University of Colorado
Boulder

ENERGY
MASTER PLAN

February 2022

June 2021

David Kang, Vice Chancellor for Infrastructure and Sustainability

To the Students, Faculty and Staff of CU Boulder,

I am pleased to present this Energy Master Plan, the first planning effort of this magnitude ever devoted to energy use and efficiency on our campus.

We know that the effects of climate change are impacting every region on our planet, often with dire consequences for people and ecosystems. Further, these impacts disproportionately affect marginalized communities. These impacts are the reason our Chancellor, on April 22, 2021, issued a Call to Climate Action in which he committed the University to carbon neutrality by no later than 2050. This commitment is just the beginning. Our upcoming Climate Action Plan update will further refine our goals and the path by which we hope to achieve them. We must be more efficient and focus in particular on the life-cycle costs of our infrastructure so that we continue to be good stewards of our limited resources. We must also become more resilient and ensure that we can continue to support the mission-critical energy needs of our campus, day in and day out.

In support of that vision, this Energy Master Plan lays out the implementation roadmap for a clean-energy future on our campus. Notably, the plan includes a 30 percent reduction in energy use intensity in our buildings by 2035, as well as a shift to 100 percent clean energy use on campus by 2050. These are aspirational goals, and executing the plan will not be easy. However, we must be aspirational if we're to ultimately address the challenges of climate change.

We will also need the full buy-in of our campus community. This means approaching not only all building and infrastructure projects with a university-first mindset toward achieving these goals; it also means a culture in which we all take personal responsibility in the micro-moments of our daily lives—turning off lights, sharing resources in our classrooms and labs, using alternative transportation to name just a few.

Aspirational becomes achievable if we all move together toward this shared vision for a more sustainable and resilient future that is so vital to our society.

Sincerely,

David Kang
Vice Chancellor for Infrastructure and Sustainability

Table of Contents

Acronyms

A&R	Academics and Research
ACUPCC	American College and University Presidents' Climate Commitment
ASF	assignable square feet
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
ATH	Athletics
B&FP	Budget and Fiscal Planning
CMP	Campus Master Plan
CNIC	Center for Innovation & Creativity
cogen	cogeneration power system
CU	University of Colorado
CU Boulder	University of Colorado Boulder
CY	Calendar Year
DOE	Department of Energy
EAG	Energy Action Group
EC	Environmental Center
ECM	energy conservation measure
EDEP	East District Energy Plant
EIA	Energy Information Agency
EMP	Energy Master Plan
ESCO	energy service company
ESO	Energy Services Organization
EUI	energy use intensity
FO	Facilities Operations
FY	Fiscal Year

GHG	greenhouse gas
GSF	gross square feet
HFS	Housing Facilities Services
HVAC	heating, ventilation, and air conditioning
IECC	International Energy Conservation Code
kBtu	thousand British thermal units
LED	light-emitting diode
LEED	Leadership in Energy and Environmental Design
LEEDv4 BD+C	LEED version 4 rating system for Building Design and Construction
MMBtu	million British thermal units
MTCO2e	metric tons of carbon dioxide equivalent
MW	megawatt
NREL	National Renewable Energy Laboratory
OSO	Office of Space Optimization
PD&C	Planning, Design and Construction
PV	photovoltaic
REC	renewable energy credits
RES	Real Estate Services
S	sustainability
SF	square foot
SR	Student Representatives
University	University of Colorado Boulder
UES	Utility and Energy Services
WDEP	West District Energy Plant

Photo of Main Campus Including the College of Engineering and Applied Science
Source: JIannone, Flickr, Creative Commons (CC BY 2.0)

Executive Summary

Introduction

The University of Colorado Boulder (CU Boulder or University) has a well-founded reputation as a leader at the forefront of sustainability in higher education. CU Boulder's past achievements and policies demonstrate a commitment to advancing sustainable energy use, including being an early leader of green power purchasing, establishing the nation's first and largest student-run environmental center, and achieving Leadership in Energy and Environmental Design (LEED) Platinum certifications for new construction. This culture permeates the campus community at many levels, from faculty, academic programs and research-advancing technology, and knowledge on energy systems, to an informed student body that is ready and inspired to realize a sustainable future, beginning with their own campus. At the 2021 Campus Sustainability Summit, Chancellor Philip DiStefano announced CU Boulder's goal to reach carbon neutrality by 2050 and the formation of a new CU Boulder Sustainability Council. With the backdrop of these commitments and an escalating climate change emergency, CU Boulder recognizes the direct impact of its operational energy use on climate change and its responsibility to act.

This imperative to act has driven CU Boulder to develop a clear energy vision for a decarbonized and resilient campus, setting ambitious but achievable goals, and defining a path toward achieving them.

Role of the Energy Master Plan

This Energy Master Plan (EMP) establishes the University's approach to realizing a financially sustainable energy program that focuses on energy efficiency, greenhouse gas (GHG) emissions reductions, and provides a reliable energy supply that enables and enhances the campus' mission of education and research.

CU Boulder has developed this EMP to articulate its energy vision and establish a roadmap to accomplish it over the next 30 years. The overarching role of the EMP is to provide a framework that enables the campus to implement a cost-conscious energy program while preparing for changes in the campus' use of space, capital investment, and technology innovation in a rapidly changing environment.

The EMP defines CU Boulder's energy goals and serves as a guide toward achieving them by using metrics and specific targets where applicable, to track success of the program.

CU Boulder's energy goals and associated targets are summarized in Table 1.

Table 1: CU Boulder's Energy Goals and Targets

Goal	Targets	Description
Increase Campus Energy Efficiency *Reduce energy use intensity by an average of 2% per year*	**Energy use intensity (EUI) reduction:** • 5% reduction by 2025 • 15% reduction by 2030 • 30% reduction by 2035 From FY20 baseline – calculated as a weighted average of building typology	Commit first to minimizing campus energy consumption, meeting ambitious benchmarks for both existing and new facilities, and avoiding additional consumption where possible through optimized use of space and infrastructure and engaging the campus community in a culture of energy conservation.
Reduce Facility Energy Emissions *Target zero energy emissions by 2050*	**Emissions reduction (from CY05 baseline)** • 25% by 2025 • 50% by 2030 • 100% by 2050 **Electricity from clean sources:** • 50% by 2025 • 80% by 2030 (including 10% on-site renewable) • 100% by 2050	Decarbonize campus facility-tied energy use by 2050 through transition to clean thermal energy and implementation of a financially viable mix of on-site and regional clean electricity.
Enhance Critical Mission Resilience		Enhance energy resilience for mission critical facilities, research, and operations.
Lead in Energy Innovation		Establish CU Boulder as a world-leading, living, learning laboratory focused on collaboration between students, faculty, staff, and the community through research and deployment of innovative energy solutions with a positive global impact.

Fiscal year (FY), calendar year (CY)

The EMP provides a summary of the existing conditions of campus infrastructure and energy use characteristics, and the organizational structure, roles, and responsibilities to support ongoing project evaluation and implement necessary actions.

The EMP is intended to be a living plan, with periodic updates as required to remain a valid and comprehensive framework as the campus, technologies, and climate conditions evolve.

> The EMP provides an adaptable framework and roadmap for a financially sustainable energy program.

Development Process and Product

The EMP is a result of an extensive yearlong stakeholder engagement process, leveraging workshops and focus sessions with groups from across campus and industry experts to establish consensus on goals, validate strategies, and develop an implementable roadmap. This engagement process ensured that the ideas, aspirations, and challenges of each stakeholder group are represented and that the plan reflects a shared vision of the future.

The development of the goals, strategies, and resulting implementation roadmap was supported by a detailed technical and financial analysis to ensure that the EMP is both technically achievable and has a clear and justifiable investment pathway for the goals to be realized.

The EMP consists of six main sections: an introduction and background to provide context, four sections that expound on each of the principal goal areas and supporting actions, and a final section that lays out the roadmap for implementation. The EMP's appendices summarize the detailed supporting analysis that provides the evidence-base for the goals, strategies, and roadmap and additional resources to support implementation.

The roadmap presented in the EMP recognizes the fundamental challenges that the University must overcome to achieve these stated goals including reliance on a natural gas-fueled steam district heating network and an aging campus facility portfolio with substantial deferred maintenance. These challenges both limit the ease of implementation and compete for campus capital funds. The EMP presents ways in which these challenges can be overcome, focusing on what must happen today to lay the foundation for a more sustainable and resilient campus.

> The EMP roadmap meets CU Boulder's goals while realizing approximately $100 million in cumulative energy cost savings over the next 30 years compared to no action. The financial cost of a five-year delay is estimated to be over $6 million.

Norlin Quad
Source: Cass/University of Colorado

Background

Aspirations and Integration

CU Boulder's Legacy of Leadership and Sustainable Stewardship

CU Boulder was an original signer of the American College & University Presidents' Climate Commitment (ACUPCC) in 2007. As such, the University committed to science-based emissions reduction targets of 20 percent, 50 percent, and 80 percent reduction in GHG emissions by 2020, 2030, and 2050, respectively, from 2005 levels in addition to accelerating its climate-related research and educational offerings.

This was followed by the development of CU Boulder's conceptual Climate Neutrality Plan in 2009, which identified initial strategies for campus decarbonization including conservation and clean energy procurement. CU Boulder is also a member of the University Climate Change Coalition, a network of universities focused on helping communities achieve their climate goals. While successful sustainability initiatives have been undertaken in subsequent years, the University recognizes that the social, environmental, technical, and regulatory landscapes have changed since these commitments were made, and that more work needs to be done to reinvigorate its climate-focused agenda.

Finally, the University's stated vision is "To be a leader in addressing the humanitarian, social, and technological challenges of the twenty-first century." If there ever was a humanitarian, social, and technological challenge, climate change is it.

In a 2020 Sustainability Survey, 95 percent of students and 97 percent of staff said it is important to them that the University has a strong public commitment to climate and the environment.

Leadership

In view of its historical legacy and its current commitments, CU Boulder is regarded as a leader among organizations that take action and devote resources in response to climate change. CU Boulder is well positioned to "lead by doing" in the challenge of decarbonizing energy systems. Given its standing within the wider CU System, CU Boulder is influencing the approach to achieving enterprise energy goals, and it is taking the necessary first steps that will, in turn, benefit all four campus' in the system. This EMP was developed with that notion in mind.

Sustaining Operations

As a premiere research university, CU Boulder relies on critical research laboratories, irreplaceable scientific materials, sensitive equipment, and uninterruptible processes to accomplish its academic mission. The campus infrastructure (particularly energy-related) that supports the research mission must, therefore, be reliable and secure. The Boulder area faces the risk of flood, drought, wildfire, extreme high winds, hail, and weather hazards. These hazards will increase in frequency and intensity as climate change proceeds.

Along with natural hazards are human-caused disruptions. Whether of a benign motive or a criminal one (e.g., cyberattacks) the effect is the same: University infrastructure (particularly energy-related) is increasingly at risk; thus, the campus research and academic missions are increasingly at risk.

As the University continues to decarbonize its operations, the material and organizational actions it pursues can consequently improve its energy security and resilience. Sustainability and security are therefore inherently linked. The EMP recognizes this fact and has been developed, in part, to amplify this beneficial dynamic.

Campus in Winter
Source: AECOM

Related Imperatives of the Community

The CU Boulder campus resides in the broader Colorado community. The faculty, staff, and students of the University are also citizens of that community. In its response to the climate emergency, CU Boulder and the wider community have a shared imperative for action. The University recognizes the value of these relationships in both the achievement of its goals and those of the collective.

State of Colorado

The State of Colorado (State) faces the same climate hazards as does the University, but on a much broader geographic scale and with respect to a larger, more varied set of economic interests. In response, the State has embarked on an ambitious strategy to combat climate change.

In 2019, the Colorado Climate Action Plan became law. It aspires to reduce the State's GHG emissions by at least 26 percent (from 2005 levels) by 2025, 50 percent by 2030, and 90 percent by 2050. It seeks a 75 percent reduction in carbon dioxide (CO2) emissions from power plants by 2030.

Governor Polis' subsequent GHG Pollution Reduction Roadmap, 2021, establishes a program to electrify transportation, transition to clean energy, increase building energy efficiency and electrification, and reduce the GHG impact of refrigerants.

City of Boulder

The City of Boulder has always been a bastion of conservation. In 2019, the City declared a climate emergency and is pursuing action that responds to the emergency: the City hopes to achieve 100 percent renewable electricity by 2030, an 80 percent reduction in city organization emissions by 2030 (from 2008 levels), and an 80 percent reduction of community GHG emissions by 2050 (from 2005 levels). While the City's goals do not directly impact CU Boulder, its efforts to achieve them may present opportunities for collaboration and mutual benefit.

Included in the City's strategy for emission reductions are the following goals:

- Implement a net zero building code so that all new buildings achieve net zero emissions by 2031.
- Expand regional electric vehicle charging infrastructure, electrify the City's vehicle fleet, and promote electrification of public transportation.
- Expand the City's distributed, renewable energy resources, evaluate options for phasing out natural gas use, and work with institutional and community partners to develop microgrids for energy resilience.

Table 2: Summary of State, City, and CU Boulder GHG Emissions Reduction Goals

Time Horizon	State of CO	City of Boulder	CU Boulder
2025	26%	-	25%
2030	50%	80% (City)	50%
2050	90%	80% (community)	100%

Utility – Xcel Energy

Xcel is the regional energy provider and serving utility (gas and electric) to CU Boulder. Xcel has committed to decarbonize its power generation portfolio according to targets that are among the most ambitious of any utility in the country. As of 2020, Xcel reduced carbon emissions by 44 percent (from 2005 levels). It aspires to reduce carbon emissions by 80 percent (by 2030) and 100 percent (by 2050). As Xcel succeeds, so does CU Boulder.

Related Imperatives of the Campus

The EMP is informed by previous or ongoing studies and plans that relate to the campus physical plant. Many of these assessments, studies, and plans concern–directly or tangentially–energy consumption/ conservation or decarbonization. The EMP subsumes opportunities revealed by previous efforts and takes care to coordinate and synchronize where it is necessary or prudent. Among these imperatives that bear some relation to the EMP, or vise-versa:

- Campus Master Plan (CMP): Every 10 years CU Boulder updates its CMP to reflect the change in anticipated campus growth and physical infrastructure needs. As a living document, the EMP will be continuously responsive to the CMP. In the other direction, the EMP will provide input to the CMP process by developing rigorous guidance for energy performance and energy-related decision making. The EMP will inform on spatial implications of future energy systems and infrastructure.
- Campus Capital Governance: All major facility owners/planners (academic/ research, athletics, housing, etc.) engage in regular capital improvements planning. The EMP will inform these efforts so that they are aligned to their approach towards energy efficiency, resilience, and decarbonization. The EMP's recommendations, subsequent project development, and ongoing energy management program will integrate with the capital planning process through explicit funding requests, annual budgeting projections, and quantified cost recovery justification.
- Future Climate Action Planning: The EMP will form one of the components of CU Boulder's forthcoming update to its climate action plan. It will provide a focused assessment of facility energy goals and strategies that will contribute to the University's sustainability and climate commitments to be articulated by the climate action plan update.
- Strategic Facilities Visioning: The EMP relies on projections from the visioning effort to comprehend future space and energy demand.
- Housing Master Plan and Transportation Master Plan: The EMP relies on these efforts to inform energy demand estimates and as a means to vet the viability of related long-term energy strategies.

Figure 1 summarizes the campus initiatives that have either contributed to or will be influenced by the EMP.

> Although CU Boulder has plans for significant growth, it is working internally to optimize the allocation of space and minimize the amount of future construction needed.

Campus Planning Initiatives

- Campus Master Plan
- Housing Master Plan
- Transportation Master Plan
- Strategic Facilities Visioning
- Space Utilization & Optimization Program
- Campus Strategic Imperatives
- Campus Utility Distribution Program Plans
- Research Master Plan

Regional Initiatives

- Colorado Climate Action Plan
- Greening of State Government Executive Order
- City of Boulder's Climate Commitment
- Xcel Colorado Clean Energy Plan

Supporting Plans and Studies

- Conceptual Plan for Carbon Neutrality
- Energy Audits and Recommissioning Studies
- National Renewable Energy Laboratory (NREL) Boulder Energy Planning Assessment
- CU Boulder Flat Roof Study
- East Research Campus Microgrid Assessment
- CU Green Labs Case Studies
- Ralphie's Green Stampede

Campus Capital Plans

- Capital Renewal and Renovation Program
- 10-Year Capital Project List
- Real Estate Services Renewal and Replacement Plan
- Housing and Dining Capital Plan
- Athletics Capital Plan

Figure 1: Related Campus Initiatives

2016 CU Boulder Homecoming Game Against Arizona State
Source: Glenn Asakawa/University of Colorado

The Plan and The Process

The EMP is the documentary expression of a comprehensive plan to develop the goals, strategies, and methods that will deliver CU Boulder's energy enterprise to a clean, efficient, and resilient future. It is a framework to enable implementation of energy related improvements to the University's infrastructure, and it is a means to evaluate the energy resilience and sustainability performance of future capital investment and infrastructure retrofit.

Document Structure

The EMP consists of six main sections: an introduction and background, four sections that expound on each of the principal goal areas, and a final section that systematizes the complexity of the EMP by way of the implementation roadmap. There are seven appendices that provide additional background material in support of the EMP that focus on: energy management, strategy evaluation, goal setting, defining energy resilience, performance benchmarking, and stakeholder outreach.

Introduction and Background

This first section of the EMP describes the institutional drivers of this plan. It contextualizes the goals of the University and the surrounding community as they relate to climate change and other energy imperatives. The introduction also catalogs existing University plans with which the EMP must be reconciled.

Principal Strategies to Execute the Energy Master Plan

Each of four subsequent sections of the EMP provides a comprehensive treatment of a principal goal area. Sections include an overview that explains the nature of the strategy and its conceptual importance to the plan. The overview provides context for the detail that follows. The EMP's principal goals, to which the document is aligned, are:

- Increase Campus Energy Efficiency
- Reduce Facility Energy Emissions
- Enhance Critical Mission Resilience
- Lead in Energy Innovation

The sections catalog metrics and targets by which to define, measure, and monitor strategic success.

Each of the four goal sections details who the primary stakeholders should be, how the effort should be arranged in time and organizationally, and what programmatic, legal, and financial constraints might come to bear. Figure 2 summarizes the focus areas that are described in the EMP and how they support the four overarching goal areas.

