STATE OF COLORADO
OFFICE OF THE STATE ARCHITECT
STATE BUILDINGS PROGRAM

REQUEST FOR QUALIFICATIONS FOR ARCHITECTURAL/ENGINEERING/CONSULTING SERVICES

For The

University of Colorado Anschutz Medical Campus

For The

CU Anschutz Bundled Energy Projects
#18_152058

REQUEST FOR QUALIFICATIONS
FOR
ARCHITECTURAL/ENGINEERING/CONSULTING SERVICES

TABLE OF CONTENTS

ADVERTISEMENT FOR QUALIFICATIONS
for
ARCHITECTURAL/ENGINEERING/CONSULTING SERVICES
State of Colorado
University of Colorado Denver | Anschutz Medical Campus (GFE)
Notice Number: 18_152058

Notice Status:	**OPEN**
Publish Date:	**February 3, 2022**
# Notice Revisions:	**0**
Revision Publish Date:	**NA**

Project No:	**18_152058**
Project Title:	**CU Anschutz Bundled Energy Projects – Third-Party Commissioning**
Estimated Construction Cost:	**TBD**

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 Description

The University of Colorado Anschutz Medical Campus (the University) seeks a firm to provide third-party commissioning services for the CU Anschutz Bundled Energy Projects. 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.

The selected firm will be asked to provide basic professional services for third-party building commissioning, analysis of the project design during the design, construction, and close-out phases for the referenced project.

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 (CO_2E) 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.

Scope of Services

The University of Colorado Anschutz Medical Campus (the University) seeks a firm to provide third-party commissioning services for the CU Anschutz Bundled Energy Projects. 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.

The selected firm will be asked to provide basic professional services for third-party building commissioning, analysis of the project design during the design, construction, and close-out phases for the referenced project.

Minimum Requirements

Minimum Requirements for this project include a license to practice Engineering in Colorado and completion of projects of similar scope and complexity.

The selected firm will be asked to provide third-party commissioning services for the CU Anschutz Bundled Energy Projects. The third-party commissioning services will include design review at the earliest possible date through construction document phase. Third-party commissioning tasks will continue through the construction closeout phase and may extend through a ten (10) month post construction phase.

Selection preference will be given to the firms with the best and most recent experience in the following areas:

- Experience in successfully delivering services for multi-building projects.
- Colorado-based firm conveniently located for coordination with University of Colorado Anschutz Medical Campus.
- Experience in delivering services for at least three (3) ECM-centric projects over the past five years.
- Demonstrate ability to complete tasks in a collaborative environment to include: expediting document review, completing field coordination, providing expertise in commissioning of systems, and ensuring readily available expertise in solving problems during the construction phase.
- Demonstrated ability to commission mechanical, electrical, and lighting control systems.

Firms meeting the minimum requirements may obtain the bidding documents on the website accompanying this advertisement.

University of Colorado Denver | Anschutz Medical Campus Facilities Projects – **Request for Proposals** website:
http://www.ucdenver.edu/about/departments/FacilitiesManagement/FacilitiesProjects/RFP/Pages/RFP.aspx

University of Colorado Denver | Anschutz Medical Campus Facilities Projects – **Request for Qualifications** website:
http://www.ucdenver.edu/about/departments/FacilitiesManagement/FacilitiesProjects/RFQ/Pages/RFQ.aspx

Colorado CORE/ColoradoVSS:
https://www.colorado.gov/pacific/osa/cdnoticces

Other Information

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

Pre-Bid Meeting

Pre-submittal Conference: To ensure sufficient information is available to firms preparing submittals, a mandatory pre-submittal conference has been scheduled. The intent of this conference is to have University of Colorado Denver | Anschutz Medical Campus staff available to discuss the project. Firms preparing submittals must attend and sign-in in order to have their submittals accepted. Sign-in instructions for the Zoom meeting will be shared during the conference. The pre-submittal conference will be held at:

Join Zoom Meeting
https://ucdenver.zoom.us/j/94554413140

Meeting ID: 945 544 13140

Thursday, February 10, 2022, 2:00 PM

Schedule/Submission Details

1. Following is a detailed schedule of events for the RFQ process and an outline of the schedule for the balance of the project.

Advertisement	February 3, 2022
RFQ Document Available	February 3, 2022
Pre-submittal Conference	February 10, 2022 at 2PM
Email Questions Due	February 16, 2022 at 2PM
Date Answers Due to all Firms	February 18, 2022 at 2PM
RFQ Submittal Due	March 8, 2022 at 2PM
Submittal Screening	March 9 - 21, 2022
Consultant Interview List Released	March 22, 2022
Consultant Oral Interviews (as scheduled)	April 5, 2022

Negotiation of Consultant Contract	April 8, 2022
Contract Approval (projected)	April 18, 2022
Anticipated Design Start	In Progress
Anticipated Design/Build Construction Start	September 2022
Anticipated Construction Start/Finish	September 2023

2. Specific requirements for submittals and scoring criteria are detailed in II. SUBMITTAL REQUIREMENTS. In order to facilitate review, One (1) copy of submittals must be provided electronically. Submittals shall be submitted via email to: https://ucdenverdata.formstack.com/forms/rfp_rfq_submission

   Deadline for receipt via electronic submission is **March 8, 2022, at 2PM**

Agency: **University of Colorado Anschutz Medical Campus**

Contact Name: **Jarrett Smith**
Email: Jarrett.smith@cuanschutz.edu

Comments: **Late bids 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.**

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.

Point of Contact/Clarification

Name:	**Jarrett Smith**
Agency:	University of Colorado Denver | Anschutz Medical Campus (GFE)
Phone:	303.956.1712
Email:	Jarrett.smith@cuanschutz.edu

This Notice is also available on the web at:

Media of Publication(s):	**University of Colorado Denver | Anschutz Medical Campus Facilities Projects Website**
Publication Dates:	**DATE POSTED**
VSS	https://codpa-vss.cloud.cgifederal.com/webapp/PRDVSS2X1/AltSelfService

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

ARCHITECTURAL/ENGINEERING/CONSULTING SERVICES
REQUEST FOR QUALIFICATIONS
University of Colorado Anschutz Medical Campus

I. INTRODUCTION

A. PROJECT DESCRIPTION

The University of Colorado Anschutz Medical Campus (the University) seeks a firm to provide third-party commissioning services for the CU Anschutz Bundled Energy Projects. 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.

The selected firm will be asked to provide basic professional services for third-party building commissioning, analysis of the project design during the design, construction, and close-out phases for the referenced project.

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 (CO_2E) 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.

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**

MINIMUM CAPABILITES

Minimum Requirements for this project include a license to practice Engineering in Colorado and completion of projects of similar scope and complexity.

The selected firm will be asked to provide third-party commissioning services for the CU Anschutz Bundled Energy Projects. The third-party commissioning services will include design review at the earliest possible date through construction document phase. Third-party commissioning tasks will continue through the construction closeout phase and may extend through a ten (10) month post construction phase.

Selection preference will be given to the firms with the best and most recent experience in the following areas:

- Experience in successfully delivering services for multi-building projects.
- Colorado-based firm conveniently located for coordination with University of Colorado Anschutz Medical Campus.
- Experience in delivering services for at least three (3) ECM-centric projects over the past five years.
- Demonstrate ability to complete tasks in a collaborative environment to include: expediting document review, completing field coordination, providing expertise in commissioning of systems, and ensuring readily available expertise in solving problems during the construction phase.
- Demonstrated ability to commission mechanical, electrical, and lighting control systems.

It is the intent of the University to be inclusive regarding Service Disable, Veteran, Minority, and Women Owned Business Enterprises (SDVMWBE). The third-party commissioning agent should demonstrate an ability to be inclusive and complete all required SDVMWBE forms within this RFQ package.

B. SELECTION PROCESS

The selection of an architect/engineer/consultant will be conducted in accordance with the Colorado Revised Statutes, 24-30-1401 et. seq. The process will involve two stages: submittals will be screened and scored. A limited number of firms will be short listed and invited to participate in oral interviews. The University of Colorado Anschutz Medical Campus will attempt to negotiate a contract with the highest ranked firm following the interview segment. Following is additional information relative to the selection process:

1. Mandatory Pre-submittal Conference: To ensure sufficient information is available to firms preparing submittals, a mandatory pre-submittal conference has been scheduled. The intent of this conference is to have University of Colorado Denver | Anschutz Medical Campus staff available to discuss the project. Firms preparing submittals must attend and sign-in in order to have their submittals accepted. Sign-in instructions for the Zoom meeting will be shared during the conference. The pre-submittal conference will be held at:

   Join Zoom Meeting
   https://ucdenver.zoom.us/j/94554413140

   Meeting ID: 945 544 13140

   Thursday, February 10, 2022, 2:00 PM

2. Architect/Engineer/Consultant's Submittals: Specific requirements for submittals and scoring criteria are detailed in II. SUBMITTAL REQUIREMENTS. In order to facilitate review, One (1) copy of submittals must be provided electronically. Submittals shall be submitted via email to: https://ucdenverdata.formstack.com/forms/rfp_rfq_submission

3. Deadline for receipt (whether mailed or hand delivered) is **March 8, 2022, at 2PM**

   Late submittals will be rejected without consideration. The University of Colorado Anschutz Medical Campus and the State of Colorado assume no responsibility for costs related to the preparation of submittals.

4. Screening Panel/Short List: Submittals will be evaluated by a panel of individuals selected in accordance with state policies. The panel will review and score the submittals. Firms ranked the highest will be invited to an oral interview. It is anticipated no fewer than three (3) or no more than Five (5) will be interviewed.

5. Oral Interviews. It is anticipated that oral interviews will be conducted during the week of April 5, 2022. Interviews will be conducted via Zoom or in person at Campus Services Building 1945 N. Wheeling St Aurora, CO 80045. The time and location for interviews will be determined when the Short List is announced. Key personnel from the firm and major consultants who will be directly involved with the project should attend the interview. The interview panel will be interested in knowing about the project approach proposed and in meeting the individuals who will act as the primary contacts with the University of Colorado Denver | Anschutz Medical Campus.

C. SCHEDULE

Following is a detailed schedule of events for the RFQ process and an outline of the schedule for the balance of the project.

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Anticipated Design/Build Construction Start	September 2022
Anticipated Construction Start/Finish	September 2023

II. SUBMITTAL REQUIREMENTS

Firms will be judged not only on their past experience for the type of work involved, but also on their ability to address issues critical to the success of the project requirements outlined in this RFQ document. **(Note that the primary focus of the prequalification evaluation will be the firm(s) capability and the primary focus of the oral interview will be the proposed Project Management Team members capabilities.)** Following are elements that will be used to evaluate each firm's qualifications:

A. PROJECT TEAM

Identify the project principal, the project manager, key staff and subconsultants. Present a brief discussion regarding how the team's qualifications and experience relate to the specific project.

- Qualifications and relevant individual experience.
- Unique knowledge of key team members relating to the project.

- Experience on projects as a team.
- Key staff involvement in project management and on-site presence.
- Time commitment of key staff.
- Qualifications and relevant subconsultant experience.

B. FIRM/TEAM CAPABILITIES

- Are the lines of authority and coordination clearly identified?
- Are essential management functions identified?
- Are the functions effectively integrated? (e.g., subconsultants' role delineated)?
- Current and projected work load.

Note: Organization charts and graphs depicting your capacity may be included.

C. PRIOR EXPERIENCE

Use this portion of your submittal to describe relevant experiences with the project type described in this RFQ document and various services to be provided.

- Experience of the key staff and firm with projects of similar scope and complexity.
- Demonstrated success on past projects of similar scope and complexity.
- References.

Note: Include the name and current telephone number of the owner's project manager for every project listed.

D. PROJECT APPROACH

For the project and services outlined in the RFQ document, describe how you plan to accomplish the following project control and management issues:

- Budget Methodology/Cost Control.
  - Establish and maintain estimates of probable cost within owner's established budget.
  - Control consultant contract costs
  - Coordinate value engineering activities
- Quality Control Methodology.
  - Insure State procedures are followed
  - Improve energy efficiency through the use of an integrated design process, life cycle costing, the use of an energy standard (current OSA energy code) and the specification of energy efficient materials, systems, and equipment
  - Insure the project is designed for durability and maintainability
- Schedule.
  - Manage the required work to meet the established schedule

E. WORK LOCATION

Describe where the prime and subconsultants will do the key work elements of this project.

- Proximity of firms office as it may affect coordination with the State's project manager and the potential project location.
- Firm's familiarity with the project area.
- Knowledge of the local labor and material markets.

Appendix A

STATE BUILDINGS PROGRAM
PRELIMINARY SELECTION/EVALUATION FORM
ARCHITECT/ENGINEERING/CONSULTANT SERVICES

QUALIFICATION BASED SELECTION (This form is to be used in the first step, i.e. short listing, of an architectural/engineering/consulting services selection process.)

Evaluator #:____Date: _______________________
Name of Firm: ____
Name of Project: _CU Anschutz Bundled Energy Projects Commissioning______________________

RFQ REFERENCE
MINIMUM REQUIREMENTS Y ____ N ____

If the minimum requirements have not been met, specify the reason(s):
____
____

Acknowledgment and Attestation included: Y _____ N _____

SCORE (PROJECT SPECIFIC QUALIFICATIONS): Weight[2] x Rating[3] = Score

1. PROJECT TEAM[1]

- Qualifications and relevant individual experience. __4__x_____=____
- Unique knowledge of key team members relating to the project. __4__x_____=____
- Experience on projects as a team. __4__x_____=____
- Key staff involvement in project management and on-site presence. __3__x_____=____
- Time commitment of key staff. __3__x_____=____
- Qualifications and relevant subconsultant experience. __4__x_____=____

2. FIRM CAPABILITIES[1]

- Are the lines of authority and coordination clearly identified __3__x_____=____
- Are essential management functions identified? __3__x_____=____
- Are the functions effectively integrated (e.g., subconsultants' roles delineated?) __3__x_____=____
- Current and projected work load. __3__x_____=____

3. PRIOR EXPERIENCE[1]

- Experience of the key staff and firm with projects of similar scope and complexity. __4__x_____=____
- Demonstrated success on past projects of similar scope and complexity. __4__x_____=____
- References. __3__x_____=____

4. PROJECT APPROACH[1]

❑ Budget methodology/cost control.	__3__x_____=____
❑ Quality control methodology.	__3__x_____=____
❑ Schedule maintenance methodology.	__3__x_____=____

5. WORK LOCATION[1]

❑ Proximity of firm’s office as it may affect coordination with the state's project manager and the potential project location.	__1__x_____=____
❑ Firm's familiarity with the project area.	__1__x_____=____
❑ Knowledge of the local labor and material markets.	__1__x_____=____

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 INTERVIEW SELECTION/EVALUATION FORM
ARCHITECTURAL/ENGINEERING/CONSULTANT SERVICES

QUALIFICATION BASED SELECTION (This form is to be used in the second step, i.e. oral interview, of an architectural/engineering/consulting services selection process.)

Evaluator #:____Date: ______________________
Name of Firm:____
Name of Project: CU Anschutz Bundled Energy Project Commissioning _____________________

SCORE (OVERALL QUALIFICATIONS)[1]:	Weight[2]	x	Rating[3]	=	Score
1. PROJECT TEAM[1]	4	x	_____	=	_____
2. TEAM CAPABILITIES[1]	4	x	_____	=	_____
3. PRIOR EXPERIENCE[1]	4	x	_____	=	_____
4. PROJECT APPROACH[1]	4	x	_____	=	_____
5. WORK LOCATION[1]	1	x	_____	=	_____
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 A2

STATE BUILDINGS PROGRAM
FINAL RANKING MATRIX

QUALIFICATION BASED SELECTION
(This form is to be used separately to rank and determine the most qualified architectural/engineering/consulting services firm for both the preliminary and interview evaluations.)

FIRM	**QUALIFICATIONS SCORE**[1]						**CUMULATIVE**[2] **TOTAL SCORE**	**RANK**[3]
Campus Safety and Emergency Preparedness Facility	EVAL #1	EVAL #2	EVAL #3	EVAL #4	EVAL #5	EVAL #6		

NOTES:
1. Insert total score from each evaluator's PRELIMINARY SELECTION AND INTERVIEW SELECTION/EVALUATION FORMS. DO NOT combine scores of the two evaluations.
2. Add all evaluators' total scores to determine the cumulative score. NOTE: Each firm's cumulative total score should be as a percentage of the total points available.
3. Rank all firms with the highest scoring firm being the most qualified.

Appendix B

CONSULTANT CONTRACT

https://drive.google.com/file/d/19F2MF12uhNu1DY29MQUiDz6K1THmhI8l/view

Appendix C

CERTIFICATION AND AFFIDAVIT REGARDING UNAUTHORIZED IMMIGRANTS

https://drive.google.com/file/d/0ByG39KP3LPlCQlNOeUxSV2JmN1k/view?resourcekey=0-oyYb-0jV7ZJ210ewmIqWCg

Appendix D

ACKNOWLEDGEMENT AND ATTESTATION FORM

By responding to these guidelines, the respondent(s) certify that he/she has reviewed the Agreement and its Exhibits contained herein, and is familiar with their terms and conditions and finds them expressly workable without change or modification.

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

Subscribed on ________________________ at ________________________,
Date City

____________________________, State of ____________________________,
County State

________________________________ ____________________
Applicant or Corporate Officer Signature Date

________________________________ _____________________
Witness Date

NOTE: Use full corporate name and affix corporate seal (if available).

(Seal)

Appendix E

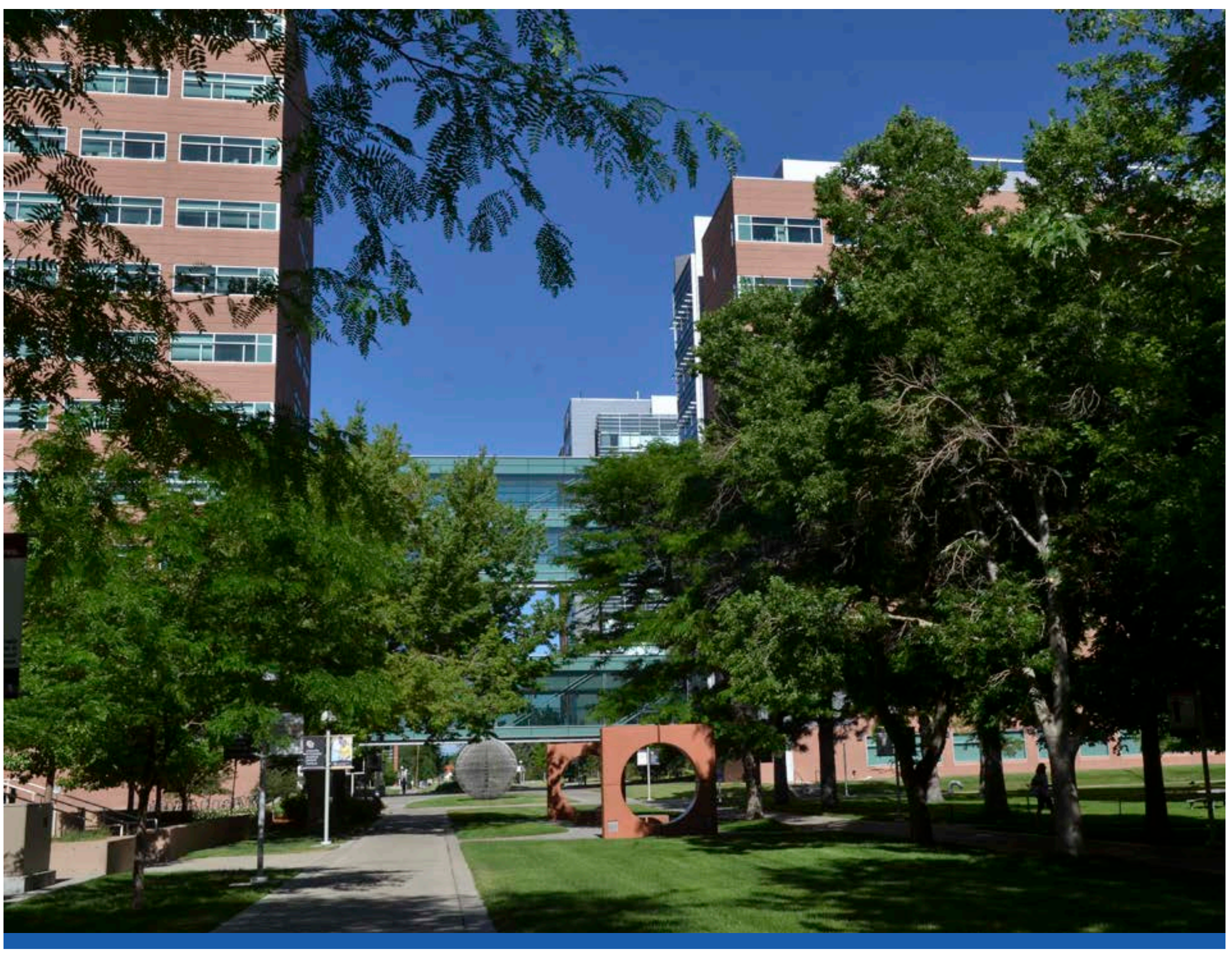
CU Anschutz Bundled Energy Program Plan

University of Colorado
Anschutz Medical Campus

CU Anschutz Bundled Energy Conservation Measures (ECMs)

PROGRAM PLAN

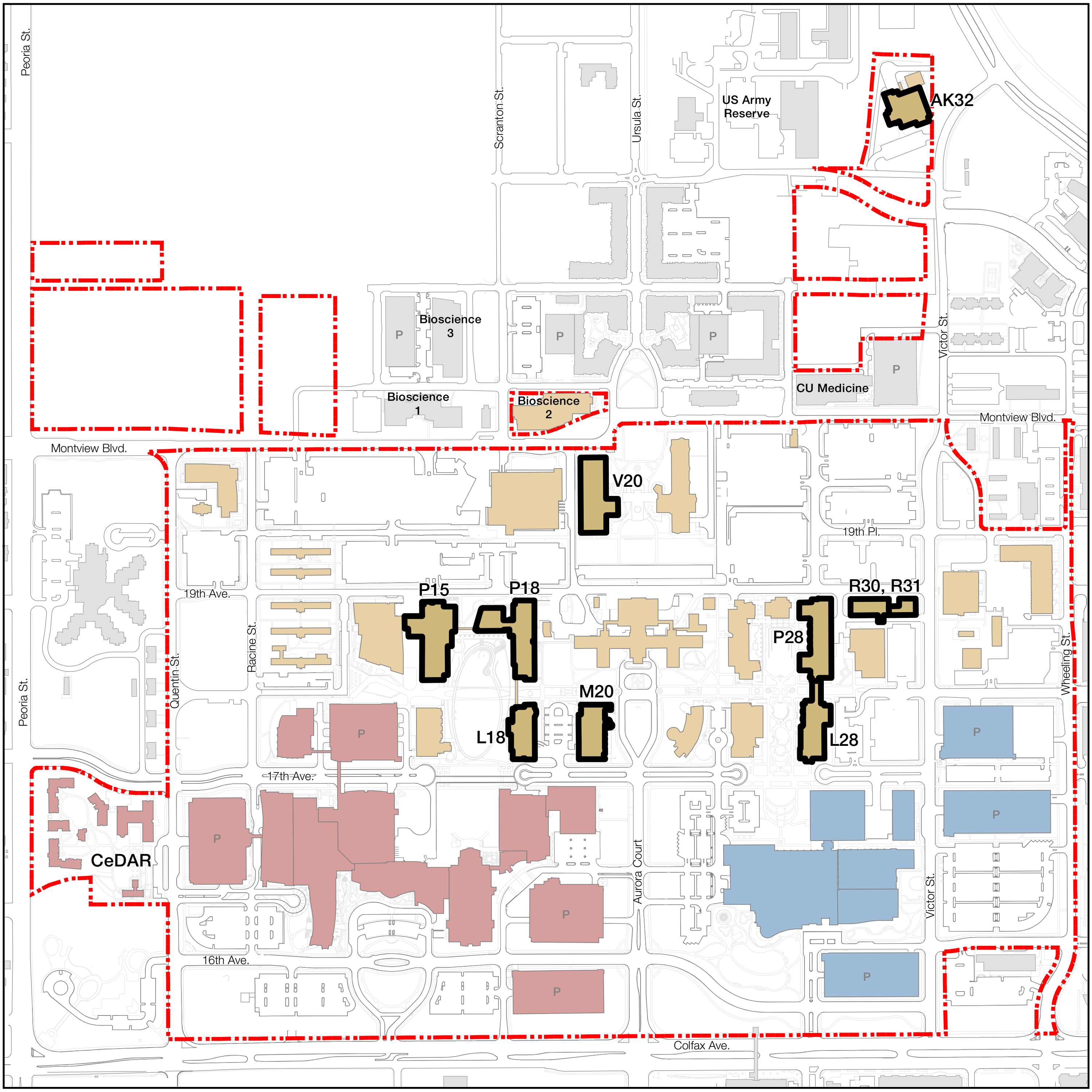
November 4, 2021



Appendix F

CU Anschutz Bundled Energy Projects Study

Table of Contents



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

Feet 0 1,200

Projects by Building and ECM Type

	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**
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

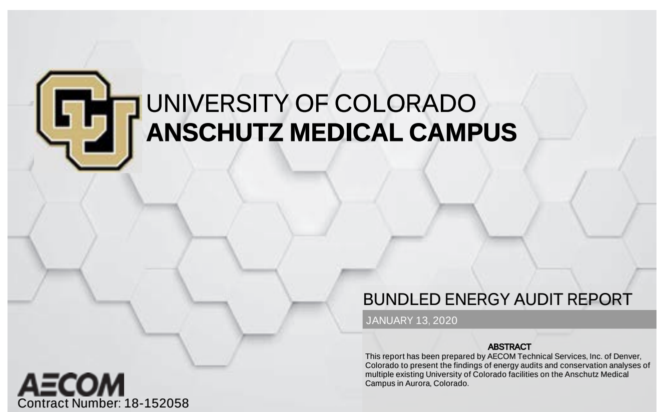
I. Executive Summary

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 (CO_2E) 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 XXXXXXXXXX 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.

