSUE PLANS	X					
RECEIVE BIDS	X					
ANALYZE BIDS	X					
RECOMMEND AWARD	1				2	
VERIFY UNIT COSTS	X					
NEGOTIATE UNION RATES AND MANPOWER COSTS REQUIRED		X				
CONDUCT PRE-AWARD CONFERENCE			X			
PREPARE CONTRACTS	X					
SUPPLIER AND SUBCONTRACTOR REVIEW	X					
ORIGINATE RFI'S AFTER SCREENING			X			
PREPARE CHANGE ORDERS			2		1	
VERIFY CORRECTNESS OF QUANTITIES AND PRICES OF CHANGE ORDERS			1		2	
COORDINATE OWNER-SUPPLIED FIXED EQUIPMENT			2		1	1

Responsibility:

x = Total

1 = Primary

2 = Secondary

Designated Services and Method of Payment

CONSTRUCTION MANAGEMENT SERVICES	REQUIRED OF CM/GC				REQUIRED OF ARCH	REQUIRED OF OWNER
PHASE: CONTRACT DOCUMENTS COORDINATION	PRE- CONST SVCS FEE	CONST SVCS FEE	GEN CONDS.	DIRECT COST OF WORK		
FEASIBILITY REVIEW AND RECOMMENDATIONS	X					
CONSTRUCTIBILITY REVIEW AND RECOMMENDATIONS	X					
SUBCONTRACTOR WORK SCOPING	X					
RESPONSIBILITY FOR: SAFETY PRECAUTIONS			X			
SAFETY PROGRAMS			X			
TEMPORARY FACILITIES			X			
COMMON USE EQUIPMENT			X			
COMMON USE SERVICES			X			
REVIEW FOR: JURISDICTIONAL OVERLAP	X					
INCLUSION OF ALL WORK	X					
PHASE CONSTRUCTION COORD.	X					
IDENTIFY LONG LEAD ITEMS	X					
OBTAIN AGENCY APPROVALS					2	1
ASSIST IN OBTAINING PERMITS (AS NEEDED)			X			

Responsibility:

x = Total

1 = Primary

2 = Secondary

Designated Services and Method of Payment

CONSTRUCTION MANAGEMENT SERVICES	REQUIRED OF CM/GC				REQUIRED OF ARCH	REQUIRED OF OWNER
PHASE: CONSTRUCTION PHASE STAFF	PRE- CONST SVCS FEE	CONST SVCS FEE	GEN CONDS.	DIRECT COST OF WORK		
PROJECT MANAGER (AS REQUIRED)			X			
PROJECT SUPERINTENDENT (AS REQUIRED)			X			
ASSISTANT PROJECT SUPERINTENDENT			X			
MECHANICAL COORDINATOR (AS REQUIRED)			X			
ELECTRICAL COORDINATOR (AS REQUIRED)			X			
OFFICE ENGINEER (AS REQUIRED)			X			
ENGINEERING AND LAYOUT (AS REQUIRED)				X		
FIELD ENGINEER-LINE AND GRADE (AS REQUIRED)				X		
DRAWING CHECKER (AS REQUIRED)			X			
TIME KEEPER/CHECKER (AS REQUIRED)			X			
SCHEDULING ENGINEER (AS REQUIRED)			X			
PROJECT COORDINATOR			X			
COST ENGINEER (AS REQUIRED)			X			
CLERK-TYPIST (AS REQUIRED)			X			
RODMAN AND HELPERS (AS REQUIRED)				X		
SAFETY ENGINEER (AS REQUIRED)			X			

Responsibility:

x = Total

1 = Primary

2 = Secondary

Designated Services and Method of Payment

CONSTRUCTION MANAGEMENT SERVICES	REQUIRED OF CM/GC				REQUIRED OF ARCH	REQUIRED OF OWNER
PHASE: TRAVEL AND LODGING	PRE- CONST SVCS FEE	CONST SVCS FEE	GEN CONDS.	DIRECT COST OF WORK		
STAFF TRAVEL COST		X				
STAFF TRANSPORTATION		X				
PROJECT STAFF MOVING EXPENSES		X				
PROJECT STAFF SUBSISTENCE COSTS			X			
PHASE: TEMPORARY FACILITIES						
SAFETY EQUIPMENT AND FIRST AID SUPPLIES			X			
HANDRAILS AND TOE BOARDS			X			
OPENING PROTECTION			X			
FIRE EXTINGUISHERS			X			
WATCHMAN SERVICE				X		
OFFICE OR TRAILER RENTAL			X			
WATERBOY CUPS			X			
TEMPORARY STAIRS			X			
PROJECT SIGNS			X			
BULLETIN BOARDS			X			
CONSTRUCTION FENCING			X			
BARRICADES AND COVERED WALKWAYS (AS REQUIRED)				X		
SAFETY NETS (AS REQUIRED)				X		
A/E TEMPORARY OFFICE			X			
TEMPORARY TOILETS			X			