Finally, each section proposes a set of actions, grouped by focus area, for the University to undertake. Actions are tasks, projects, programs, and initiatives that, by their continued implementation or completion, should improve the value of a related metric or advance progress toward a target. These actions are the work dictated by the EMP.

1 Increase Campus Energy Efficiency

A. Energy Monitoring Strategy
B. Energy Management Program Reporting
C. Energy Performance Benchmarking
D. Energy Auditing and Conservation Measures
E. Commissioning
F. Staff Development
G. Outreach, Education, and Engagement
H. Campus Building Operations Standards
I. Deferred Maintenance
J. Energy Performance
K. Design Standards Update
L. Performance-Focused Design Process
M. Space Optimization
N. Funding Mechanisms
O. Campus Energy Policy

2 Reduce Facility Energy-related Emissions

A. On-Site Clean Energy Generation
B. Community Solar
C. Clean Energy Procurement
D. Plan for Heating Decarbonization
E. Power Plant Optimization
F. East Campus District Energy

3 Enhance Critical Mission Resilience

A. Energy Resilience Design Requirements
B. On-Site Energy Generation and Storage
C. Campus Microgrid

4 Lead in Energy Innovation

A. Living, Learning Laboratory
B. Energy Research Opportunities
C. Engagement with Community Partners in Energy and Sustainability Goals
D. Periodic Energy Master Plan Validation

Figure 2: Energy Strategy Summary

A Roadmap to Integrate, Position, and Prioritize Actions

The final section of the EMP document provides a flexible pathway for CU Boulder to act while accommodating uncertainty and change. Executing the strategic vision of the EMP will encounter many challenges and diversions; however, this will be no match for the commitment of the community of people who believe in the plan and its aspirations.

Energy Planning Process

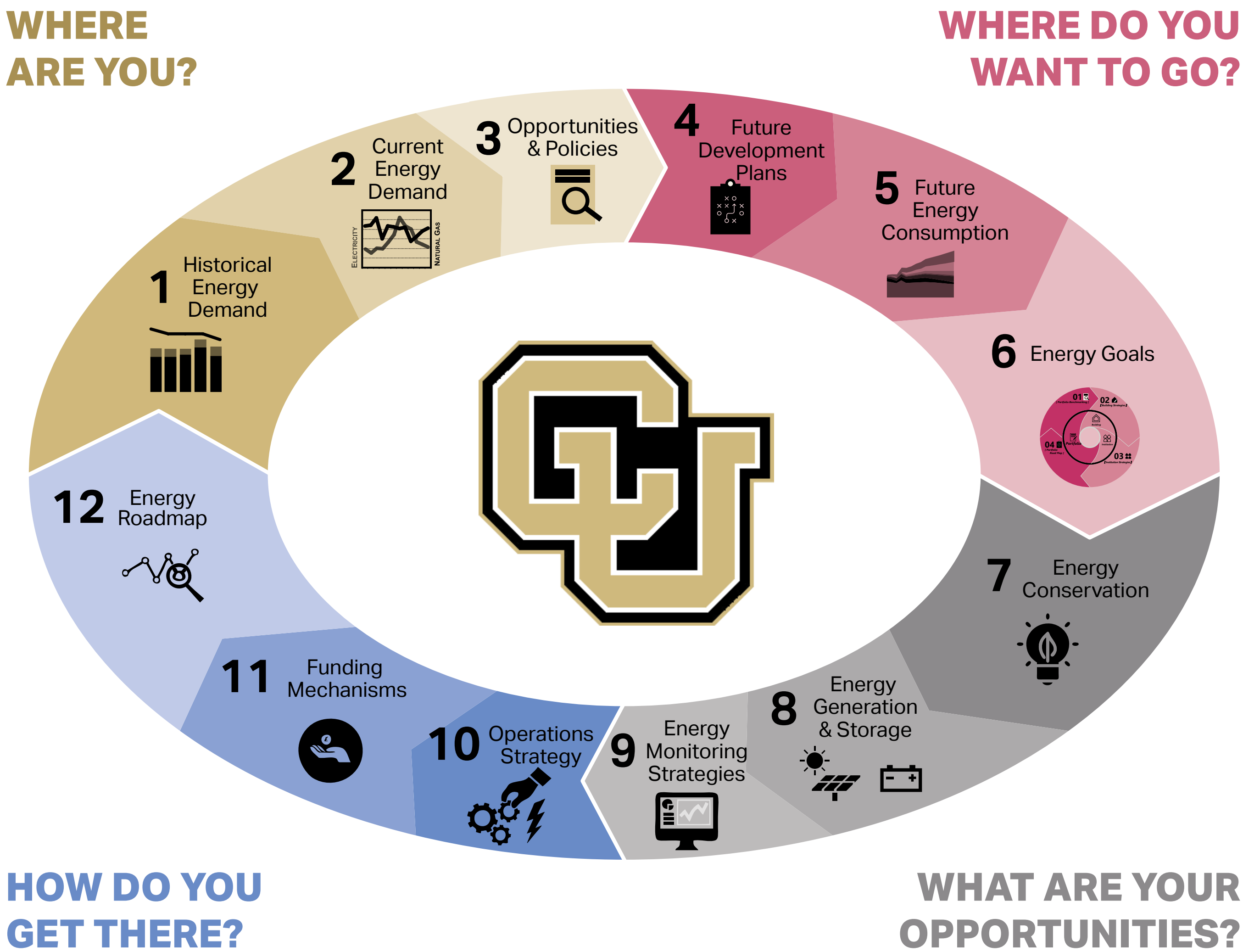


Figure 3: CU Boulder's Energy Planning Process

Developing the EMP was a yearlong effort, requiring the participation of more than 50 people. The approach was choreographed by AECOM's energy planning team following the comprehensive planning process summarized in Figure 3 that focuses on exploring ideas and synergies that derive from four foundational questions:

- Where are you? (Understand existing conditions, performance, and commitments)
- Where do you want to go? (Project future needs and set appropriate goals)
- What are your opportunities? (Evaluate and quantify potential strategies)
- How do you get there? (Develop a clear implementation framework to maximize success)

It was essential to the process to engage the campus stakeholders whose organizations, facilities, and operations will be impacted by the EMP.

Stakeholder Engagement

Stakeholder engagement meant bringing students, faculty, and staff from across the campus to contribute throughout the process. In addition to campus stakeholders, AECOM assisted in the development of the EMP with industry-leading professionals contributing subject matter expertise to enhance the quality of the effort.

Stakeholder engagement was a sure way to bring to bear one of the most powerful resources CU has at its disposal, culture. CU Boulder's team that created the EMP are the ones who are empowered to drive its success. CU Boulder recognizes that an engaged campus community will be an essential part of implementing the EMP, and the legacy connections of this development process will be invaluable to its success.

During the EMP development process, three distinct groups were formed to serve specific functions.

Energy Master Plan Working Group

The centerpiece of stakeholder engagement was the development of a cross-department EMP Working Group. Members of this group worked through a series of seven workshops and focus sessions to build consensus around the definition of energy resilience, to set goals, and to formulate an implementation roadmap. This team included representatives from the following campus organizations:

- Facilities Operations (FO)
- Utility and Energy Services (UES)
- Budget and Fiscal Planning (B&FP)
- Real Estate Services (RES)
- Athletics (ATH)
- Academics and Research (A&R)
- Housing Facilities Services (HFS)
- Environmental Center (EC)
- Sustainability (S)
- Planning, Design and Construction (PD&C)
- Student Representatives (SR)

Campus Energy Teams

Upon acceptance by the EMP Working Group members, the campus will need to develop an Energy Policy and Program Plan that will ensure the identified goals and timelines stated in the EMP are met.

In order to achieve the EMP goals, all campus organizations that own, operate, maintain, and/or support energy infrastructure will create independent "Campus Energy Teams" to develop organization-specific energy programs, projects, initiatives, and engagement plans. Each organization will designate an individual from their energy team to represent them on a CU Boulder Energy Action Group (EAG) as defined in the EMP.

Energy Action Group

The designated individual organization representatives will collectively form the EAG. Student representation will be a core component of the EAG.

The EAG's role will be to lead CU Boulder's collective effort towards achieving the campus energy goals through priority setting, coordination of stakeholders for project and program delivery, and communication to the wider campus community.

The EAG will be charged with making recommendations for necessary changes to CU Boulder's policy, management, and operations including the development of campus energy policies in support of the energy program. It will develop a charter that empowers the establishment of work processes, meeting schedules, project requests, timeline reviews, and guidelines/ protocols for implementation of energy actions recommended by the EMP.

Energy Services

The current Utility and Energy Services department will be reorganized to oversee the EMP recommendations. A new independent Energy Services Organization (ESO) is designated to have management and oversight of the campus energy portfolio. It will act as the centralized energy reporting group for any required campus, local, state, and federal entities.

The ESO will function as an internal campus resource for energy management and expertise, coordinating the activities of the EAG and supporting each member organization in scaling energy conservation within their organization. The ESO will support stakeholders in identifying opportunities and in project development, and it will assist specific project administrative tasks such as incentive or funding applications.

The ESO will manage the campus energy metering program and work with PD&C staff to communicate campus energy performance standards in new construction, renovations and equipment purchases.

Figure 4 shows the relationship between the ESO, the EAG, and the campus energy teams. See Appendix A for more detail on the roles and structure of Campus Energy Teams, the ESO and the EAG.

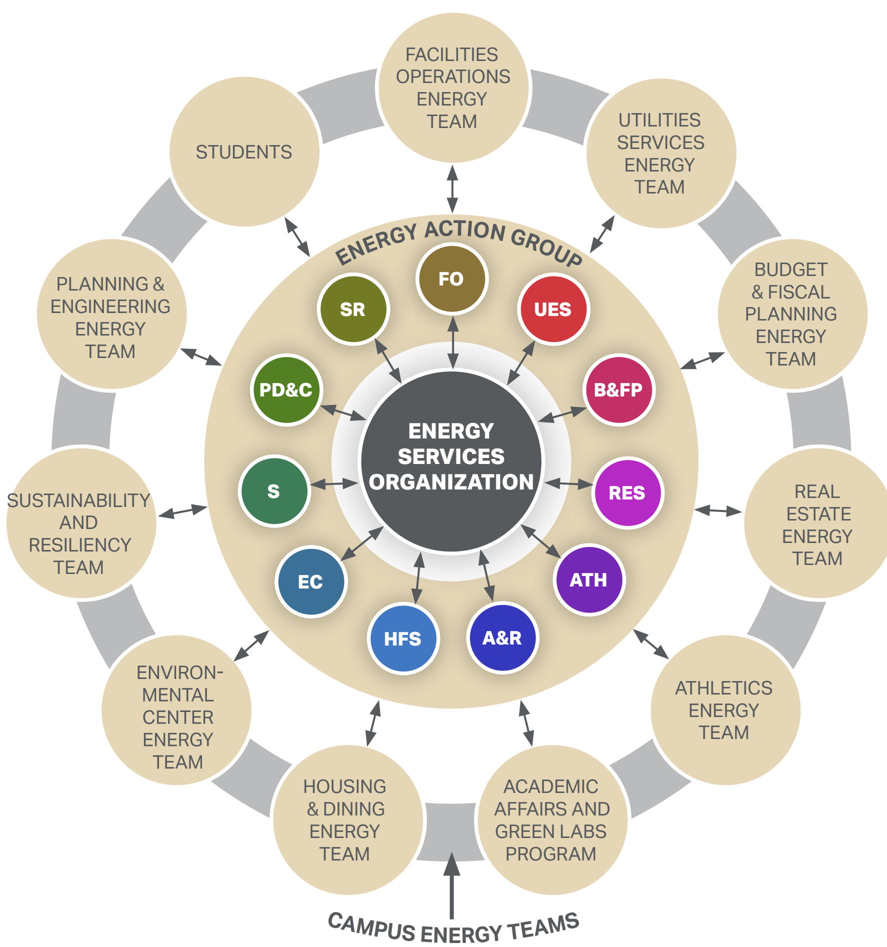


Figure 4: The Relationship Between the Campus Energy Teams, the EAG, and the ESO

CU Boulder Campus in Spring
Source: Glenn Asakawa/University of Colorado, Flickr, Creative Commons (CC BY 2.0)

Existing Energy Usage and Infrastructure

Energy master planning begins with acquiring a detailed understanding of the nature of energy consumption and the systems that enable it. The sources and demands of energy must be accounted for with a degree of resolution appropriate to the goals of the energy master planning effort. This knowledge establishes the baseline condition, and it allows for the construction of a high-resolution campus energy model. The model uses measured building energy data and the relevant characteristics of existing energy infrastructure. The calibrated model simulates hourly campus energy demand, and it provides a basis for parametric assessment of prospective future energy actions.

Energy Use at CU Boulder

On average, CU Boulder consumes 1.4 million British thermal units (MMBtu) of energy per year. Approximately 63 percent of that energy comes from natural gas use; 37 percent comes from electricity use. Total campus energy use has increased slightly over the past three years due to the addition of new research facilities. A four percent increase in campus energy use intensity over the past three years (110 thousand British thermal units (kBtu) per square foot in 2020) indicates this change. Moreover, campus consumption of natural gas is increasing.

Figure 5 shows CU Boulder's annual energy consumption split by end use and fuel source. Space heating of campus buildings, delivered mostly by the district energy networks, accounts for more than half of the total energy use. The second largest energy demand is electric equipment and plug loads (about 16 percent of campus demand) which primarily serve the University's research mission.

Figure 6 depicts energy use by building type. Energy use is concentrated primarily in research and learning buildings; housing buildings are the third largest consumer.

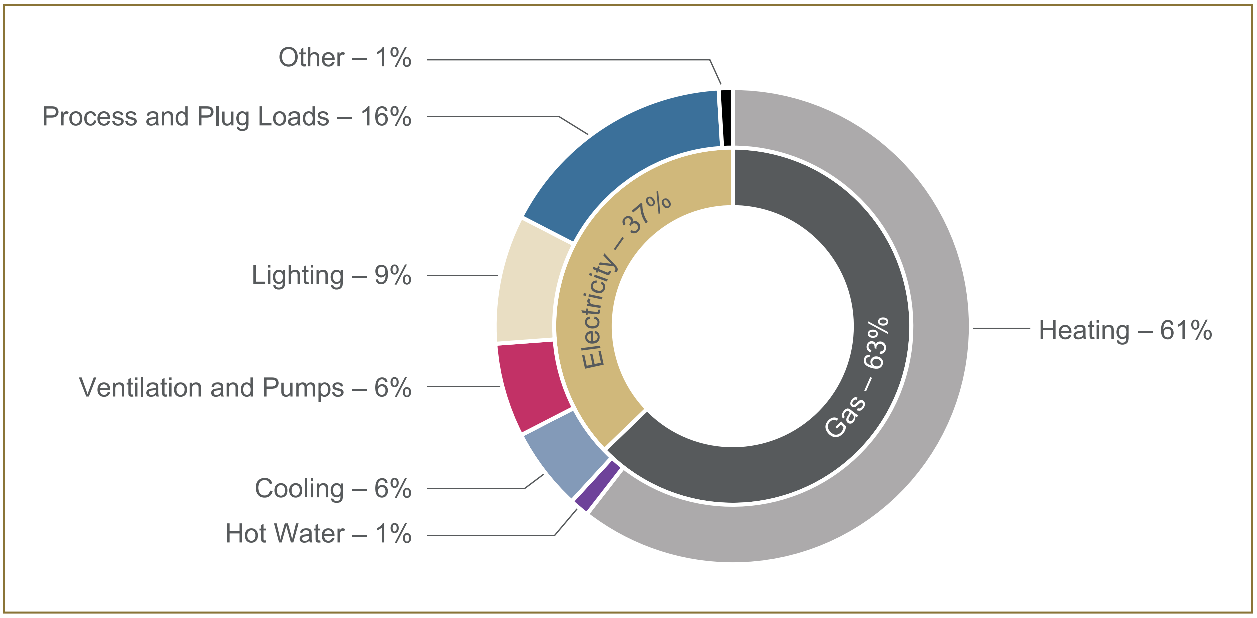


Figure 5: Energy Consumption by End Use and Fuel Source

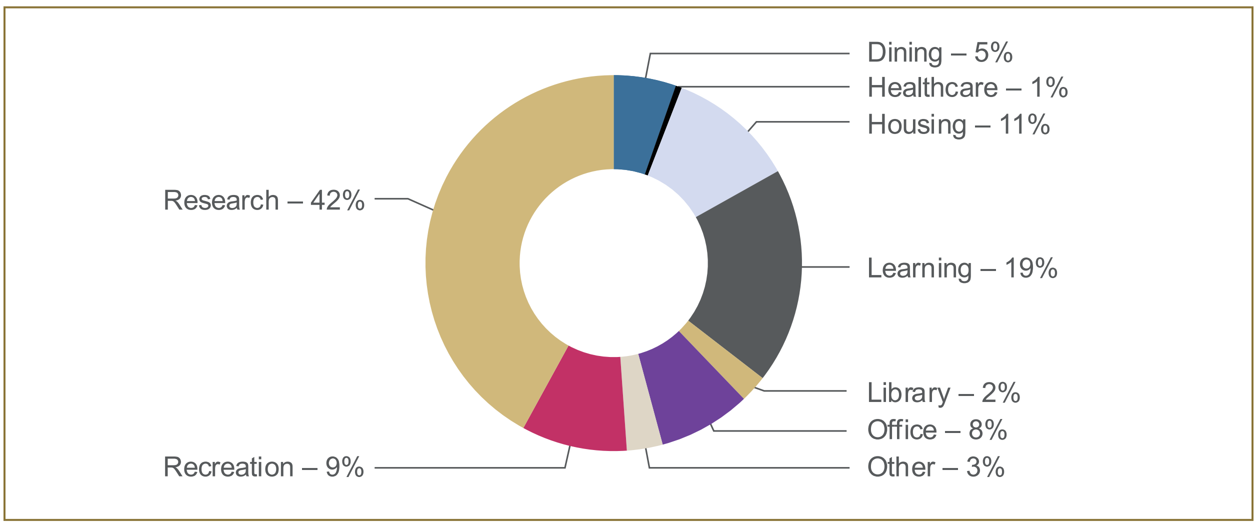


Figure 6: Energy Use by Building Type

Energy Spend

CU Boulder's annual energy charges are approximately $14 million. Charges have remained mostly steady (accounting for inflation) for the past few years. 80 percent of this cost is for the purchase of electricity, 20 percent is for the purchase of natural gas. The relatively low cost of natural gas and high cost of transitioning gas infrastructure has impeded attempts to build a compelling business case for switching to other fuels. Of the non-fixed electricity costs, approximately 52 percent are tied to demand charges, and 48 percent vary with consumption. This split is an important consideration in directing areas of intervention—those which reduce demand savings, such as energy storage, also increase energy resilience.