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 heath 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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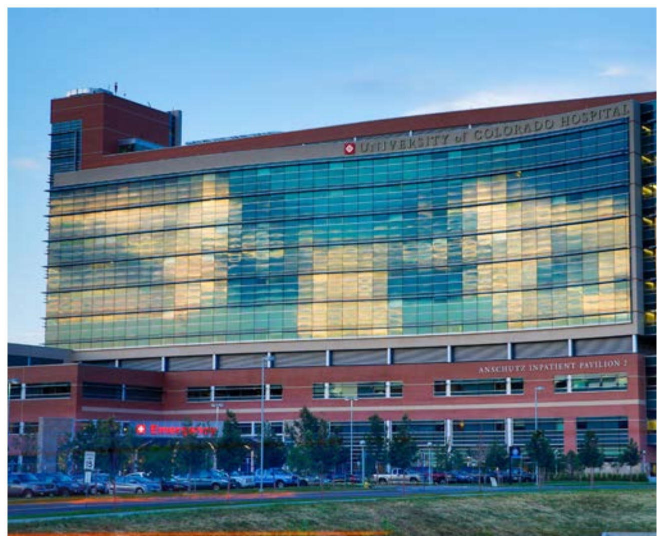
III. Program Information

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, UCHealth 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.



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.

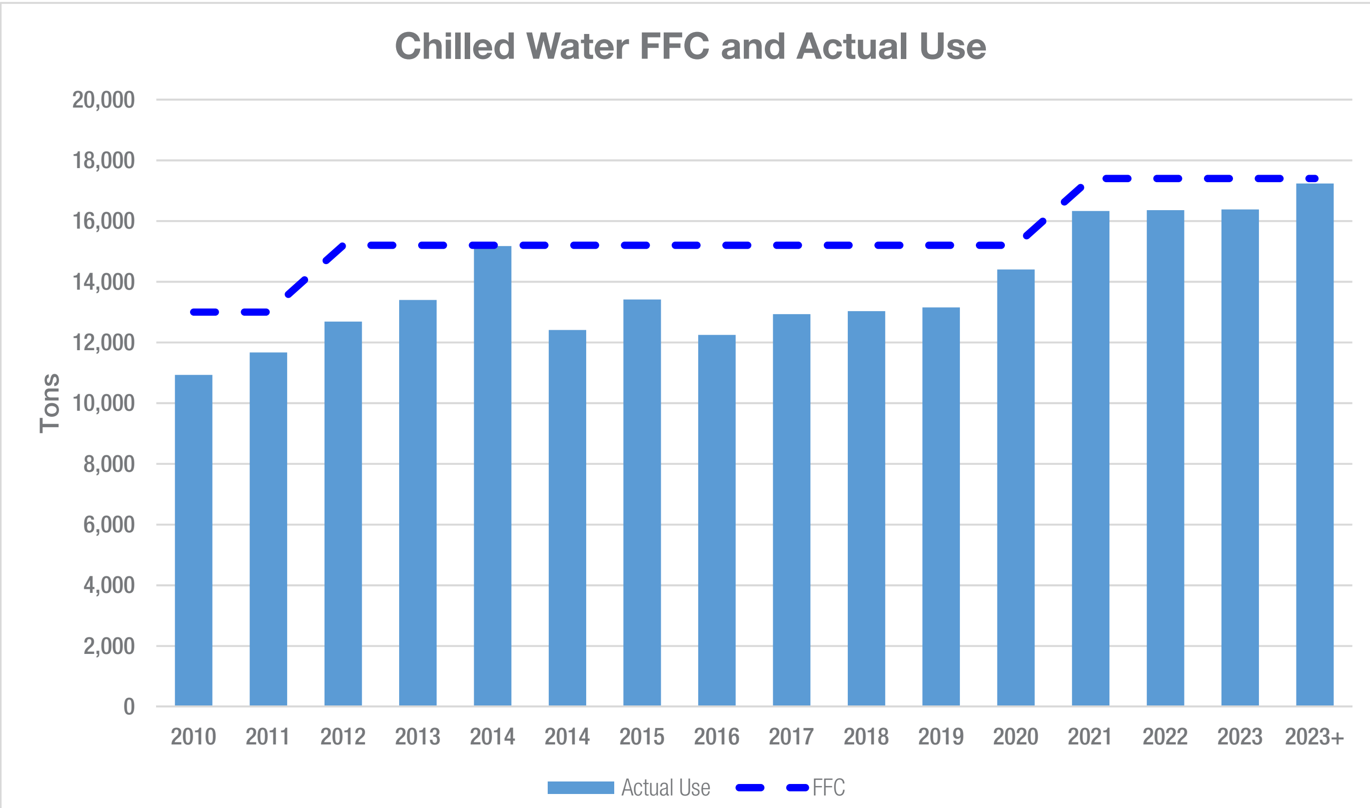
ECMs that reduce the use of steam and chilled water will drop the height of the bars. This would then result in additional available generation capacity for future growth or extreme weather events.

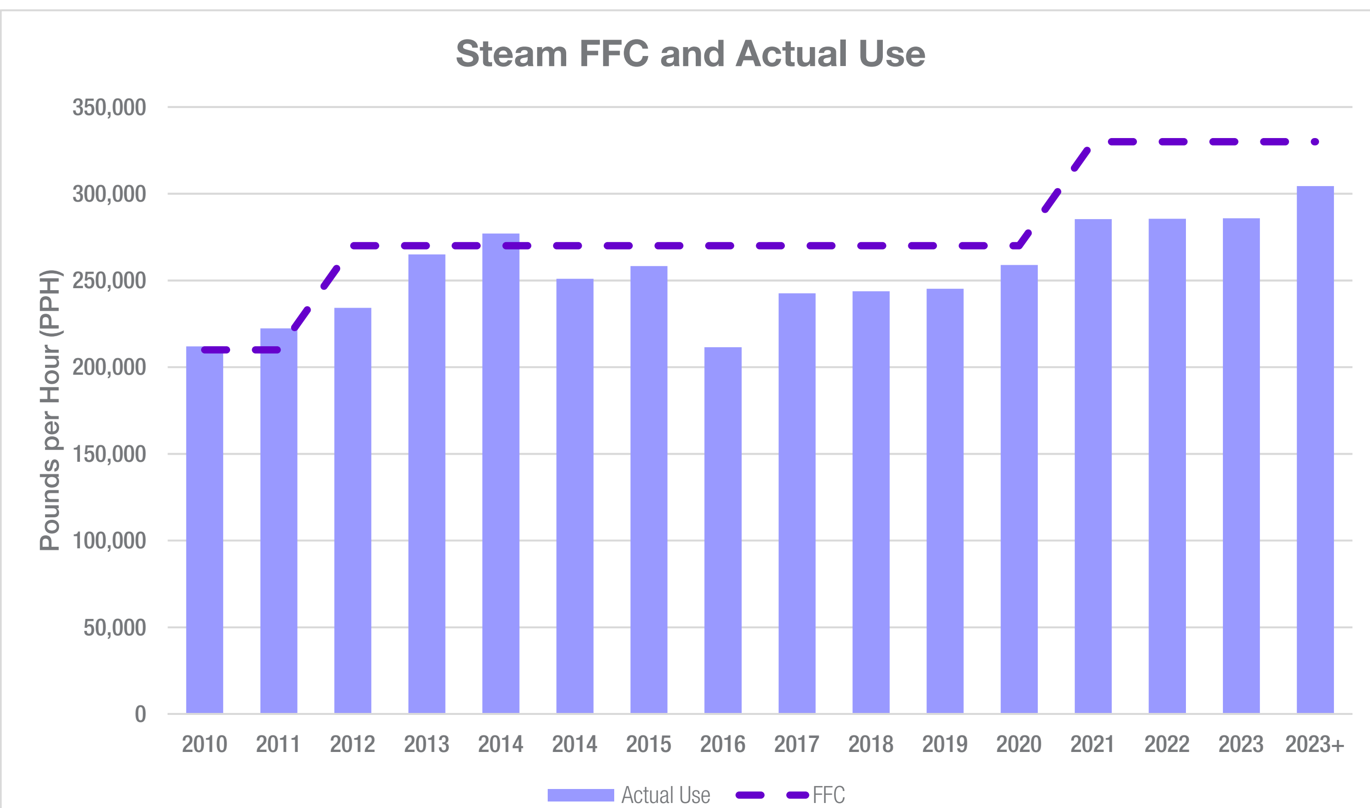
Electric Capacity

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 reduces, less gas will be required to be burned to generate heat.


Chilled Water FFC and Actual Use
Tons
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
2010
2011
2012
2013
2014
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2023+
Actual Use
FFC


Steam FFC and Actual Use
Pounds per Hour (PPH)
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
2010
2011
2012
2013
2014
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2023+
Actual Use
FFC

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 Purseud: 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

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**

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 (CO_2E) 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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Item	Start	Completion
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

AECOM
7595 Technology Way
Denver, CO 80237
aecom.com

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
AECOM
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M: 719-505-6046
E: mark.ferguson@aecom.com

cc: Kevin Keady, Ryan Meador

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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

This Report was Prepared and Approved by:

Prepared by	Checked by	Verified by	Approved by
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This Report was Prepared for and Supported by:

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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

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.

Table of Contents

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 ECM Validation Area (SF)	Facility Energy Audit 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.

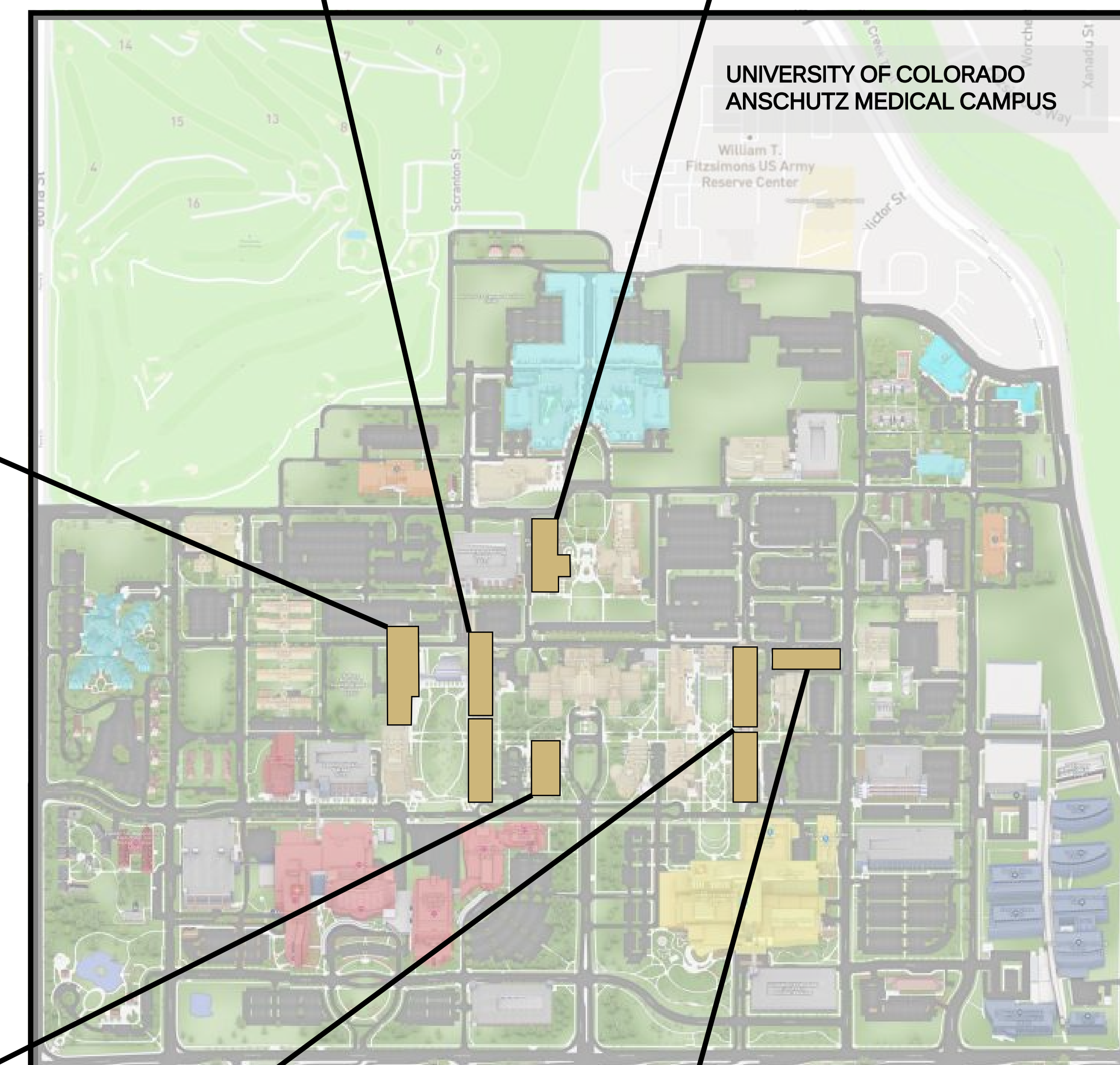
The selected measures were a result of utility analysis and walk-through audits with focus on systems and components including lighting and occupancy controls, HVAC systems and controls, domestic water heating, laboratory equipment process and plug loads, thermal building envelope, commissioning, and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

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	$		

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			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 8 . 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		1 5 0	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		1 5 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 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		8 4 5	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.

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	[illegible]		
27	Education 2	Energy Recovery - HVAC	Energy Recovery	Energy Recovery Loop Additions	27,083.33	1.43	164,726.00	-	30,275.00	[illegible]		
28	Education 2	HVAC - Upgrades	AHU Modification	Community Room Return Additions	157,400.00	3.41	370,127.00	-	105,388.00	[illegible]		
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			

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

AECOM

Table of Contents

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 How 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^{o}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

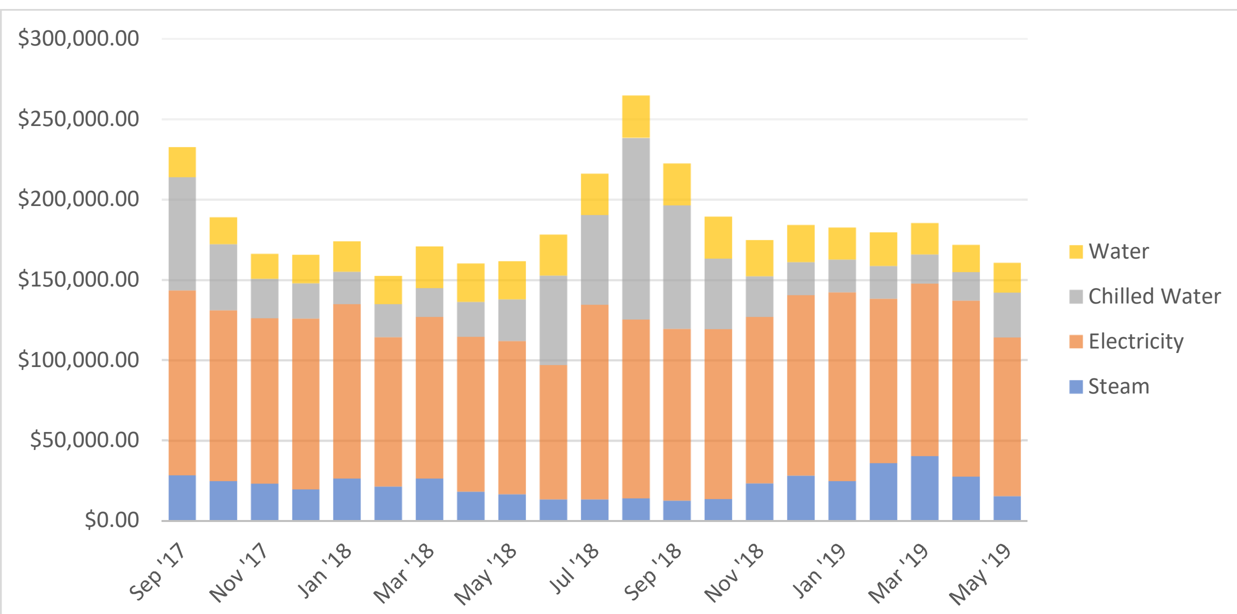


Figure 3 plots electricity consumption and spending each month for an entire year.

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

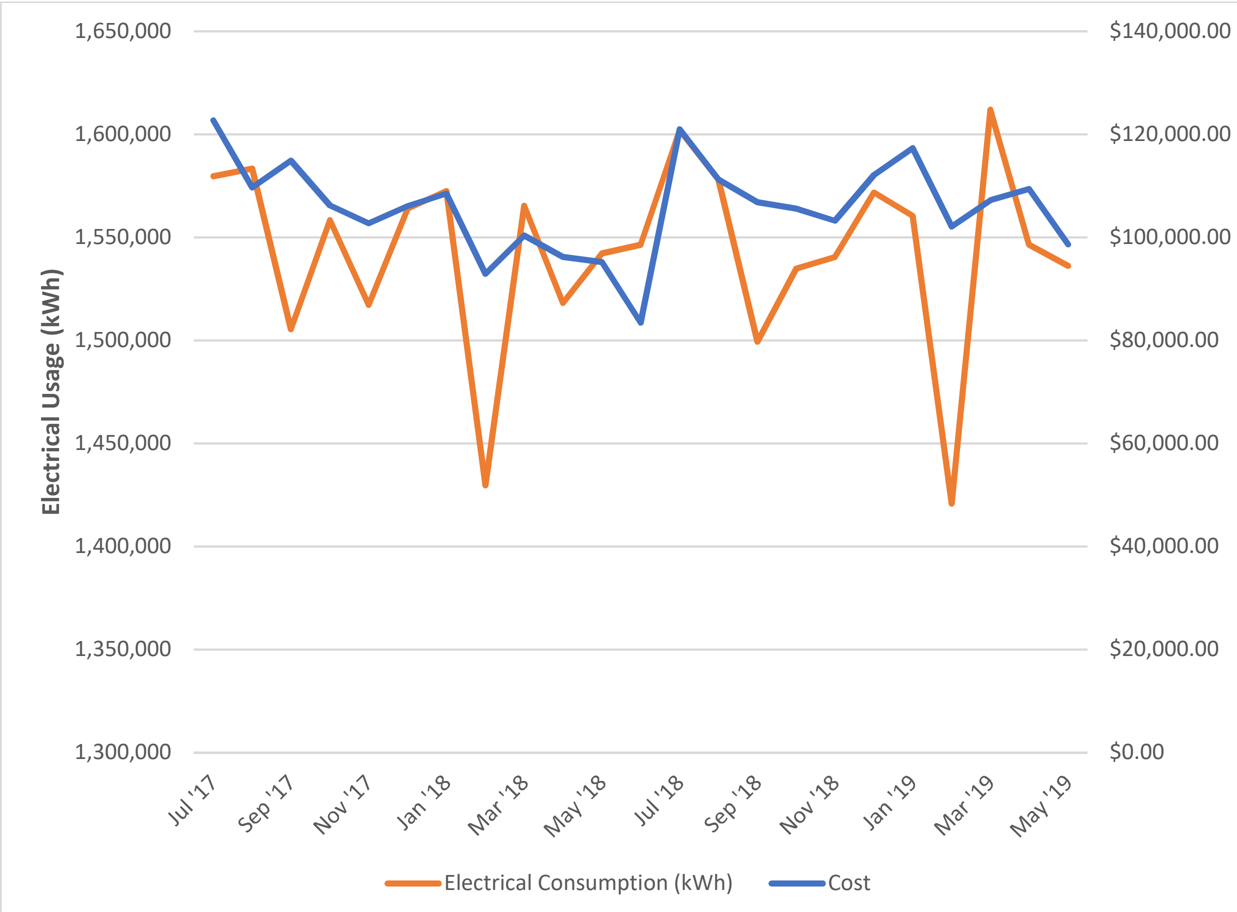


Figure 4 plots steam consumption and spending each month for an entire year.

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

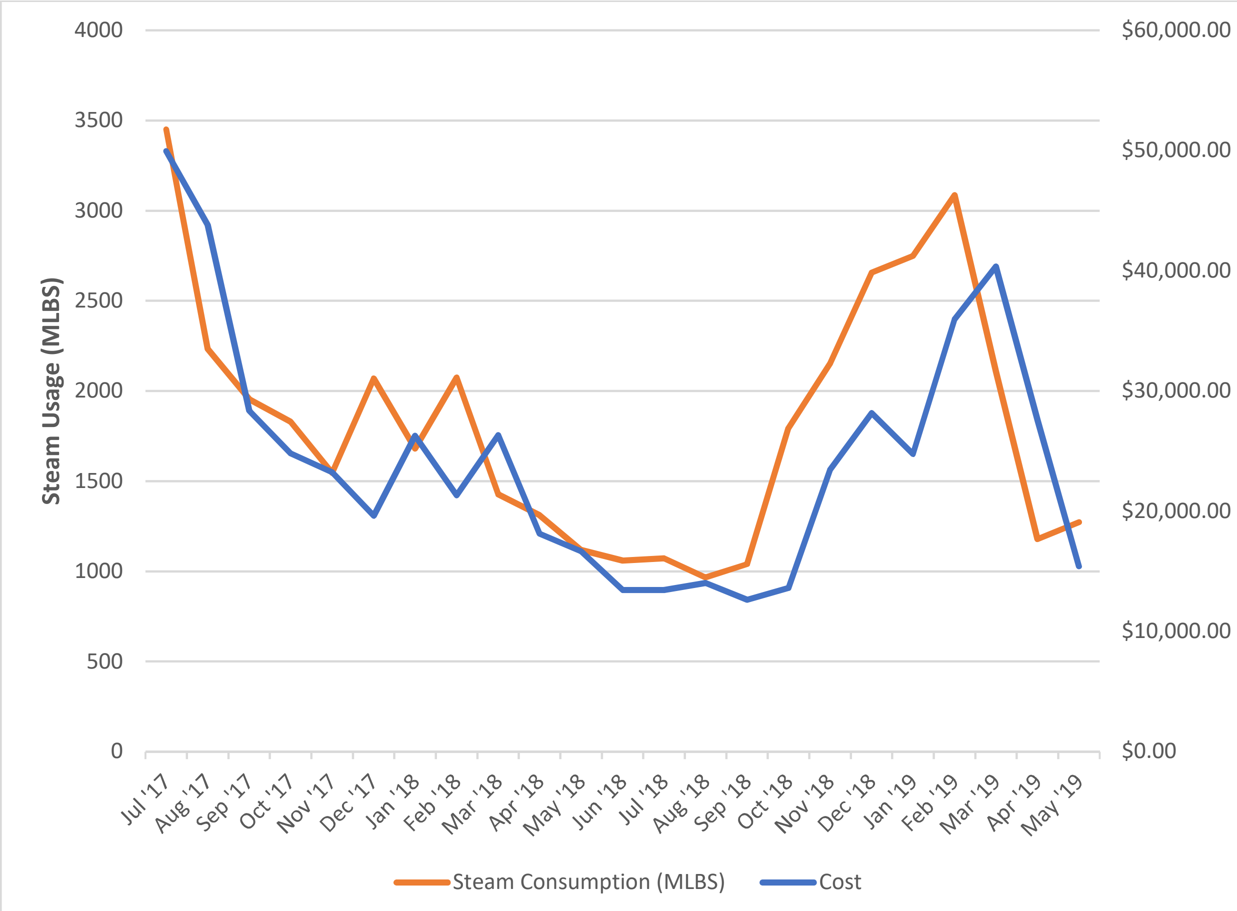


Figure 5 plots chilled water usage and spending each month for an entire year.