Responsibility:

x = Total

1 = Primary

2 = Secondary

Designated Services and Method of Payment

CONSTRUCTION MANAGEMENT SERVICES	REQUIRED OF CM/GC				REQUIRED OF ARCH	REQUIRED OF OWNER
PHASE: ON-SITE UTILITIES AND SERVICES	PRE- CONST SVCS FEE	CONST SVCS FEE	GEN CONDS.	DIRECT COST OF WORK		
TEMPORARY TELEPHONE INSTALLATION AND EXPENSE (INCLUDING LOCAL A/E)			X			
TEMPORARY POWER SERVICE			X			
POWER SERVICE			X			
TEMPORARY WATER AND HEATING			X			
HEATING ENERGY CHARGES				X		
TEMPORARY WIRING				X		
LIGHT BULBS				X		
DAILY CLEAN-UP			1	2		
WEEKLY TRASH-REMOVAL			1	2		
FINAL CLEAN-UP			1	2		
DUMP PERMITS AND FEES				X		
DEBRIS HAULING/REMOVAL				X		
FLAGMAN/TRAFFIC CONTROL (AS REQUIRED)				X		
FUELS FOR INITIAL TANK FILLING				X		
TEMPORARY ROADS				X		
ROADWAY MAINTENANCE				X		
DUST CONTROLS				X		
TEMPORARY EROSION CONTROL				X		
TEMP. WATER /SEWER EXPENSE & WATER EXPENSES - SITE GRADING & COMPACTION				X		
TWO-WAY RADIO EQUIPMENT (AS REQUIRED)			X			
TRASH CHUTE AND HOPPERS (AS REQUIRED)				X		

Responsibility:

x = Total

1 = Primary

2 = Secondary

Designated Services and Method of Payment

CONSTRUCTION MANAGEMENT SERVICES	REQUIRED OF CM/GC				REQUIRED OF ARCH	REQUIRED OF OWNER
PHASE: ON-SITE EQUIPMENT	PRE- CONST SVCS FEE	CONST SVCS FEE	GEN CONDS.	DIRECT COST OF WORK		
AUTOMOBILE AND FUEL (AS REQUIRED)			X			
PICK-UP TRUCK AND FUEL (AS REQUIRED)			X			
FLATBED TRUCK AND FUEL (AS REQUIRED)			X			
WATER TRUCK (AS REQUIRED)				X		
AIR COMPRESSOR AND FUEL (AS REQUIRED)				X		
DEWATERING EQUIPMENT AND FUEL (AS REQUIRED)				X		
TEMPORARY GENERATOR AND FUEL (AS REQUIRED)			X			
DEBRIS REMOVAL/HAULING EQUIPMENT (AS REQUIRED)				X		
SNOW REMOVAL (AS REQUIRED)			X			
TIRES AND MAINTENANCE COST (AS REQUIRED)			X			
FORKLIFT OPERATOR				X		
MATERIAL HOIST OPERATOR			X			
PERSONNEL OPERATOR			X			
FIXED CRANE OPERATOR				X		
TRAVEL CRANE OPERATOR				X		

Responsibility:

x = Total

1 = Primary

2 = Secondary

Designated Services and Method of Payment

CONSTRUCTION MANAGEMENT SERVICES	REQUIRED OF CM/GC				REQUIRED OF ARCH	REQUIRED OF OWNER
PHASE: TEMPORARY HEATING	PRE- CONST SVCS FEE	CONST SVCS FEE	GEN CONDS.	DIRECT COST OF WORK		
REMOVE SNOW AND ICE (AS REQUIRED)			X			
TEMPORARY ENCLOSURES (AS REQUIRED)				X		
PIPING COST IN BUILDING (AS REQUIRED)			X			
FUEL COST FOR HEATING (AS REQUIRED)				X		
POWER COST FOR HEATING (AS REQUIRED)			X			
FURNACE RENTAL (AS REQUIRED)			X			
HEATER RENTAL (AS REQUIRED)			X			
BOILER RENTAL (AS REQUIRED)			X			
OPERATOR - TEMPORARY SYSTEMS (AS REQUIRED)			X			
OPERATION FIRE WATCH (AS REQUIRED)				X		
CLEANING COST (AS REQUIRED)				X		
MAINTENANCE COST (AS REQUIRED)				X		
EXTENDED WARRANTY COST (AS REQUIRED)				X		
FILTER CHANGE (AS REQUIRED)				X		
TEMPORARY OFFICE HEATING (AS REQUIRED)			X			
TEMP WEATHER PROTECTION & HEATING FOR SUBCONTRACTORS (AS REQ'D)				X		