GHG Emissions

Facility energy-related GHG emissions have steadily decreased as shown in Figure 7. GHG emissions by fuel type are 60 percent electricity and 40 percent natural gas. As of 2019, CU Boulder facility energy-related GHG emissions are down approximately seven percent from their ACUPCC 2005 baseline. The decrease has been driven primarily by Xcel's reduction in emissions from electricity-generation.

A predominance of CU Boulder's energy consumption comes from its least expensive but most carbon-intensive fuel. The institution is committed to decarbonizing and to becoming more energy resilient. This is the challenge.

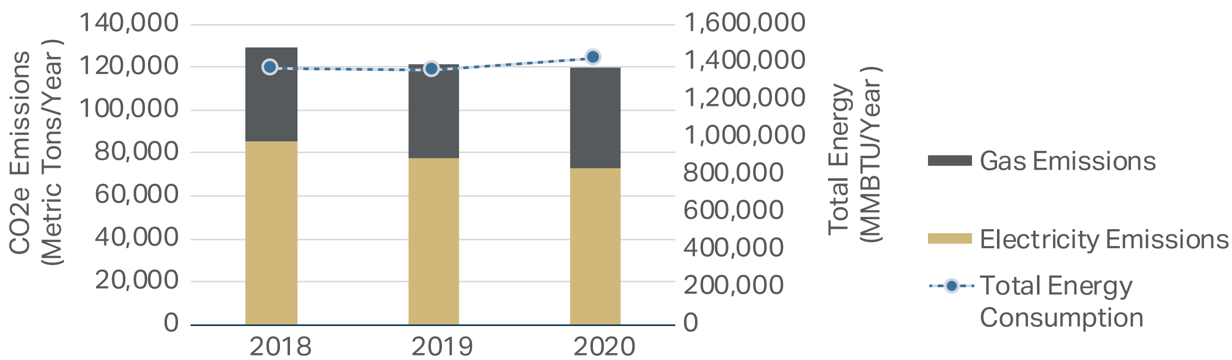


Figure 7: Historical Facility Energy-Related Emissions

Existing Energy Infrastructure

Power Infrastructure

Xcel Energy provides electric service to CU Boulder via three feeders, each through a dedicated substation-interconnection to the campus. Each feeder is individually metered. The feeders have integrated redundancy and the campus can operate fully on service from any two of the feeders. A catastrophic failure is therefore unlikely.

Behind the Xcel substation meters, the University owns, operates, and maintains an electric distribution grid that serves the Main Campus. The Main Campus distribution grid is interconnected with the East Campus grid at two points. Some buildings located on the East Campus, and all buildings at Williams Village, North of Boulder Creek, and other University locations are supplied directly by Xcel and have individual meters and accounts.

The University has a gas-fired cogeneration (cogen) system, located at the West District Energy Plant (WDEP). The cogen provides 33 megawatt (MW) and can power the entire Main Campus and parts of East Campus. However, it does not have black-start capability (i.e., it requires external power to restart its operation), which is a critical fault if it is not already operating when at least two of Xcel's feeders are disrupted.

Natural Gas Infrastructure

Natural gas for CU Boulder is also provided by Xcel. The utility owns and maintains the gas distribution infrastructure on campus and serves buildings via individual feeders. Buildings are individually metered. Gas is used mostly for heating during the winter, domestic hot water production, reheating during the summer, and dining and research laboratory equipment.

District Energy Systems

CU Boulder's district energy system delivers half of all the energy consumed by campus buildings. Two district energy plants, the WDEP and the East District Energy Plant (EDEP) are interconnected to serve the campus thermal load via 15 plus miles of steam and chilled water distribution piping on the Main Campus. The WDEP cogen plant supplements steam production in addition to generating electricity. The steam distribution network serves all buildings on Main Campus; the chilled water distribution network serves 14 percent of buildings on Main Campus. Williams Village has its own dedicated district energy system.

As the campus grows, so does the thermal load on the district energy system. Over the next decade, the University plans to expand the chilled water system to serve more than 10 additional buildings on the Main Campus. CU Boulder will expand the heating and cooling capacity at the EDEP to meet growing needs and improve redundancy and reliability.

The centralized supply of thermal energy via the district energy system has served the campus well. It provides for efficient operations and maintenance, it operates at high efficiency, and it delivers stable, reliable baseload heating and cooling, year-round. This performance may not be possible to achieve to the same degree via a decentralized approach.

Given the University's climate goals, the fact that the district energy plants are responsible for more than 80 percent of the University's gas use, and that gas is the University's most carbon-intensive fuel, it's clear that the central plants are a significant decarbonization opportunity. A transition to a decarbonized system on this scale, however, will be a monumental endeavor. The EMP roadmap recognizes this and addresses the matter with a multi-phased approach.

Building Portfolio and Deferred Maintenance

CU Boulder is consistently recognized as one of America's most attractive Universities. This results from a legacy of architectural care dating to the late 1800s. The University has continued that legacy by suffusing its stately campus with high-performance building design: all new buildings must achieve a minimum certification of LEED Gold. Currently, there are 28 buildings certified through LEED: 11 Platinum, 16 Gold, and 1 Silver.

As with many universities across the country, however, CU Boulder has a significant backlog of deferred maintenance. This is partly a consequence of age: 70 percent of the campus portfolio is older than 50 years, and some buildings are over 100 years old. While the maintenance effort is focused mostly on emergency repairs, there is limited funding available for larger renewal projects that slow the growth of the mounting maintenance backlog.

CU Boulder's capital renewal and renovation program is reconfiguring its approach to deferred maintenance. The program will systematically address existing backlog in a way that comports with the Campus Master Plan and Strategic Facilities Visioning. The capital renewal and renovation program will offer additional means to advance the goals of the EMP.

Figure 8 summarizes the existing district energy network areas and renewable generation locations at CU Boulder.

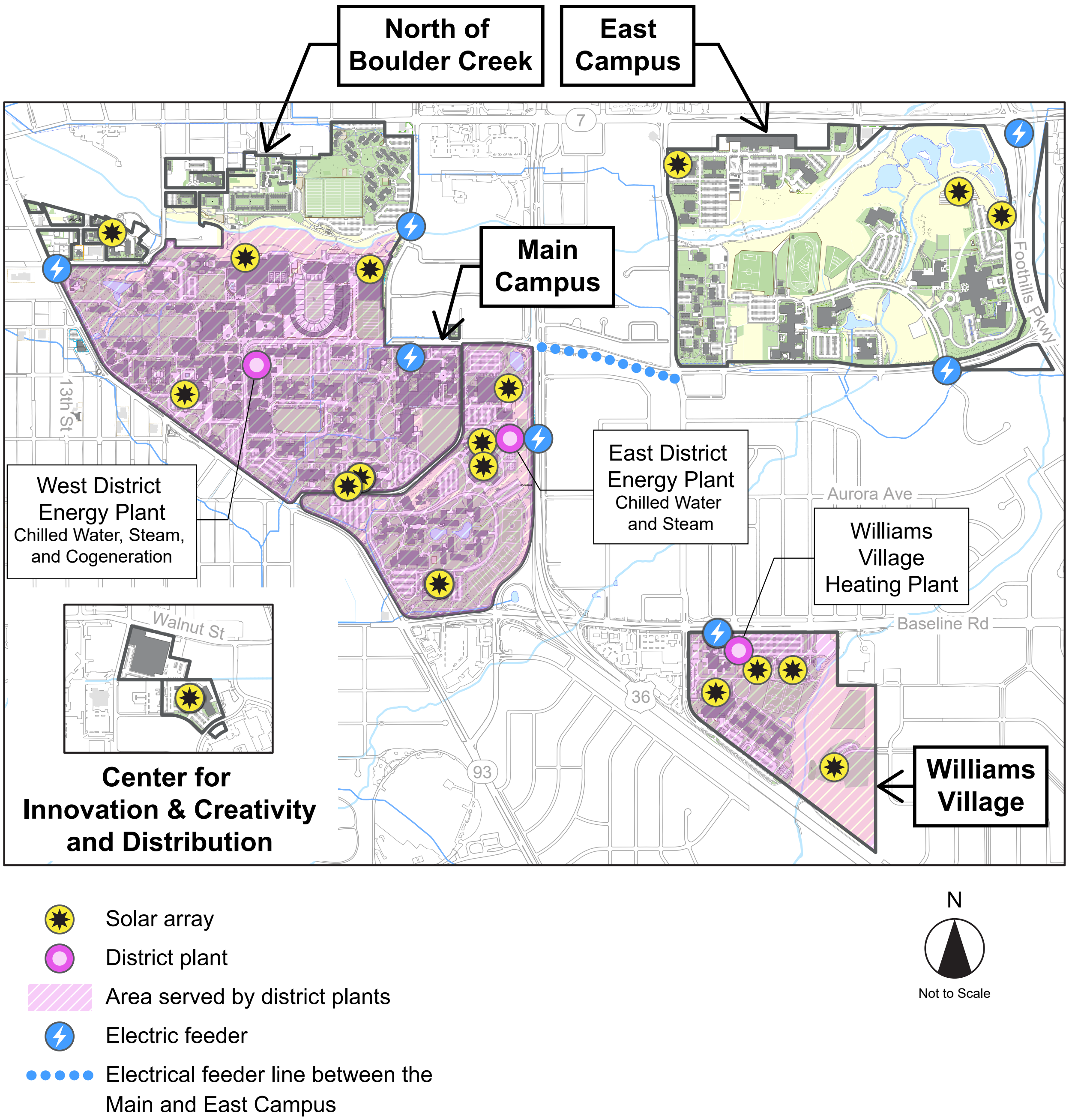


Figure 8: Key Campus Energy Infrastructure

1

Old Main and the Flatirons
Source: Glenn Asakawa/University of Colorado, Flickr, Creative Commons (CC BY 2.0)

Increase Campus Energy Efficiency

Commit first to minimizing campus energy consumption, meeting ambitious benchmarks for both existing and new facilities, and avoiding additional consumption where possible through optimized use of space and infrastructure and engaging the campus community in a culture of energy conservation.

Overview

The first steps towards an effective and comprehensive energy strategy are to reduce demand through conservation measures and to utilize energy in the most efficient manner possible. Energy conservation can provide a high return on investment, and CU Boulder has identified several opportunities to better use and manage energy. Reducing energy use has direct positive impact on GHG emissions and operational costs and can enhance resilience by reducing the load that needs to be supported. The EMP builds upon energy conservation and efficiency opportunities implemented by CU Boulder in the past by identifying additional areas for investment that provide room for growth. The plan approaches energy conservation from several angles, including establishing an energy monitoring and management program strategy; expanding the existing energy auditing program and implementing energy conservation measures; influencing the behavior of those who occupy, use, design, and operate the facilities; setting energy performance targets for existing and new facilities; optimizing space utilization to reduce the need for new facility construction; and leveraging alternative funding streams to implement the projects.

Metrics and Targets

To track the performance of energy conservation efforts, the following metrics will be used:

- Energy use (kBtu) per square foot of the overall campus portfolio (weighted average of building types)
- Energy use (kBtu) per square foot of each distinct building type
- Total energy consumption of the campus (kBtu/year)
- Total energy consumption (kBtu) for each building typology and stakeholder group
- Total space (in square feet) of each building typology and stakeholder group
- Annual performance scorecard for each building on campus to be distributed to relevant stakeholders

Energy use per square foot, or energy use intensity (EUI), will be used as the overarching metric to measure performance improvements in comparison to the FY20 baseline year. EUI is a metric designed to normalize energy use measurement across scale and type of building.

The University's future space projections show a rapidly evolving mission with an increasing commitment to energy-intensive research. If EUI were calculated as one single number for the campus it would be skewed upwards by this mission growth and not accurately capture performance improvements through conservation and efficiency. CU Boulder will, therefore, measure EUI reduction at a building typology level, with the aggregate campus performance calculated as a weighted average.

Table 3 summarizes CU Boulder's aggregated campus-level targets for energy conservation and efficiency.

Table 3: Energy Conservation Targets

Energy Use Intensity Reduction (from FY20 Baseline)	Target Year
5%	2025
15%	2030
30%	2035

Focus Area Descriptions

In support of these energy conservation and efficiency targets, CU Boulder has identified the following focus areas in which to take action.

A. Energy Monitoring Strategy
B. Energy Management Program Reporting
C. Energy Performance Benchmarking
D. Energy Auditing and Conservation Measures
E. Commissioning
F. Staff Development
G. Outreach, Education, and Engagement
H. Campus Building Operations Standards
I. Deferred Maintenance
J. Energy Performance
K. Design Standards Update
L. Performance-Focused Design Process
M. Space Optimization
N. Funding Mechanisms
O. Campus Energy Policy

A. Energy Monitoring Strategy

A vital component of effective energy conservation and improvements to efficiency is the implementation of a robust energy metering and data collection program. This provides University stakeholders and tenants with energy performance analytics and feedback required to actively learn and improve behaviors and operations. Energy performance information must be effectively collected and reported to the proper recipients to ensure CU Boulder can effectively assess the need, priority, and success of energy projects.

Sub-Monitoring

CU Boulder currently uses a combination of real and virtual (estimated based on available related data) energy meters to measure building-level energy usage trends, but the quality of metering in place varies depending on where the building is located.

The Main Campus has a single electricity and natural gas meter, and most buildings on Main Campus rely upon building-level submeters for electricity, natural gas, steam and chilled water for billing. There are key exceptions, such as the Engineering Center

Operations Desk at the East District Energy Plant
Source: AECOM Site Visit

on Main Campus, which is a complex of 12 buildings totaling over 580,000 square feet that is currently tracked under a single meter. Buildings located outside of Main Campus typically have individual electricity and natural gas and, therefore, dedicated meters.

However, to support a sophisticated energy program, whole-building-level energy readings are insufficient. They do not provide the granularity required to understand how and why that energy is being used, and where there are opportunities for improvement.

The image on the previous page shows the monitoring station at the EDEP where live monitoring data is used by staff to optimize plant operations.

CU Boulder will expand its energy monitoring capabilities through the installation of additional meters and monitors that can measure the performance of key energy-consuming systems or spaces, such as research equipment and laboratories, and from which energy data can be monitored through a comprehensive and user-friendly energy management system. These data can then be used to advise further energy conservation and efficiency strategies across the University's portfolio.

Energy Data Management

CU Boulder currently relies on a centralized utility bill accounting software to track campus utility customers for their energy consumption. However, the system does not currently consolidate all energy consumption on campus and cannot accurately track building-level energy use intensity. Therefore, to obtain a complete picture of campus energy consumption, energy management staff are required to undertake a time-consuming manual data input process. The University is working on expanding the capabilities of the existing system to reduce the amount of manual processing required to collect energy data. In addition to making these changes, CU Boulder will work with campus stakeholders to standardize and align the type of energy data to be collected to ensure that the information can be easily integrated with the campus-wide system and that these stakeholders can access the type of data that is useful to them when they need it and in the right format.

> Using a comprehensive integrated data analytics platform to measure and monitor energy usage will enable the University to create energy use dashboards, trends, and reports that are publicly accessible and can be used to engage building occupants in the energy conservation process, and also to inform the wider community and industry on the progress of the energy program.

B. Energy Management Program Reporting

As part of the development of the EMP, CU Boulder has established an energy management plan that supports the ongoing tracking and improvement of campus operations. The plan aligns with industry-recognized energy management protocols such as the National Renewable Energy Laboratory (NREL), Strategic Energy Management Evaluation Protocol and the International Standards Organization (ISO) 50001 Energy Management standard. Measuring, verifying, and reporting on the progress of key performance metrics is crucial to the success of any management plan, and is a useful tool to increase accountability and drive change on campus.

- **Measurement and Verification:** leveraging energy data and the approaches outlined in the energy monitoring strategy, CU Boulder will measure the year-on-year total energy use and energy use intensity of buildings and the campus as a whole. The ESO will lead the effort to analyze the distribution of energy use by building type and customer group to make targeted recommendations on energy management. The ESO will also track the implementation of energy conservation strategies and measure and verify their performance annually to ensure the expected energy savings are being achieved and verify progress towards achieving energy conservation and efficiency goals.
- **Reporting:** the ESO will periodically report the outcomes of the energy management plan and the progress towards achieving campus goals to students, leadership, and other key stakeholders across campus. Leadership reporting will focus on the campus-wide performance towards the goals laid out by the EMP. The ESO will prepare an annual report on the state of the campus energy program based on the timelines and long-range energy performance objectives as they relate to the campus energy performance goals. Stakeholder-level reporting will notify campus users about the performance of their buildings and provide insight into areas where there is the most significant opportunity for improvement. Providing stakeholders with targeted information on their energy performance can help drive behavioral and organizational change that can accelerate progress towards achieving energy goals. In practice, stakeholder-level reporting could include activities ranging from the creation and publication of energy scorecards shared with stakeholders to reporting the daily energy usage and GHG emissions of research laboratories and housing facilities, which could spur competition.

C. Energy Performance Benchmarking

Energy performance benchmarking is the process of determining an appropriate metric with which to measure building energy efficiency. Benchmarks are used to evaluate current performance, the impact of implemented energy measures, and to determine a valid target for future building operations. To date, CU Boulder has been using American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) 100 benchmarks to establish energy use intensity targets for several building types across campus.

However, these current ASHRAE targets are based on average performance from buildings across the United States and an assessment of campus' portfolio performance has determined that they are not well aligned with the education and research mission of CU Boulder. For example, the average learning building at CU Boulder has an energy use intensity of more than twice that of its ASHRAE benchmark, whereas the median research building is 20 percent below its benchmark. These misalignments undermine the benefits of benchmarking in setting ambitious but achievable building performance goals.