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

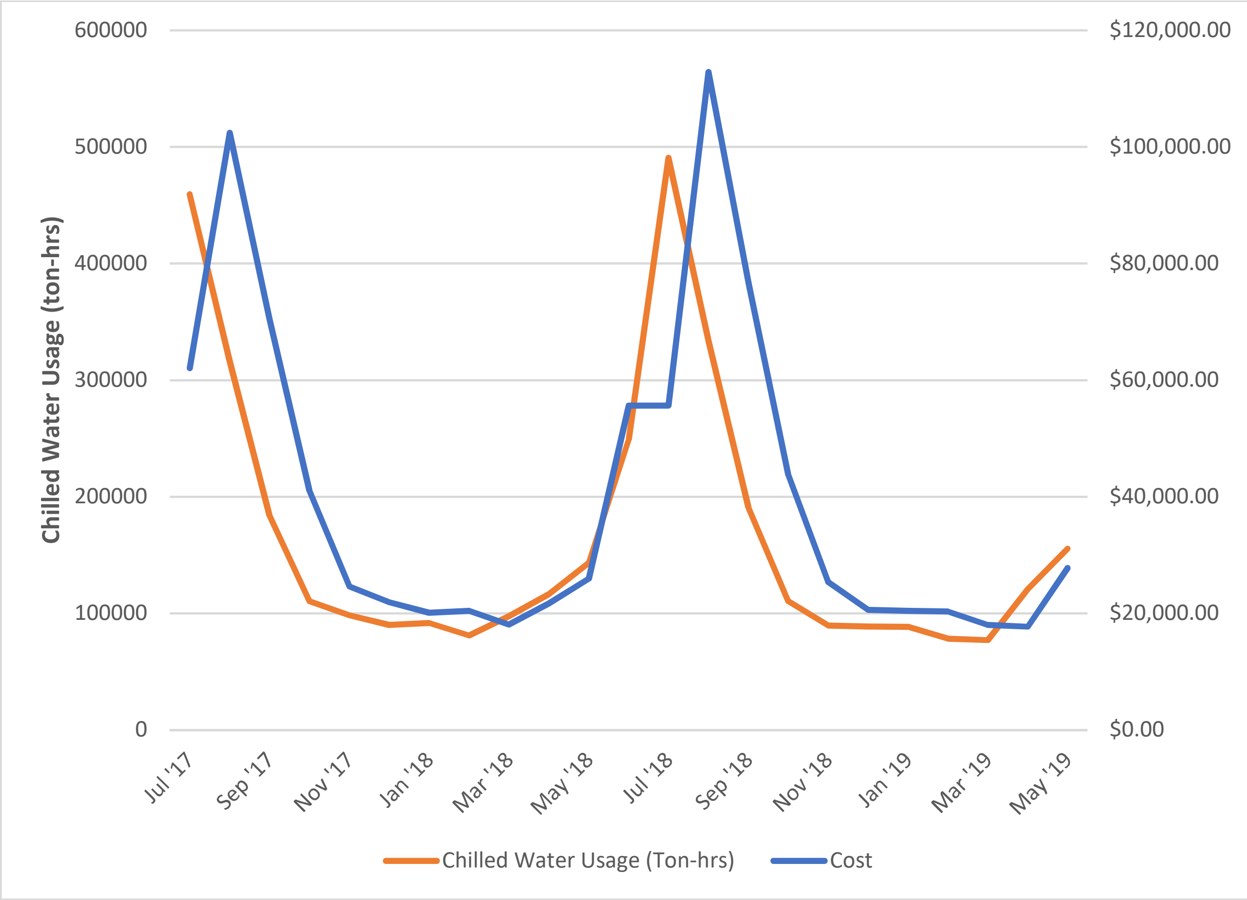
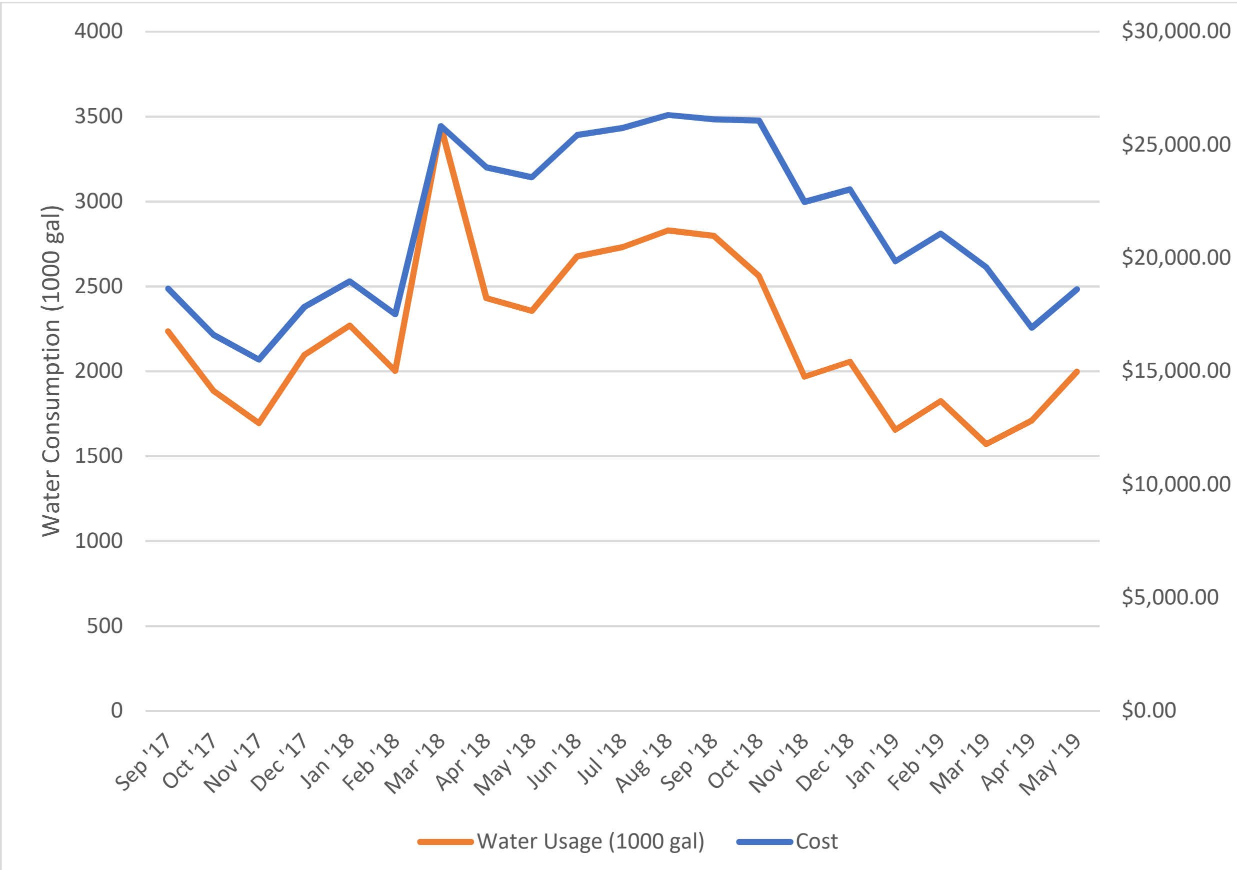


Figure 6 plots domestic water usage and spending each month for an entire year.

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/ft²		kWh/ft²	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/ft²	kBtu/ft²	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

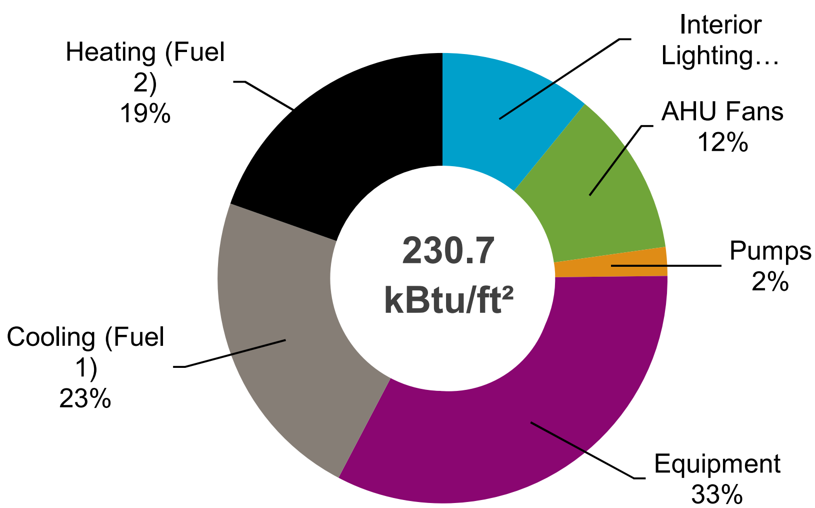
Table 7: Annual End-Use Chilled Water Consumption – Research II Building

End-Use	Installed Capacity	Demand Intensity	Consumption		Energy Cost
			Intensity	Absolute	
	kBtu/h	Btu/ft²	kBtu/ft²	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/ft^2.

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


LED Lamp Replacements for Fluorescent Tubes

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.

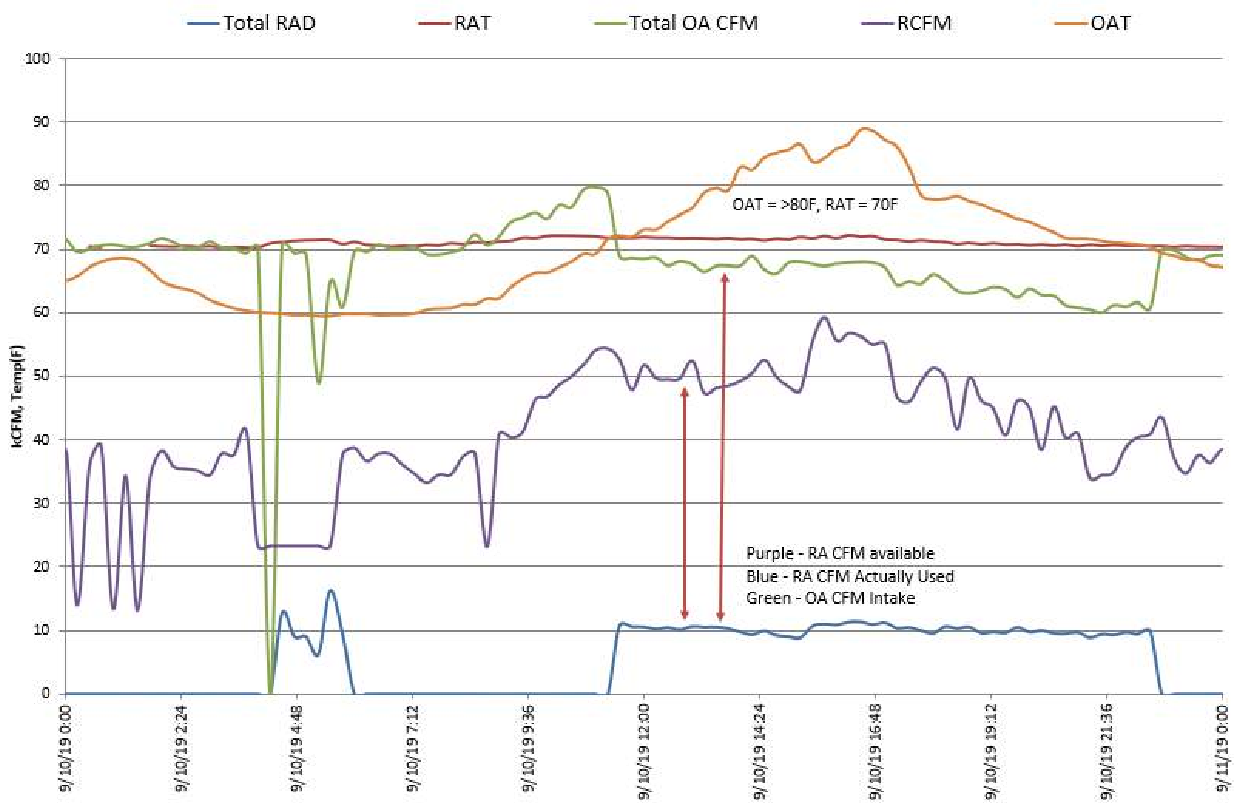
Optimization of Existing Mechanical Systems:

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 and 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

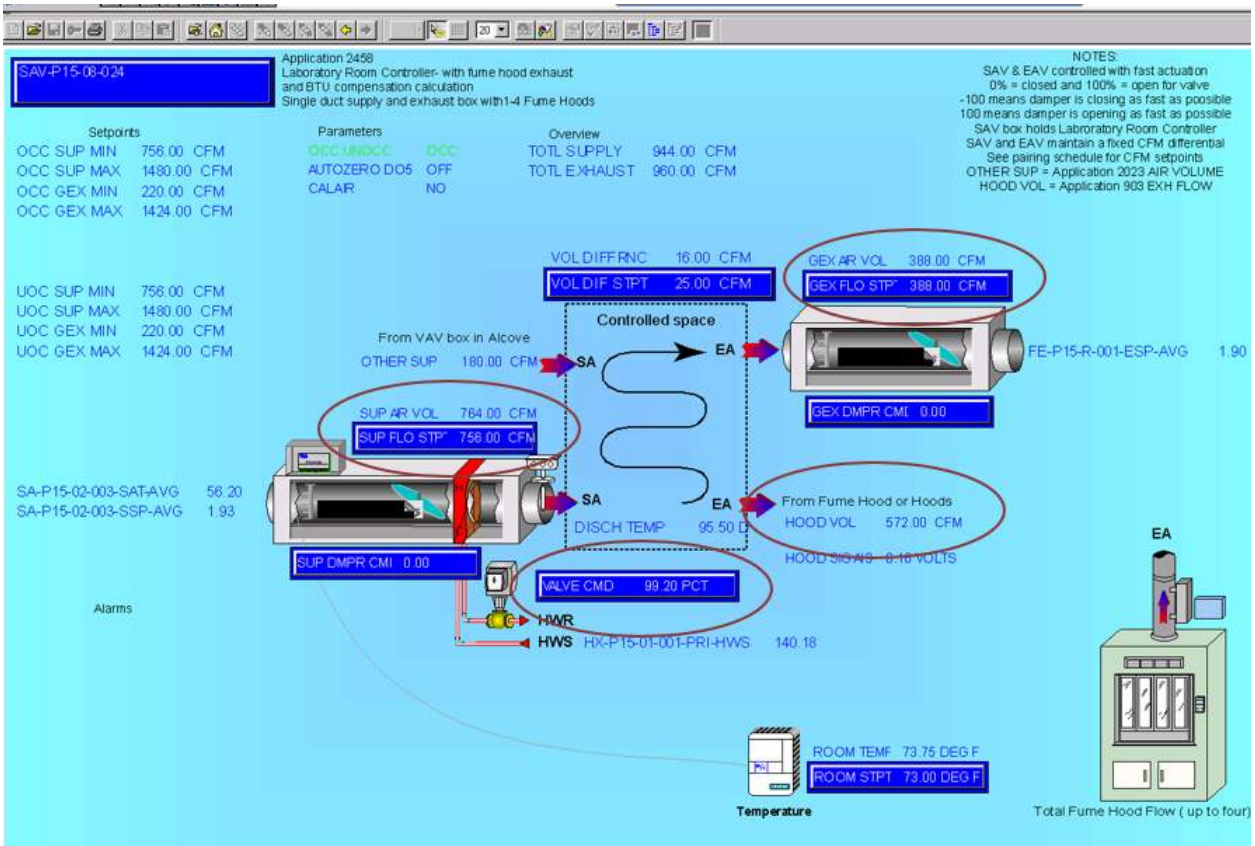
heating and cooling energy used by the building AHUs to meet the supply air temperature and CFM requirements.

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 it's 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

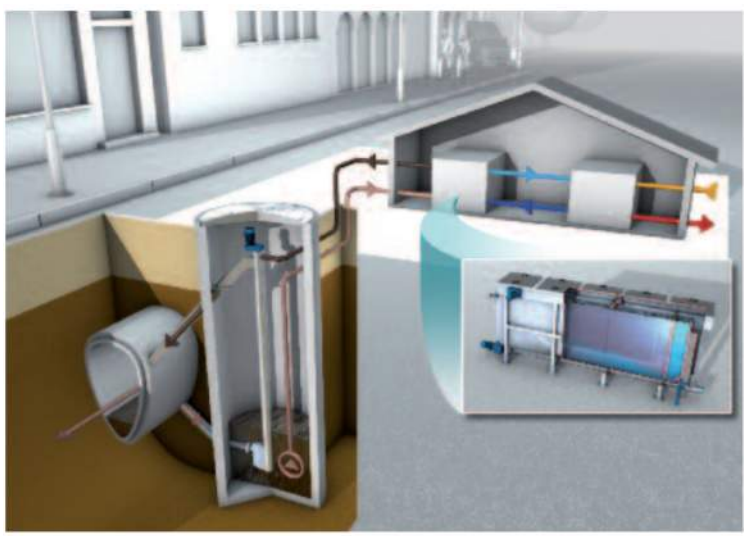
Estimate includes the cost to replace all plumbing fixtures in the main restrooms on every level. In order to estimate savings, similar buildings with low-flow fixtures were analyzed and given a gal/sf consumption value. This value was averaged across multiple buildings and applied to Research II to 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 then a conventional geothermal system.

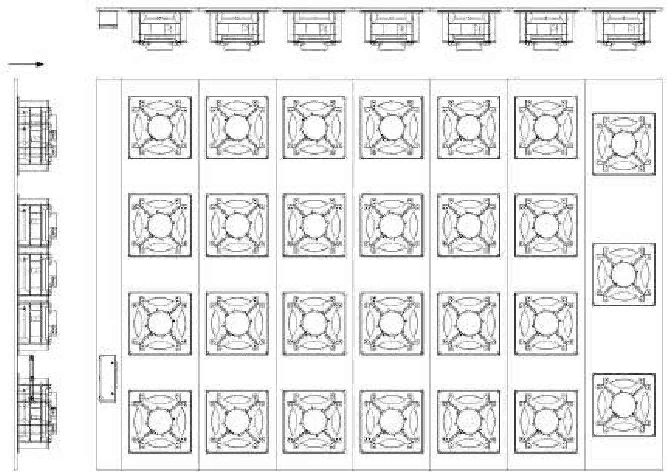
7.3.2 Regenerative Braking for Elevators

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 then 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.

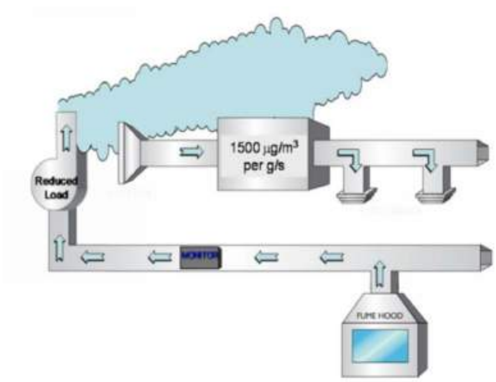


Figure 8. Higher intake concentrations are allowable when the exhaust stream is essentially "clean."

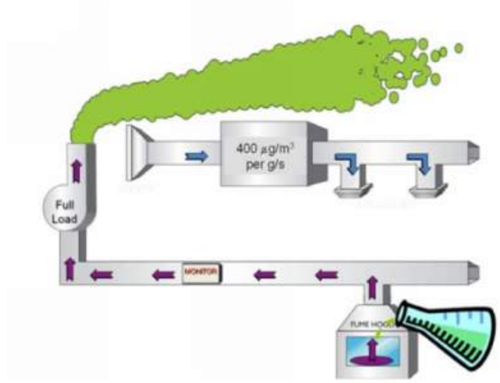


Figure 9. When chemical concentrations are detected in the exhaust stream, the exhaust volume flow rate is increased, reducing downwind intake concentrations.

Appendix B ASHRAE Audit Pharmacy Building

ASHRAE Level II Energy Audit Report

University of Colorado – Anschutz

Pharmacy Facility

AECOM

Table of Contents

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)	($/yr)	($)	(years)	($)	
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	AUDIT LEVEL II	AUDIT LEVEL 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**	**AUDIT LEVEL II**	**AUDIT LEVEL 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 How 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 -80ºF. 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

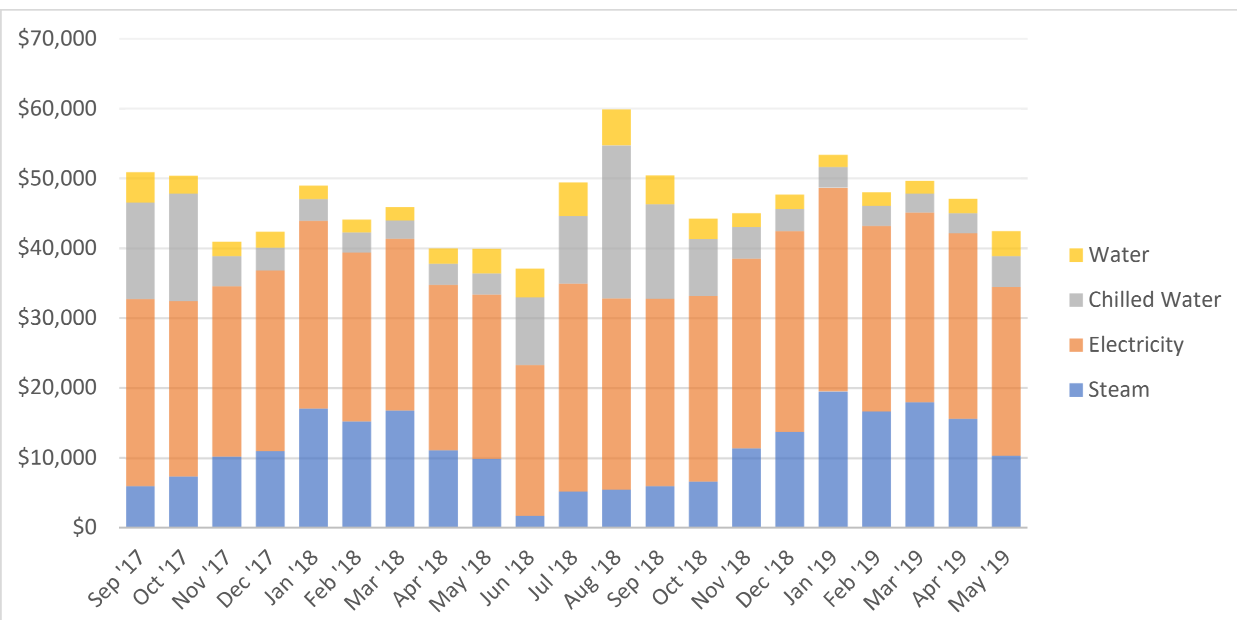


Figure 3 plots electricity consumption and spending each month for an entire year.