Responsibility:

x = Total

1 = Primary

2 = Secondary

Designated Services and Method of Payment

CONSTRUCTION MANAGEMENT SERVICES	REQUIRED OF CM/GC				REQUIRED OF ARCH	REQUIRED OF OWNER
PHASE: REPRODUCTION/PRINTING AND DATA PROCESSING	PRE- CONST SVCS FEE	CONST SVCS FEE	GEN CONDS.	DIRECT COST OF WORK		
COST STUDY DOCUMENTS					X	
SYSTEMS STUDY DOCUMENTS					X	
BID PACKAGE SETS (SEE PARAGRAPH 5.1.4)				2		1
BIDDING INSTRUCTIONS	X					
CONSTRUCTION DOCUMENTS ORIGINAL					X	
POSTAGE AND EXPRESS COSTS (CM/GC ISSUES PLANS)			X			
AS-BUILT SUB-DOCUMENTS				X		
AS-BUILT DOCUMENTS			X			
ACCOUNTING FORMS		X				
FIELD REPORTING FORMS			X			
SUBCONTRACT AGREEMENT FORMS	X					
SCHEDULE REPORT FORMS			X			
ESTIMATING FORMS	X					
COST REPORTING FORMS	X					
VALUE ANALYSIS STUDIES PRINTING	X					
DATA PROCESSING (MAIN OFFICE)		X				
REFERENCE MATERIALS			X			
SHOP DRAWING PRINTING				X		
ON-SITE FAX AND COPIER			X			
DATA PROCESSING (ON-SITE)			X			
MAINTENANCE MANUALS (FROM SUBS) AND OPERATIONS MANUALS (FROM SUBS)				X		

Responsibility:

x = Total

1 = Primary

2 = Secondary

Designated Services and Method of Payment

CONSTRUCTION MANAGEMENT SERVICES	REQUIRED OF CM/GC				REQUIRED OF ARCH	REQUIRED OF OWNER
PHASE: QUALITY CONTROL	PRE- CONST SVCS FEE	CONST SVCS FEE	GEN CONDS.	DIRECT COST OF WORK		
FIELD INSPECTOR (AS REQUIRED)			X			
INSPECTORS' OFFICE (AS REQUIRED)			X			
INSPECTORS' TRANSPORTATION (AS REQUIRED)			X			
INSPECTORS' EQUIPMENT (AS REQUIRED)			X			
SPECIAL INSPECTION CONSULTANTS						X
SPECIAL TESTING CONSULTANTS						X
CONCRETE SUBSTRUCTURE- OBSERVATIONS						X
CONCRETE TESTING						X
MASONRY TESTING						X
COMPACTION TESTING						X
WELDING TESTING						X
PIER INSPECTION/TESTING						X
SOILS INVESTIGATION						X
SPECIAL TESTING SERVICES (EXCEPT AS NOTED)						X
PROJECT PHOTOGRAPHS			X			
WARRANTY INSPECTIONS		1			2	
AIR AND WATER BALANCING				X		
OPERATOR ON-SITE TRAINING			X			
PREPARE OPERATION/MAINTENANCE MANUALS			2	1		

Responsibility:

x = Total

1 = Primary

2 = Secondary

Designated Services and Method of Payment

CONSTRUCTION MANAGEMENT SERVICES	REQUIRED OF CM/GC				REQUIRED OF ARCH	REQUIRED OF OWNER
PHASE: PERMITS AND SPECIAL FEES	PRE- CONST SVCS FEE	CONST SVCS FEE	GEN CONDS.	DIRECT COST OF WORK		
STORAGE YARD RENTAL				X		
PARKING LOT RENTALS AND SHUTTLE EXPENSES (AS REQUIRED)				2		1
FIELD OFFICE STAFF PARKING FEES			X			
SIGN PERMITS			X			
STREET/CURB PERMIT				X		
BUILDING PERMITS						X
PLAN CHECK FEES						X
WATER SYSTEM DEV. FEE						X
SEWER USE & DRAINAGE PERMIT/DEV. FEE						X
STORM CONNECTION FEE						X
GAS AND POWER SERVICE CHARGE (PERMANENT)						X
GAS AND POWER SERVICE CHARGE (TEMPORARY)				X		
STEAM SERVICE CHARGE						X
CHILLER WATER SERVICE CHARGE						X
SPECIAL TAP FEES						X
CONTRACTORS LICENSES		X				
CONSTRUCTION EQUIPMENT LICENSES		X				
CONSTRUCTION EQUIPMENT PERMITS				X		