To better reflect the variety of building types and technologies present on campus, the University will explore the adoption of alternative industry performance benchmarks or developing its own set of benchmarks. A CU Boulder-specific benchmark would be based upon measured historical usage data for the campus and other CU campuses

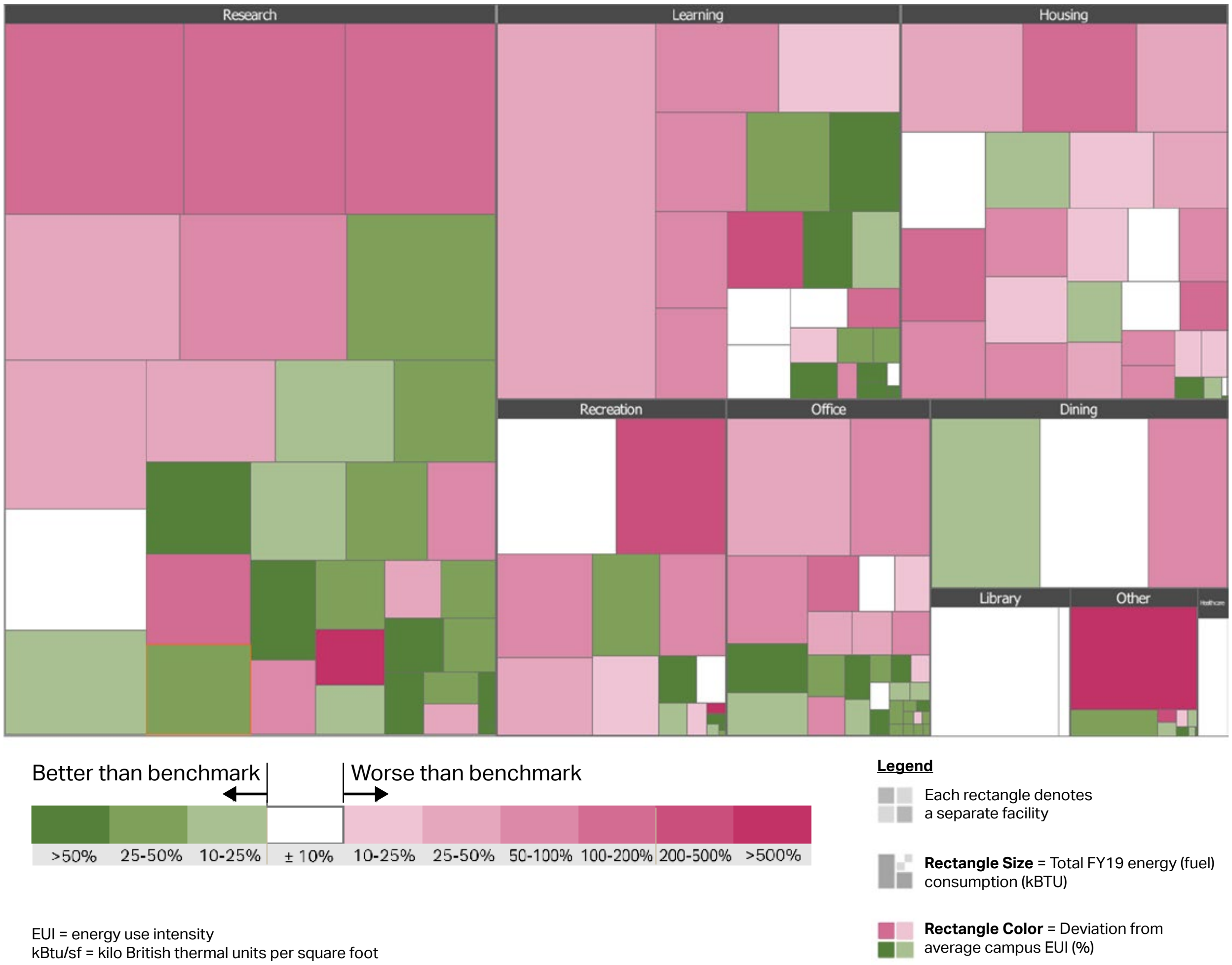


Figure 9: Treemap Showing the Distribution of Existing Energy Use by Building

where applicable. Past performance data will be used to develop representative models of campus building types that can then be used to develop energy use intensity targets that more closely represent their climate, operational profile, and equipment characteristics. The resultant benchmarks can then be used for setting targets and evaluating performance for both existing buildings and new construction or renovation projects.

A treemap allows the visual identification of key outlying facilities. Figure 9 shows a treemap of building energy consumption (the size of the box) and each building's performance against the average EUI of others of the same type (the color of the box). It highlights which building is performing better (green) or worse (red) than its peers, indicating those that may have more potential for energy savings. Appendix F shows CU Boulder's existing EUI by building.

D. Energy Auditing and Conservation Measures

CU Boulder takes pride in its campus and has been consistently recognized as one of America's most attractive colleges, showcasing CU Boulder's dedication to planning and design since its inception in 1876. Today, the University aims to blend this campus pride with high-performance building design by ensuring that all new buildings achieve a minimum of LEED Gold certification as required by the State of Colorado's High Performance Certification Program. CU Boulder recognizes that buildings are its most significant energy consumer and that there is ample opportunity for improving building energy performance through the deployment of energy efficiency strategies.

The performance of building energy systems tends to decrease over time. Regular energy auditing provides a mechanism to identify performance improvement opportunities in CU Boulder facilities and, when combined with continuous commissioning, to ensure that all energy conservation measures implemented remain effective. Energy auditing and subsequent commissioning are not a one-time event, but rather a long-term, ongoing maintenance activity, providing periodic "tune-ups" for facilities with sub-optimal performance.

An effective auditing process will include reviewing all under-performing facilities identified through the energy benchmarking process at least once every five years until facilities are performing better than their benchmark. CU Boulder has already begun its energy auditing process, and energy audits conducted at over 25 of the most energy-intensive buildings on campus identified close to $1.8 million in annual energy cost saving opportunities. Many of these opportunities are still to be implemented, and part of this strategy is to create a comprehensive database of potential energy conservation projects that can serve as a base for the implementation of energy conservation measures and be built upon through new energy audits. The University will begin a process of systematically funding and implementing identified energy conservation projects that, when bundled, maximize energy savings and achieve life-cycle cost savings. Table 4 shows the distribution of potential energy conservation opportunities on campus that were assessed as part of the development of the EMP. More information on the strategy assessment methodology is provided in Appendix C.

CU Boulder is a member of the national Smart Labs Accelerator program which supports laboratory buildings in identifying and implementing energy conservation efficiency projects.

Table 4: Energy Conservation Opportunity Summary

	Percent Energy Savings by Building Type									
Strategy	Dining	Healthcare	Housing	Learning	Library	Office	Other	Recreation	Research	**Total Savings (MMBtu/Year)**
Building Envelope Upgrades	4%	6%	5%	6%	5%	5%	8%	6%	6%	**79,000**
Commissioning	3%	4%	4%	4%	4%	4%	5%	4%	4%	**56,000**
Fume Hood Controls	-	-	-	-	-	-	-	-	2%	**9,000**
Heat Recovery	1%	5%	1%	5%	4%	1%	6%	5%	1%	**34,000**
HVAC Controls	3%	13%	4%	12%	11%	3%	15%	14%	2%	**87,000**
Lighting Upgrades	5%	2%	1%	4%	10%	2%	-	2%	1%	**27,000**
Piping/Equipment Insulation	0%	1%	0%	1%	0%	0%	1%	1%	0%	**4,000**
Ventilation Upgrades	0%	3%	1%	3%	3%	1%	4%	3%	0%	**19,000**
Window Upgrades	2%	3%	3%	3%	3%	3%	4%	3%	3%	**40,000**
Total	18%	36%	18%	37%	41%	19%	42%	38%	19%	**355,000**

This campus-scale assessment highlighted the large savings opportunities related to building envelope improvements, effective HVAC controls, and retro-commissioning of existing energy systems. While only applicable to research buildings, there is a great opportunity to save energy in optimizing the use of existing fume hoods and transitioning laboratory ventilation from constant air to variable air volume systems.

E. Commissioning

Commissioning in the context of buildings is the integrated and systematic process of ensuring that all building systems—heating, ventilation, and air conditioning (HVAC), lighting, energy generation, etc.—are installed and operating in accordance with design requirements. Commissioning is a requirement for LEED certification, which all new CU Boulder buildings are required to meet. In an ideal scenario, commissioning happens both during building construction and start-up, and throughout the lifetime of the building in the form of re- and retro-commissioning to account for changes in occupancy and operational profile. CU Boulder has begun the process of commissioning its facilities, and projects have been completed at Gold Biosciences Building, Porter Biosciences Building, and the University Memorial Center, with several other buildings underway. A continuous commissioning program that monitors performance in real-time, and allows a building's ongoing performance to be optimized, is crucial for organizations like CU Boulder that have a dynamic mission centered around rapidly changing educational and research needs. The establishment of a continuous commissioning program that covers both CU Boulder's existing building portfolio and creates a plan for commissioning future buildings consists of three key steps:

1. **Develop a prioritized list of existing facilities to undergo retro-commissioning:** the buildings selected should be informed by age, energy use and benchmarking, and outcomes of energy audits where applicable.
2. **Document and deploy a continuous commissioning program:** establish the goals of the program, outline processes for collecting, validating, and using data, and evaluate internal and external resources to support implementation. Begin deploying the program by conducting retro-commissioning at prioritized facilities over a five-year period and expand the program so that all under-performing buildings are commissioned periodically.
3. **Expand the program to enable monitoring-based commissioning:** monitoring-based commissioning relies on data gathered from energy meters, building automation systems, and other sources to identify and highlight areas for improvement in building system performance on a continuous basis. The availability of near real-time data for analysis will also enable fault detection and diagnostics, helping CU Boulder to quickly identify and address reliability issues.

F. Staff Development

CU Boulder employs approximately 10,000 staff and faculty to conduct its educational and research mission. The University's staff can influence energy performance across CU Boulder in two ways: first, through facilities management and operations, and second through planning and design. The Facilities Operations staff is responsible for the maintenance and operations of campus buildings and often controls temperature setpoints and schedules. Planning, design, space optimization, engineering, and facilities operations staff within the Office of Infrastructure and Sustainability have a direct role in the design, development, and operation of buildings and, therefore, need to drive energy performance best practices in their everyday work.

These teams, already familiar with performance design concepts, prioritize sustainability and look to drive this agenda on all projects. However, there is currently no systematic training program focused on energy performance. Training staff that can influence building energy use on the design and operational parameters (such as space temperature setpoints, building envelope performance, and others) will help them become better advocates for performance improvements in building operations.

CU Boulder has an energy management team within the Utilities and Energy Services group that works collaboratively with stakeholders across the campus to identify and implement energy conservation measures. As the energy management program grows, additional staff skills and resources will be required to help achieve the goals of the EMP through energy data management, providing energy project scoping and management support services and performing measurement and verification of projects. This additional resource requirement will be met through a combination of training existing staff within the Infrastructure and Sustainability team and selected stakeholders across campus. Additional staffing within Utilities and Energy Services may be required to support the growth in program requirements and will be self-funded through energy cost savings that result from a well-managed energy program.

G. Outreach, Education, and Engagement

> Integral to the successful implementation of the plan is the engagement of the broader campus community in making energy efficient choices that include changes in campus practices and processes to enhance efficiency.

Stakeholder engagement was a crucial part of the development of the EMP and will continue to be a fundamental part of implementing the EMP. A broad spectrum of stakeholders are actively engaged in the validation of strategies and actions to help CU Boulder meet its goals. One of the strategies that every stakeholder recognized as integral to the success of the plan is the engagement of the broader campus community in making energy efficient choices that include changes in campus practices and processes to enhance efficiency. This community includes students, staff, faculty, and other visitors that regularly use campus facilities and services and whose behavior directly impacts energy consumption at the University. CU Boulder is already making efforts towards engaging students and other campus occupants via outreach programs led by the Environmental Center, Facilities Management, Housing and Dining Services, and other stakeholders on campus. The Environmental Center also supports the CU Green Labs Program, which seeks to minimize the consumption of energy, water, and other resources in CU Boulder laboratories and promote a culture that encourages the optimized use of equipment and space.

West District Energy Plant
Source: AECOM Site Visit

CU Boulder will continue to build on these efforts, growing their influence and positive impact through support and establishing an energy engagement initiative spanning all campus stakeholders. By leveraging energy monitoring strategies and connecting outreach and engagement efforts with those strategies, the University will help empower campus users to make decisions and choose behaviors that are energy efficient.

Further information on potential outreach strategies is included in Appendix G: Communication and Engagement Plan.

H. Campus Building Operations Standards

CU Boulder has established standards and guidelines for building operations that specify space temperature setpoints and hours of operations for heating and cooling systems and are designed to minimize energy consumption. However, it is common for buildings to deviate from these guidelines at the request of building occupants, to accommodate special environmental requirements for research activities that must be conducted outside of typical operating hours, or occasionally, for personal preference. Establishing a process that empowers the Facilities Operations groups to review, respond to, and accept or reject special operation requests as needed will ensure building operations are optimized and in alignment with energy efficiency and conservation goals.

I. Deferred Maintenance

In recent years CU Boulder has made a concerted effort to document the condition of buildings in its portfolio and identify areas where additional maintenance resources are required. This process has uncovered a significant backlog of deferred maintenance projects needed to bring the facilities up to optimal operating condition. Since deferred maintenance can undermine the savings obtained from energy conservation measures and reduce the reliability of building systems, addressing it is a crucial element of a well-rounded energy plan.

With its Capital Renewal and Renovation Program, CU Boulder is redesigning its deferred maintenance approach to systematically address the existing backlog, focusing on developing a set of prioritization criteria for investing in maintenance projects. This set of criteria will include the energy and carbon emissions impact of each project, giving higher priority to those projects with the highest potential for reducing energy consumption and energy-related emissions on campus. The prioritized list of projects will also be cross-checked with projects identified as part of the energy auditing and continuous commissioning process that the University will implement to reduce life cycle costs and capture all energy conservation opportunities.

J. Energy Performance Design Targets

Beyond incentivizing energy conservation and efficiency through ongoing energy management and occupant engagement, CU Boulder will embed its energy stewardship mission into the design phase of capital projects, both capital renewal and construction. The design phase represents a crucial time in the development process where future energy use can be limited and controlled from the onset through proactive design while maintaining the project's life-cycle cost-effectiveness.

CU Boulder currently uses sustainability certification to guide building design and construction by requiring all new buildings to achieve LEED Gold certification or better under the LEED version 4 rating system for Building Design and Construction (LEEDv4 BD+C). This requirement stems from the High-Performance Certification Program mandated by the State of Colorado, which includes a provision to meet the 2018 International Energy Conservation Code (IECC). However, as there are many potential routes towards LEED Gold certification, it does not guarantee high energy performance.

Benchmark-based, whole-building energy performance targets are becoming the best practice method for designing energy-efficient and net zero energy buildings. National leaders in energy research, such as NREL, are embracing these targets as the most holistic method for designing high-performance buildings. There are several advantages to energy performance targets, including a static baseline (to allow for comparison of building performance over time), the ability to capture energy use and efficiency for all building energy loads (not just the loads regulated by code), and the ability to carry design targets through to operation.

This benchmark, typically presented in the form of an allowed building EUI, can be developed by creating energy models of typical CU Boulder facilities based upon advanced building design standards and codes, such as the American Society of Heating, Refrigerating and Air-Conditioning Engineers Standard 189.1: Standard for the Design of High-Performance Green Buildings (ASHRAE 189.1), Passive House, or Zero Code, but use operation setpoints, schedules, and technologies relevant to the campus.

The added flexibility of a whole-building energy performance target allows design or design-build teams to uncover bigger and otherwise-missed opportunities in innovation and lifecycle cost savings, which can range from optimizing a building orientation for daylight and solar gain management to embracing novel control and feedback systems.

K. Design Standards Update

The addition of a performance design target is only one of the required updates to the design standards to adequately revise the design guidance to meet the University's energy and GHG emissions reduction goals. Another critical addition is a requirement that all new buildings and retrofits that impact the HVAC systems are set up to be able to transition to a decarbonized hot water and heating supply. Buildings that are or will be connected to the district energy network will be required to design the heating and hot water systems to operate with a lower supply temperature, where possible, and have the building plant space allocated so that it would not be detrimentally impacted by a future district energy steam to hot water conversion.

For buildings that will not be connected to the district energy network, this flexibility for decarbonized heating will likely be in the form of supply electrification. This could, for example, require air- or ground-source heat pumps to be used in new projects as opposed to natural gas boilers, which are currently the norm. The updates to the design standards would, therefore, discourage new campus connections of natural gas for the provision of heating or hot water.

Other updates to the design standards may include energy performance requirements for new equipment purchased in standard end-of-life replacements, the requirement to evaluate building orientation and massing for energy improvements, and other references to best practice guidance on high performance building design, procurement, and operational control capability. These updates to the design standards are the first steps in ensuring all new construction and renovation is compliant with the future, decarbonized campus.

L. Performance-Focused Design Process and Standards

While current facility standards require new construction to achieve LEED Gold certification and comply with the 2018 IECC, current standards do not specify an integrated sustainability approach for building design nor provide specific energy performance targets to be achieved. Instead, decisions are often made on a first-cost basis, with design elements that can reduce energy consumption or enhance energy resilience often value-engineered out of the final product. By updating the planning and design process to prioritize performance, CU Boulder will meet the needs of its growing mission while improving the energy performance of its building portfolio.

CU Boulder uses a "Phase Gate Approval Process" as a policy for implementing capital improvement projects. This process gives CU Boulder the flexibility to integrate performance throughout the planning, design and construction phases and ensures projects cannot move forward into construction and delivery if they don't meet performance requirements. Specifically, CU Boulder can require the design team to demonstrate, through performance modeling, that the design is on track to meet its required benchmark target—as defined in the planning stage. Figure 10 illustrates points in the process where a performance focus can be integrated.