Figure 3: Monthly Electricity Usage and Cost – Pharmacy Building

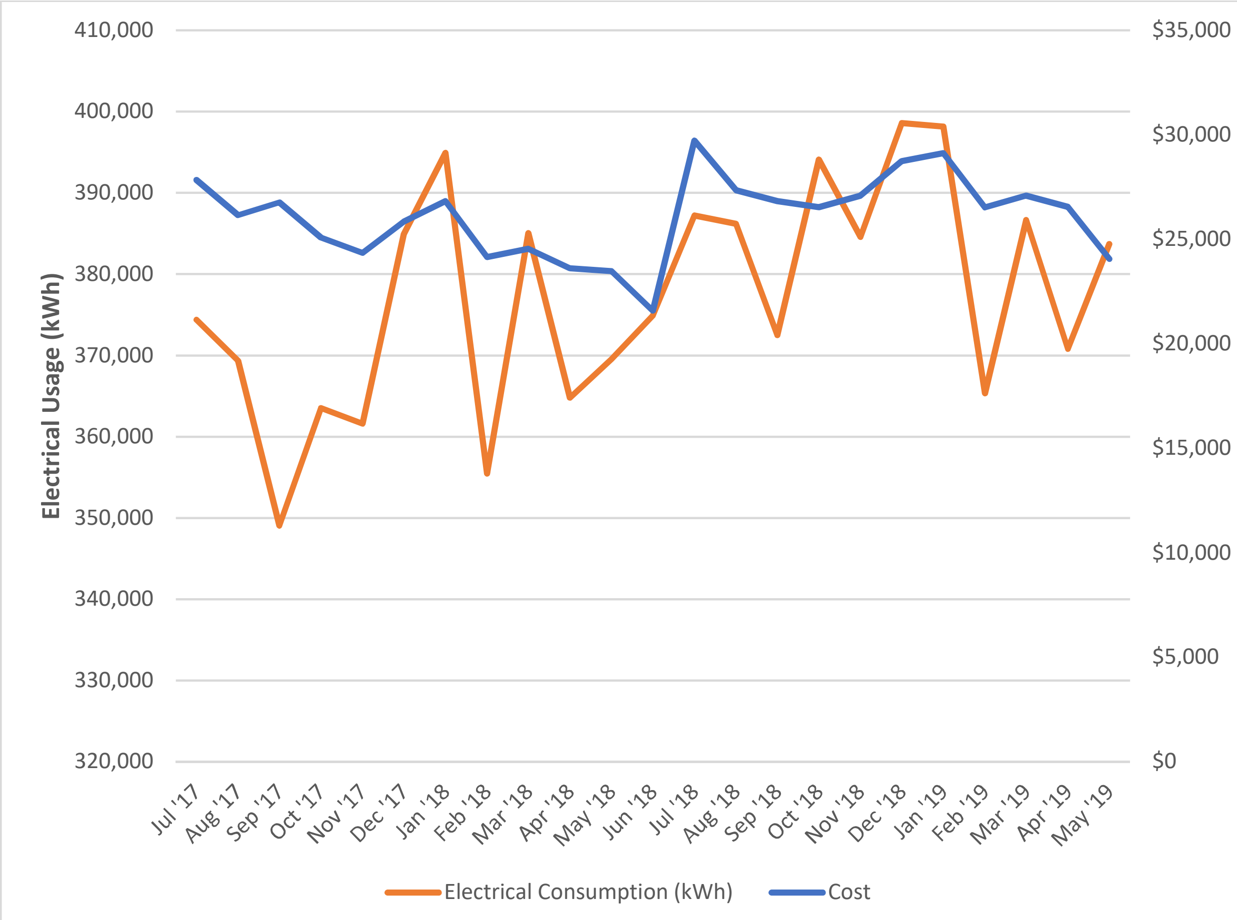


Figure 4 plots steam consumption and spending each month for an entire year.

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

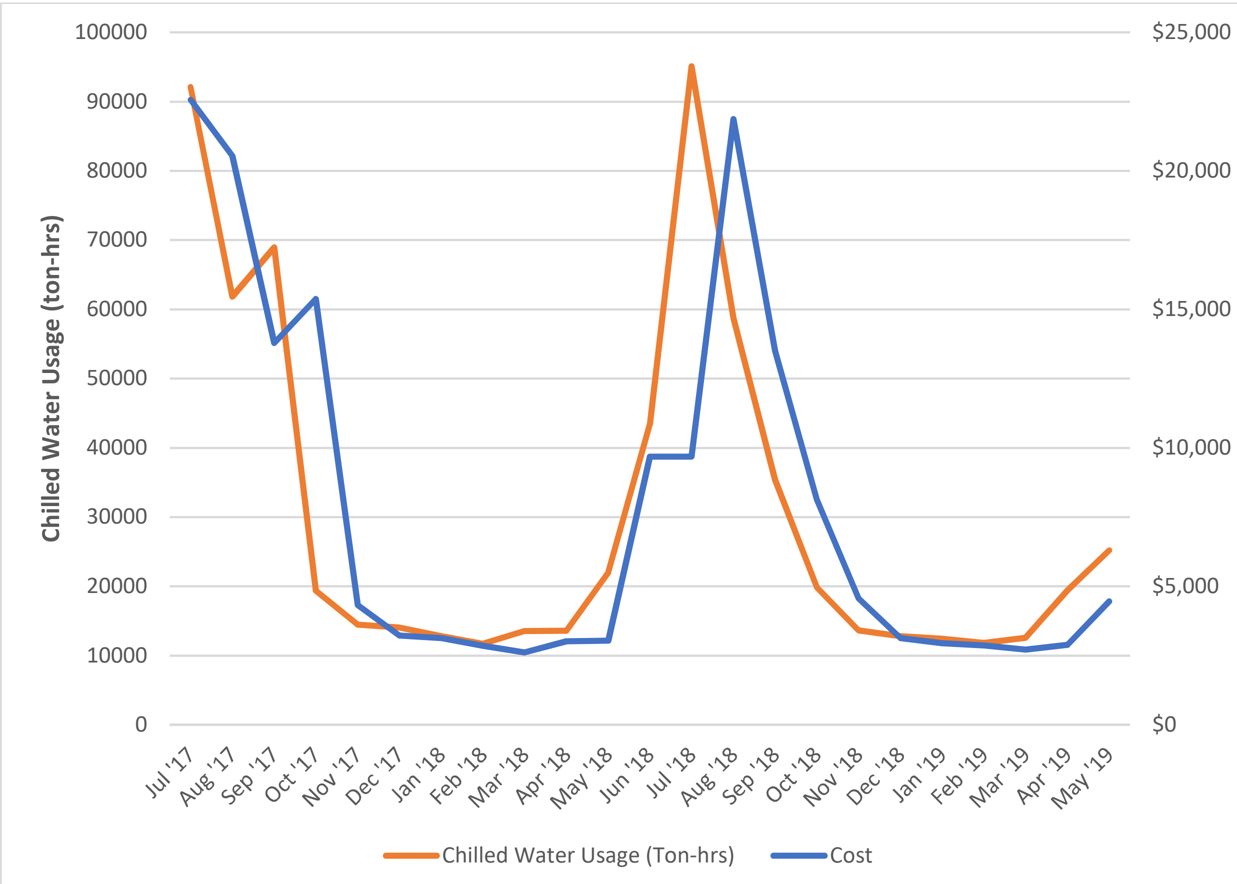
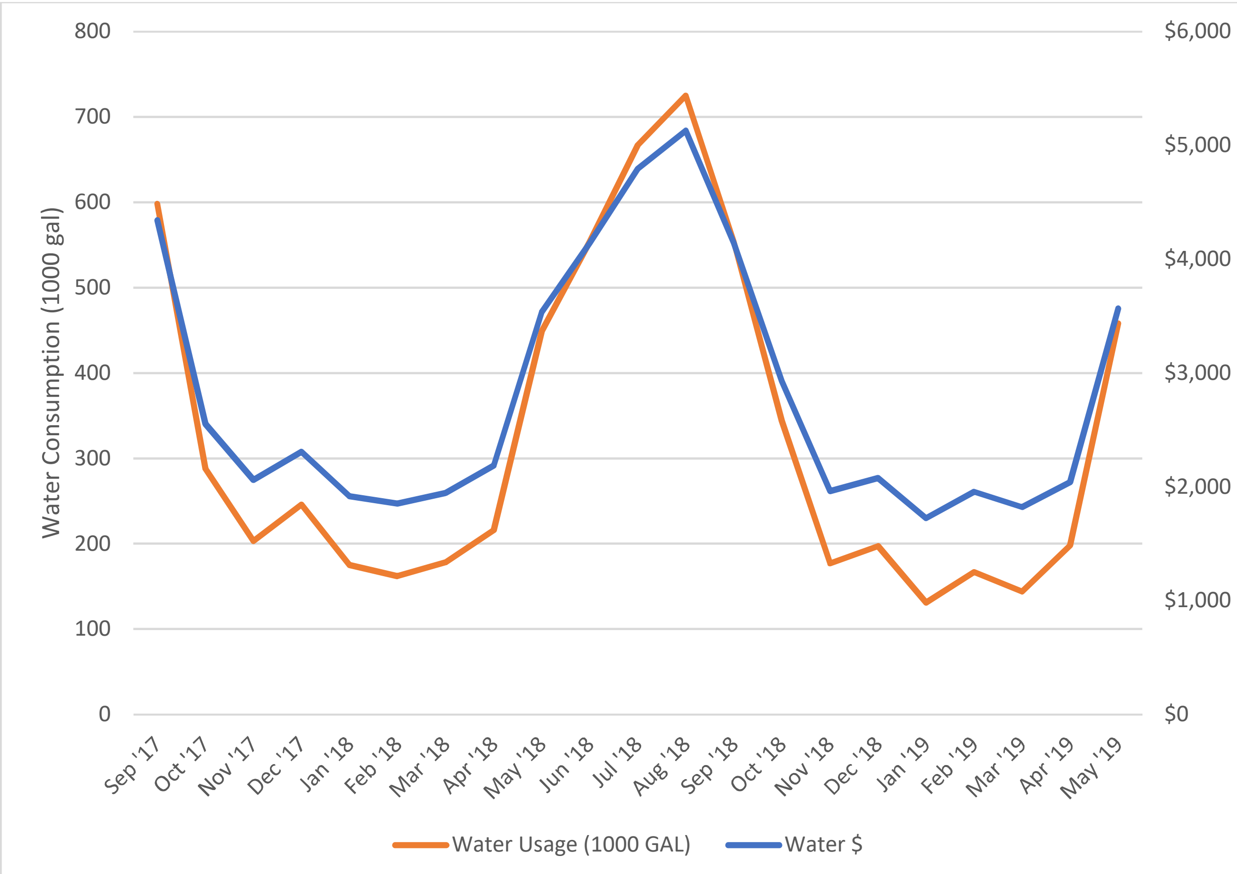


Figure 6 plots domestic water usage and spending each month for an entire year.

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	Demand Intensity	Effective Full Load Hours	Consumption		Energy Cost
				Intensity	Absolute	
	kW	W/ft²		kWh/ft²	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	Demand Intensity	Consumption		Energy Cost
			Intensity	Absolute	
	kBtu/h	Btu/ft²	kBtu/ft²	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

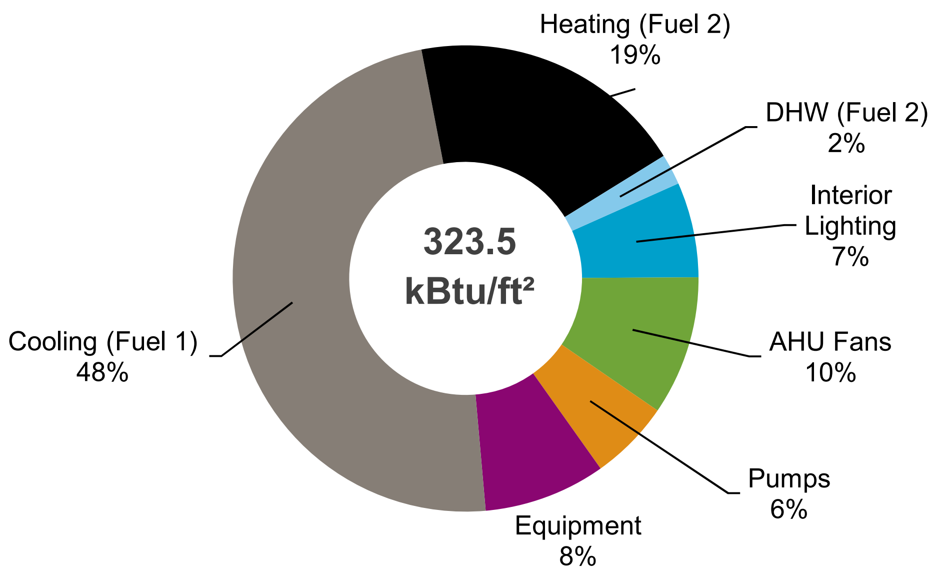
Table 7: Annual End-Use Chilled Water Consumption – Pharmacy Building

End-Use	Installed Capacity	Demand Intensity	Consumption		Energy Cost
			Intensity	Absolute	
	kBtu/h	Btu/ft²	kBtu/ft²	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/ft^2.

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	NPV	SIR
		Electricity (kWh)	Steam (MLBS)	Chilled Water (ton-hrs)	($)	($)	(years)	($)	
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	NPV	SIR
		Electricity (kWh)	Electricity (kWh)	Natural Gas (therms)	($)	($)	(years)	($)	
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

LED Lamp Replacements for Fluorescent Tubes

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

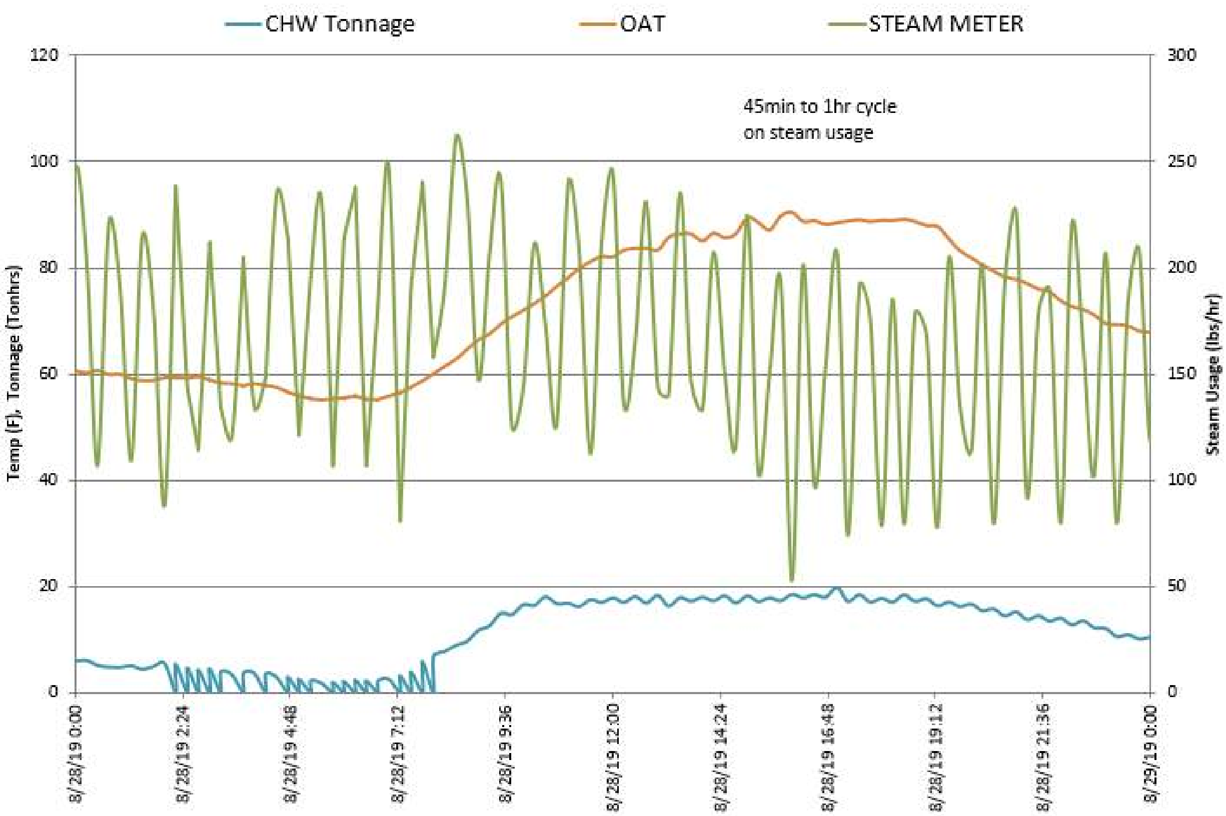
This recommendation is split into two sections: Optimization of the existing mechanical systems and continuous commissioning and diagnostics of systems and ECMs after they are implemented.

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

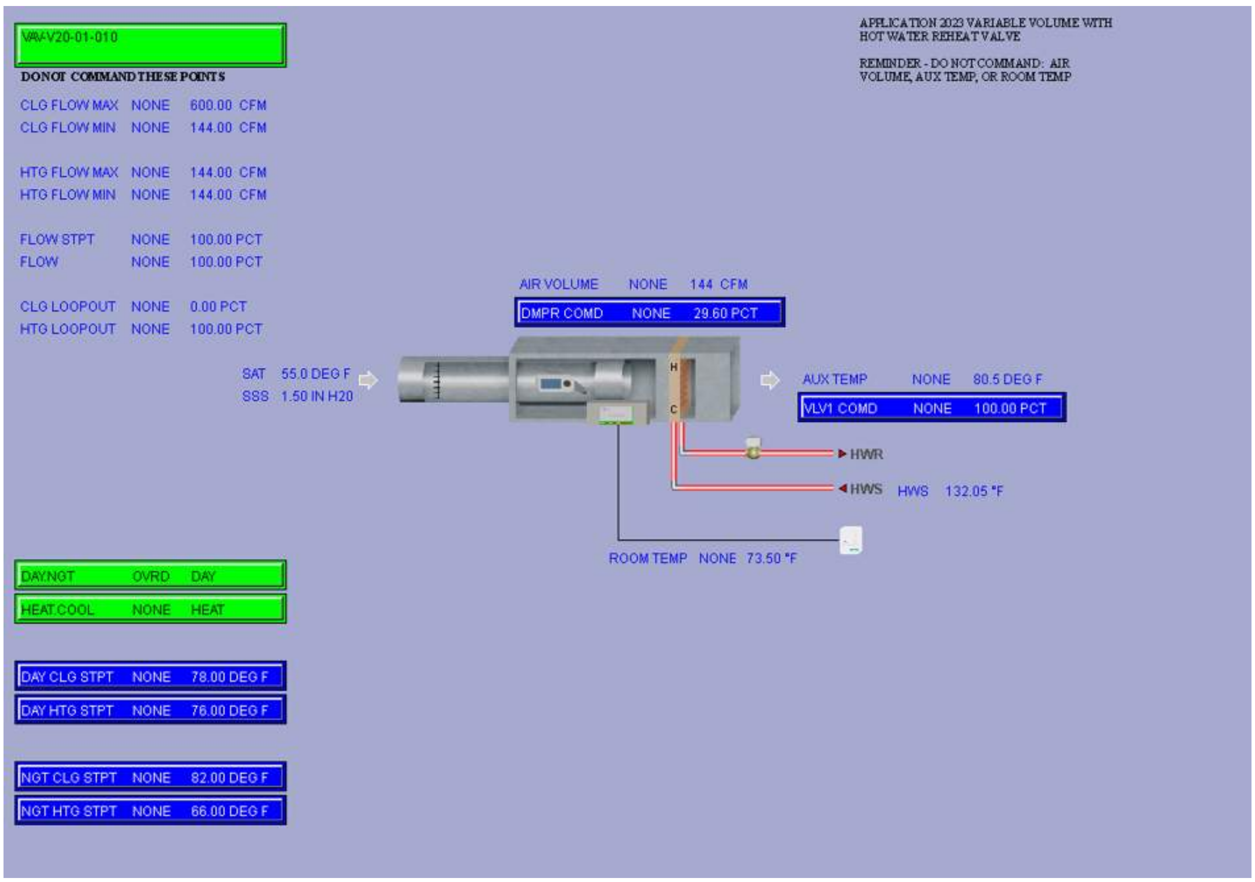
Figure 12: Total building heating load showing nearly 100% increase in demand cycling every 45 minutes.



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, Overidden 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

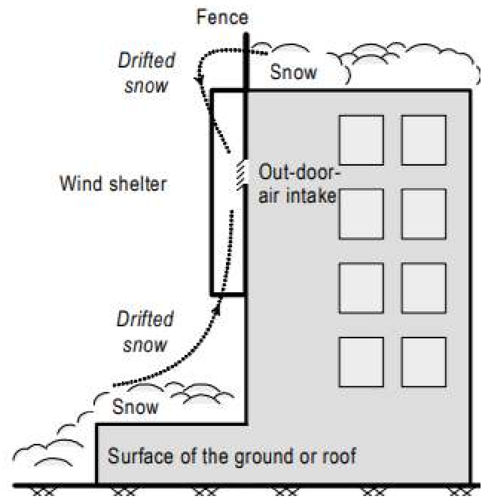
This measure involves replacing the existing garage doors that open to the exterior. It was observed that these doors take approximately 30 seconds to open-close which causes infiltration of cold air and thus increasing the heating load. By replacing them with high performance, high speed doors, which 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.

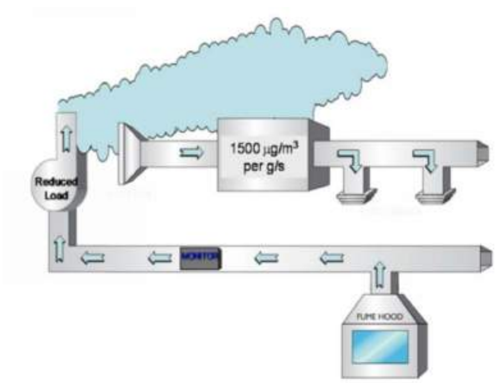


Figure 8. Higher intake concentrations are allowable when the exhaust stream is essentially "clean."

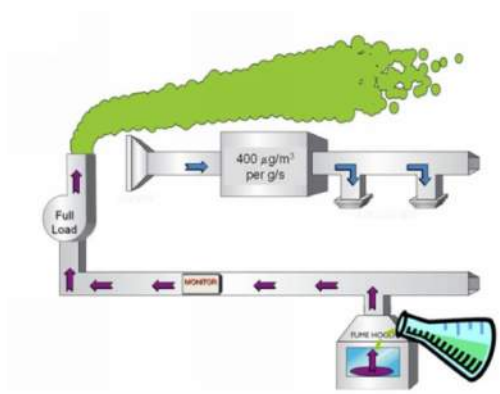


Figure 9. When chemical concentrations are detected in the exhaust stream, the exhaust volume flow rate is increased, reducing downwind intake concentrations.

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.