Responsibility:

x = Total

1 = Primary

2 = Secondary

Designated Services and Method of Payment

CONSTRUCTION MANAGEMENT SERVICES	REQUIRED OF CM/GC				REQUIRED OF ARCH	REQUIRED OF OWNER
PHASE: INSURANCE AND BONDS	PRE- CONST SVCS FEE	CONST SVCS FEE	GEN CONDS.	DIRECT COST OF WORK		
BUILDERS RISK INSURANCE			X			
GENERAL LIABILITY, INCLUDING AUTOMOBILE			X			
PRODUCT LIABILITY			X			
EXCESS LIABILITY COVERAGE			X			
WORKERS COMPENSATION (FIELD OFFICE STAFF)			X			
FICA INSURANCE (FIELD OFFICE STAFF)			X			
FEDERAL UNEMPLOYMENT (FIELD OFFICE STAFF)			X			
STATE UNEMPLOYMENT (FIELD OFFICE STAFF)			X			
CONSTRUCTION MANAGER'S PAYMENT BOND			X			
CONSTRUCTION MANAGER'S PERFORMANCE BOND			X			
STATE/LOCAL BONDS				X		
* SUBCONTRACTOR BONDS				X		

Responsibility:

x = Total

1 = Primary

2 = Secondary

* ONLY AS MUTUALLY AGREED UPON BETWEEN THE PRINCIPAL REPRESENTATIVE AND THE CM.

Designated Services and Method of Payment

CONSTRUCTION MANAGEMENT SERVICES	REQUIRED OF CM/GC				REQUIRED OF ARCH	REQUIRED OF OWNER
PHASE: OTHER COSTS	PRE- CONST SVCS FEE	CONST SVCS FEE	GEN CONDS.	DIRECT COST OF WORK		
CONSTRUCTION EQUIPMENT				X		
CONSTRUCTION SERVICES LABOR				X		
CONSTRUCTION MATERIALS				X		
COST OF DESIGN AND ENGINEERING						X
A/E FAST TRACK COST EXTRAS						X
PRELIMINARY SOILS INVESTIGATION						X
TITLE/DEVELOPMENT COST						X
BUILDING OPERATION AFTER MOVE-IN						X
BUILDING MAINTENANCE AFTER MOVE-IN						X
MOVING COORDINATION						X
MOVING COSTS						X
COSTS OF EMERGENCY WORK				X		
CM GENERAL OVERHEAD COST		X				
CM PROFIT MARGIN		X				
GMP FINANCIAL RESPONSIBILITIES		X				
STATE REQUIRED INSPECTIONS						X

Responsibility:

x = Total

1 = Primary

2 = Secondary

Designated Services and Method of Payment

CONSTRUCTION MANAGEMENT SERVICES	REQUIRED OF CM/GC				REQUIRED OF ARCH	REQUIRED OF OWNER
PHASE: OFF-SITE SERVICES	PRE- CONST SVCS FEE	CONST SVCS FEE	GEN CONDS.	DIRECT COST OF WORK		
CORPORATE EXECUTIVES (AS REQUIRED)	X	X				
PRINCIPAL IN CHARGE (AS REQUIRED)	X	X				
PROJECT EXECUTIVE (AS REQUIRED)	X	X				
LEGAL - BASIC SERVICES (AS REQUIRED)	X	X				
ACCOUNTING (AS REQUIRED)		X				
PURCHASING (AS REQUIRED)	X					
SAFETY OFFICER (AS REQUIRED)		X				
EEO OFFICER (AS REQUIRED)	X	X				
SECRETARIAL AND CLERK-TYPIST (AS REQUIRED)	X	X				
BENEFITS AND VACATIONS FOR ABOVE	X	X				

Responsibility:

x = Total

1 = Primary

2 = Secondary

APPENDIX J

UNIVERSITY SUPPLEMENTAL TERMS AND CONDITIONS

**STATE OF COLORADO
OFFICE OF THE STATE ARCHITECT
STATE BUILDINGS PROGRAM**

**CONSTRUCTION MANAGER/GENERAL CONTRACTOR (CM/GC) AGREEMENT
(STATE FORM SC-6.4)**

EXHIBIT P

**UNIVERSITY OF COLORADO DENVER | ANSCHUTZ MEDICAL CAMPUS CONSTRUCTION
MANAGER/GENERAL CONTRACTOR – SUPPLEMENTARY GENERAL CONDITIONS**

The Construction Manager/General Contractor Agreement shall be amended as follows:

Article 3.4.2.2 Change language to: The construction contingency for the Work shall be equal to three percent (3.0%) of the initial Guaranteed Maximum Price.

The terms University, University of Colorado, University of Colorado Denver, University of Colorado Anschutz Medical Campus, CU Denver, CU Anschutz, Principal Representative, are the interchangeable for this replacement of Article 11.

ARTICLE 11 INSURANCE - Replace Article 11 as follows:

For purposes of this supplement “Contractor” as used herein shall mean, as appropriate to the State Contract form being used, Contractor, Standing Order Contractor, Construction Manager/General Contractor, or Design/Build Entity.

The Contractor shall obtain and maintain, at its own expense and for the duration of the contract including any warranty periods under the Contract are satisfied, the insurance coverages set forth below.