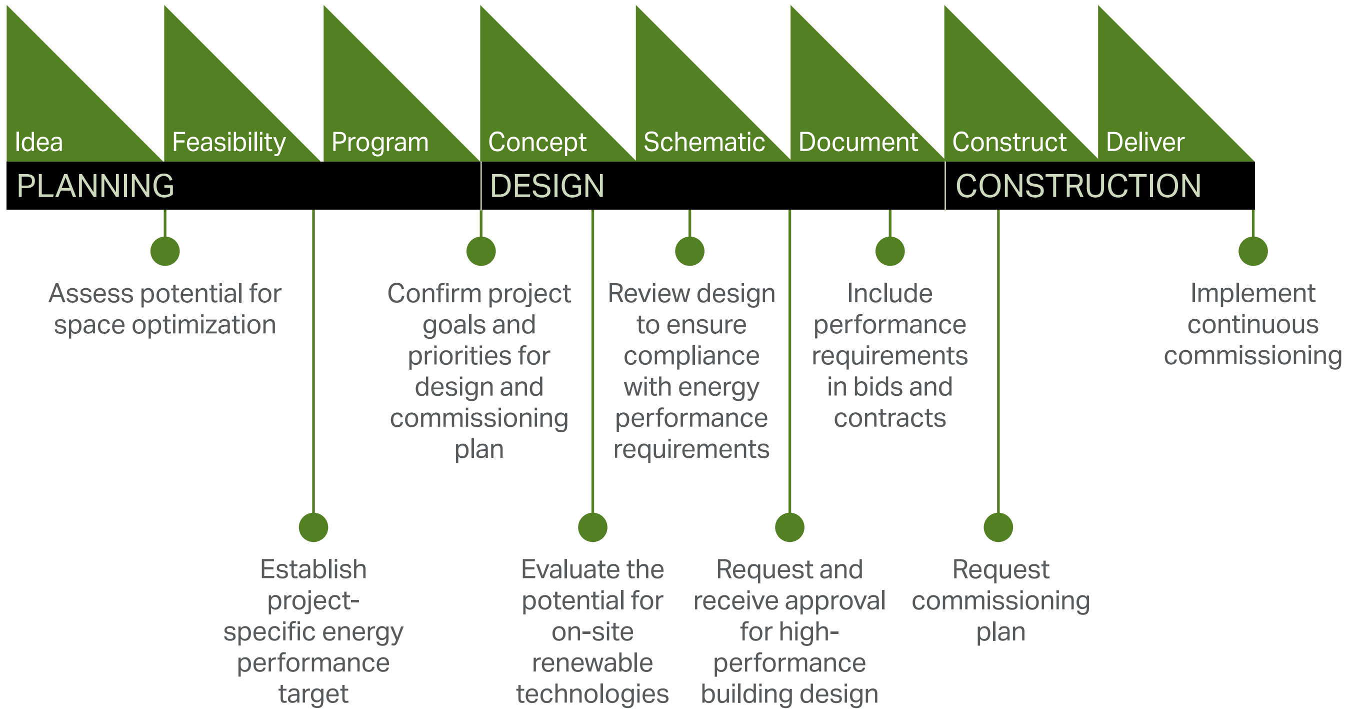


Figure 10: Energy Performance Interactions in Planning, Design and Construction Process

The Planning Stage

Before construction, CU Boulder planning and design teams will work closely with stakeholders to evaluate future buildings' programmatic needs and establish the design requirements for the project. This stage of the process presents a unique moment to identify ways to incorporate high-performance elements into the design and allow for the development of an appropriate budget and business case in the early stages of the project. The project team will also be able to evaluate and identify potential opportunities for using existing facilities on campus to meet the proposed program, reducing the need for new construction.

The Design Stage

In this stage of the process, CU Boulder's planning and design team will work with its project consultants to evaluate, using energy modeling and other methods, design features and alternatives that can enhance the performance of the building. Strategies can range from the use of on-site renewable energy and low carbon HVAC technologies to incorporating passive design features and pursuing advanced building design standards such as upcoming ASHRAE 189.1-2020, Passive House, Zero Code, and others. This effort will be supported by an update to the campus building design standards to prescribe energy performance targets for new as well as renovated facilities and promote the use of technologies that will aid the campus' future transition to a low carbon heating system. Working closely with design consultants and future building stakeholders will be crucial to ensuring the project meets all program requirements while minimizing trade-offs in performance.

The Construction Stage

As the project enters the construction stage CU Boulder will work with selected bidders to ensure that all performance requirements are met and that there is a clear plan for measuring performance once the building is in operation. This will include creating a detailed sequence of operations and commissioning plans that enable campus staff to maintain optimal building operations.

The construction stage and subsequent operation is where the biggest disconnect between design aspirations and realized building performance is greatest. This stage is where the value of the "Phase Gate Approval Process" is at its highest. It will require that a constructed building must perform in line with the agreed upon performance target established during planning and validated during design, ensuring that the University's performance aspirations, and the greater energy goals, can be realized. As the construction phase ends and operations & maintenance phase of the building life cycle begins, the University should implement continuous commissioning to ensure building energy performance targets are sustained.

M. Space Optimization

> "The most efficient building is the one that we do not build."
>
> *David Kang, Vice Chancellor for Infrastructure and Sustainability*

The Office of Space Optimization (OSO) within CU Boulder's Planning, Design and Construction group strives to improve the way the campus uses space to create efficiencies that allow more resources to be directed toward areas of transformation for the campus. Recognizing that the most energy-efficient building is the one that is not built, the OSO works closely with PD&C to ensure space is efficiently allocated within existing and proposed new construction buildings and that space utilization information is available to everyone on campus.

CU Boulder will continue to build upon these efforts by incorporating energy performance and resilience considerations into how space is allocated and facilitate the sharing of resources across the University. For example, spaces that require significant space cooling and high levels of power supply reliability may be grouped into facilities that have highly efficient, centralized HVAC systems and local backup generation—minimizing the need to have multiple dispersed assets which can compromise performance, cost more, and require additional maintenance resources.

One of the most significant resource-sharing opportunities for the University lies in its research laboratories, which currently drive a significant amount of campus space and energy needs. Leveraging the work conducted by CU Green Labs in collaboration with faculty and researchers, the University aims to identify areas for optimization that can help free up resources for meeting other needs of the campus research community, such as energy resilience and additional shared research equipment facilities.

N. Funding Mechanisms

With the development of the EMP, energy projects and programs have been identified that will require large-scale, coordinated investment over a long period. Unlike many other campus capital investments, investment into energy projects results in a direct reduction in operating expenditure, providing a return on the investment over the project's life cycle. These projects range from direct investment into existing facilities and infrastructure to new infrastructure projects and the support of campus-wide energy programs.

To meet the ambitious goals outlined in the EMP, significant additional funding will be required. There has historically been preference from the University to self-fund infrastructure improvements due to access to lower rate funds. However, with many competing demands for campus funding, and the long-term financial impact of the COVID-19 pandemic still uncertain, the University will almost certainly have to look to leverage external funding for part of this infrastructure transformation.

The University plans to explore alternative financing opportunities and potential partnerships to help fund energy projects on campus and will leverage synergies between deferred maintenance, capital renewal, and energy management where applicable. The ESO will work collaboratively with the Office of Budget and Fiscal Planning to leverage all available financing and help stakeholders identify and procure funding for vetted and prioritized energy projects.

O. Campus Energy Policy

> It is essential that a campus energy policy is adopted and recognized by campus stakeholders at all levels for CU Boulder to achieve the goals in this EMP.

The strategies outlined in this plan, from establishing building operation standards through performance design targets and the option of using alternative financing, all require the support of campus executive leadership to be fully effective.

Campus policy provides the required emphasis on challenges and highlights key priorities when it comes to funding, design, or building operations. A campus energy policy will provide clear endorsement for certain actions and help align the campus stakeholder on key objectives.

Historically, without this support and regulatory oversight during decision-making, other components of a project or operational considerations have taken priority leading to inefficient operations and missed opportunities. For example, without a clear adopted energy management policy, campus facilities staff have been unable to impose the building operating standards, designed to minimize conditioning energy use. This has led to buildings across campus being conditioned when unoccupied, wasting energy.

A lack of clarity on leadership expectations compromises the ability of the University to drive performance in design, or access the funding required to implement identified opportunities. It is, therefore, essential that a campus energy policy is adopted and recognized by campus stakeholders at all levels for CU Boulder to achieve the goals in this EMP.

The drafting of a campus energy policy for adoption is one of the first actions that the EAG will undertake to ensure the successful implementation of the EMP roadmap. Once drafted the EAG will take advantage of the newly formed Sustainability Council, described in Appendix G, to access the highest levels of campus leadership and ensure that the campus energy policy is successfully adopted.

Implementation Plan

The following implementation plan identifies the key actions the University will undertake to progress the described focus areas.

Focus Area	Action Number	Action	Responsible Party	Time Horizon
A. Energy Monitoring Strategy	A.1	Identify locations for additional data monitors, with priority for major energy consuming systems.	ESO + FO	Short
	A.2	Develop a sub-monitoring deployment strategy, prioritizing systems with higher energy use or serve critical loads.	ESO + FO	Short
	A.3	Install sub-monitoring across all major existing building energy systems.	ESO + FO + PD&C	Medium
	A.4	Identify and implement a data management platform for the integration, storage, and viewing of collected information.	ESO	Medium
	A.5	Assign staff to the regular review and validation of energy data, including central plant and building energy demand and consumption data.	ESO	Short
	A.6	Evaluate existing data to determine what sources are currently underutilized for use beyond tracking.	ESO	Short
	A.7	Establish and automate reporting outputs for key energy performance indicators for systems and facilities.	ESO	Medium
	A.8	Align reporting units and processes across stakeholder groups.	ESO	Short
	A.9	Build on existing energy software platform to allow tracking of central plant and building EUI data.	ESO	Short
	A.10	Create a user guide for CU Boulder's energy data platform to make it intuitive for campus stakeholders to obtain data.	ESO + S + EC	Short
	A.11	Determine and adopt the appropriate platform for enhanced monitoring and analytics of energy performance.	ESO	Short
B. Energy Management Program Reporting	B.1	Automate a periodic performance report or scorecard to University departments/ stakeholders.	ESO + SR	Short
	B.2	Assign responsibilities for annual program performance reporting to leadership.	ESO + S + SR	Short
	B.3	Establish process for measurement and verification of energy project performance.	ESO	Short

Responsible parties: Energy Action Group (EAG); Energy Services Organization (ESO); Facilities Operations (FO); Utility and Energy Services (UES); Budget and Fiscal Planning (B&FP); Real Estate Services (RES); Athletics (ATH); Academics and Research (A&R); Housing Facilities Services (HFS); Environmental Center (EC); Sustainability (S); Planning, Design and Construction (PD&C); and Student Representatives (SR).

Time Horizons : Short = 0-3 years, Medium = 0-5 years, Long = 5-10 years.

Focus Area	Action Number	Action	Responsible Party	Time Horizon
C. Energy Performance Benchmark-ing	C.1	Draft a benchmarking policy, outlining methodology for its implementation.	ESO + S + SR	Short
	C.2	Determine CU-specific benchmarks for each distinct building typology.	ESO	Short
	C.3	Establish tracking of existing buildings against benchmarks as a basis for prioritization for energy projects.	ESO	Short
	C.4	Establish the methodology for continued improvement in benchmark targets in line with conservation goal.	ESO	Short
D. Energy Auditing and Conservation Measures	D.1	Develop a schedule for building energy auditing where every building on campus is audited at least once every 5 years.	ESO	Short
	D.2	Expand and formalize a partnership with the engineering faculty to maximize student-led building auditing assessments.	ESO + EC + A&R	Short
	D.3	Where additional auditing capacity is required, leverage Xcel's energy analysis program or other external resource.	ESO	Short
	D.4	Investigate the value of combining audits with facility condition assessments to help establish an asset database for preventive maintenance.	ESO + FO	Short
	D.5	Investigate combining audits with resilience/ vulnerability assessments for applicable buildings.	ESO + FO	Short
	D.6	Conduct a feasibility assessment of additional buildings being connected to the district energy network.	ESO + FO	Short
	D.7	Standardize the collation of data from audits into a centralized database and report for prioritization and tracking.	ESO + A&R	Short
	D.8	Create a comprehensive database/clearing house of energy conservation projects.	ESO	Short
	D.9	Refine procurement protocols to facilitate the expedited deployment of energy projects identified through audit	ESO + B&FP	Medium

Responsible parties: Energy Action Group (EAG); Energy Services Organization (ESO); Facilities Operations (FO); Utility and Energy Services (UES); Budget and Fiscal Planning (B&FP); Real Estate Services (RES); Athletics (ATH); Academics and Research (A&R); Housing Facilities Services (HFS); Environmental Center (EC); Sustainability (S); Planning, Design and Construction (PD&C); and Student Representatives (SR).

Time Horizons : Short = 0-3 years, Medium = 0-5 years, Long = 5-10 years.

Focus Area	Action Number	Action	Responsible Party	Time Horizon
D. Energy Auditing and Conservation Measures (continued)	D.10	Review previously identified energy projects to validate with view towards funding and implementation.	ESO + B&FP	Medium
	D.11	Establish a protocol for the bundling of identified conservation measures into larger projects for greater impact.	ESO + B&FP	Long
	D.12	Leverage students, faculty, and staff outreach program to communicate implementation of energy conservation projects and encourage changes in occupant behavior.	EC + ESO + SR	Medium
	D.13	For projects identified but not implemented, re-evaluate with a reduced "green premium" cost for implementation at end of equipment life-cycle.	ESO + FO + B&FP	Short
E. Commissioning	E.1	Develop a target list for facility retro-commissioning—prioritized by age and energy use.	ESO	Short
	E.2	Identify and engage on and off-campus resources to implement a comprehensive commissioning program.	ESO	Short
	E.3	Conduct retro-commissioning on facilities, phased over 5 years based upon priority.	ESO + FO	Medium
	E.4	Develop an approach to continuous or monitoring-based commissioning including scope, goals, and process.	ESO	Short
	E.5	Conduct a gap analysis of the data available to support a monitoring-based commissioning program and establish a preferred technology for collection.	ESO	Short
	E.6	Implement monitoring-based commissioning program - phased based upon priority of data source.	ESO + FO + B&FP	Medium
F. Staff Development	F.1	Reassign or hire additional staff to support the ongoing deployment of the energy management program.	ESO	Medium
	F.2	Develop training program for personnel whose work affects the organization's energy performance and energy management system.	ESO + S + EC	Short

Responsible parties: Energy Action Group (EAG); Energy Services Organization (ESO); Facilities Operations (FO); Utility and Energy Services (UES); Budget and Fiscal Planning (B&FP); Real Estate Services (RES); Athletics (ATH); Academics and Research (A&R); Housing Facilities Services (HFS); Environmental Center (EC); Sustainability (S); Planning, Design and Construction (PD&C); and Student Representatives (SR).

Time Horizons : Short = 0-3 years, Medium = 0-5 years, Long = 5-10 years.

Focus Area	Action Number	Action	Responsible Party	Time Horizon
G. Outreach, Education, and Engagement	G.1	Establish an engagement and awareness plan for students, faculty, and staff that leverages existing modes of communication such as orientation, incoming paperwork, and others.	ESO + EC + SR	Short
	G.2	Establish a newsletter or similar (for example, social media) which periodically reports energy performance metrics to campus population.	ESO + EC + SR	Short
	G.3	Draft CU Boulder energy policy materials to inform visitors and contractors and set expectations for best practice operations.	ESO + PD&C + SR	Short
	G.4	Ensure personnel and on-site contractors are aware of CU Boulder's energy policy and their energy-related roles and responsibilities.	ESO + PD&C + EC + SR	Short
	G.5	Establish a "one-stop-digital-shop" for awareness, promotion, and monitoring of energy initiatives.	EC + ESO + SR + S	Short
	G.6	Increase recognition of outstanding performance of University departments, facilities, and student housing.	EC + ESO + SR + H	Short
	G.7	Enhance incentive programs for students and researchers that work to improve building operations on campus.	EC + S + ESO + SR	Short
H. Campus Building Operations Standards	H.1	Develop and adopt a campus-wide building operations standard which ties system settings such as setpoints to mission requirements.	ESO + FO	Short
	H.2	Implement a waiver process that requires approval to deviate from building operation standards.	ESO + FO	Short
	H.3	Communicate policy and processes to building occupants.	ESO + EC + SR	Short
I. Deferred Maintenance	I.1	Add energy and carbon impact criteria to the current prioritization framework for investment into deferred maintenance.	ESO + FO + B&FP	Short
	I.2	Incorporate outcomes of energy auditing program into deferred maintenance project prioritization.	ESO + FO + B&FP	Medium
	I.3	Maintain a list of preferred equipment replacements based upon life cycle cost-benefit analysis.	FO	Medium

Responsible parties: Energy Action Group (EAG); Energy Services Organization (ESO); Facilities Operations (FO); Utility and Energy Services (UES); Budget and Fiscal Planning (B&FP); Real Estate Services (RES); Athletics (ATH); Academics and Research (A&R); Housing Facilities Services (HFS); Environmental Center (EC); Sustainability (S); Planning, Design and Construction (PD&C); and Student Representatives (SR).

Time Horizons : Short = 0-3 years, Medium = 0-5 years, Long = 5-10 years.

Focus Area	Action Number	Action	Responsible Party	Time Horizon
J. Energy Performance	J.1	Establish minimum performance-based requirements per building type and add them to the design standards.	ESO + FO + PD&C	Short
	J.2	Evaluate and establish requirements in design standards for new building connections to central cooling and heating systems.	ESO + UES + FO + PD&C	Short
	J.3	Establish a threshold (square foot or percentage based) for renovation projects to trigger the use of new building performance standards.	ESO + UES + FO + PD&C	Short
	J.4	Expand the existing design variance process to include energy performance design targets and require justification and mitigation measures for new buildings and major renovations that deviate from the standard.	ESO + UES + FO + PD&C	Short
K. Design Standards Update	K.1	Update design standards to require new heating equipment capable of transitioning to hot water from steam (if connecting to district heating network).	PD&C + ESO + FO	Short
	K.2	Update design standards to require high-efficiency electrified heating and hot water systems (if not connecting district network).	PD&C + ESO + FO	Short
	K.3	Set energy performance requirements for new equipment purchased in standard end-of-life replacements.	FO + ESO + B&FP	Short
L. Performance-Focused Design Process	L.1	Create energy performance and resilience checklist for project development.	ESO + FO + PD&C	Short
	L.2	Assess project needs to determine whether needs can be better met through existing building renovation instead of new building construction.	PD&C + EC + A&R	Short
	L.3	Create standardized modeling assumptions for energy model development per building typology to ensure like-for-like comparison.	ESO + PD&C + A&R	Short
	L.4	Ensure the use of projected design performance against energy benchmarks on each project.	PD&C + ESO + A&R	Short
	L.5	Enhance communications between customers, project managers, maintenance staff, and designers throughout the design process to ensure alignment in project outcome.	PD&C + ESO + FO	Short
	L.6	Add performance requirements to design contracts for new buildings that tie expected building energy performance to actual performance.	PD&C + ESO + FO	Medium

Responsible parties: Energy Action Group (EAG); Energy Services Organization (ESO); Facilities Operations (FO); Utility and Energy Services (UES); Budget and Fiscal Planning (B&FP); Real Estate Services (RES); Athletics (ATH); Academics and Research (A&R); Housing Facilities Services (HFS); Environmental Center (EC); Sustainability (S); Planning, Design and Construction (PD&C); and Student Representatives (SR).

Time Horizons : Short = 0-3 years, Medium = 0-5 years, Long = 5-10 years.