AECOM

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	Not Required	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	Not Required	0.00%	*$ -*
Bidding Contingency	Not Required	0.00%	*$ -*
Total Construction Costs			**$ (797,265)**

AECOM	AECOM	University of Colorado Denver			
	Bldg	Location:	Denver, CO	Estimate Date:	Monday, September 30, 2019
	xxx Street	Client:	University of Colorado Denver		
	Denver, CO xxxxxx	Job#:	60599515 Task 2	Type:	Concept

Item #	Description	Quantity	UOM	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.												
	see #3												
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 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:												
	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 N116	810	LBS	0.08	Q5	$ 65.00	$ 1.25	$ -	$ -	$ 6.45	$ 5,224.50	0.00%	$5,224.50
	Install return air ducting for N117	891	LBS	0.08	Q5	$ 65.00	$ 1.25	$ -	$ -	$ 6.45	$ 5,746.95	0.00%	$5,746.95
	Install return air ducting for N118	810	LBS	0.08	Q5	$ 65.00	$ 1.25	$ -	$ -	$ 6.45	$ 5,224.50	0.00%	$5,224.50
	Install return air ducting for N119	648	LBS	0.08	Q5	$ 65.00	$ 1.25	$ -	$ -	$ 6.45	$ 4,179.60	0.00%	$4,179.60
	Install return air ducting for N120	648	LBS	0.08	Q5	$ 65.00	$ 1.25	$ -	$ -	$ 6.45	$ 4,179.60	0.00%	$4,179.60
	Install return air devices for N108	8	EA	0.85	Q5	$ 65.00	$ 65.00	$ -	$ -	$ 120.25	$ 944.82	0.00%	$944.82
	Install return air devices for N109	7	EA	0.85	Q5	$ 65.00	$ 65.00	$ -	$ -	$ 120.25	$ 876.11	0.00%	$876.11
	Install return air devices for N110	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 N116	9	EA	0.85	Q5	$ 65.00	$ 65.00	$ -	$ -	$ 120.25	$ 1,030.71	0.00%	$1,030.71
	Install return air devices for N117	9	EA	0.85	Q5	$ 65.00	$ 65.00	$ -	$ -	$ 120.25	$ 1,133.79	0.00%	$1,133.79
	Install return air devices for N118	9	EA	0.85	Q5	$ 65.00	$ 65.00	$ -	$ -	$ 120.25	$ 1,030.71	0.00%	$1,030.71
	Install return air devices for N119	7	EA	0.85	Q5	$ 65.00	$ 65.00	$ -	$ -	$ 120.25	$ 824.57	0.00%	$824.57
	Install return air devices for N120	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, (thus) 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-NP01,04	2	EA	24.00	Q5	$ 65.00	$ -	$ -	$ -	$ 1,560.00	$ 3,120.00	0.00%	$3,120.00
	TAB of AHU-NP02,NP03,SP02,SP03	4	EA	24.00	Q5	$ 65.00	$ -	$ -	$ -	$ 1,560.00	$ 6,240.00	0.00%	$6,240.00
	TAB of AHU-SP01,04	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	Q6	$ 65.00	$ -	$ 20,285.00	$ 20,285.00	$ 20,285.00	$ 20,285.00	0.00%	$20,285.00
	Total 2019 Cost for ECM -3 Community Room Return Air Additions												**($273,416.77)**
	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												($143,868.01)
	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											$	134,082.97
	Net Savings in 2020 for ECM -3 Community Room Return Air Additions												($9,785.04)
	Total 2020 Cost for ECM -3 Community Room Return Air Additions												**($9,785.04)**
	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					**PAYBACK YEAR**							$128,990.83
ECM -4	**Lighting Replacement in Large Auditorium**												
1	Demo: Remove existing incandescent Lighting Fixtures												
	500w Quartz pendents	24	EA	0.75	ELEC	$ 65.00	$ -	$ -	$ -	$ 48.75	$ 1,170.00	0.00%	$1,170.00
	250w Quartz pendents	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												
	500w Quartz pendents	24	EA	2.00	ELEC	$ 65.00	$ 1,250.00	$ -	$ -	$ 1,380.00	$ 33,120.00	0.00%	$33,120.00
	250w Quartz pendents	11	EA	2.00	ELEC	$ 65.00	$ 950.00	$ -	$ -	$ 1,080.00	$ 11,880.00	0.00%	$11,880.00
	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	$ -	$ -	$ -	$ 128,604.25	$128,604.25	5.00%	$6,430.21
	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	$ 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											$	11,639.82
	Net Savings in 2019 for ECM -4 Lighting Replacement in Large Auditorium												($157,649.81)
	Total 2020 Cost for ECM -4 Lighting Replacement in Large Auditorium					**NOT A PAYBACK YEAR**							**($157,649.81)**
	Savings in 2020 for ECM -4 Lighting Replacement in Large Auditorium											$	12,047.21
	Net Savings in 2020 for ECM -4 Lighting Replacement in Large Auditorium												($145,602.60)
ECM -6	**Occupancy Sensor Additions – Lighting Only**												
1	Add: Occupancy Sensors												
	Occupancy Sensor - Wall IR	397	EA	0.50	ELEC	$ 65.00	$ 90.00	$ -	$ -	$ 122.50	$ 48,632.50	0.00%	$48,632.50
	Occupancy Sensor - Ceiling Dual Tech	76	EA	1.20	ELEC	$ 65.00	$ 200.00	$ -	$ -	$ 278.00	$ 21,128.00	0.00%	$21,128.00
	Occupancy Sensor - Remote Power Pack	76	EA	1.00	ELEC	$ 65.00	$ 65.00	$ -	$ -	$ 130.00	$ 9,880.00	0.00%	$9,880.00
	Allowance for ceiling space disruptions	1	LS	124.00	ELEC	$ 65.00	$ -	$ -	$ -	$ 8,060.00	$ 8,060.00	0.00%	$8,060.00
	Sub-contractor General Conditions & Provisions @ 5%	1	LS	0.00	ELEC	$ 65.00		$ -	$ -	$ 87,700.50	$87,700.50	5.00%	$4,385.03
	Sub contractor Overhead & Profit @ 15%	1	LS	0.00	ELEC	$ 65.00		$ -	$ -	$ 92,085.53	$92,085.53	15.00%	$13,812.83
	Engineering Fees	1	LS	0.00	ELEC	$ 65.00		$ 9,189.00	$ 9,189.00	$ 9,189.00	$ 9,189.00	0.00%	$9,189.00
	Total 2019 Cost for ECM -6 Occupancy Sensor Additions – Lighting Only												**($115,087.35)**
	Savings in 2019 for ECM -6 Occupancy Sensor Additions – Lighting Only											$	14,738.77
	Net Savings in 2019 for ECM -6 Occupancy Sensor Additions – Lighting Only												($100,348.58)

AECOM
Bldg
xxx Street
Denver, CO xxxxxx

University of Colorado Denver
Location: Denver, CO
Client: University of Colorado Denver
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
	Total 2020 Cost for ECM -6 Occupancy Sensor Additions – Lighting Only				**NOT A PAYBACK YEAR**								**($100,348.58)**
	Savings in 2020 for ECM -6 Occupancy Sensor Additions – Lighting Only												$ 15,254.63
	Net Savings in 2020 for ECM -6 Occupancy Sensor Additions – Lighting Only												($85,093.95)
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	0.00%	$1,660.00
	Total 2019 Cost for ECM -8 Daylight Sensors												**($19,766.16)**
	Savings in 2019 for ECM -8 Daylight Sensors												$ 12,752.29
	Net Savings in 2019 for ECM -8 Daylight Sensors												($7,013.87)
	Total 2020 Cost for ECM -8 Daylight Sensors												**($7,013.87)**
	Savings in 2020 for ECM -8 Daylight Sensors												$ 13,198.63
	Net Savings in 2020 for ECM -8 Daylight Sensors				**PAYBACK YEAR**								$6,184.76

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.

AECOM

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	Project: **University of Colorado Denver**
Bldg	Location: Denver, CO
xxx Street	Client: University of Colorado Denver
Denver, CO xxxxxx	Job #: 60599515 Task 2 — 9/30/2019
	By: SM — Chkd: JL

Energy Studies - Barbara Davis Facility

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		Not Required	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		Not Required	0.00%	$	-
Bidding Contingency		Not Required	0.00%	$	-
Total Construction Costs				**$**	**(1,498,675)**

AECOM	University of Colorado Denver	Estimate Date:	Monday, September 30, 2019
Bldg	Location: Denver, CO		
xxx Street	Client: University of Colorado Denver	Type:	Concept
Denver, CO xxxxx	Job#: 60599515 Task 2		

Item #	Description	Quantity	UOM	MH/Unit	Crew	$/MH	Material	Other	Other Total	Unit Cost	Subtotal	Sub Markups	Total Cost
023 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	2	EA	12.00	Q5	$ 65.00	0.00	$ -	$ -	$ 780.00	$ 1,560.00	0.00%	$1,560.00
	New plate/ frame heat exchangers (feeding high pressure atomizer nozzles)	2	EA	8.00	Q5	$ 65.00	6000.00	$ -	$ -	$ 6,520.00	$ 13,040.00	0.00%	$13,040.00
	New high pressure atomizer units (installed downstream of primary heating coil) assume 30,000 cfm capacity each for make up air units	2	EA	12.00	Q5	$ 65.00	15000.00	$ -	$ -	$ 15,780.00	$ 31,560.00	0.00%	$31,560.00
2	Add: New domestic water and sanitary for new atomizing nozzles												
	Install 2" Copper "L", 95 / 5 soldered water piping/ insulation /valves, allow 80' ea	160	LF	0.26	Q5	$ 65.00	15.00	$ -	$ -	$ 31.90	$ 5,104.00	0.00%	$5,104.00
	Install 3" SWCI no-hub sanitary piping (from base of condensate pan in unit to floor drain not included)	160	LF	0.38	Q5	$ 65.00	10.00	$ -	$ -	$ 34.70	$ 5,552.00	0.00%	$5,552.00
3	Add: New controls for the new nozzle ATC operation												
	Provide additional control point connections/ manifold to existing DDC control panel for unit (12 pts ea)	24	PTS	4.50	Q5	$ 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	Q5	$ 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	Q5	$ 65.00	0.00	$ -	$ -	$ 520.00	$ 1,040.00	0.00%	$1,040.00
	Sub-contractor General Conditions & Provisions @ 5%	1	LS	0.00	Q5	$ 65.00	$ -	$ -	$ -	$ 83,356.00	$83,356.00	5.00%	$4,167.80
	Sub contractor Overhead & Profit @ 15%	1	LS	0.00	Q5	$ 65.00	$ -	$ -	$ -	$ 87,523.80	$87,523.80	15.00%	$13,128.57
	Total 2019 Cost for ECM -2 Direct Evaporative Cooling (via atomizing)												**($102,212.37)**
	Savings in 2019 for ECM -4 Indirect Evaporative Cooling (via atomizing)											$	*45,371.73*
	Net Savings in 2019 for ECM -4 Indirect Evaporative Cooling (via atomizing)												($56,840.64)
	Total 2020 Cost for ECM -4 Indirect Evaporative Cooling (via atomizing)												**($56,840.64)**
	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)												($9,880.89)
	Total 2021 Cost for ECM -4 Indirect Evaporative Cooling (via atomizing)												**($9,880.89)**
	Savings in 2021 for ECM -4 Indirect Evaporative Cooling (via atomizing)											$	*48,603.34*
	Net Savings in 2021 for ECM -4 Indirect Evaporative Cooling (via atomizing)					**PAYBACK YEAR**							$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	Q5	$ 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 fans	2	EA	24.00	Q5	$ 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	Q5	$ 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	Q5	$ 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 "L", 95 / 5 soldered water piping/ insulation /valves, allow 80' ea	160	LF	0.26	Q5	$ 65.00	15.00	$ -	$ -	$ 31.90	$ 5,104.00	0.00%	$5,104.00
	Install 3" SWCI no-hub sanitary piping (from base of condensate pan in unit to floor drain not included)	160	LF	0.38	Q5	$ 65.00	10.00	$ -	$ -	$ 34.70	$ 5,552.00	0.00%	$5,552.00
4	Add: New controls for the new nozzle ATC operation												
	Provide additional control point connections/ manifold to existing DDC control panel for unit (12 pts ea)	24	PTS	4.50	Q5	$ 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	Q5	$ 65.00	0.00	$ -	$ -	$ 520.00	$ 1,040.00	0.00%	$1,040.00
	Sub-contractor General Conditions & Provisions @ 5%	1	LS	0.00	Q5	$ 65.00	$ -	$ -	$ -	$ 95,916.00	$95,916.00	5.00%	$4,795.80
	Sub contractor Overhead & Profit @ 15%	1	LS	0.00	Q5	$ 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)											$	*18,785.00*
	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)											$	*20,122.96*
	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)					**NOT A PAYBACK YEAR**							**($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 flows												
	Perform Initial meaurements of static air pressures as low as required to balance to all VAV zones	84	Hours	1.00	Q5	$ 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	Q5	$ 65.00	$ -	$ -	$ -	$ 130.00	$ 13,000.00	0.00%	$13,000.00
	Sub-contractor General Conditions & Provisions @ 5%	1	LS	0.00	Q5	$ 65.00	$ -	$ -	$ -	$ 18,460.00	$18,460.00	5.00%	$923.00
	Sub contractor Overhead & Profit @ 15%	1	LS	0.00	Q5	$ 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											$	*7,979.44*
	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					**PAYBACK YEAR**							$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	Q5	$ 65.00	$ 200.00	$ -	$ -	$ 362.50	$ 4,350.00	0.00%	$4,350.00
2	Add: AMS Add: AMS 26 SF (30000 to 30600 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	Q5	$ 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	Q5	$ 65.00	$ -	$ -	$ -	$ 32,610.00	$32,610.00	5.00%	$1,630.50
	Sub contractor Overhead & Profit @ 15%	1	LS	0.00	Q5	$ 65.00	$ -	$ -	$ -	$ 34,240.50	$34,240.50	15.00%	$5,136.08
	Total 2019 Cost for ECM-8 AHU- Ventilation optimization and DCV												**($35,026.58)**
	Savings in 2019 for ECM-8 AHU- Ventilation optimization and DCV											$	*2,991.93*
	Net Savings in 2019 for ECM-8 AHU- Ventilation optimization and DCV												($32,034.64)
	Total 2020 Cost for ECM-8 AHU- Ventilation optimization and DCV												**($32,034.64)**
	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												($28,937.99)
	Total 2021 Cost for ECM-8 AHU- Ventilation optimization and DCV					**NOT A PAYBACK YEAR**							**($28,937.99)**
	Savings in 2021 for ECM-8 AHU- Ventilation optimization and DCV											$	*3,205.03*
	Net Savings in 2021 for ECM-8 AHU- Ventilation optimization and DCV												($25,732.96)
ECM-9 HVAC integration with lighting occupancy sensors													
1	Provide control point connections to existing DDC control panel for occupancy sensors - assume 50 rooms (2 pt ea)	100	PTS	4.50	Q5	$ 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	Q5	$ 65.00	$ -	$ -	$ -	$ 104,250.00	$104,250.00	5.00%	$5,212.50
	Sub contractor Overhead & Profit @ 15%	1	LS	0.00	Q5	$ 65.00	$ -	$ -	$ -	$ 109,462.50	$109,462.50	15.00%	$16,419.38
	Total 2019 Cost for ECM-9 HVAC integration with lighting occupancy sensors												**($125,881.88)**
	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												($119,893.73)
	Total 2020 Cost for ECM-9 HVAC integration with lighting occupancy sensors												**($119,893.73)**
	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												($113,695.99)
	Total 2021 Cost for ECM-9 HVAC integration with lighting occupancy sensors					**NOT A PAYBACK YEAR**							**($113,695.99)**
	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												($107,281.34)
ECM-10 Lab air change rate reduction													
1	Provide MUA-1,2 control modifications to existing DDC control panel for programming air changes flow monitoring-allow 4 points ea	8	PTS	4.50	Q5	$ 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	Q5	$ 65.00	$ -	$ -	$ -	$ 8,340.00	$8,340.00	5.00%	$417.00
	Sub contractor Overhead & Profit @ 15%	1	LS	0.00	Q5	$ 65.00	$ -	$ -	$ -	$ 8,757.00	$8,757.00	15.00%	$1,313.55
	Total 2019 Cost for ECM-10 Lab air change rate reduction												**($10,070.55)**
	Savings in 2019 for ECM-10 Lab air change rate reduction											$	*47,881.62*
	Net Savings in 2019 for ECM-10 Lab air change rate reduction					**PAYBACK YEAR**							$37,811.07
ECM-11 Flooded high pressure steam heat exchanger													

AECOM

AECOM University of Colorado Denver
Bldg 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
1	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/ SRVs to heat exchanger steam system	1	LS	60.00	Q5	$ 65.00	$ -	$ -	$ -	$ 3,900.00	$ 3,900.00	0.00%	$3,900.00
	Removal allowance of existing steam/ condensate piping/ valves	1	LS	200.00	Q5	$ 65.00	$ -	$ -	$ -	$ 13,000.00	$ 13,000.00	0.00%	$13,000.00
	Remove existing horizontal HPS- LPS heat exchanger	1	EA	48.00	Q5	$ 65.00		$ -	$ -	$ 3,120.00	$ 3,120.00	0.00%	$3,120.00
	Remove existing steam condensate trap	1	EA	12.00	Q5	$ 65.00	$ -	$ -	$ -	$ 780.00	$ 780.00	0.00%	$780.00
	New vertical HPS flooded HX	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				**NOT A PAYBACK YEAR**								**($214,391.41)**
	Savings in 2021 for ECM-11 Flooded high pressure steam heat exchanger												*$ 15,007.31*
	Net Savings in 2021 for ECM-11 Flooded high pressure steam heat exchanger												($199,384.10)
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												**($14,441.70)**
	Savings in 2019 for ECM-12 Variable flow vacuum pump												*$ 7,060.44*
	Net Savings in 2019 for ECM-12 Variable flow vacuum pump												($7,381.26)
	Total 2020 Cost for ECM-12 Variable flow vacuum pump												**($7,381.26)**
	Savings in 2020 for ECM-12 Variable flow vacuum pump												*$ 7,307.56*
	Net Savings in 2020 for ECM-12 Variable flow vacuum pump												($73.70)
	Total 2021 Cost for ECM-12 Variable flow vacuum pump												**$7,307.56**
	Savings in 2021 for ECM-12 Variable flow vacuum pump												*$ 7,563.32*
	Net Savings in 2021 for ECM-12 Variable flow vacuum pump				**PAYBACK YEAR**								$14,870.88
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	$ -	$ -	$ -	$ 25,230.00	$25,230.00	5.00%	$1,261.50
	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)												**($30,465.23)**
	Savings in 2019 for ECM-14 Variable flow exhaust fan (controls option #2)												*$ 6,519.48*
	Net Savings in 2019 for ECM-14 Variable flow exhaust fan (controls option #2)												($23,945.75)
	Total 2020 Cost for ECM-14 Variable flow exhaust fan (controls option #2)				**NOT A PAYBACK YEAR**								**($23,945.75)**
	Savings in 2020 for ECM-14 Variable flow exhaust fan (controls option #2)												*$ 6,747.66*
	Net Savings in 2020 for ECM-14 Variable flow exhaust fan (controls option #2)												($17,198.09)
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 (1/ 300sf)	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												**($386,572.07)**
	Savings in 2019 for ECM-16 LED luminaires with daylight responsive controls												*$ 22,993.84*
	Net Savings in 2019 for ECM-16 LED luminaires with daylight responsive controls												($363,578.22)
	Total 2020 Cost for ECM-16 LED luminaires with daylight responsive controls				**NOT A PAYBACK YEAR**								**($363,578.22)**
	Savings in 2020 for ECM-16 LED luminaires with daylight responsive controls												*$ 23,798.63*
	Net Savings in 2020 for ECM-16 LED luminaires with daylight responsive controls												($339,779.59)

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.

AECOM

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 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 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 todays 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	**Project:**	**University of Colorado Denver**
Bldg	Location:	Denver, CO
xxx Street	Client:	University of Colorado Denver
Denver, CO xxxxxx	Job #:	60599515 Task 2 — 9/30/2019
	By: SM	Chkd: JL

Energy Studies - EH&S Building

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		
Bldg	Location: Denver, CO	Estimate Date:	Monday, September 30, 2019
xxx Street	Client: University of Colorado Denver		
Denver, CO xxxxxx	Job#: 60599515 Task 2	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	Demo: 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	0.00%	$2,340.00
2	Add: Add 30% glycol run-around piping loop to AHU-1 heat recovery coil (in the space of former existing steam pre-heat coil section removed)												
	Allowance for AHU-1/ EF ERC coils and piping loop system in-between	1	LS	0.00	Q5	$ 65.00	$ 53,827.89	$ -	$ -	$ 53,827.89	$ 53,827.89	0.00%	$53,827.89
	Allowance for heating hot water and condensate supplemental piping, insulation, valves and connections to ERC coil	1	LS	0.00	Q5	$ 65.00	$ 6,500.00	$ -	$ -	$ 6,500.00	$ 6,500.00	0.00%	$6,500.00
3	Add: Add 30% glycol run-around piping loop 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 ERC coils and piping loop system in-between	1	LS	0.00	Q5	$ 65.00	$ 53,827.89	$ -	$ -	$ 53,827.89	$ 53,827.89	0.00%	$53,827.89
	Allowance for heating hot water and condensate supplemental piping, insulation, valves and connections to ERC coil	1	LS	0.00	Q5	$ 65.00	$ 6,500.00	$ -	$ -	$ 6,500.00	$ 6,500.00	0.00%	$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	0.00%	$1,560.00
	Sub-contractor General Conditions & Provisions @ 5%	1	LS	0.00	Q5	$ 65.00	$ -	$ -	$ -	$ 124,555.79	$124,555.79	5.00%	$6,227.79
	Sub contractor Overhead & Profit @ 15%	1	LS	0.00	Q5	$ 65.00	$ -	$ -	$ -	$ 130,783.58	$130,783.58	15.00%	$19,617.54
	Total 2019 Cost for ECM-1 Exhaust air heat recovery												**($150,401.11)**
	Savings in 2019 for ECM-1 Exhaust air heat recovery											$	*33,432.93*
	Net Savings in 2019 for ECM-1 Exhaust air heat recovery												($116,968.18)
	Total 2020 Cost for ECM-1 Exhaust air heat recovery					**NOT A PAYBACK YEAR**							**($116,968.18)**
	Savings in 2020 for ECM-1 Exhaust air heat recovery											$	*34,603.08*
	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	0.00%	$24,840.00
	New EHU 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	0.00%	$38,430.00
2	Add: Reconfigure access door to nozzles, if required												
	Remove existing access door on ERC unit	3	EA	4.00	Q5	$ 65.00	0.00	$ -	$ -	$ 260.00	$ 780.00	0.00%	$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	0.00%	$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	0.00%	$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	0.00%	$8,328.00
4	Add: New controls for the new nozzle ATC 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	0.00%	$37,530.00
5	Add: Power for the new evaporative nozzle operations												
	Provide electrical connections	3	EA	8.00	ELEC	$ 65.00	1200.00	$ -	$ -	$ 1,720.00	$ 5,160.00	0.00%	$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	0.00%	$1,560.00
	Sub-contractor General Conditions & Provisions @ 5%	1	LS	0.00	Q5	$ 65.00	$ -	$ -	$ -	$ 134,124.00	$134,124.00	5.00%	$6,706.20
	Sub contractor Overhead & Profit @ 15%	1	LS	0.00	Q5	$ 65.00	$ -	$ -	$ -	$ 140,830.20	$140,830.20	15.00%	$21,124.53
	Total 2019 Cost for ECM -3 Indirect Evaporative Cooling (via atomizing)												**($161,954.73)**
	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)											$	*37,078.85*
	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)					**NOT A PAYBACK YEAR**							**($50,674.29)**
	Savings in 2022 for ECM -3 Indirect Evaporative Cooling (via atomizing)											$	*39,719.79*
	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	0.00%	$3,120.00
	New Lab grade Phoenix Variable Exhaust Valve 1300 cfm (active)	24	EA	1.85	Q5	$ 65.00	$ 1,275.00	$ -	$ -	$ 1,395.25	$ 33,486.00	0.00%	$33,486.00
	Sensors for air valves	24	EA	0.50	Q5	$ 65.00	$ 250.00	$ -	$ -	$ 282.50	$ 6,780.00	0.00%	$6,780.00
	New Lab grade Phoenix Variable Exhaust Valve 1300 cfm (passsive)	10	EA	1.75	Q5	$ 65.00	$ 975.00	$ -	$ -	$ 1,088.75	$ 10,887.50	0.00%	$10,887.50
	Misc for valve electrical disconnection/ re-connnection	24	EA	2.00	Elec	$ 65.00	$ 150.00	$ -	$ -	$ 280.00	$ 6,720.00	0.00%	$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	0.00%	$390.00
	Remove EF VFDs assume at 25 hp	3	EA	8.00	Q5	$ 65.00	$ -	$ -	$ -	$ 520.00	$ 1,560.00	0.00%	$1,560.00
	New EF VFD assume 45 hp for full room exhaust	3	EA	0.00	Q5	$ 65.00	$ -	$ -	$ -	$ -	$ -	0.00%	$0.00
	Misc for opening/ closing fans	3	EA	4.00	Q5	$ 65.00	$ 250.00	$ -	$ -	$ 510.00	$ 1,530.00	0.00%	$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	0.00%	$1,560.00
	New SF VFD assume 65 hp	3	EA	14.00	Q5	$ 65.00	$ 7,500.00	$ -	$ -	$ 8,410.00	$ 25,230.00	0.00%	$25,230.00
	Misc for opening/ closing fans	3	EA	4.00	Q5	$ 65.00	$ 250.00	$ -	$ -	$ 510.00	$ 1,530.00	0.00%	$1,530.00
	Sub-contractor General Conditions & Provisions @ 5%	1	LS	0.00	Q5	$ 65.00	$ -	$ -	$ -	$ 92,793.50	$92,793.50	5.00%	$4,639.68
	Sub contractor Overhead & Profit @ 15%	1	LS	0.00	Q5	$ 65.00	$ -	$ -	$ -	$ 97,433.18	$97,433.18	15.00%	$14,614.98
	Total 2019 Cost for ECM-4 Variable exhaust air / makeup air (fans)												**($112,048.15)**
	Savings in 2019 for ECM -3 Indirect Evaporative Cooling (via atomizing)											$	*21,699.80*
	Net Savings in 2019 for ECM -3 Indirect Evaporative Cooling (via atomizing)												($90,348.35)
	Total 2020 Cost for ECM -3 Indirect Evaporative Cooling (via atomizing)												**($90,348.35)**
	Savings in 2020 for ECM -3 Indirect Evaporative Cooling (via atomizing)											$	*22,459.30*
	Net Savings in 2020 for ECM -3 Indirect Evaporative Cooling (via atomizing)												($67,889.05)
	Total 2021 Cost for ECM -3 Indirect Evaporative Cooling (via atomizing)												**($67,889.05)**
	Savings in 2021 for ECM -3 Indirect Evaporative Cooling (via atomizing)											$	*23,245.37*
	Net Savings in 2021 for ECM -3 Indirect Evaporative Cooling (via atomizing)												($44,643.68)
	Total 2022 Cost for ECM -3 Indirect Evaporative Cooling (via atomizing)					**NOT A PAYBACK YEAR**							**($44,643.68)**
	Savings in 2022 for ECM -3 Indirect Evaporative Cooling (via atomizing)											$	*24,058.96*
	Net Savings in 2022 for ECM -3 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-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	$ 30,000.00	$ -	$ -	$ 35,460.00	$ 35,460.00	0.00%	$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	0.00%	$3,900.00
	Removal allowance of existing steam/ condensate piping/ valves	1	LS	200.00	Q5	$ 65.00	$ -	$ -	$ -	$ 13,000.00	$ 13,000.00	0.00%	$13,000.00
		1	EA	48.00	Q5			$ -	$ -	$ 3,120.00	$ 3,120.00	0.00%	$3,120.00
	Remove existing horizontal HPS- LPS heat exchanger					$ 65.00							
	Remove existing steam condensate trap	1	EA	12.00	Q5	$ 65.00	$ -	$ -	$ -	$ 780.00	$ 780.00	0.00%	$780.00
	New vertical HPS flooded HX	1	EA	60.00	Q5	$ 65.00	$ 18,750.00	$ -	$ -	$ 22,650.00	$ 22,650.00	0.00%	$22,650.00
	Install new 1" 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	0.00%	$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	0.00%	$22,100.00
	Sub-contractor General Conditions & Provisions @ 5%	1	LS	0.00	Q5	$ 65.00	$ -	$ -	$ -	$ 107,510.00	$107,510.00	5.00%	$5,375.50
	Sub contractor Overhead & Profit @ 15%	1	LS	0.00	Q5	$ 65.00	$ -	$ -	$ -	$ 112,885.50	$112,885.50	15.00%	$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											$	*4,125.29*
	Net Savings in 2019 for ECM-7 Flooded high pressure steam heat exchanger												($125,693.04)
	Total 2020 Cost for ECM-7 Flooded high pressure steam heat exchanger												**($125,693.04)**
	Savings in 2020 for ECM-7 Flooded high pressure steam heat exchanger											$	*4,269.67*
	Net Savings in 2020 for ECM-7 Flooded high pressure steam heat exchanger												($121,423.36)
	Total 2021 Cost for ECM-7 Flooded high pressure steam heat exchanger					**NOT A PAYBACK YEAR**							**($121,423.36)**
	Savings in 2021 for ECM-7 Flooded high pressure steam heat exchanger											$	*4,419.11*
	Net Savings in 2021 for ECM-7 Flooded high pressure steam heat exchanger												($117,004.25)
ECM-8 HID lighting change to LED													
1	Add: Replace existing halide light fixtures with LED												
	Demo: 250 W – TXR 250M PA22C TB, Lithonia - Metal halide fixtures to be replaced with LED fixtures	63	EA	1.00	ELEC	$ 65.00	$ -	$ -	$ -	$ 65.00	$ 4,095.00	0.00%	$4,095.00
	Demo: 250 W – TXC 250M 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	0.00%	$1,235.00
	Demo: 100 W – LGH 100M 7RW FFL 277, Lithonia - Recessed metal halide fixture to be replaced with LED	11	EA	1.00	ELEC	$ 65.00	$ -	$ -	$ -	$ 65.00	$ 715.00	0.00%	$715.00