By requiring such insurance, the Principal Representative shall not be deemed or construed to have assessed the risk that may be applicable to the Contractor its agents, representatives, employees or subcontractors under this contract. The insurance requirements herein for this Contract in no way limit the indemnity covenants contained in the Contract. The Principal Representative in no way warrants that the limits contained herein are sufficient to protect the Contractor from liabilities that might arise out of the performance of the work under this Contract by the Contractor, its agents, representatives, employees, or subcontractors. The Contractor shall assess its own risks and if it deems appropriate and/or prudent, maintain higher limits and/or broader coverages. The Contractor is not relieved of any liability or other obligations assumed or pursuant to the Contract by reason of its failure to obtain or maintain insurance in sufficient amounts, duration, or types.

COVERAGES AND LIMITS OF INSURANCE - - Contractor shall provide coverage with limits of liability not less than those stated below.

1. **Commercial General Liability – ISO CG 0001 or equivalent. Coverage to include:**
 - Premises and Operations
 - Explosions, Collapse and Underground Hazards
 - Personal / Advertising Injury

- Products / Completed Operations
- Liability assumed under an Insured Contract (including defense costs assumed under contract)
- Independent Contractors
- Designated Construction Projects(s) General Aggregate Limit, ISO CG 2503 (1997 Edition)
- Additional Insured—Owners, Lessees or Contractors Endorsement, ISO Form 2010 (2004 Edition or equivalent)
- Additional Insured—Owners, Lessees or Contractors Endorsement (Completed Operations), ISO CG 2037 (7/2004 Edition or equivalent)
- **The policy shall be endorsed to include the following additional insured language on the Additional Insured Endorsements specified above: “The Regents of the University of Colorado, a Body Corporate, named as an additional insured with respect to liability and defense of suits arising out of the activities performed by, or on behalf of the Contractor, including completed operations”.**
- Commercial General Liability Completed Operations policies must be kept in effect for up to three (3) years after completion of the project. For buildings with a construction cost greater than \$99 million, the Commercial General Liability Completed Operations policies must be kept in effect for up to eight (8) years after the completion of the project.
- **An umbrella and/or excess liability policy may be used to meet the minimum liability requirements provided that the coverage is written on a “following form” basis.**

Liability Limits	General Aggregate	Products/Completed Operation Aggregate	Each Occurrence	Personal/Advertising Injury
Primary General Liability	\$2,000,000	\$2,000,000	\$1,000,000	\$1,000,000
Umbrella or Excess Liability*	\$5,000,000	\$5,000,000	\$5,000,000	\$5,000,000

***Umbrella or Excess Liability does not apply to projects totaling \$500,000 or under.**

The following exclusionary endorsements are prohibited in the CGL policy:

1. Damage to work performed by subcontract/vendor (CG 22-94 or similar);
2. Contractual liability coverage exclusion modifying or deleting the definition of an “insured contract”;
3. If applicable to the work to be performed: Residential or multi-family;
4. If applicable to the work to be performed: Exterior insulation finish systems;
5. If applicable to the work to be performed: Subsidence or earth movement.

2. **Automobile Liability**

Bodily Injury and Property Damage for any owned, hired, and non-owned vehicles used in the performance of this contract

Minimum Limits:

Bodily Injury/Property Damage (Each Accident)	\$	1,000,000
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3. **Workers Compensation**

- Statutory Benefits (Coverage A)
 - Employers Liability (Coverage B)
- a. Policy shall contain a waiver of subrogation in favor of the Principal Representative.
- b. This requirement shall not apply when a contractor or subcontractor is exempt under Colorado Workers' Compensation Act., **AND** when such contractor or subcontractor executes the appropriate sole proprietor waiver form.

Minimum Limits:

Coverage A (Workers' Compensation)	Statutory
Coverage B (Employers Liability)	
Each accident	\$ 100,000
Disease each employee	\$ 100,000
Disease policy limit	\$ 500,000

4. **Contractors Pollution Liability**

- Coverage shall apply to sudden and gradual pollution conditions resulting from the escape of release of smoke, vapors, fumes, acids, alkalis, toxic chemicals, liquids, or gases, natural gas, waste materials, or other irritants, contaminants, or pollutants (including asbestos). Policy shall cover the Contractor's completed operations.
- If the coverage is written on a claims-made basis, the Contractor warrants that any retroactive date applicable to coverage under the policy precedes the effective date of this Contract; and that continuous coverage will be maintained or an extended discovery period will be exercised for a period of three (3) years beginning from the time that work under this contract is completed.
- **The policy shall be endorsed to include the following as Additional Insureds: The Regents of the University of Colorado, a Body Corporate, named as an additional insured with respect to liability and defense of suits arising out of the activities performed by, or on behalf of the Construction Manager, including completed operations.**
- Endorsements CA9948 and MCS-90 are required on the Automobile Liability Coverage if the Contractor is transporting any type of hazardous materials.
- **Contractors Pollution Liability policies must be kept in effect for up to three (3) years after completion of the project.**

Minimum Limits (Projects at or under \$500,000):

Per Loss	\$	1,000,000
Aggregate	\$	1,000,000

Minimum Limits (Projects over \$500,000):

Per Loss	\$	2,000,000
Aggregate	\$	2,000,000

5. **Professional Liability (Errors and Omissions)**

(This Professional Liability requirement applies only to Design/Build Entity SC-8.0 and 9.0.)