Focus Area	Action Number	Action	Responsible Party	Time Horizon
M. Space Optimization	M.1	Create a comprehensive inventory of research equipment and system for annual review of spatial needs to identify areas for optimization through sharing and space reallocation.	PD&C + EC + A&R	Short
	M.2	Incorporate space optimization into researcher onboarding process.	EC + A&R	Short
N. Funding Mechanisms	N.1	Develop the protocol for leveraging existing and incorporating new funding mechanisms into energy projects.	ESO + B&FP + PD&C	Medium
	N.2	Include energy performance standards into lease agreements, where applicable.	PD&C + RES + B&FP	Short
	N.3	Establish a 'painshare/gainshare' program that financially incentivizes facilities that perform better than their normalized benchmark.	PD&C + ESO + B&FP	Short
	N.4	Investigate incorporating the cost of carbon and other triple-bottom-line benefits into energy project business case analysis.	ESO + PD&C + B&FP	Short
	N.5	Establish life-cycle cost analysis as a requirement in design option evaluation.	PD&C + ESO + B&FP	Short
	N.6	Integrate cost estimating of high performance building requirements into the planning of new buildings, ensuring adequate funding requests.	PD&C + ESO + B&FP	Short
	N.7	Identify seed money sources for 'green fund' to support sustainable building and infrastructure investments.	B&FP + S + SR	Short
	N.8	Establish a 'green fund' for energy projects.	B&FP + S+ ESO	Short
	N.9	Set up the green fund to allow external donor funding to be explicitly allocated for green infrastructure projects.	B&FP + S + ESO	Short
	N.10	Explore the use of alternative financing to enable the investments required in facilities and green infrastructure.	ESO + B&FP	Short
	N.11	Explore additional grant opportunities for energy generation and resilience technologies.	EC + B&FP + ESO	Short
O. Campus Energy Policy	O.1	Draft a campus energy policy tying key management strategies and procedures to energy goals.	FO + UES + PD&C + S	Short
	O.2	Submit campus energy policy for adoption by executive leadership.	EAG	Short

Responsible parties: Energy Action Group (EAG); Energy Services Organization (ESO); Facilities Operations (FO); Utility and Energy Services (UES); Budget and Fiscal Planning (B&FP); Real Estate Services (RES); Athletics (ATH); Academics and Research (A&R); Housing Facilities Services (HFS); Environmental Center (EC); Sustainability (S); Planning, Design and Construction (PD&C); and Student Representatives (SR).

Time Horizons : Short = 0-3 years, Medium = 0-5 years, Long = 5-10 years.

2

Sunrise at Hellems Arts and Sciences Building
Source: Creative Commons

Reduce Facility Energy Emissions

Decarbonize campus facility-tied energy use by 2050 through transition to clean thermal energy and implementation of a financially viable mix of on-site and regional clean electricity.

Overview

Greenhouse gas emissions from electricity and natural gas consumption are the predominant metric for determining the negative environmental impact of facility operations. The EMP presents an ambitious yet achievable plan for the University to exceed its ACUPCC commitments, targeting carbon neutrality through the elimination of all campus facility energy-related GHG emissions by 2050.

Reductions in facility energy-related emissions can be achieved through a combination of energy conservation and clean energy generation and procurement strategies. To this end, the University has set energy conservation and efficiency goals and strategies as outlined in Energy Conservation and Efficiency, but also goals focused on achieving concrete levels of clean energy use on campus. Maximizing the cost-effective implementation of on-site renewable energy generation will help the University make progress towards its GHG emissions reduction goals and cement its commitment to overall sustainability and energy resilience. To fully eliminate emissions on campus, CU Boulder will have to implement innovative alternatives to the existing fossil fuel-based heating systems on campus.

Metrics and Targets

To track the performance of GHG emissions reduction efforts, three metrics will be used:

- Total metric tons of carbon dioxide equivalent (MTCO2e) associated with campus energy use
- Percent (%) emissions reduction from Calendar Year (CY) 2005 levels
- Metric tons of carbon dioxide equivalent (MTCO2e) per square foot (SF) of the overall campus portfolio

The total-metric-tons metric will be used to measure year-on-year change in comparison to the CY05 baseline year.

Events Center Solar PV
Source: Creative Commons

Table 5 summarizes CU Boulder's commitments to reducing absolute GHG emissions associated with facility energy use. The 50 percent target for 2030 is consistent with CU Boulder's existing ACUPCC commitment; however, the 100 percent GHG emissions reduction by 2050 is an increase on the target previously established. CU Boulder will look for opportunities to accelerate this timeline where possible. The University goals also recognize the importance of making strides in the short-term and has committed to reducing GHG emissions by 25 percent by 2025.

By focusing first on reducing the demand for heating through energy management and conservation, the University will be able to direct resources towards decarbonizing the heating system and transitioning away from fossil fuel use.

CU Boulder's clean electricity (defined as having zero net GHG emissions in generation) target, shown inTable 6, is aligned with Xcel's goals for the Colorado grid, but builds upon it with the addition of an on-site clean energy goal. An on-site target has been established that is representative of the maximum technically feasible capacity for PV on the campus. CU Boulder's progress towards meeting this goal is the percentage of its energy supply portfolio that comes from clean sources, both through on-site and off-site generation. The metrics that will be monitored include the following:

- Percent (%) of electricity generated by on-site clean energy sources.
- Percent (%) of total energy generated by on-site clean energy sources.
- Total percent (%) of energy demand met by clean sources (including off-site).

In 2020, Xcel's electricity was approximately 30 percent renewable, with CU Boulder generating 3 percent of its electricity demand from onsite clean sources.

Table 5: CU Boulder GHG Reduction Targets

GHG Emissions Reduction	Target Year
25%	2025
50%	2030
100%	2050

Table 6: CU Boulder Clean Energy Targets

% of Clean Electricity	Target Year
50%	2025
80% (10% on-site)	2030
100%	2050

Focus Area Descriptions

In support of these GHG reduction targets, CU Boulder has identified the following focus areas in which to take action.

A. On-Site Clean Energy Generation
B. Community Solar
C. Clean Energy Procurement
D. Plan for Heating Decarbonization
E. Power Plant Optimization
F. East Campus District Energy

A. On-Site Clean Energy Generation

With over 2 MW of existing solar photovoltaic (PV) on the campus, approximately three percent of the campus' energy is currently generated by PV.

The University investigated opportunities to increase its renewable energy capacity and recently conducted a campus spatial assessment to identify areas and quantify the scale of the opportunity. However, capacity growth has been slowed by limits on incentive programs like Xcel's Solar Rewards program that has a 500 kW threshold for projects to receive rebates. The campus has reached this threshold on its master meters which has made it more challenging to build the business case or hit return on investment targets for new PV.

Based on a recent spatial assessment of the campus, CU Boulder can construct up to 10 MW of PV generation capacity across Main and East Campus roofs, carports, and open areas. The installation of PV on these areas will be required for the campus to achieve its 2030 target of 10 percent renewable energy on-site.

The campus also has significant potential for energy storage systems to leverage this renewable energy and increase resilience while reducing energy cost. These systems can capture the full on-site generating capacity, allowing CU Boulder to harness and use this power at any time of day. Analysis in support of this plan development identified that capacity of up to 4 MWh of battery energy storage can be justified by reducing peak demand charges when combined with solar generation. When strategically located around critical energy demands such as research equipment or data centers, the systems can also serve to provide a buffer to the utility grid should any outages occur.

The benefits of onsite solar go beyond direct energy cost savings, improving energy resilience (when coupled with energy storage) and making progress towards their clean energy goals.

B. Community Solar

As CU Boulder explores opportunities to eliminate facility-related emissions on campus, one of the approaches it will investigate is investment into Community Solar. Community Solar is a type of PV installation where the facilities and the benefits are shared by multiple subscribers. This arrangement enables customers with lower purchasing power to access clean energy and benefit from reduced emissions and potentially lower energy bills. CU Boulder will work with community partners such as the City of Boulder and other local authorities to assess interest in Community Solar projects and promote community inclusion in the University's transition to clean energy on campus.

C. Clean Energy Procurement

CU Boulder has a long history of environmental stewardship and was the first university in the United States to create a student-led environmental center. CU Boulder students recognized early on the potential for renewable energy credits (REC) to accelerate electrical grid decarbonization and implemented the first REC purchasing program in the nation to power student-run buildings with renewable energy.

An essential part of CU Boulder's future reduction in electricity emissions is taking advantage of Xcel's transition to the use of clean power generation technologies in Colorado. Xcel plans to generate 55 percent of its electricity in Colorado from renewable sources by 2026 and reduce overall emissions across its territories by 80 percent in 2030.

While the utility has made good progress on these goals thus far, CU Boulder will build upon its history of clean energy purchases and evaluate opportunities to eliminate emissions associated with electricity generation in advance of Xcel's 2050 goal or to achieve the University's' clean energy goals should Xcel's transition fall short. The opportunities evaluated may range from off-site investment opportunities for renewable energy generation to green energy procurement through Xcel's programs. To ensure its clean energy purchasing is supporting the wider initiatives to decarbonize the electrical grid, CU Boulder will prioritize options that represent additive capacity rather than take advantage of existing renewable generation assets.

D. Plan for Heating Decarbonization

With current electricity emission factors, building heating is currently responsible for nearly 40 percent of the campus facility-based GHG emissions. As the electricity grid continues to decarbonize, the proportional contribution of heating to campus GHG emissions is projected to increase to upwards of 70 percent by 2030. Xcel's planned transition to cleaner electricity by 2050 will mean that all remaining facility energy GHG emissions will be directly tied to natural gas consumption, predominantly for heating and hot water.

Therefore, the top priority in the University's GHG emission reduction plan, and possibly its biggest challenge, is identifying a pathway to decarbonize the campus heating systems that rely primarily on gas. Decarbonizing heat for such a large campus with many legacy systems is a long-term strategy that will require close collaboration between stakeholders at the University to both solve complex technical challenges and adequately fund the transition. The technical approach to heating decarbonization can be broken down into two fundamental steps:

1. Transitioning the Main Campus off steam heating to a lower temperature distribution network
2. Developing and implementing alternative (zero carbon) heating supplies in all areas of the campus

Steam to Hot Water Conversion

Converting steam heating systems to a low or ambient-temperature, water-based system is an enabling strategy to facilitate the campus' transition away from natural gas consumption, especially on the Main Campus. This type of system is not only less energy-intensive but would allow CU Boulder to use low-grade heat for space heating and would open the door to alternative and low carbon heat sources such as electric heat pumps or waste heat recovery. Options for conversion range from a fully centralized low temperature hot water system with limited building-level supplemental heat to a fully decentralized approach that decommissions the existing steam system and uses building-level systems to provide heat. Other solutions such as a fifth generation ambient loop system that leverages a mix of centralized and decentralized equipment or a district system that supplies a mix of low and high-temperature hot water are also viable alternatives. The University will evaluate the available alternatives to identify and implement the most energy-efficient and cost-effective approach, starting in the short-term with a focus on the building systems and taking into consideration any specialized heating needs that may exist at research, dining, and other facilities.

Alternative Heating Supply

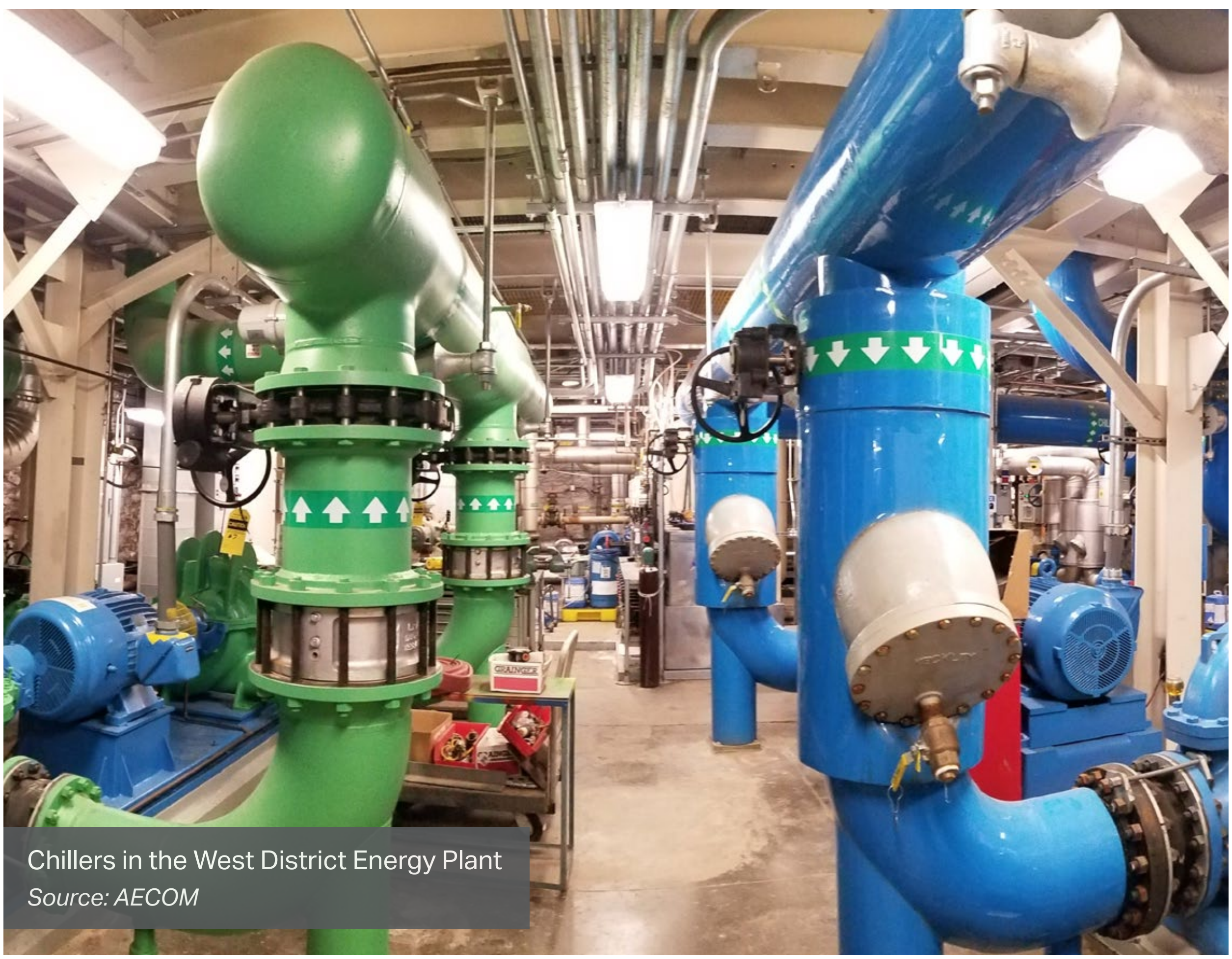
The second step in decarbonizing the heating system will be to convert all energy supplies to low carbon alternatives. Decarbonization of the heating supply can be achieved at both the centralized and decentralized scale through strategic combinations of technologies. Thermal generation options include electric boilers and chillers, heat recovery chillers, air and ground-source heat pumps, and other heat recovery technologies that may be found suitable for the future configuration of the campus. The right configuration for CU Boulder will vary depending on the future campus, and specific building needs and will be assessed as part of a comprehensive plan for heating system decarbonization.

The comprehensive heating decarbonization plan will contain a strategy encompassing all three infrastructure scales that will define what, where, and when the intervention should happen. These three scales, which all influence each other, are as follows:

1. **Building system transition plan:** Ordered list of facilities, their required upgrades, and timeframe. This will differ if connected to a district energy plant compared to a stand-alone facility. The plan schedule will depend on condition, location, and type of system.
2. **Distribution infrastructure upgrade plan:** Phased plan by section. Scheduling would be informed by a combination of condition, existing configuration, and readiness of connected buildings.
3. **Decarbonized heating supply strategy:** Specific recommendations on what system, at what size, to be implemented where. Some systems may be implemented before the thermal network is upgraded, others will require transition to a new network or decentralized before they can be adopted.

A Realistic Plan

The scale of the challenge facing CU Boulder to transition from the existing campus steam backbone to a decarbonized heating network cannot be understated. The steam network currently serves hundreds of buildings, only a very few of which currently have internal building systems set up to allow for a transition to a lower temperature heating supply, be it from a central network or a building-scale electrified heating source. Many of these buildings will lack the space or



Chillers in the West District Energy Plant
Source: AECOM

accessibility to practically upgrade the heating system. Many more will require a full building retrofit to replace internal building steam distribution systems that have been operating adequately for decades. Each building will therefore require its own focused transition plan, design, and renovation over the next 15 to 20 years to meet the University's goals.

Upgrades to the distribution network will be no less complex. The more than 15 miles of steam piping across the Main Campus must be decommissioned and replaced. Some of the network is difficult to access, and sections of any new distribution will likely require establishing new pathways.

The Boulder cold winter climate means that heating is a critical energy demand. Buildings will have to be taken offline while the required improvements are made – necessitating a well thought-out multi-phased transition plan to avoid major disruption to the University's primary education and research mission.

Beyond the technical design and implementation challenges, an endeavor of this scale will require close coordination and development of a implementable funding strategy. Identifying the right route and combinations of financing for this long-term program will require years of planning, research, and partnership development. It will be critical to align building and infrastructure upgrades with the Capital Renewal program to take advantage of the synergy with reducing campus deferred maintenance.

In committing to eliminating campus facility energy related emissions, CU Boulder recognizes the scale of this effort and is confident in its ability to successfully carry it out. The University has already demonstrated its ability to do this with the recent steam to hot water conversion of the Williams Village campus. Industry-leading district energy expertise is already on campus at Department of Civil, Environmental and Architectural Engineering which can be leveraged in development of the transition plan. With updated design standards discussed previously, all new construction and renovation projects will be future-proofed for a decarbonized heating supply, and work is being done to identify the viable combination mechanisms required to fund this investment.

E. Power Plant Optimization

CU Boulder is planning for a future without the use of fossil fuels on campus. While this transition is happening, there is an opportunity in the short-term to improve the operations of the existing WDEP to reduce the emissions associated with heat and power generation. The WDEP houses a natural gas-fired combined heat and power system, which is operated when there is sufficient heat demand to allow it to run economically and efficiently.

The cogen is configured to operate as heat-following (output dictated by heat demand) and the efficiency is reduced when the load is less than the full output of the system. Under optimal conditions it operates at an overall efficiency of around 75 percent, at which time the power generated has a significantly lower emissions factor (around 40 percent) than the electricity that CU Boulder currently purchases.