AECOM

AECOM	University of Colorado Denver	Estimate Date:	Monday, September 30, 2019
Bldg	Location: Denver, CO		
xxx Street	Client: University of Colorado Denver		
Denver, CO xxxxxx	Job#: 60599515 Task 2	Type:	Concept

Item #	Description	Quantity	UOM	MH/Unit	Crew	$/MH	Material	Other	Other Total	Unit Cost	Subtotal	Sub Markups	Total Cost
	Demo: 250 W – SXP 25H 04-GG-P/SR25D-Q, 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 KACVG, 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 7RW 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/SR25D-Q, 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 KACVG, 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	Q5	$ 65.00	$ -	$ -	$ -	$ 152,549.75	$152,549.75	5.00%	$7,627.49
	Sub contractor Overhead & Profit @ 15%	1	LS	0.00	Q5	$ 65.00	$ -	$ -	$ -	$ 160,177.24	$160,177.24	15.00%	$24,026.59
	Total 2019 Cost for ECM-8 HID lighting change to LED												**($191,418.82)**
	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												($188,461.17)
	Total 2020 Cost for ECM-8 HID lighting change to LED												**($188,461.17)**
	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												($185,400.00)
	Total 2021 Cost for ECM-7 Flooded high pressure steam heat exchanger				**NOT A PAYBACK YEAR**								**($185,400.00)**
	Savings in 2021 for ECM-7 Flooded high pressure steam heat exchanger											$	*3,168.31*
	Net Savings in 2021 for ECM-7 Flooded high pressure steam heat exchanger												($182,231.69)

Item #	Description	Quantity	UOM	MH/Unit	Crew	$/MH	Material	Other	Other Total	Unit Cost	Subtotal	Sub Markups	Total Cost
ECM-9	**LED lighting with occupancy sensors**												
	Allowance for sensors	19,000	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	Q5	$ 65.00	$ -	$ -	$ -	$ 20,520.00	$20,520.00	5.00%	$1,026.00
	Sub contractor Overhead & Profit @ 15%	1	LS	0.00	Q5	$ 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												($19,010.42)
	Total 2020 Cost for ECM-7 Flooded high pressure steam heat exchanger												**($19,010.42)**
	Savings in 2020 for ECM-7 Flooded high pressure steam heat exchanger											$	*5,969.34*
	Net Savings in 2020 for ECM-7 Flooded high pressure steam heat exchanger												($13,041.09)
	Total 2021 Cost for ECM-7 Flooded high pressure steam heat exchanger				**NOT A PAYBACK YEAR**								**($13,041.09)**
	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												($6,862.82)

University of Colorado Anschutz Medical Campus

Energy Studies Cost Estimates
Perinatel Research Facility

Contents:

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

AECOM

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	**Project:** **University of Colorado Denver**
Bldg	Location: Denver, CO
xxx Street	Client: University of Colorado Denver
Denver, CO xxxxxx	Job #: 60599515 Task 2 — 9/30/2019
	By: SM — Chkd: JL

Energy Studies Design #4

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%	*$*	*20,000*
Phasing Requirements	Not Required	0.00%	*$*	*-*
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	Not Required	0.00%	*$*	*-*
Bidding Contingency	Not Required	0.00%	*$*	*-*
Total Construction Costs			**$**	**920,259**

AECOM

AECOM University of Colorado Denver
Bldg 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
023 HVAC													
ECM #1	**Variable Speed HW Pumping Modification**												
	(VFD from plan M-3 schedule, 1987)												
1	Add VFDs: Premium to pump cases for disconnections/ connections	2	EA	12.00	Q5	$ 65.00	$ 200.00	$ -	$ -	$ 980.00	$ 1,960.00	0.00%	$1,960.00
2	Add VFDs: Electrical power to pump motor VFDs	2	EA	3.00	Q5	$ 65.00	$ 75.00	$ -	$ -	$ 270.00	$ 540.00	0.00%	$540.00
3	Add VFDs: P-1,2 245 gpm HHW pumps VFD @7.5 hp	2	EA	8.00	Q5	$ 65.00	$ 2,500.00	$ -	$ -	$ 3,020.00	$ 6,040.00	0.00%	$6,040.00
	Sub-contractor General Conditions & Provisions @ 5%	1	LS	0.00	Q5	$ 65.00	$ -	$ -	$ -	$ 8,540.00	$8,540.00	5.00%	$427.00
	Sub contractor Overhead & Profit @ 15%	1	LS	0.00	Q5	$ 65.00	$ -	$ -	$ -	$ 8,967.00	$8,967.00	15.00%	$1,345.05
	Total 2019 Cost for ECM #1 Variable Speed HW Pumping Modification												**($10,312.05)**
	Savings in 2019 for ECM #1 Variable Speed HW Pumping Modification												$ 2,340.50
	Net Savings in 2019 for ECM #1 Variable Speed HW Pumping Modification												($7,971.55)
	Total 2020 Cost for ECM #1 Variable Speed HW Pumping Modification												**($7,971.55)**
	Savings in 2020 for ECM #1 Variable Speed HW Pumping Modification												$ 2,422.42
	Net Savings in 2020 for ECM #1 Variable Speed HW Pumping Modification												($5,549.13)
	Total 2021 Cost for ECM #1 Variable Speed HW Pumping Modification												**($5,549.13)**
	Savings in 2021 for ECM #1 Variable Speed HW Pumping Modification												$ 2,507.20
	Net Savings in 2021 for ECM #1 Variable Speed HW Pumping Modification												($3,041.92)
	Total 2022 Cost for ECM #1 Variable Speed HW Pumping Modification												**($3,041.92)**
	Savings in 2022 for ECM #1 Variable Speed HW Pumping Modification												$ 2,594.96
	Net Savings in 2022 for ECM #1 Variable Speed HW Pumping Modification												($446.97)
	Total 2023 Cost for ECM #1 Variable Speed HW Pumping Modification												**($446.97)**
	Savings in 2023 for ECM #1 Variable Speed HW Pumping Modification												$ 2,685.78
	Net Savings in 2023 for ECM #1 Variable Speed HW Pumping Modification				**PAYBACK YEAR**								**$2,238.81**
ECM #3	**Lighting**												
	(Fixtures from plan E-3, 1987)												
1	Add: Remove existing exterior flourescent Lighting fixtures with wiring and lifts (conduit remains as is)	6	EA	6.00	ELEC	$ 65.00	$ -	$ 100.00	$ 600.00	$ 490.00	$ 2,940.00	0.00%	$2,940.00
2	Add: Exterior LED Lighting replacements, H1 and lifts	2	EA	2.50	ELEC	$ 65.00	$ 350.00	$ 100.00	$ 200.00	$ 612.50	$ 1,225.00	0.00%	$1,225.00
3	Add: Exterior LED Lighting replacements, H2 and lifts	4	EA	2.50	ELEC	$ 65.00	$ 350.00	$ 100.00	$ 400.00	$ 612.50	$ 2,450.00	0.00%	$2,450.00
4	Add: New wiring in existing conduit and lifts	410	LF	0.09	ELEC	$ 65.00	$ 15.00	$ -	$ -	$ 20.85	$ 8,548.50	0.00%	$8,548.50
5	Add: Remove existing interior flourescent Lighting fixtures with wiring (conduit remains as is)	177	EA	0.50	ELEC	$ 65.00	$ -	$ -	$ -	$ 32.50	$ 5,752.50	0.00%	$5,752.50
6	Add: LED Interior lighting- T12 replacements, assume fixtures A2,A3,A4,C3,C4, E2, E3,E3a,E4	163	EA	1.00	ELEC	$ 65.00	$ 275.00	$ -	$ -	$ 340.00	$ 55,420.00	0.00%	$55,420.00
7	Add: LED Interior lighting- U-tube replacements, assume fixtures B, (not D), F, G1, G2, I	14	EA	1.00	ELEC	$ 65.00	$ 300.00	$ -	$ -	$ 365.00	$ 5,110.00	0.00%	$5,110.00
8	Add: New wiring in existing conduit	13,275	LF	0.08	ELEC	$ 65.00	$ 12.50	$ -	$ -	$ 17.70	$ 234,967.50	0.00%	$234,967.50
	Sub-contractor General Conditions & Provisions @ 5%	1	LS	0.00	ELEC	$ 65.00	$ -	$ -	$ -	$ 81,446.00	$81,446.00	5.00%	$4,072.30
	Sub contractor Overhead & Profit @ 15%	1	LS	0.00	ELEC	$ 65.00	$ -	$ -	$ -	$ 317,545.80	$317,545.80	15.00%	$47,631.87
	Total 2019 Cost for ECM #3 Lighting												**($368,117.67)**
	Savings in 2019 for ECM #3 Lighting												$ 1,568.53
	Net Savings in 2019 for ECM #3 Lighting												($366,549.14)
	Total 2020 Cost for ECM #3 Lighting												**($366,549.14)**
	Savings in 2020 for ECM #3 Lighting												$ 1,623.43
	Net Savings in 2020 for ECM #3 Lighting												($364,925.71)
	Total 2021 Cost for ECM #3 Lighting				**NOT A PAYBACK YEAR**								**($364,925.71)**
	Savings in 2021 for ECM #3 Lighting												$ 1,680.25
	Net Savings in 2021 for ECM #3 Lighting												($363,245.46)
ECM #4	**AHU1 - Control + RTU at front office**												
	(From report)	**1**	**VAV**										
1	Add: Night set back, controls to RTU ATC- BAS system	4	PTS	4.00	Q5	$ 65.00	$ 750.00	$ -	$ -	$ 1,010.00	$ 4,040.00	0.00%	$4,040.00
2	Add: Supply Air reset, controls to RTU ATC- BAS system	2	PTS	4.00	Q5	$ 65.00	$ 750.00	$ -	$ -	$ 1,010.00	$ 2,020.00	0.00%	$2,020.00
3	Add: VAV at 1250 cfm+ duct+rhc piping to separate the office zone with RTU	1	EA	48.00	Q5	$ 65.00	$ 5,000.00	$ -	$ -	$ 8,120.00	$ 8,120.00	0.00%	$8,120.00
4	Add: new VAV controls	3	PTS	4.00	Q5	$ 65.00	$ 750.00	$ -	$ -	$ 1,010.00	$ 3,030.00	0.00%	$3,030.00
5	Add: power to new VAV	1	EA	2.00	Q5	$ 65.00	$ 200.00	$ -	$ -	$ 330.00	$ 330.00	0.00%	$330.00
	Sub-contractor General Conditions & Provisions @ 5%	1	LS	0.00	Q5	$ 65.00	$ -	$ -	$ -	$ 17,540.00	$17,540.00	5.00%	$877.00
	Sub contractor Overhead & Profit @ 15%	1	LS	0.00	Q5	$ 65.00	$ -	$ -	$ -	$ 18,417.00	$18,417.00	15.00%	$2,762.55
	Total 2019 Cost for ECM #4 AHU1 - Control + RTU at front office												**($21,179.55)**
	Savings in 2019 for ECM #4 AHU1 - Control + RTU at front office												$ 28,076.19
	Net Savings in 2019 for ECM #4 AHU1 - Control + RTU at front office				**PAYBACK YEAR**								$6,896.64
ECM #5	**Reduce Duct Static Pressure**												
	(From plan M-4 schedule & report)												
1	Add PH-1 modifications: Premium to open AHU unit for disconnections/ connections	2	EA	12.00	Q5	$ 65.00	$ 200.00	$ -	$ -	$ 980.00	$ 1,960.00	0.00%	$1,960.00
2	Add modifications: Remove attenuator 22,000 cfm; 58"x20"	1	LS	6.00	Q5	$ 65.00	$ -	$ -	$ -	$ 390.00	$ 390.00	0.00%	$390.00
3	Add modifications: Add dynamic air filter at AHU-1	1	LS	6.00	Q5	$ 65.00	$ 2,500.00	$ -	$ -	$ 2,890.00	$ 2,890.00	0.00%	$2,890.00
4	Add modifications: Work needed to unit & duct	1	LS	12.00	Q5	$ 65.00	$ 7,500.00	$ -	$ -	$ 8,280.00	$ 8,280.00	0.00%	$8,280.00
	Sub-contractor General Conditions & Provisions @ 5%	1	LS	0.00	Q5	$ 65.00	$ -	$ -	$ -	$ 13,520.00	$13,520.00	5.00%	$676.00
	Sub contractor Overhead & Profit @ 15%	1	LS	0.00	Q5	$ 65.00	$ -	$ -	$ -	$ 14,196.00	$14,196.00	15.00%	$2,129.40
	Total 2019 Cost for ECM #5 Reduce Duct Static Pressure												**($16,325.40)**
	Savings in 2019 for ECM #5 Reduce Duct Static Pressure												$ 10,728.94
	Net Savings in 2019 for ECM #5 Reduce Duct Static Pressure												($5,596.46)
	Total 2020 Cost for ECM #5 Reduce Duct Static Pressure												**($5,596.46)**
	Savings in 2020 for ECM #5 Reduce Duct Static Pressure												$ 11,104.45
	Net Savings in 2020 for ECM #5 Reduce Duct Static Pressure				**PAYBACK YEAR**								$5,507.99
ECM #6	**PH1 - VVT/DDC Conversion**												
	(From report)	**31**	**VAVs**										
	Add: Change VAVs (terminal boxes) on Pneumatics for DDC- remove air tubing back to system	31	Ea	6.00	Q5	$ 65.00	$ 150.00	$ -	$ -	$ 540.00	$ 16,740.00	0.00%	$16,740.00
	Add: Connect VAVs to DDC (3 pts each)	93	PTS	2.50	Q5	$ 65.00	$ 500.00	$ -	$ -	$ 662.50	$ 61,612.50	0.00%	$61,612.50
	Add: Replace plenum.	31	LS	12.00	Q5	$ 65.00	$ 2,250.00	$ -	$ -	$ 3,030.00	$ 93,930.00	0.00%	$93,930.00
	Add: To VAV Valve RHC Actuators, add reset sensors.	1	PTS	4.00	Q5	$ 65.00	$ 750.00	$ -	$ -	$ 1,010.00	$ 1,010.00	0.00%	$1,010.00
	Add: Add unit ventilation night setback sensor (PH-1)	1	PTS	4.00	Q5	$ 65.00	$ 750.00	$ -	$ -	$ 1,010.00	$ 1,010.00	0.00%	$1,010.00
	Add: Add VAV temperature night setback sensors (PH-2).	31	PTS	4.00	Q5	$ 65.00	$ 750.00	$ -	$ -	$ 1,010.00	$ 31,310.00	0.00%	$31,310.00
	Misc Allowance	1	LS	8.00	Q5	$ 65.00	$ 500.00	$ -	$ -	$ 1,020.00	$ 1,020.00	0.00%	$1,020.00
	Functional Testing allowance	1	LS	15.50	Q5	$ 65.00	$ -	$ -	$ -	$ 1,007.50	$ 1,007.50	0.00%	$1,007.50
	Sub-contractor General Conditions & Provisions @ 5%	1	LS	0.00	Q5	$ 65.00	$ -	$ -	$ -	$ 207,640.00	$207,640.00	5.00%	$10,382.00
	Sub contractor Overhead & Profit @ 15%	1	LS	0.00	Q5	$ 65.00	$ -	$ -	$ -	$ 218,022.00	$218,022.00	15.00%	$32,703.30
	Total 2019 Cost for ECM #6 PH1 - VVT/DDC Conversion												**($250,725.30)**
	Savings in 2019 for ECM #6 PH1 - VVT/DDC Conversion												$ 10,467.11
	Net Savings in 2019 for ECM #6 PH1 - VVT/DDC Conversion												($240,258.19)
	Total 2020 Cost for ECM #6 PH1 - VVT/DDC Conversion												**($240,258.19)**
	Savings in 2020 for ECM #6 PH1 - VVT/DDC Conversion												$ 10,833.46
	Net Savings in 2020 for ECM #6 PH1 - VVT/DDC Conversion												($229,424.73)
	Total 2021 Cost for ECM #6 PH1 - VVT/DDC Conversion				**NOT A PAYBACK YEAR**								**($229,424.73)**
	Savings in 2021 for ECM #6 PH1 - VVT/DDC Conversion												$ 11,212.63
	Net Savings in 2021 for ECM #6 PH1 - VVT/DDC Conversion												($218,212.10)

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

Table of Contents

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 – CO_2 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.

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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 $/cfm) = [(200,424 cfm total)/(161,477 cfm without AHU-SP02 & 04)] * ($ 35,646/yr) = $ 44,244 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

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	260,436	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	72	81	47	10	12	12	33	65	88	93	97	therms/hr
Purchased CHW															
	On-Peak Cons. (therms)	2,180	1,926	2,888	3,235	9,041	18,090	17,647	17,379	12,049	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)						$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)						$18.93	$18.93	$18.93	$18.93					
	Off-Peak Demand (Oct-May)	$15.43	$15.43	$15.43	$15.43	$15.43					$15.43	$15.43	$15.43		
	Consumption	$9,343.09	$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	$12,801.75	$14,200.73	$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		
	Total Monthly Xcel Bill (no steam)	$22,093.32	$21,547.36	$24,684.03	$25,370.83	$32,679.73	$54,615.68	$53,673.98	$53,887.12	$46,047.87	$28,230.44	$23,484.64	$23,125.05	$409,440.04	
	Total Steam Bill	$20,360.69	$18,645.13	$13,095.25	$14,214.99	$4,677.98	$3,081.84	$3,216.67	$3,298.85	$3,863.86	$9,810.52	$17,994.09	$19,031.65	$131,291.52	
	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	$18,976.48	
	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	$3,859.49	$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	289,736	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	1,651	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)						$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)						$18.93	$18.93	$18.93	$18.93					
	Off-Peak Demand (Oct-May)	$15.43	$15.43	$15.43	$15.43	$15.43					$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		
	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	$372,710.77	
	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	$129,433.43	
	Total Add'l Water Bill 2.22 gal/ton-hr @ 3 cycles of concentration @ $5.67/1,000gals	$29.69	$27.38	$129.76	$155.14	$434.89	$512.83	$318.46	$400.28	$585.42	$256.05	$53.18	$38.18	$2,941.26	
	Total Peak Demand Savings (kW)	24	42	99	98	17	50	25	4	20	88	83	79		

To include AHU-SP02 & 04, a factor of 20,0424 / 16,1477 was used.