- The Contractor shall maintain Errors and Omissions Liability covering negligent acts, errors and/or omissions, including design errors of the Contractor for damage sustained by reason of or in the course of operations under this Contract. The policy/coverages shall be amended to include the following:

Amendment of any Contractual Liability Exclusion to state: "This exclusion does not apply to any liability of others which you assume under a written contract provided such liability is caused by your negligent acts."

- In the event that any professional liability insurance required by this Contract is written on a claims-made basis, Contractor warrants that any retroactive date under the policy shall precede the effective date of this Contract; and that either continuous coverage will be maintained or an extended discovery period will be exercised for a period of three (3) years beginning at the time work under this Contract is completed.
- Policy shall contain a waiver of subrogation against The Regents of the University of Colorado, a Body Corporate.

Wrongful Act	\$2,000,000
General Aggregate	\$2,000,000

6. **Builder's Risk/ Installation Floater**

Unless otherwise provided or instructed by the Principal Representative, the Contractor shall purchase and maintain, in a company or companies lawfully authorized to do business in the jurisdiction in which the project is located, Builder's Risk Insurance in the amount of the initial contract amount as well as subsequent modifications for the entire project at the site on a replacement cost basis without optional deductibles. This coverage is required for new buildings or additions to existing buildings and for materials and equipment to be installed in existing structures.

- Covered Cause of Loss: Special Form
 - Include Theft and Vandalism
 - Labor costs to repair damaged work
 - Shall be written for 100% of the completed value (replacement cost basis)
 - Deductible maximum is \$50,000.00
 - Waiver of Subrogation is to apply
 - The Regents of the University of Colorado, a body corporate, shall be added as **Additional Named Insured on Builders Risk.**
1. Policy must provide coverage from the time any covered property becomes the responsibility of the Contractor, and continue without interruption during construction, renovation, or installation, including any time during which the covered property is being transported to the construction installation site, or awaiting installation, whether on or off site.
 2. The Policy shall be maintained, unless otherwise provided in the contract documents or otherwise agreed in writing by all persons and entities who are beneficiaries of such insurance, until final payment has been made or until no person or entity other than the Principal Representative has insurable interest in the property to be covered, whichever is later.
 3. The Builder's Risk insurance shall include interests of the Principal Representative, and if applicable, affiliated or associated entities, the General Contractor,

- subcontractors and sub-tier contractors in the project.
4. Builders' Risk Coverage shall be on a **Special** Covered Cause of Loss Form and shall include theft, vandalism, malicious mischief, collapse, false-work, temporary buildings and debris removal including demolition, increased cost of construction, architect's fees and expenses, flood (including water damage), earthquake, and if applicable, all below and above ground structures, piping, foundations including underground water and sewer mains, piling including the ground on which the structure rests and excavation, backfilling, filling, and grading. Equipment Breakdown Coverage (a.k.a. Boiler & Machinery) shall be included as required by the Contract Documents or by law, which shall specifically cover insured equipment during installation and testing (including hot testing, where applicable). Other coverages may be required if provided in contract documents.
 5. The Builders' Risk shall be written for 100% of the completed value (replacement cost basis) of the work being performed. The Builders' Risk shall include the following provisions:
 - a. Replacement Cost Basis - including modification of the valuation clause to cover all costs needed to repair the structure or work (including overhead and profits) and will pay based on the values figured at the time of rebuilding or repairing, not at the time of loss
 - b. Modify or delete exclusion pertaining to damage to interior of building caused by an perils insured against are covered; also provide coverage for water damage

Note, if the addition, or renovation is to an existing building, The Principal Representative requires that the Contractor provide as an option to include the existing building into the Builders' Risk Policy. The Principal Representative shall provide the replacement cost value of the existing building
 6. At the option of the Principal Representative, the Principal Representative may include Soft Costs (including Loss of Use)/Delay in Opening Endorsement under the builder's risk policy. The Principal Representative agrees to provide the necessary exposure base information for quotation by the Builder's Risk carrier. The Principal Representative agrees to pay the premium associated with the Soft Costs coverage, the Principal Representative decides to purchase this coverage.
 7. The Builders' Risk Policy shall specifically permit occupancy of the building during construction. Partial occupancy or use of the work shall not commence until the insurance company or companies providing insurance have consented to such partial occupancy or use. The Principal Representative and Contractor shall take reasonable steps to obtain consent of the insurance company or companies and delete any provisions with regard to restrictions within any Occupancy Clauses within the Builders' Risk Policy. The Builders' Risk Policy shall remain in force until acceptance of the project by the Principal Representative.
 8. The deductible shall not exceed \$50,000 and shall be the responsibility of the Contractor except for losses such as flood (not water damage), earthquake, windstorm, tsunami, volcano, etc. Losses in excess of \$50,000 insured shall be adjusted in conjunction with the Principal Representative. Any insurance payments/proceeds shall be made payable to the Principal Representative subject to requirements of any applicable mortgagee clause.