As the utility grid continues to become cleaner, this period of improved emissions performance will close rapidly. The emissions factor of the utility grid is currently projected to be lower than optimal cogen operation by 2027. With this in mind, CU Boulder will plan for eliminating the operation of the cogen for prime generation, but keep it maintained to allow it to provide backup power should it be needed. Longer term use of cogen on the campus will only be viable if a cleaner fuel source such as biogas or green hydrogen can be identified.

This plan for a future without the use of cogen must be balanced with the resilience and reliability requirements of the campus. In the short- to medium-term the solution might be the continued maintenance of the cogen system until enough supply capacity of alternative on-site power can be established.

This plan for a future without the use of cogen must be balanced with the resilience and reliability requirements of the campus. CU Boulder plans to decommission the WDEP in the medium- to long-term which will require the University to determine the best use of cogen and other dispatchable power generation assets to support operations. There is enough space in the EDEP to house a relocated clean-fuel cogen system either at full capacity or in a reduced role should the campus be successful in its focus on reducing the steam load. Effective load reduction would also reduce the capital required to move all Main Campus heat load to the EDEP. In the short- to medium-term, the University plans to maintain the cogen system so that it can fulfill its role in providing backup power supply to the campus.

CU Boulder also recognizes the opportunity to optimize plant operation for thermal energy in both the WDEP and EDEP. The University is working on ways to have the plant operations be more closely aligned, balancing the thermal load across the heating and cooling networks to reduce the net load on the plants. With the plans more in sync, equipment could be staged and operated more efficiently and reduce the fuel needed to supply heating and cooling. The current focus is on implementing control upgrades to improve the alignment of the entire system. In the long-term, all Main Campus heating will be supplied by the EDEP.

> The cogen plant produces electricity at a carbon factor around 40 percent cleaner than the current grid.

F. East Campus District Energy

CU Boulder seeks to grow the research footprint on its campus significantly over the next 30 years and expects most growth to occur on the East Campus. This growth presents the University with an opportunity to explore the use of centralized district systems in this area. Centralized systems can have the advantage of providing higher-efficiency heating and cooling supply, lower maintenance costs, and higher reliability than traditional building-level systems. A district energy system on the East Campus may not be viable until growth allows it to reach sufficient density; however, CU Boulder expects that the benefits of a centralized system for efficient operations, resilience, and supply flexibility will be the preferred solution.

As a first step in exploring East Campus district energy options, CU Boulder is ensuring that the Campus Master Plan process is being developed with future-proofing for district systems in mind. This includes ensuring that campus planning accounts for future infrastructure routes and the space allocation required for a district energy plant. Additional strategies that CU Boulder will embed in the master planning process are site planning for passive, low energy building design, optimizing building orientation and massing, and purposefully allocating unshaded roof and canopy space for renewable energy generation and supporting infrastructure.

At a building level, new construction on the East Campus will plan for a potential future district energy system by incorporating a stubbed valve connection and planning for the service route. This is a low-cost strategy that will mitigate any future disruptions and expenses. CU Boulder will continue the integration work between the EMP and Campus Master Plan in the coming months and years to ensure that these performance and future-proofing concepts are fully aligned and implemented.

The EMP is informing the Campus Master Plan process by providing guidelines for high performance buildings, infrastructure flexibility, and spatial allocations for on-site generation.

View from the East District Plant
Source: AECOM Site Visit

Implementation Plan

The following implementation plan identifies the key actions the University will undertake to progress the described focus areas.

Strategy	Action Number	Action	Responsibility	Time Horizon
A. On-Site Clean Energy Generation	A.1	Validate locations identified in previous studies (NREL and AMERESCO).	ESO + PD&C	Short
	A.2	Identify and enlist stakeholders for potential partnerships at key locations to identify priority sites, including sites with resilience benefits.	PD&C + A&R + SR	Short
	A.3	Select project(s) for implementation and determine preferred funding mechanism(s).	ESO + UES + PD&C + B&FP	Medium
	A.4	Work with Xcel to define incentive opportunities. Investigate alternatives to 'single account' limits and stand-by charges.	ESO + UES + B&FP	Short
	A.5	Establish concept design(s) and request required approvals.	ESO + UES + PD&C	Medium
	A.6	Develop Request for Proposal (RFP) for selected system(s).	ESO + UES + PD&C + B&FP	Medium
	A.7	Identify and set-aside areas for future solar capacity.	PD&C + ESO + UES	Short
	A.8	Install solar PV of sufficient capacity to meet 10% of campus electricity demand on-site.	PD&C + UES	Long
B. Community Solar	B.1	Identify areas of CU land that might be suitable for large (>10 MW) solar array.	PD&C + UES	Short
	B.2	Work at the System-level to identify the appetite for a shared investment in a Community Solar project.	S + UES	Short
	B.3	Establish the appropriate scale of energy that should be procured through a Community Solar program.	ESO + UES	Short
	B.4	Develop an RFP to identify preferred ESCO partner for community solar program.	UES + ESO + PD&C	Short
C. Clean Energy Procurement	C.1	Investigate off-site investment opportunities for renewable energy generation. This could be as part of CU System partnership.	ESO + UES + S + B&FP	Short
	C.2	Engage with Xcel to seek green-power partnership opportunities such as Renewable Connect or Windsource.	UES + S + B&FP	Short
	C.3	Advocate with Xcel to encourage a faster decarbonization of the local utility grid.	S + UES	Short

Responsible parties: Energy Action Group (EAG); Energy Services Organization (ESO); Facilities Operations (FO); Utility and Energy Services (UES); Budget and Fiscal Planning (B&FP); Real Estate Services (RES); Athletics (ATH); Academics and Research (A&R); Housing Facilities Services (HFS); Environmental Center (EC); Sustainability (S); Planning, Design and Construction (PD&C); and Student Representatives (SR).

Time Horizons : Short = 0-3 years, Medium = 0-5 years, Long = 5-10 years.

Strategy	Action Number	Action	Responsibility	Time Horizon
D. Plan for Heating De-carbonization	D.1	Assess existing building and distribution infrastructure against potential lower temperature options or decentralization for network decarbonization.	UES + ESO + PD&C	Medium
	D.2	Assess existing building and distribution infrastructure against potential lower temperature options or decentralization for network decarbonization.	UES + ESO + PD&C	Medium
	D.3	Evaluate existing building HVAC systems to determine upgrades required to operate with a lower heat supply temperature (hot water).	FO + ESO + A&R	Short
	D.4	Update condition assessment of the steam distribution infrastructure.	UES	Short
	D.5	Update design standards to require new building heating systems to be compatible with a lower supply temperature.	PD&C + UES	Short
	D.6	Identify waste heat opportunities to be integrated into heating system.	ESO + UES	Medium
	D.7	Develop phased implementation plan for conversion considering condition, end of life, and growth areas.	UES + PD&C	Medium
	D.8	Implement district steam infrastructure transition by 2040 at the latest, with phasing program starting in 2030 (stretch goal 2025).	UES + ESO + FO	Long
E. Power Plant Optimization	E.1	Leverage the existing combined heat and power system as a cleaner source of energy during times when there is sufficient heat demand.	UES + ESO	Short
	E.2	Develop a cogen transition or decommissioning plan.	UES + ESO + PD&C	Medium
F. East Campus District Energy	F.1	Incorporate the flexibility to serve new buildings on the East Campus with district energy within the Campus Master Plan.	PD&C + UES	Short
	F.2	Update design standards to require new construction on East Campus to be future-proofed for potential district energy connection.	PD&C + UES	Short
	F.3	Develop a concept for a decarbonized district energy network on the East Campus.	PD&C + UES + A&R	Medium

Responsible parties: Energy Action Group (EAG); Energy Services Organization (ESO); Facilities Operations (FO); Utility and Energy Services (UES); Budget and Fiscal Planning (B&FP); Real Estate Services (RES); Athletics (ATH); Academics and Research (A&R); Housing Facilities Services (HFS); Environmental Center (EC); Sustainability (S); Planning, Design and Construction (PD&C); and Student Representatives (SR).

Time Horizons : Short = 0-3 years, Medium = 0-5 years, Long = 5-10 years.

3

Solar PV Array
Source: Creative Commons

Enhance Critical Mission Resilience

Enhance energy resilience for mission critical facilities, research, and operations.

Overview

Energy resilience is the ability of energy systems to prepare for and adapt to changing conditions and withstand and recover rapidly from disruptions. For CU Boulder, energy resilience is critical for meeting mission requirements and providing adequate service to research and other essential campus functions. To enhance resilience at the University, CU Boulder will establish a minimum set of mission-tied resilience requirements for systems in both existing and new construction and explore infrastructure improvements that can positively contribute to these efforts.

Metrics and Targets

An explicit focus on energy resilience within an energy plan is a relatively new consideration and a standard protocol for assigning a value and measuring and tracking resilience has yet to be established. CU Boulder will measure its success in increasing its energy resilience by first evaluating the needs of stakeholders on campus and conducting a survey of resilience requirements that should be implemented into new construction and renovation projects.

The following types of metrics will also be captured where possible to communicate the wider value of energy resilience benefits:

- Outage Time: time in minutes or hours where critical systems have experienced a critical resource outage, including power, natural gas, heating, cooling, and water. This may incorporate utility reliability metrics such as Momentary Average Interruption Frequency Index (MAIFI) that are relevant to campus operations.
- Monetary Cost of Lost Research: working with University Risk Management, track the total monetary value of lost research per outage event and in aggregate each year. Reported in terms of $/outage and $/year.

- Monetary Cost of Lost Housing Services: monetary value of lost housing and dining services due to outages. This may include cost of student relocation, cost of outside vendors for food service, and lost conference revenue. Reported in terms of $/event and $/year.
- Brand Impact: resource outages that impact research activities can have a negative effect on CU Boulder's reputation as a research institution by signaling that the University does not have reliable energy resources. Reported in terms of negative, positive, or neutral impact.
- Service Assurance: The number of hours for which the building can continue its operations in the event of grid power, heating, or cooling outages at varying levels of service.

As part of the EMP process, CU Boulder has identified the attributes that constitute its definition of energy resilience and weighted how important each attribute is to the campus. These attributes provide the basis for CU Boulder to evaluate potential new energy projects for their ability to positively improve the campus' energy resilience posture. Table 7 summarizes these attributes and lists them in order of relative importance to CU Boulder. Appendix E provides more information on CU Boulder's definition of energy resilience.

Table 7: CU Boulder's Prioritized List of Energy Resilience Attributes

Attribute	Attribute Qualities
Physical Hardening	Protection of energy infrastructure (e.g., electrical supply lines and switch stations, district heating plants and pipes, etc.) from threats such as flooding, fire, and strong winds
Response Personnel	Ability to access staff (be it University, contractor, or local specialists) of appropriate expertise for damage assessment and repair
Emergency Management	Level of emergency response planning and personnel training (e.g., response protocols for campus personnel in different threat scenarios, accessibility to critical infrastructure for repair teams, etc.)
Equipment and Procurement	Ensuring replacement critical equipment and parts are available. Also includes standardization of components and secured procurement practices
Redundancy	Separated supply paths to minimize the system infrastructure's vulnerability to the same local threat (e.g., having multiple electrical supply lines from the same source routed through the north and south of campus respectively)
Load Sustainment	Ability to maintain energy supply to critical demand from on-site sources. Includes power generation, fuel storage, controls, and infrastructure
Islanding Capabilities	Automation of backup systems, predicting threats, performance indicators to support response efforts
Energy Demand Reduction	Conservation and management of energy use in order to reduce the requirement for critical backup capacity and increase outage sustainment time
Cybersecurity	Protection in place for energy systems (e.g., HVAC controls, centralized monitoring, etc.) to resist a cyber attack

Focus Area Descriptions

In support of these resilience goals, CU Boulder has identified the following focus areas in which to take action.

A. Energy Resilience Design Requirements
B. On-Site Energy Generation and Storage
C. Campus Microgrid

A. Energy Resilience Design Requirements

As extreme weather events impact the public infrastructure's ability to provide high-quality and reliable utility services, higher education institutions like CU Boulder have placed increasing focus on enhancing energy resilience within their facilities. CU Boulder has made strides towards improving the resilience performance of its energy systems by centralizing energy supply for electrical power, heating, and cooling on the Main Campus. This centralization and the implementation of a robust maintenance program have enabled the University to take control of its infrastructure and improve reliability for campus customers. However, because resilience is a relatively new focus, resilience requirements have not been codified into the campus design and operation standards. As a result, building-level systems that are critical to activities on campus—such as ultra-low temperature freezers, sensitive research equipment, dining equipment, and others—have not always been equipped with technologies that could help provide resilience.

Recognizing that the research conducted on campus is precious and in many instances, irreplaceable, CU Boulder will continue to take decisive action to identify and correct any resilience gaps that currently exist. Engagement from campus stakeholders to accurately define their reliability requirements will be crucial to the success of this process, particularly where it concerns supporting researchers with specific resource needs. The first step is conducting surveys at all research facilities to assess the critical and non-critical loads within the facility and verify what loads have the appropriate backup power sources in place. CU Boulder will also develop and integrate energy resilience components into building design standards to ensure that those requirements cannot be value-engineered out of the design process. Resilient design standards may include adequate sizing of emergency generators, dedicated rooms for uninterruptible power supply battery banks, redundancies in the power distribution and HVAC design to avoid single points of failure, and remote monitoring and alarms that ensure adequate response time in case of equipment failure. CU Boulder will investigate opportunities to tie these resiliency elements into facility design standards.

B. On-Site Energy Generation and Storage

The transition of our energy fuel source from fossil fuels to renewable energy equates to reduced GHG emissions, reduced operational costs, and when on-site, an invaluable source of power for resilience. CU Boulder will benefit from Xcel's clean energy transition to support

Jennie Smoley Caruthers Biotechnology Building
Source: Casey A. Cass/University of Colorado, Flickr, Creative Commons (CC BY 2.0)

their decarbonization plans, but unless this is paired with strategies to generate and store energy on-site, it still leaves the campus vulnerable to regional power outages and power fluctuations.

The University has already established a strong backbone of on-site energy generation on campus with nearly 35 MW of installed capacity between PV and cogen, but there are opportunities for further expansion and to leverage what exists more effectively for resilience. Distributed energy generation, such as rooftop and carport solar PV installations, are in the early stages of deployment across the campus, and there are several areas flagged throughout the campus where future solar PV installations may be possible. CU Boulder has established an on-site target which is representative of the maximum technically feasible capacity for PV on the campus. This includes distributed applications such as rooftop-, carport-, or ground-mounted applications where land is expected to remain available per the CMP.

The West District Energy Plant (WDEP) has existing cogen capacity of >30 MW that can support the full load of the main campus electrical grid when there is a planned grid outage. However, it does not have the ability to respond to an unplanned outage due to lack of black-start system. CU Boulder has identified the need for 1 MW of generation capacity and associated controls to be added to provide this. Installing the black-start capability is likely to have the single largest impact in the short term on improving power reliability. In addition to on-site energy generation, energy storage is an essential component of a resilient campus electrical grid. Energy storage works to match supply to demand and would allow the campus to make use of its available on-site generation resources during a utility outage. At the building scale, this can lead to facilities with on-site solar, battery energy storage, and emergency diesel generators being established as "nanogrids" that can operate in isolation from the grid for extended periods, beyond what conventional emergency generators and diesel fuel storage would allow. Energy storage may further help manage power quality requirements for a facility or groups of facilities as well by contributing to voltage and frequency regulation at the distribution scale, and reduce impact of utility power quality issues for sensitive research equipment. Energy storage solutions may be financed through savings from energy peak demand charges and other grid services.

C. Campus Microgrid

CU Boulder's ownership of most of the electrical distribution systems on its campus places it in a prime position to enhance resilience via the implementation of a university-wide microgrid. The Main Campus currently has islanding capability that utilizes manual transfer switches and the on-site cogen at the WDEP. This gives the Main Campus the ability to power its grid and maintain operations during an extended utility power outage once the cogen is up and running—typically requiring a few hours. An expanded microgrid could provide several additional benefits to the CU Boulder campuses, including reduced downtime, the potential for emissions reductions by effective use of on-site renewable energy, and improved power reliability for critical loads. In addition, as a prominent institution within the City of Boulder, CU Boulder recognizes that having a resilient campus can help support the community during an emergency. While CU Boulder has an excellent electrical infrastructure backbone, there are three areas where improvements are required to realize a smart and islandable campus microgrid.

1. **On-Site Dispatchable Generation:** the availability of dispatchable power, i.e., power that can be used at any time, is an essential component of a microgrid. The University currently owns dispatchable power exclusively in the form of diesel generators. Other on-site generation resources are not considered dispatchable because they either experience variability, as in the case of PV, or cannot start operations during a power outage like the cogeneration plant. The cogen can be leveraged as dispatchable power with the addition of a 1 MW generator or battery to allow for black-start. With black-start capability, there would be more than enough capacity available to meet the demand of the connected campus, as long as there is no disruption to the natural gas and diesel fuel supply. The University is also exploring alternatives such as battery energy storage to expand the capabilities of on-site generation resources so they can be dispatched as needed.
2. **Electrical Distribution Controls:** the Main Campus electrical distribution system does not have the automated controls and switches in place to enable the load management and power distribution capabilities that a microgrid would require to operate efficiently. Advanced controls will be required to shed load and dispatch on-site generation as needed to allow for power to be routed to where it's needed most in an emergency. This is especially important should the availability of on-site power or fuel be a constraint as there would be no mechanism to manage its use. Even when sufficient on-site power generation is available, load shedding is essential for controlled transitions between sources, distribution circuit balancing, and the ability to respond to different types of campus outage events.
3. **Microgrid Interconnection:** the existing electrical feeder interconnecting the Main Campus and East Campus can be used as part of a University-wide microgrid. However, this is a single point of failure, and the East Campus does not currently have the ability to island itself. The East Campus has on-site solar generation and backup generators tied to specific buildings but lacks the microgrid controller and switches to operate independently. There is interest in developing a smart microgrid that would support the existing, as well as the future, buildings and infrastructure on East Campus. The microgrid would provide energy resilience to these critical research buildings and serve as a research testbed for grid resilience and cybersecurity. CU Boulder will continue to evaluate and make progress on this effort as well as identify additional opportunities outside of the Main Campus.

Implementation Plan

The following implementation plan identifies the key actions the University will undertake to progress the described focus areas.