Energy Savings:	$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

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: ☑ No Design ☐ Prelim. Design ☐ Final Design ☐ 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

	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)						$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)						$18.93	$18.93	$18.93	$18.93				
	Off-Peak Demand (Oct-May)	$15.43	$15.43	$15.43	$15.43	$15.43					$15.43	$15.43	$15.43	
	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	$22,851.62	$16,965.26	$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	$29,475.77	$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 - Energy Recovery	January	February	March	April	May	June	July	August	September	October	November	December	FY total
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
	On-Peak Demand (kW)	724	722	756	776	787	812	812	809	801	775	757	732	812 kW
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	94,665 therms
	On-Peak Demand (therms/hr)	73	72	67	66	41	11	14	14	28	55	73	71	73 therms/hr
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	93,707 therms
	On-Peak Demand (therms/hr)	17	21	30	33	52	66	65	67	60	49	25	24	67 therms/hr
	On-Peak Demand (kW)	99	122	175	192	303	385	379	391	350	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)						$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)						$18.93	$18.93	$18.93	$18.93				
	Off-Peak Demand (Oct-May)	$15.43	$15.43	$15.43	$15.43	$15.43					$15.43	$15.43	$15.43	
	Consumption	$9,497.18	$8,523.51	$10,333.41	$10,304.88	$15,472.78	$30,237.65	$29,880.28	$29,853.25	$23,351.96	$11,751.45	$9,467.39	$9,524.82	
	Demand	$12,701.45	$13,030.62	$14,365.31	$14,943.94	$16,823.82	$22,659.17	$22,548.74	$22,712.80	$21,788.39	$16,368.63	$13,930.71	$13,454.95	
	Total Monthly Xcel Bill (no steam)	$22,553.44	$21,908.94	$25,053.54	$25,603.62	$32,651.41	$53,251.63	$52,783.83	$52,920.86	$45,495.16	$28,474.89	$23,752.91	$23,334.58	$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

	January	February	March	April	May	June	July	August	September	October	November	December
Total Peak Demand Savings (kW)	28	28	28	27	45	114	70	69	56	39	28	28

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)						$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)						$18.93	$18.93	$18.93	$18.93				
	Off-Peak Demand (Oct-May)	$15.43	$15.43	$15.43	$15.43	$15.43					$15.43	$15.43	$15.43	
	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	$23,451.07	$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	$28,248.87	$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)						$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)						$18.93	$18.93	$18.93	$18.93				
	Off-Peak Demand (Oct-May)	$15.43	$15.43	$15.43	$15.43	$15.43					$15.43	$15.43	$15.43	
	Consumption	$7,992.42	$7,190.82	$8,763.57	$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	$46,092.94	$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

	January	February	March	April	May	June	July	August	September	October	November	December
Total Peak Demand Savings (kW)	83	94	85	101	130	141	134	151	119	82	101	104

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:
- ☑ No Design
- ☐ Prelim. Design
- ☐ Final Design
- ☐ 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

<u>**Energy Conservation Measure ECM-4 – Lighting Replacement In Large Auditorium**</u>

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 requires 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	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)						$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)						$18.93	$18.93	$18.93	$18.93				
	Off-Peak Demand (Oct-May)	$15.43	$15.43	$15.43	$15.43	$15.43					$15.43	$15.43	$15.43	
	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	$22,851.62	$16,965.26	$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	$29,475.77	$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	January	February	March	April	May	June	July	August	September	October	November	December	FY total
Electric														
	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	18,581	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)						$18.93	$18.93	$18.93	$18.93				
	Off-Peak Demand (Oct-May)	$15.43	$15.43	$15.43	$15.43	$15.43					$15.43	$15.43	$15.43	
	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	$3,437.54	$3,536.41	$4,223.40	$10,651.61	$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

	January	February	March	April	May	June	July	August	September	October	November	December
Total Peak Demand Savings (kW)	21	13	26	15	14	14	25	14	27	14	14	14

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: ☑ No Design ☐ Prelim. Design ☐ Final Design ☐ 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	January	February	March	April	May	June	July	August	September	October	November	December	FY total
Electric														
	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)						$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)						$18.93	$18.93	$18.93	$18.93				
	Off-Peak Demand (Oct-May)	$15.43	$15.43	$15.43	$15.43	$15.43					$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	$15,283.40	$17,497.59	$24,754.08	$23,870.68	$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	$47,342.33	$29,262.14	$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	$4,116.82	$10,385.80	$19,249.94	$20,361.97	$140,120.99

	UCD Ed 2 - CO2 Sensors	January	February	March	April	May	June	July	August	September	October	November	December	FY total
Electric														
	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)						$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)						$18.93	$18.93	$18.93	$18.93				
	Off-Peak Demand (Oct-May)	$15.43	$15.43	$15.43	$15.43	$15.43					$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

	January	February	March	April	May	June	July	August	September	October	November	December
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: ☑ No Design ☐ Prelim. Design ☐ Final Design ☐ 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:							
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 KW x 2917 hrs/year = 840,100 KWh energy used for lighting

15% x 840,100 KWh = 126,000 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)						$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)						$18.93	$18.93	$18.93	$18.93				
	Off-Peak Demand (Oct-May)	$15.43	$15.43	$15.43	$15.43	$15.43					$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	$22,589.11	$25,695.49	$26,460.63	$33,794.63	$56,940.49	$55,411.83	$55,815.48	$47,527.96	$29,455.05	$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	$10,660.60	$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)						$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)						$18.93	$18.93	$18.93	$18.93				
	Off-Peak Demand (Oct-May)	$15.43	$15.43	$15.43	$15.43	$15.43					$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	
	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	$413,484.50
	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	$144,929.95

Based on ASHRAE 90.1 App G (15% savings)

Energy Savings:	$11,218.92 per year
Maintenance	$771.00 per year
Total Savings:	$11,989.92 per year
Estimated Construction Costs	$101,074.00
Estimated Simple Payback	8.4 years

	January	February	March	April	May	June	July	August	September	October	November	December
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: ☑ No Design ☐ Prelim. Design ☐ Final Design ☐ 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 KW x 2917 hrs/year = 16,000 KWh energy used for lighting

50% x 50% x 16,000 KWh = 4,000 KWh

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

ECM-7

		January	February	March	April	May	June	July	August	September	October	November	December	FY total
	UCD Ed 2 Base													
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
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	
	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

		January	February	March	April	May	June	July	August	September	October	November	December	FY total
	UCD Ed 2 - Light Switch													
Electric	On-Peak Cons. (kWh)	284,242	256,255	290,372	278,294	291,585	298,338	297,935	305,772	283,748	286,268	278,013	280,160	3,430,982 kWh
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	
	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:
- [x] No Design
- [ ] Prelim. Design
- [ ] Final Design
- [ ] 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 KW x 8760 hrs/year = 191,000 KWh energy used for lighting

33% x 191,000 KWh = 63,700 KWh

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

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)						$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)						$18.93	$18.93	$18.93	$18.93				
	Off-Peak Demand (Oct-May)	$15.43	$15.43	$15.43	$15.43	$15.43					$15.43	$15.43	$15.43	
	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	$22,851.62	$16,965.26	$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	$29,475.77	$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)						$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)						$18.93	$18.93	$18.93	$18.93				
	Off-Peak Demand (Oct-May)	$15.43	$15.43	$15.43	$15.43	$15.43					$15.43	$15.43	$15.43	
	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

	January	February	March	April	May	June	July	August	September	October	November	December
Total Peak Demand Savings (kW)	18	14	18	18	25	18	24	19	19	24	17	15

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:

- [x] No Design
- [ ] Prelim. Design
- [ ] Final Design
- [ ] 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.

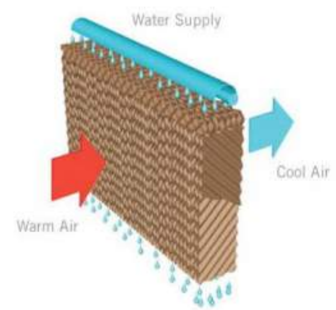


Figure 1 – Evaporative media diagram (courtesy Nature Cool)

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.

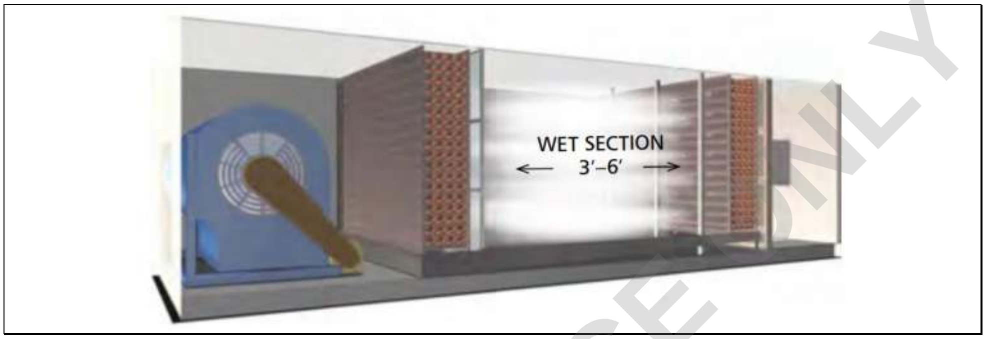


Figure 2 - High pressure atomizing humidifier/evaporative cooling (courtesy Mee Industries)

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 requires 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.

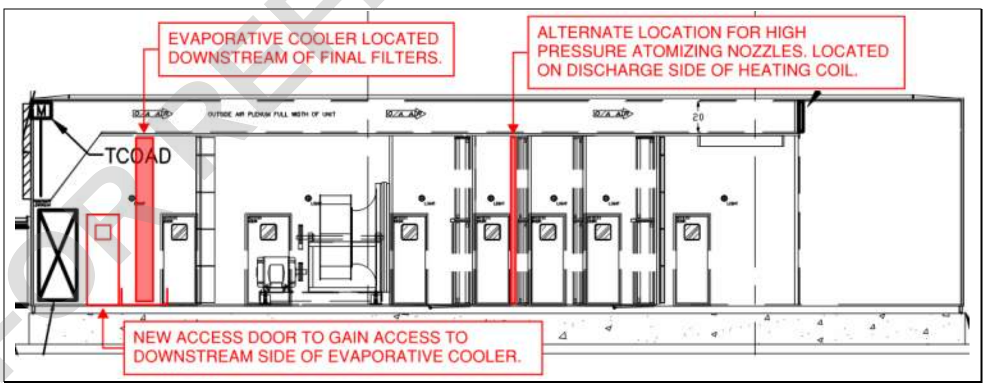


Figure 3 – Proposed MAU evaporative cooler and alternate high pressure atomizing nozzle location.

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.

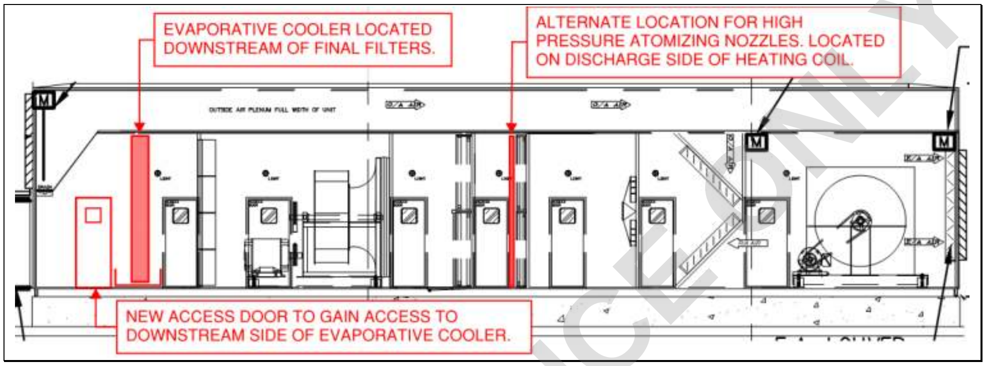


Figure 4 - Proposed AHU evaporative cooler and alternate high pressure atomizing nozzle location.

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.

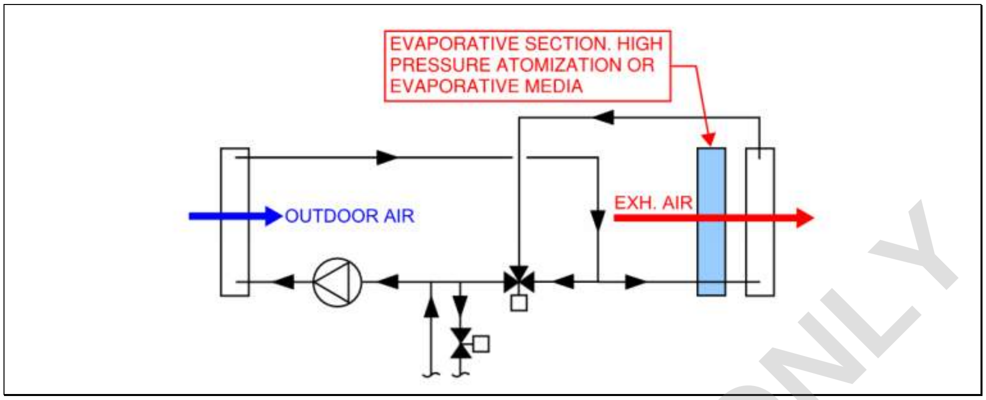


Figure 5 - Schematic of indirect evaporative cooling using a run around loop.

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.

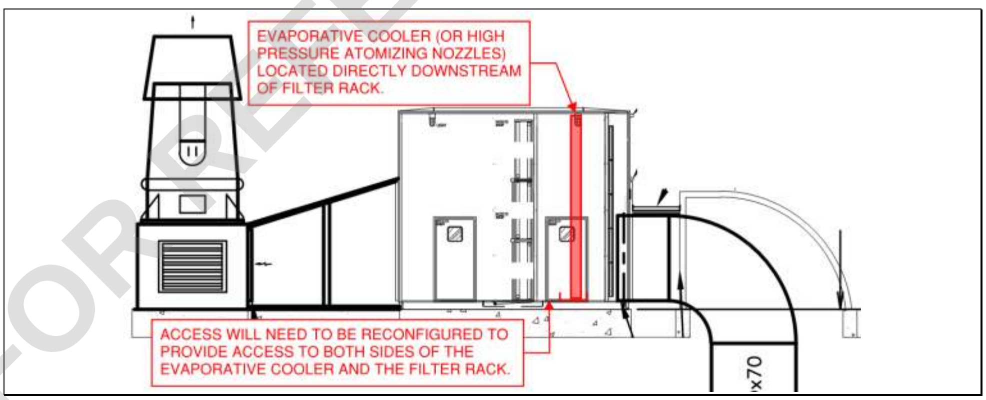


Figure 6 - Proposed EHU-1 evaporative cooler (or alternate high pressure atomizing nozzle) location.

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.

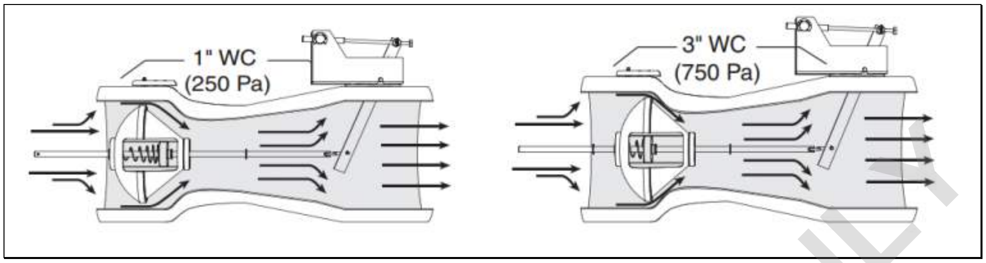


Figure 7 - Typical mechanically pressure independent air valve diagram illustrating constant flow at two different pressure differentials. Courtesy Phoenix Controls.

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.

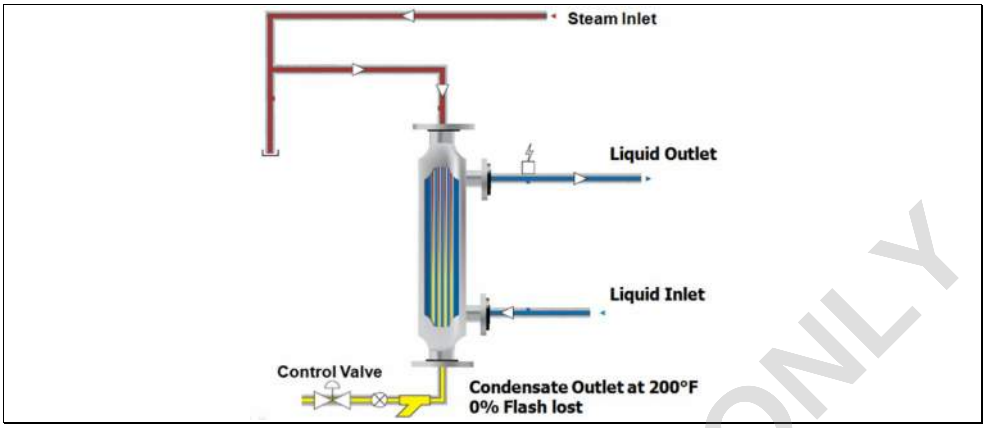


Figure 8- High pressure flooded type steam heat exchanger. Courtesy Maxi-therm.

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.

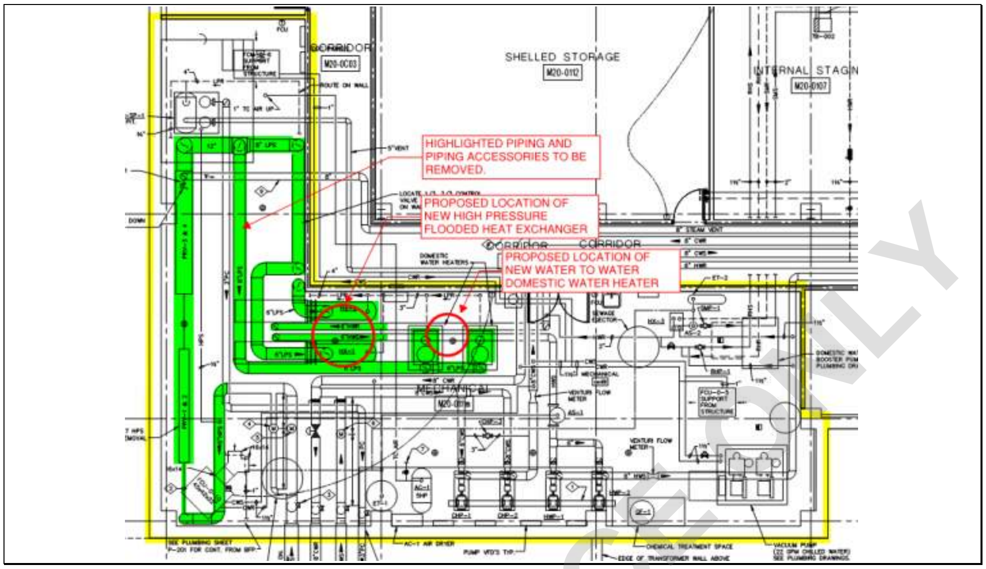


Figure 9 - Proposed location and modifications to the existing mechanical room.

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.

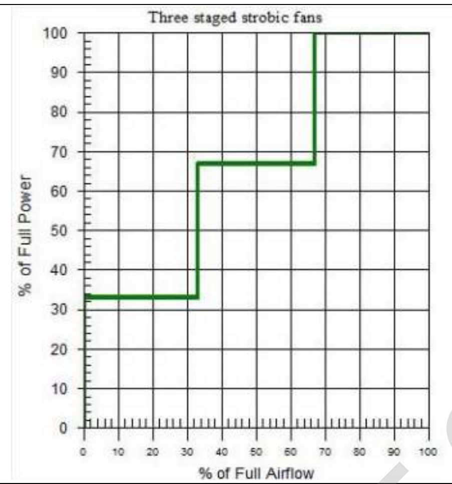


Figure 10 - Currently used (baseline) lab exhaust fan staging strategy.

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.

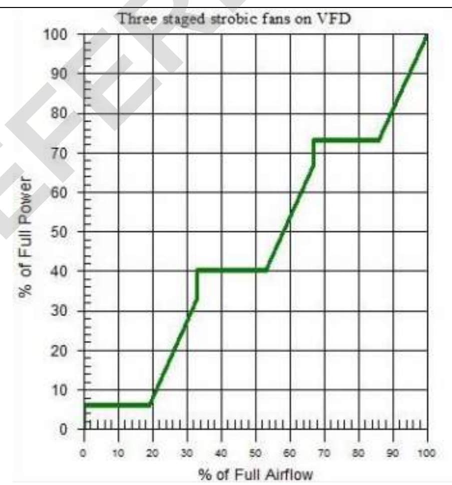


Figure 11 - Use of varying individual lab exhaust fan speeds in conjunction with staging fans.

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.

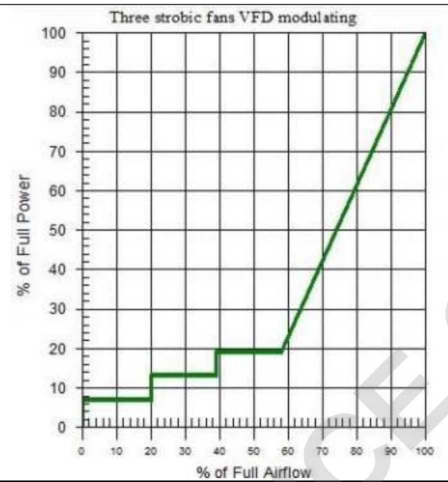


Figure 12 - Vary the speed of all lab exhaust fans in unison. Staging only occurs at minimum fan speed.

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.

FINANCIAL ANALYSIS						
Energy Conservation Option	**Chilled Water Savings** dth	**Steam Savings** dth	**Electricity Savings** kWh	**Utility Cost Savings** $	**Approximate 1st 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.

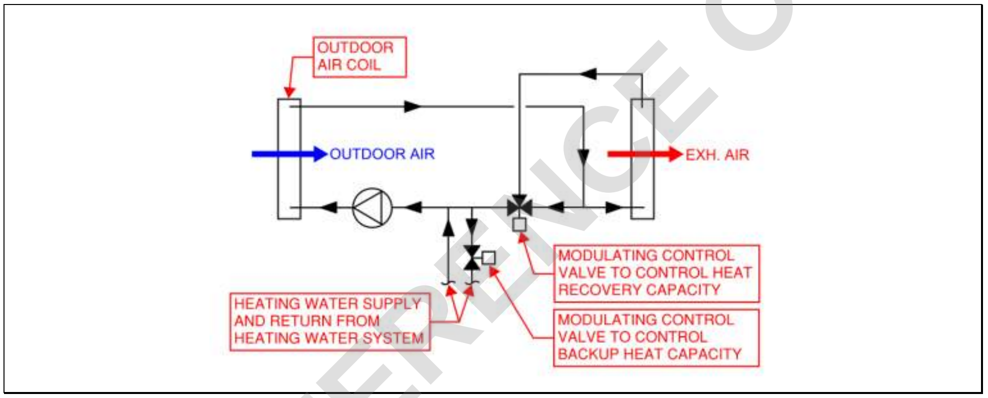


Figure 2 - Run-around loop schematic with backup hydronic heat.

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.

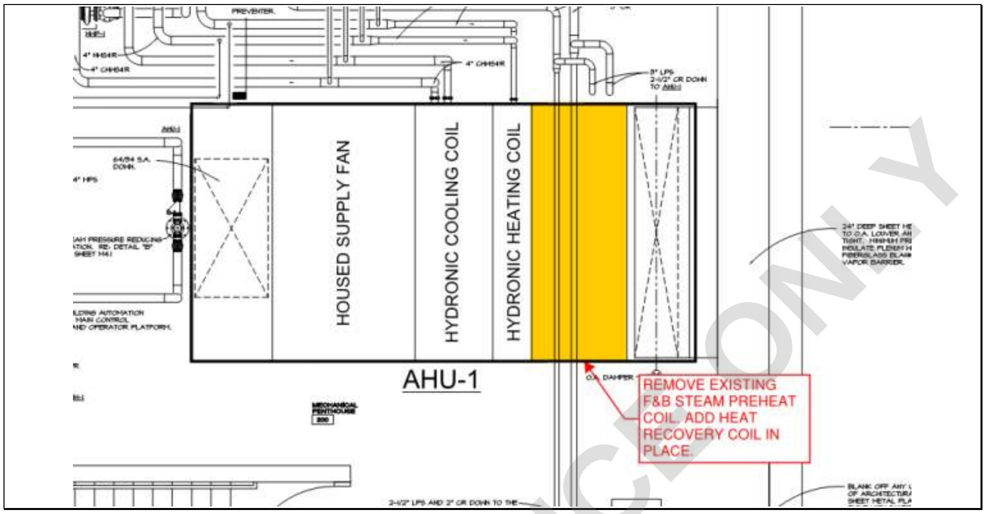


Figure 3 - Phase I building make-up air unit proposed heat recovery coil location.

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.