The Contractor shall pay subcontractors their just shares of insurance proceeds received by the Contractor, and by appropriate agreements, written where legally required for validity, shall require subcontractors to make payments to their sub-subcontractors in similar manner.

The Principal Representative shall have the authority to adjust and settle any losses in excess of \$50,000 with insurers unless one of the parties in interest shall object in writing within five days after occurrence of loss to the Principal Representative exercise of this power. It is expressly agreed that nothing in this section shall be subject to arbitration and any references to arbitration are expressly deleted.

9. The Contractor is responsible for providing 45 days' notice of cancellation to the Principal Representative. The policy shall contain all generally applicable conditions, definitions, exclusions and endorsements related to the Project.

If the Contractor does not intend to purchase such Builder's Risk Insurance required by the Contract and with all of the coverages in the amount described above, the Contractor shall so inform the Principal Representative as stated in writing prior to commencement of the work. The Principal Representative may then affect insurance that will protect the interests of the Principal Representative, the General Contractor, Subcontractors and sub-tier contractors in the project. Coverages applying shall be the same as stated above including other coverages that may be required by the Principal Representative. The cost shall be charged to the Contractor. Coverage shall be written for 100% of the completed value of the work being performed, with a deductible not to exceed \$50,000 per occurrence for most projects.

All deductibles will be assumed by the Contractor. Waiver of Subrogation is to apply against all parties named as insureds, but only to the extent the loss is covered, and Beneficial Occupancy Endorsements are to apply.

If the Principal Representative is damaged by the failure or neglect of the Contractor to purchase or maintain insurance as described above, without so notifying the Principal Representative, then the Contractor shall bear all reasonable costs properly attributable thereto.

ADDITIONAL INSURANCE REQUIREMENTS

1. All insurers must be licensed or approved to do business within the State of Colorado, and unless otherwise specified, all policies must be written on a per occurrence basis.
2. Contractor's insurance carrier should possess a minimum A.M. Best's Insurance Guide rating of A- VI.
3. On insurance policies where the Principal Representative are named as additional insureds, the Principal Representative shall be additional insureds to the full limits of liability purchased by the Contractor even if those limits of liability are in excess of those required by this Contract.

4. Contractor shall furnish the Principal Representative with certificates of insurance (ACORD form or equivalent approved by the Principal Representative) as required by this Contract. The certificates for each insurance policy are to be signed by a person authorized by that insurer to bind coverage on its behalf.

All certificates and any required endorsements are to be received and approved by the Principal Representative before work commences.

Each insurance policy required by this Contract must be in effect at or prior to commencement of work under this Contract and remain in effect for the duration of the project. Failure to maintain the insurance policies as required by this Contract or to provide evidence of renewal is a material breach of contract.

5. Upon request by the Principal Representative, Contractor must provide a copy of the actual insurance policy effecting coverage(s) required by the contract.
6. The Contractor's insurance coverage shall be primary insurance and non-contributory with respect to all other available resources.

7. The Contractor shall advise the Principal Representative in the event any general aggregate or other aggregate limits are reduced below the required per occurrence limit. At their own expense, the Contractor will reinstate the aggregate limits to comply with the minimum requirements and shall furnish to the Principal Representative a new certificate of insurance showing such coverage is in force.
8. Provide a minimum of thirty (30) days advance written notice to the Principal Representative for cancellation, non-renewal, or material changes to policies required under the Contract (45 days for builders' risk coverage).
9. Certificate Holder: The Regents of the University of Colorado, Project Management, 1945 North Wheeling Street, Campus Mail stop F-418, Aurora, CO 80045.

Failure of the Contractor to fully comply with these requirements during the term of the Contract may be considered a material breach of contract and may be cause for immediate termination of the Contract at the option of the Principal Representative. The Principal Representative reserves the right to negotiate additional specific insurance requirements at the time of the contract award.

Subcontractors

Contractor's certificate(s) shall include all subcontractors as additional insureds under its policies **or** subcontractors shall maintain separate insurance as determined by the Contractor, however, subcontractor's limits of liability shall not be less than \$1,000,000 per occurrence / \$2,000,000 aggregate.

Non-Waiver

The parties hereto understand and agree that The Principal Representative is relying on, and does not waive or intend to waive by any provision of this Contract, the monetary limitations or any other rights, immunities, and protections provided by the Colorado Governmental Immunity Act, et seq., as from time to time amended, or otherwise available to the Principal Representative or its officers, employees, agents, and volunteers.

Mutual Cooperation

The Principal Representative and Contractor shall cooperate with each other in the collection of any insurance proceeds which may be payable in the event of any loss, including the execution and delivery of any proof of loss or other actions required to effect recovery.

(Revised 12/09/2019)

ARTICLE 21. MISCELLANEOUS. PROVISIONS

Delete the following section except for Projects that are ARRA funded:

21.22 STATEWIDE CONTRACT MANAGEMENT SYSTEM

Add the following:

21.24 UNIVERSITY OF COLORADO DENVER | ANSCHUTZ MEDICAL CAMPUS POLICY ON SEXUAL HARASSMENT

- .1 The Contractor shall vigorously pursue to the greatest extent possible, adherence to the university Policy on Sexual Harassment and also require all employees, and employees of all professional consultants of any kind, working on this project to adhere to this Policy.

- .2 Statement of Policy: It is the policy of the university to maintain the community as a place of work, study, and residence free of sexual harassment or exploitation of students, faculty, staff, and administrators. Sexual harassment is prohibited on campus and in the university programs. The university is committed to taking appropriate action against any of its officials, employees or students who violate the policy prohibiting sexual harassment.
- .3 Definition of Sexual Harassment: For purposes of this Policy, sexual harassment is defined as conduct which is unwelcome and consists of:

1. sexual advances; 2. requests for sexual favors; or 3. other verbal or physical conduct of a sexual nature when submission to such conduct is made either explicitly or implicitly a term or condition of an individual's employment or academic decisions affecting the individual; or when such conduct has the purpose or effect, of unreasonably interfering with an individual's work or academic performance by creating an intimidating, hostile, or offensive working or educational environment.

Conduct prohibited under this policy may occur between persons of the same sex or of different sexes and may manifest itself in different ways. For example, sexual harassment may be as undisguised as a direct solicitation of sexual favors, or arise from behavior which has the effect of creating an intimidating, hostile, or offensive educational or working environment. In this regard, the following types of acts, if pervasive and continuous, are more likely than not to be considered sexual harassment: unwelcome physical contact, sexual remarks about a person's clothing, body, or sexual relations, conversation of a sexual nature or similar jokes and stories, and the display of sexually explicit materials in the workplace or their use in the classroom without defensible educational purpose.

- .4 Consequence of Sexual Offenses: The university may require the Architect/Engineer to remove from the university property any individual or individuals who violate the policy prohibiting sexual harassment.
- .5 Contractor acknowledges that all Contractor employees, agents and representatives providing services to the University of Colorado Denver | Anschutz Medical Campus are responsible for complying with University policies and procedures. This includes, without limitation, policies related to professional conduct, sexual misconduct (including non-consensual sexual intercourse, non-consensual sexual contact, sexual exploitation, sexual harassment, intimate partner abuse, and stalking), and discrimination and harassment based on protected characteristic identity (including race, color, national origin, pregnancy, sex, age, disability, creed, religion, sexual orientation, gender identity, gender expression, veteran status, political affiliation, or political philosophy). Please see <http://equity.ucdenver.edu/policies-procedures/>.
- .6 Contractor agrees that its employees, agents and representatives who engage in conduct prohibited by University policies, including related retaliation or failure to report, as determined in the University's sole discretion, will be subject to

disciplinary action, up to and including termination by Contractor consistent with Contractor's policies and procedures

- .7 Further, as Contractor recognizes and agrees that its selection and hiring of individuals who possess expertise and professional skills to carry out Contractor's obligations in an appropriate and non-discriminatory manner that reflects positively on the University's goodwill and reputation is an essential condition to inducing the University to enter into the Agreement, Contractor agrees to remove or replace any individual whose work or performance under this Agreement is considered by the University as acting inappropriately, unprofessionally, or violating any University policy, in the University's sole discretion, including, without limitation, the aforementioned policies.
- .8 Contractor acknowledges that Contractor's activities involve heightened risks as a result of access or exposure by Contractor's employees or agents to one or more security sensitive environments. Contractor expressly acknowledges that Contractor shall take all commercially reasonable measures to mitigate any such risks, which measures shall include but are not limited to conducting criminal history checks, financial background checks when appropriate, and reference checks on all employees or agents who will be performing work at the University. Upon University request, Contractor shall certify in writing that it has complied with this provision and that all employees, agents, and subcontractors performing work hereunder have satisfactorily completed Contractor's background check.

21.25 UNIVERSITY OF COLORADO DENVER | ANSCHUTZ MEDICAL CAMPUS POLICY ON SECURITY BADGING

- 1) All costs and time associated with obtaining a University security badge for Contractor employees working on campus shall be borne by the Contractor.