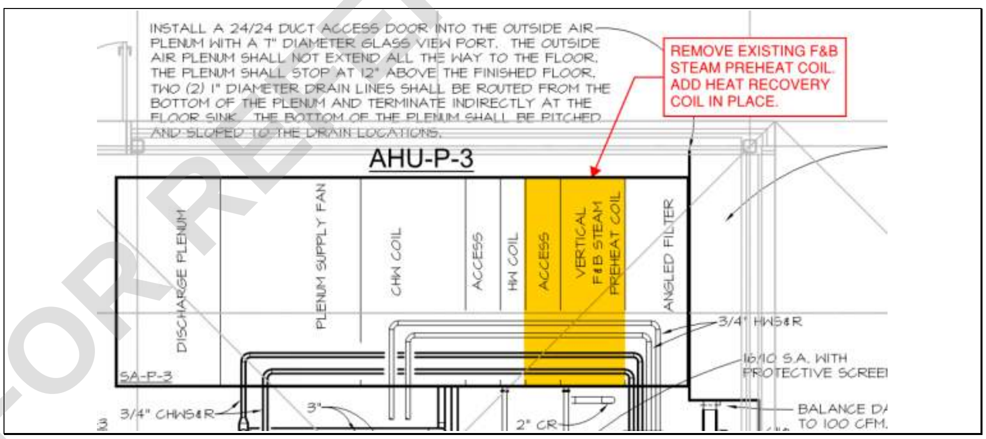


Figure 4 - Phase II building make-up air unit proposed heat recovery coil location.

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.

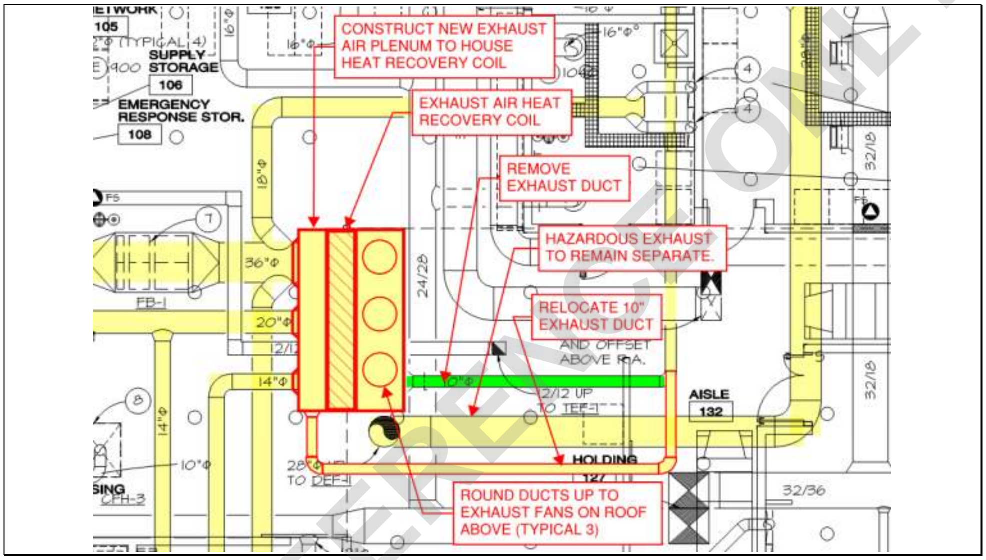


Figure 5 - Phase I building proposed exhaust air heat recovery coil locations.

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.

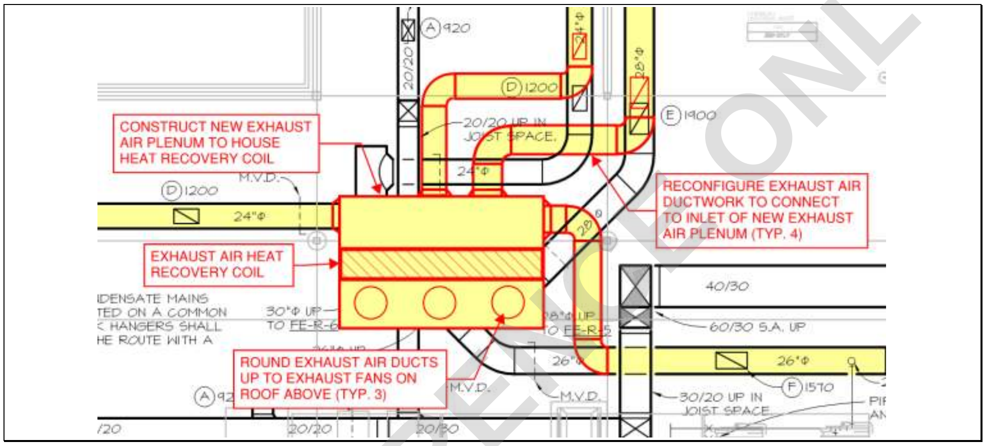


Figure 6 - Phase II building proposed exhaust air heat recovery coil locations.

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.

3. 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.

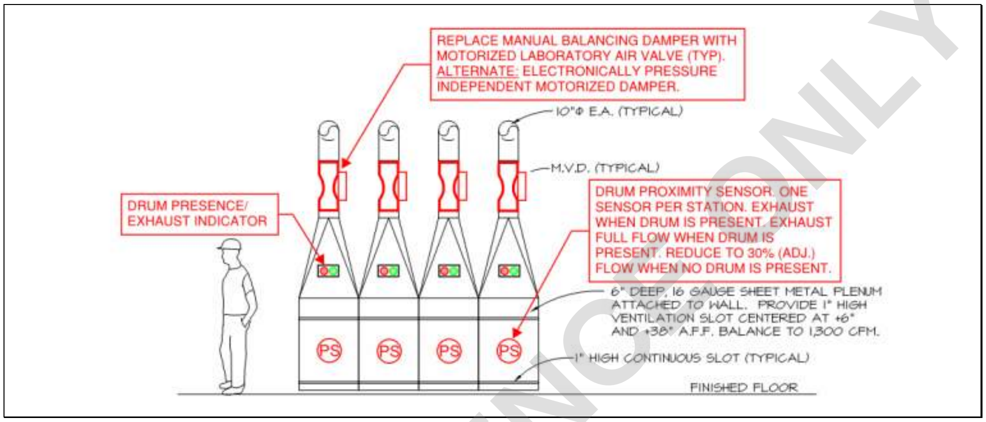


Figure 7 - Proposed drum exhaust station variable flow implementation.

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 ACH[1]. 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.

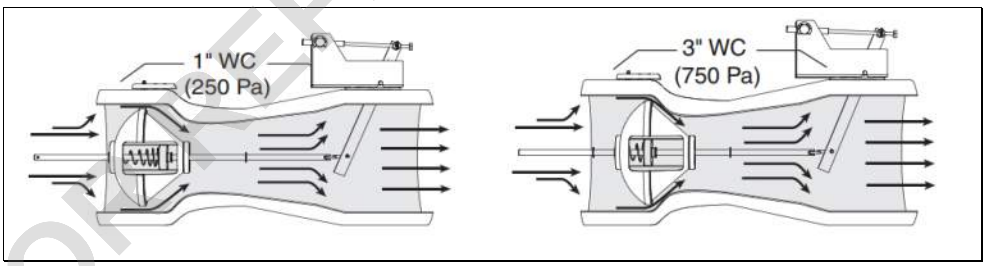


Figure 8 - Typical mechanically pressure independent air valve diagram illustrating constant flow at two different pressure differentials. Courtesy Phoenix Controls.

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.

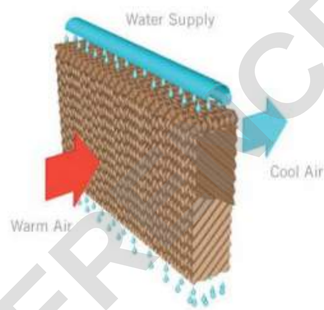


Figure 9 – Evaporative media diagram (courtesy Nature Cool)

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 requires 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.

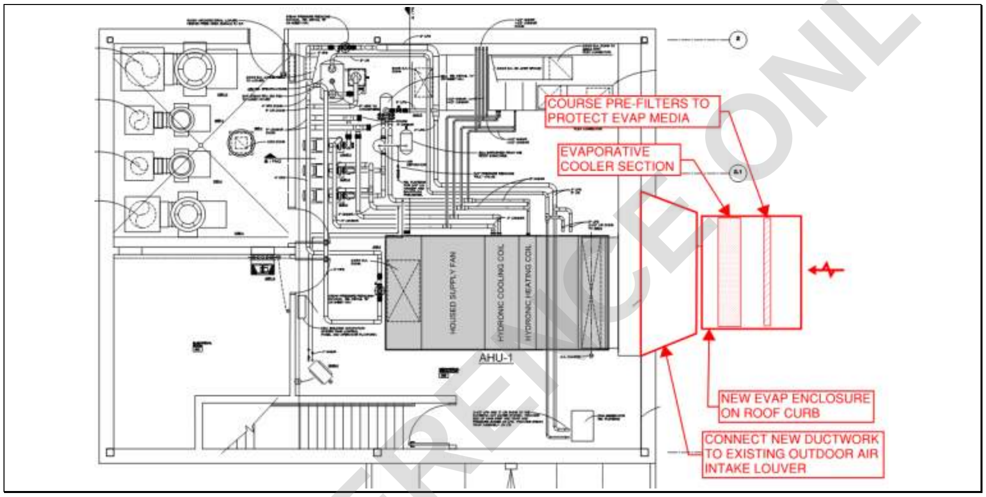


Figure 10 - Evaporative cooler addition to Phase I make up air unit.

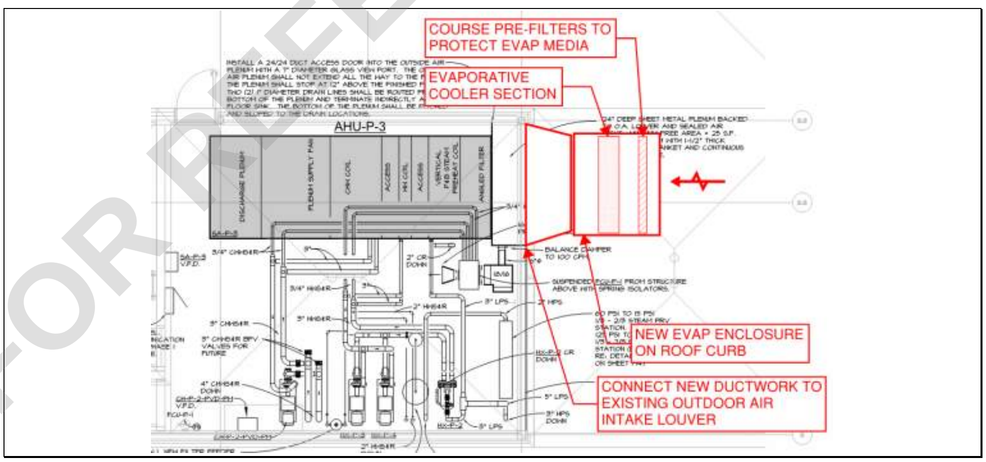


Figure 11 - Evaporative cooler addition to Phase II make up air unit.

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.

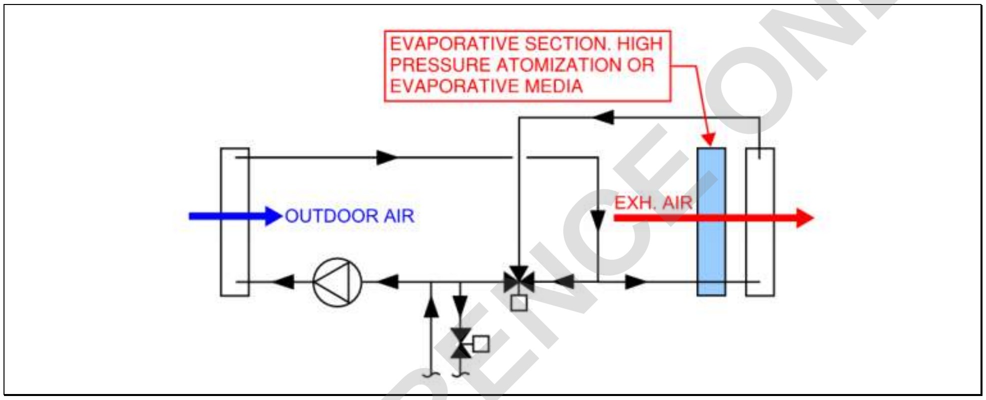


Figure 12 - Schematic of indirect evaporative cooling using a run around loop.

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, CO_2 sensors would be added to the occupied spaces. CO_2 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 CO_2 setpoints are satisfied. If either space reaches a CO_2 level of 1000 ppm, the AHU outdoor air flow will increase until the CO_2 setpoint is satisfied. If the CO_2 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.

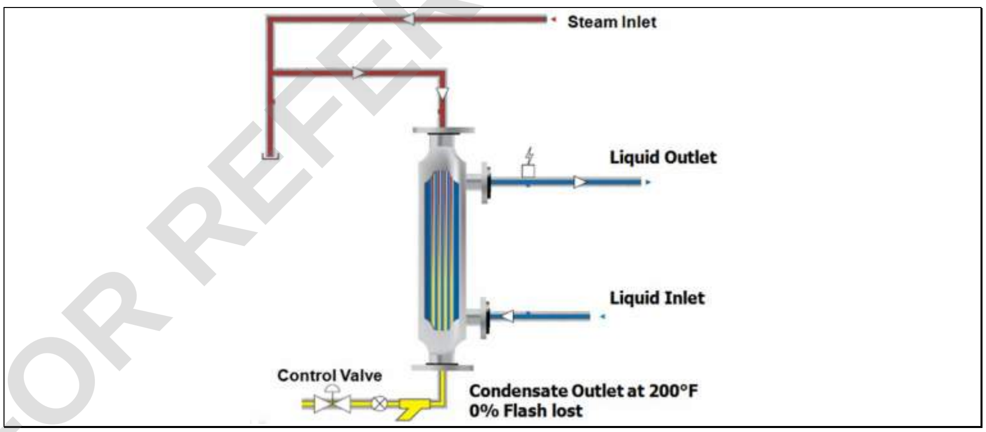


Figure 13- High pressure flooded type steam heat exchanger. Courtesy Maxi-therm.

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/ft^2 and 0.98 W/ft^2 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.

FINANCIAL ANALYSIS						
Energy Conservation Option	**Chilled Water Savings** dth	**Steam Savings** dth	**Electricity Savings** kWh	**Utility Cost Savings** $	**Approximate 1st 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 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.

Perinatal Research Facility

Preliminary Work Session

November 26, 2013

University of Colorado Denver

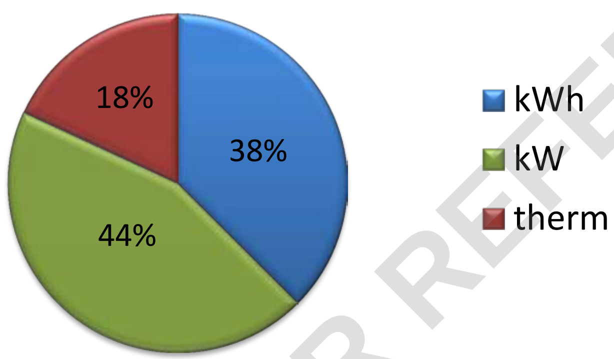
AMERESCO
Green • Clean • Sustainable

Agenda

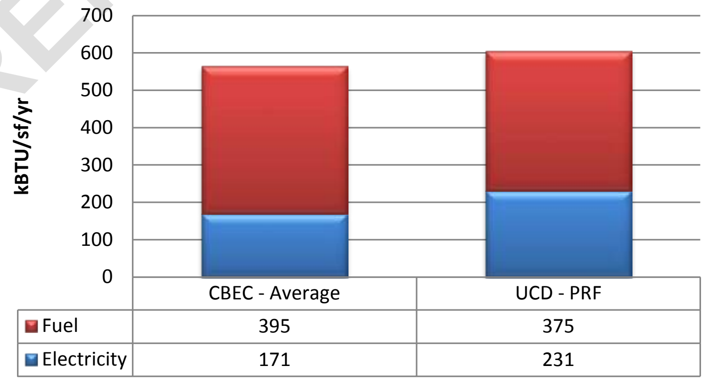
- Utility Analysis
- Proposed Measures
- Cost/Benefit Review
- Additional Needs
- Next Steps

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

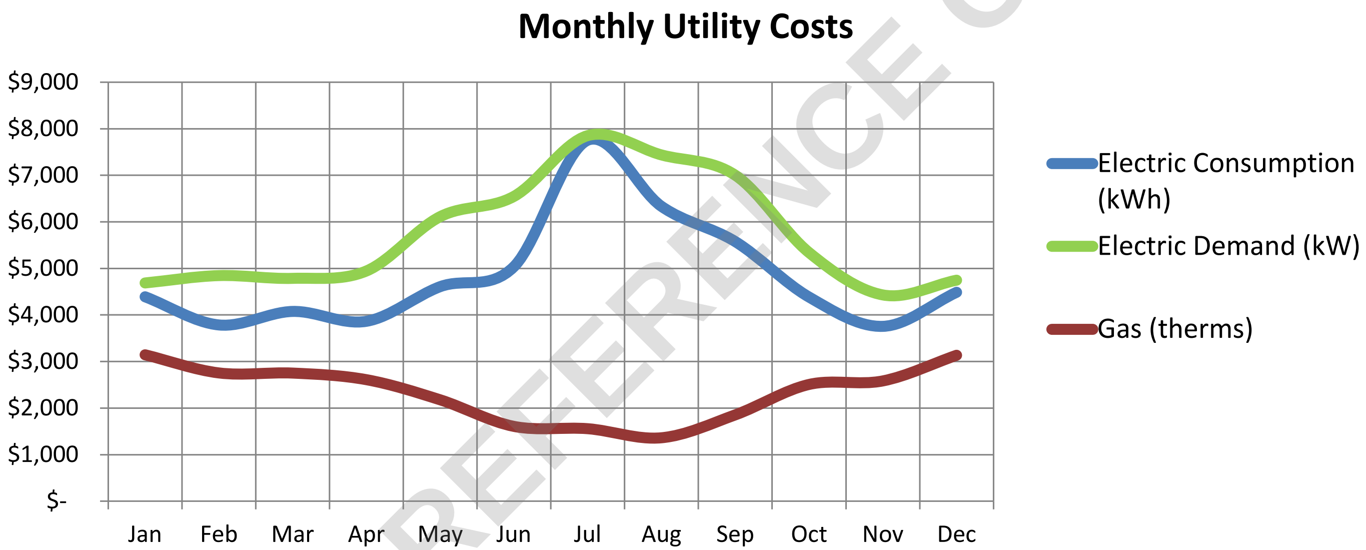
Energy Costs



Energy Use Index

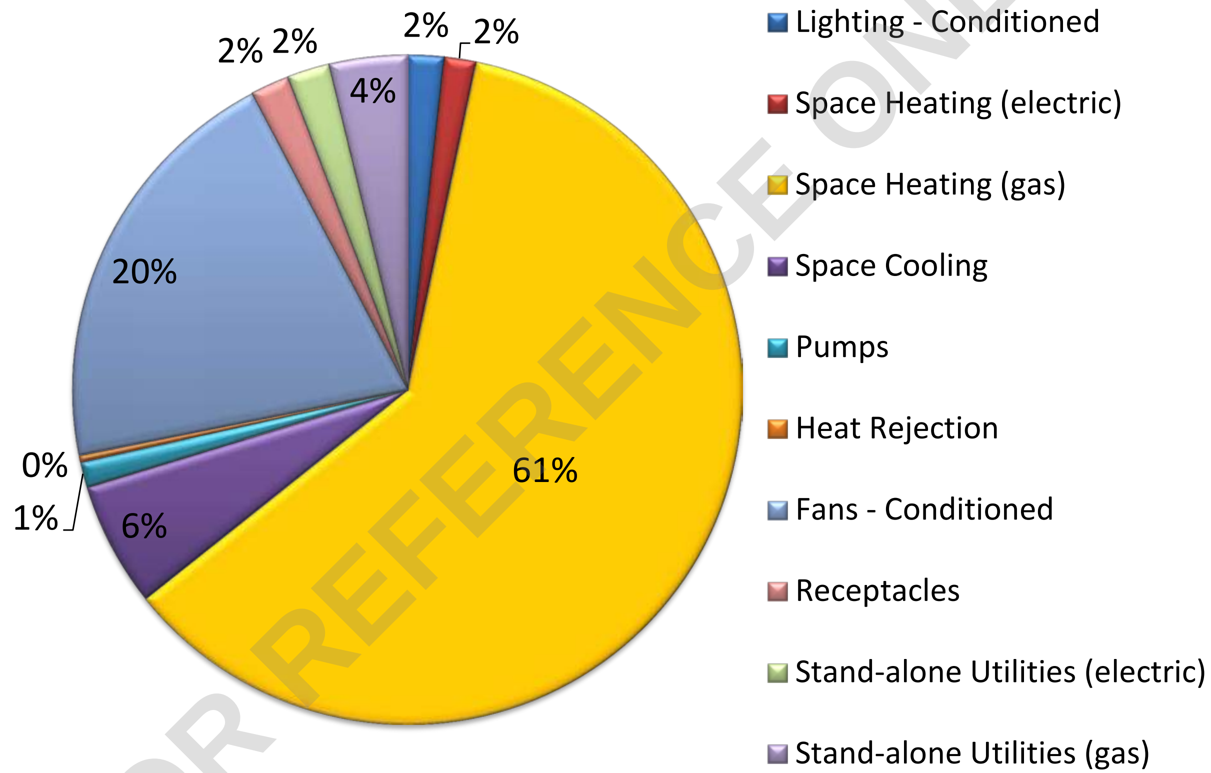


Measures

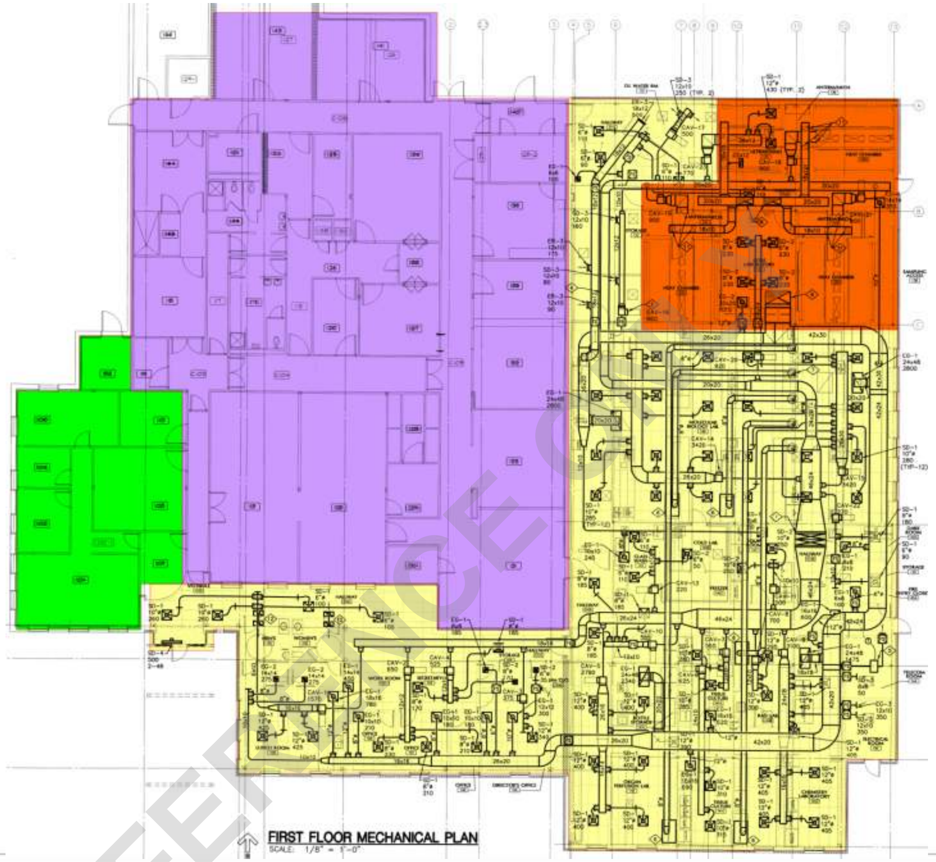


Monthly Utility Costs
$9,000
$8,000
$7,000
$6,000
$5,000
$4,000
$3,000
$2,000
$1,000
$-
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Electric Consumption (kWh)
Electric Demand (kW)
Gas (therms)

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