Strategy	Action Number	Action	Responsibility	Time Horizon
A. Energy Resilience Design Requirements	A.1	Develop a framework for documenting campus mission-critical loads.	ESO + FO + EC + A&R	Short
	A.2	Work with Green Labs and RIO Director of Cores and Shared Instrumentation to interview research-owners and establish energy resilience requirements.	EC + A&R + ESO	Short
	A.3	Develop baseline requirements for resilience for mission-critical loads and incorporate into building design standards.	ESO + FO + EC + A&R + PD&C	Short
	A.4	Conduct an assessment of existing assets against the resilience requirements to identify vulnerabilities.	ESO +FO + A&R	Short
	A.5	Establish process to review resilience requirements for new research prior to grant application.	A&R + FO + PD&C	Short
	A.6	Establish requirements in design standards to install uninterruptible power supply (UPS) systems for critical loads.	PD&C + FO + UES	Short
B. On-Site Energy Generation and Storage	B.1	Determine locations where on-site generation and/or storage will provide the most benefit to resilience.	ESO + UES + FO + A&R + PD&C	Short
	B.2	Implement 3 MW battery storage system in alignment with the NREL East Research Campus Microgrid Assessment and Conceptual Design Report.	UES + PD&C + B&FP	Medium
	B.3	Enable the use of the cogen as prime generation when there is a utility outage by installing 1 MW emergency generator that can provide black-start capability.	UES + B&FP	Medium
	B.4	Explore opportunities to use the cogen to provide ancillary services to the grid.	UES + B&FP	Short

Responsible parties: Energy Action Group (EAG); Energy Services Organization (ESO); Facilities Operations (FO); Utility and Energy Services (UES); Budget and Fiscal Planning (B&FP); Real Estate Services (RES); Athletics (ATH); Academics and Research (A&R); Housing Facilities Services (HFS); Environmental Center (EC); Sustainability (S); Planning, Design and Construction (PD&C); and Student Representatives (SR).

Time Horizons : Short = 0-3 years, Medium = 0-5 years, Long = 5-10 years.

Strategy	Action Number	Action	Responsibility	Time Horizon
C. Campus Microgrid	C.1	Map out the resource availability and quality requirement of critical assets to establish priority loads.	ESO + FO + A&R + PD&C	Short
	C.2	Develop a plan to install the equipment required to automate islanding process.	FO + UES + PD&C	Medium
	C.3	Using SCADA system and existing building controls, develop a load-shedding strategy that allows key assets to maintain supply via the microgrid in a grid outage.	UES + ESO	Medium
	C.4	Evaluate proposed East Campus microgrid concepts and select one for implementation.	UES + ESO + PD&C	Medium
	C.5	Implement a energy management and demand response system covering the Main Campus, East Campus, and North of Boulder Creek through controls, storage, and other capabilities.	UES + ESO + PD&C	Long

Responsible parties: Energy Action Group (EAG); Energy Services Organization (ESO); Facilities Operations (FO); Utility and Energy Services (UES); Budget and Fiscal Planning (B&FP); Real Estate Services (RES); Athletics (ATH); Academics and Research (A&R); Housing Facilities Services (HFS); Environmental Center (EC); Sustainability (S); Planning, Design and Construction (PD&C); and Student Representatives (SR).

Time Horizons : Short = 0-3 years, Medium = 0-5 years, Long = 5-10 years.

4

East Campus Research Park
Source: AECOM Site Visit

Lead in Energy Innovation

Establish CU Boulder as a world-leading, living, learning laboratory focused on collaboration between students, faculty, staff, and the community through research and deployment of innovative energy solutions with a positive global impact.

Overview

CU Boulder's mission is not limited to changing its own campus for the better. With a reputation as a leader in sustainability, the University is both responsible and privileged to lead those in its sphere of influence through knowledge sharing, best practices, and lessons learned.

CU Boulder looks to establish itself as a world-renowned, living, learning laboratory, a place that builds upon its existing status as a hub for knowledge sharing and research and takes a more purposeful role in leading a partnership of campus stakeholders, researchers, students, and academic colleagues to drive forward development in resilience and fossil fuel-free solutions to our current and future energy needs. In practice this translates as building upon, creating, and facilitating new knowledge-sharing networks and offering up campus energy infrastructure and operations as a test bed for the application of research projects and technology demonstrations.

Metrics and Targets

CU Boulder's EMP leadership goals are expressed as statements of intent rather than metrics. These include the following:

1. Establish partnerships with local/regional agencies, research, and faculty for knowledge sharing and development opportunities
2. Create a model for University collaboration with industry with intention of fostering innovation

There may be opportunity to track certain engagements such as percent of new construction projects with technical network input, number of members of a technical practice network, number of related publications, or the number of community events hosted. The appropriate metrics may be identified as the programs/networks are established.

Focus Area Descriptions

In support of these leadership targets, CU Boulder has identified the following focus areas in which to take action.

A. Living, Learning Laboratory
B. Energy Research Opportunities
C. Engagement with Community Partners in Energy and Sustainability Goals
D. Periodic Energy Master Plan Validation

A. Living, Learning Laboratory

CU Boulder has a mix of world-class faculty and researchers working on advancing sustainability and energy sciences and a student population that has historically been committed to advancing progress in these areas. The campus buildings and supporting infrastructure can greatly benefit by embracing an innovative transformation to achieve higher efficiency and resilience. This combination exhibits the elements required for transitioning the campus into a living, learning laboratory that provides students valuable experiential opportunities while supporting the University's energy, GHG emissions, and energy resilience goals.

A living, learning laboratory is a campus where faculty, staff, students, industry, and the community actively work together to develop ideas and test potential solutions to the challenges facing the region, the nation, and the world. A key component of this effort will be the integration of energy management into the University's educational curriculum. There are countless opportunities for students and researchers to advance their learning while supporting the development of the campus. Below are several subject areas where stakeholders could use the campus infrastructure to advance learning, research and demonstration:

- Building high performance buildings, the integration of passive design and high efficiency building and envelope systems.
- Providing deep energy retrofits, combating one of the biggest challenges in energy savings—existing building stock.
- Creating smart buildings, the controls and interactivity between occupants and systems.
- Providing data analytics and reporting to optimize ongoing operations and occupant behavior.
- Defining and assessing energy resilience.
- Decarbonizing building HVAC systems through electrification or connection to low temperature district energy.
- Transitioning the district heating distribution from steam to zero-carbon-facilitating medium- or low-temperature.
- Providing central plant equipment and controls, and zero carbon sources for heat.
- Integrating renewable and clean energy on campus, and adding microgrids that allow them to support campus energy resilience.
- Innovative funding for energy and resilience projects such as premiums for enhanced reliability or decentralized clean energy transactions.

By tying the research being conducted across the University to a campus-wide program with a dedicated technical practice network there will be more support for a systematic knowledge sharing program which can be leveraged to support campus initiatives and research innovation.

CU Boulder has the perfect combination of infrastructure improvement opportunities and bright minds to realize this living laboratory and demonstrate true, international leadership.

B. Energy Research Opportunities

Beyond academic integration of campus infrastructure into a living, learning laboratory for students, CU Boulder has a strong opportunity to enhance the capabilities of existing academic research programs through integration with campus infrastructure. CU Boulder already hosts research that is well aligned with the challenges that the campus is looking to solve, but the academic and operational components of the University have not historically been well connected. For example, a group at the University recently received a grant from the Department of Energy (DOE) to study next generation, low-carbon district energy systems. These types of research grant awards create tremendous opportunity to increase collaboration between operations staff, academic programs and researchers to leverage campus infrastructure as a real-world case study and demonstration site.

Additional opportunities for integrating energy research into existing campus infrastructure for academic leadership include the following:

- Developing open-source software for streamlining district energy optimization problems.
- Applying new and emerging technologies to district infrastructure to study their applications in a real-world environment.
- Allowing limited access to real-world microgrid operations data for use by research programs studying ways to improve operations and cybersecurity of microgrid optimization software and direct digital controls (DDC).
- Studying the impact of on-site alternative energy technologies on local environmental quality such as air and noise pollution.

With the plethora of engineering and environmental research occurring at CU Boulder, there are many opportunities to enhance both the scholarship and energy performance of the University through enhanced partnerships between academic and research programs with campus operations.

C. Engagement with Community and Partners in Energy and Sustainability Goals

CU Boulder's position as a sustainability leader in higher education is demonstrated by its long legacy of sustainability achievements and community partnerships. Recent community partnerships range from the Environmental Center's Foundations for Leaders Organizing for Water and Sustainability (FLOWS) program which offers low-income communities with energy and water conservation audits and upgrades to collaboration with Xcel Energy and the National Renewable Energy Lab (NREL) on a variety of energy-related research opportunities and grant proposals. The University also works through its government affairs division to engage with community, state and federal agencies on policies, regulations and funding opportunities.

D. Periodic Energy Master Plan Validation

The EMP will be a living document that will continually be referenced and assessed for its relevancy by the EAG and other stakeholders. The implementation actions will be reviewed at each meeting of the EAG to determine their current status, their relevancy, and inclusion of new action items, as necessary. The goals and strategies of the EMP need to become integrated and inherently represented in annual University infrastructure capital improvement and planning cycles. The University will undertake a comprehensive review of the overarching EMP every five years to ensure that the stated goals remain valid and aligned with the University's mission, external reporting commitments, and statutory requirements. This revalidation cycle will allow CU Boulder to holistically assess the success of the various strategies and programs already implemented, and evaluate how emerging technologies might provide additional routes to advancing the energy program.

Implementation Plan

The following implementation plan identifies the key actions the University will undertake to progress the described focus areas.

Strategy	Action Number	Action	Responsibility	Time Horizon
A. Campus Living Laboratory	A.1	Establish the mission statement for formalized living, learning laboratory network.	S + EC + A&R + SR	Short
	A.2	Identify on and off-campus research institutions looking for partners to test new clean energy, resilience, and efficiency technologies and concepts.	S + EC + A&R + SR	Medium
	A.3	Determine projects to test the living, learning laboratory concept.	S + ESO + UES + EC + A&R + SR	Medium
B. External Partnerships	B.1	Expand upon the existing academic and facilities programs to further support the identification and deployment of energy projects.	ESO + A&R + SR	Short
	B.2	Establish a working group to leverage existing student and faculty expertise to scope required future district energy assessments.	ESO + A&R + SR	Short
	B.3	Establish broader energy focused industry partnerships and grant opportunities through collaboration with the Industry and Foundation Relations team within the Research and Innovation Office.	EC + ESO + S + A&R + SR	Short
C. Community Outreach	C.1	Assess and evaluate potential partnerships or outreach opportunities with community entities.	EC + S + SR	Short
	C.2	Develop a community energy outreach program that is focused on the education of the local community.	EC + S + SR	Short
	C.3	Establish community access to the University TPN or similar information for further resources.	EC + SR + A	Short
D. Periodic Master Plan Validation	D.1	Update the Energy Master Plan every 5 years or as deemed necessary by the EAG.	ESO + PDC + S + EC	Medium

Responsible parties: Energy Action Group (EAG); Energy Services Organization (ESO); Facilities Operations (FO); Utility and Energy Services (UES); Budget and Fiscal Planning (B&FP); Real Estate Services (RES); Athletics (ATH); Academics and Research (A&R); Housing Facilities Services (HFS); Environmental Center (EC); Sustainability (S); Planning, Design and Construction (PD&C); and Student Representatives (SR).

Time Horizons : Short = 0-3 years, Medium = 0-5 years, Long = 5-10 years.

Aerial View of CU Events Center
Source: University of Colorado

Implementation Roadmap

Campus Vision for the Future

Without the implementation of a robust energy program, CU Boulder's energy footprint will continue to grow for the foreseeable future. This is due to several components including campus growth, mission evolution, facility and infrastructure degradation, and climate change.

Campus Mission Growth

The 2021 Campus Master Plan has defined the vision for campus over the next thirty years and projects a net growth of nearly 3 million assignable square feet (ASF) of facilities, 4 million from new construction and 1.3 million for demolition. 70 percent of this new construction is in housing and research with the latter representing 45 percent (around 1.2 million ASF) of the net growth. Table 8 summarizes the projected growth by 2051, both in ASF and gross square footage (GSF). This growth signals a significant shift from predominantly learning and office uses to more energy-intensive research space, in alignment with the University's strategic goals. Despite future improvements to local building standards, this growth will result in a significant increase to campus energy use that must be offset by increasing the energy efficiency of our existing building portfolio. These projections in research growth highlight the importance for optimizing research space in the future. Suggested strategies for reducing future demand of research space include establishing research space allocation guidelines, periodic research space audits to verify and confirm optimal utilization post-occupancy, and developing programs that promote co-location and sharing of research equipment in an effort to reduce energy demand and increase resiliency.

Table 8: Campus Master Plan Growth Projections

Space Type	Existing ASF	Existing GSF	Future ASF	Future GSF
Athletics	435,000	670,000	435,000	670,000
Campus Life	652,000	1,004,000	919,000	1,415,000
Dining 2	15,000	331,000	352,000	542,000
Housing	1,899,000	2,925,000	2,697,000	4,153,000
Learning	749,000	1,153,000	1,016,000	1,565,000
Office	1,778,000	2,738,000	2,003,000	3,085,000
Recreation	270,000	416,000	312,000	480,000
Research	937,000	1,443,000	2,591,000	3,990,000
Other	NA	2,246,000	NA	2,334,000
Total	NA	**12,926,000**	NA	**18,234,000**

Recycling Operations Center Rooftop Solar PV
Source: University of Colorado

Other Energy Growth Factors

Climate Change

The future projections for energy use must take into consideration the rapidly increasing impact of the climate emergency on the local environment. Modeling of climate change in Boulder suggests that, by 2050, annual cooling energy use is likely to increase by 10 percent while heating energy use will decrease by 8 percent. As such, CU Boulder will likely experience a new, cooling-led paradigm in energy systems planning and an increase in capital expenditure for new cooling equipment. Existing HVAC systems will also have to work harder for longer periods of time to meet growing demand, thereby shortening equipment life span. CU Boulder has identified the importance of incorporating the impacts of climate change into future infrastructure and systems planning.

System Degradation

As with most equipment, building and energy systems experience reductions in performance efficiency throughout their lifespan. This performance degradation reveals itself as an increase in energy consumption for that system or building. This can be exacerbated without effective equipment monitoring, assessment, or ongoing commissioning. The EMP assumes a 0.5 percent annual degradation of general system performance in the campus energy growth model.

Considerations for Implementation

Accelerating Technology Development

This roadmap was developed considering the technologies and efficiencies currently accessible to the University. Technological development will play a major role in future energy and GHG emissions reductions that are not currently considered in this plan. Existing technologies like solar PV and battery energy storage may also see increases in efficiency and cost reductions that will need to be considered at a later date. In addition, the evolution of transportation electrification has been considered as part of this EMP. The Transportation Master Plan recommends the development of a strategy and a focus on transitioning the CU Boulder light and heavy duty feet vehicles to electric vehicles. It also encourages development of a plan to provide electric vehicle charging infrastructure to support charging of fleet vehicles and support to both workforce and public vehicle charging. As these plans develop, the campus will have to be mindful of the potential large impact these charging requirements will have on the energy demand profile of the campus. It may require significant power distribution infrastructure upgrades and smart charging strategies to adequately manage the increased demand.

Changing Energy Pricing

The costs of energy commodities like electricity and natural gas have been considered in this plan insofar as they affect the cost-effectiveness of the recommended measures. The EMP applied commodity price change projections created by the Energy Information Agency (EIA) for the Mountain region to the analysis of the proposed projects. The resulting roadmap is achievable and cost-effective, but the financial performance of the proposed projects may require reevaluation as commodity prices change.

The Cost of Delay

To meet the goals in the timeframe outlines in this EMP, the University must act immediately. Beyond increasing the challenge of meeting the University's targets, the impact of delaying meaningful action towards the EMP goals has large cost implications. Scenario modeling conducted in the development of the EMP estimated that financial cost of a five-year delay is estimated to be over $6 million over those five years. This reflects lost energy cost savings and doesn't account for the sunk costs for purchasing equipment that is not compatible with decarbonized heat source, or the premium required to replace it. While the University could still meet its long-term goals, the lost opportunity to reduce the absolute GHG emissions in the interim time period would go against its stated commitments.

Conversely, if the opportunity arises to act more quickly in implementing the EMP roadmap—for example, if project funding can be secured earlier—then CU Boulder could both meet its goals ahead of plan and reduce total financial expenditure.

Alignment with Strategic Priorities

The EMP roadmap will not be implemented in isolation. The University has a number of strategic priorities that will overlap and complement the efforts to implement the EMP. The current and future campus and climate action planning efforts will interact with EMP, and the University's Capital Renewal Program provides a great opportunity to implement deep energy retrofit projects while reducing the deferred maintenance backlog. Integrating the short and long-term goals and objectives of the EMP into any program that supports campus infrastructure projects; new construction, renewal and repair, will be essential to the plan's success.

Funding mechanisms

The University currently funds energy projects through a mixture of different sources and mechanisms both centralized and decentralized. Typically, campus stakeholders fund building improvements and efficiency projects through their respective capital plans with support, where applicable, from the centralized utility fund. In order to meet the ambitious goals outlined in the EMP, significant additional funding will be required. There's historically been preference from the University to self-fund infrastructure improvements due to access to lower rate funds. However, with many competing demands for campus funding, and the long-term financial impact of the COVID-19 pandemic still uncertain, the University will almost certainly have to look to leverage external funding for part of this infrastructure transformation.

No financial commitments have been made regarding energy project implementation, but the University is committed to working with campus stakeholders to identify the best funding sources for projects and help them pursue alternative financing mechanisms where available. These mechanisms may include the following:

- **Incentives:** funding incentives for energy projects available through the local utility, state, DOE, and others that could be used to mitigate the project cost.
- **Third Party Loans:** large-scale loans acquired by the University to provide an influx of capital for funding energy projects. This type of financing mechanism is best suited for large-scale investment.
- **Energy Savings Performance Contracts:** a form of third-party financing that creates a partnership between the University and an energy service company (ESCO). Capital costs for projects are provided by the ESCO and costs are recovered through the resulting energy savings.
- **Public-Private Partnerships:** long-term contract between the University and a private organization that allows the University to leverage private capital in support of energy projects.
- **Capital Renewal:** funding earmarked for deferred maintenance will also benefit energy performance if an integrated implementation approach is established.
- **Others:** energy and sustainability projects are attractive to donors and sponsors, and a these are a strong option for supplemental investment if communicated effectively.

CU Boulder will aim to leverage all available financing mechanisms to successfully implement the proposed roadmap.

Project / Program Areas

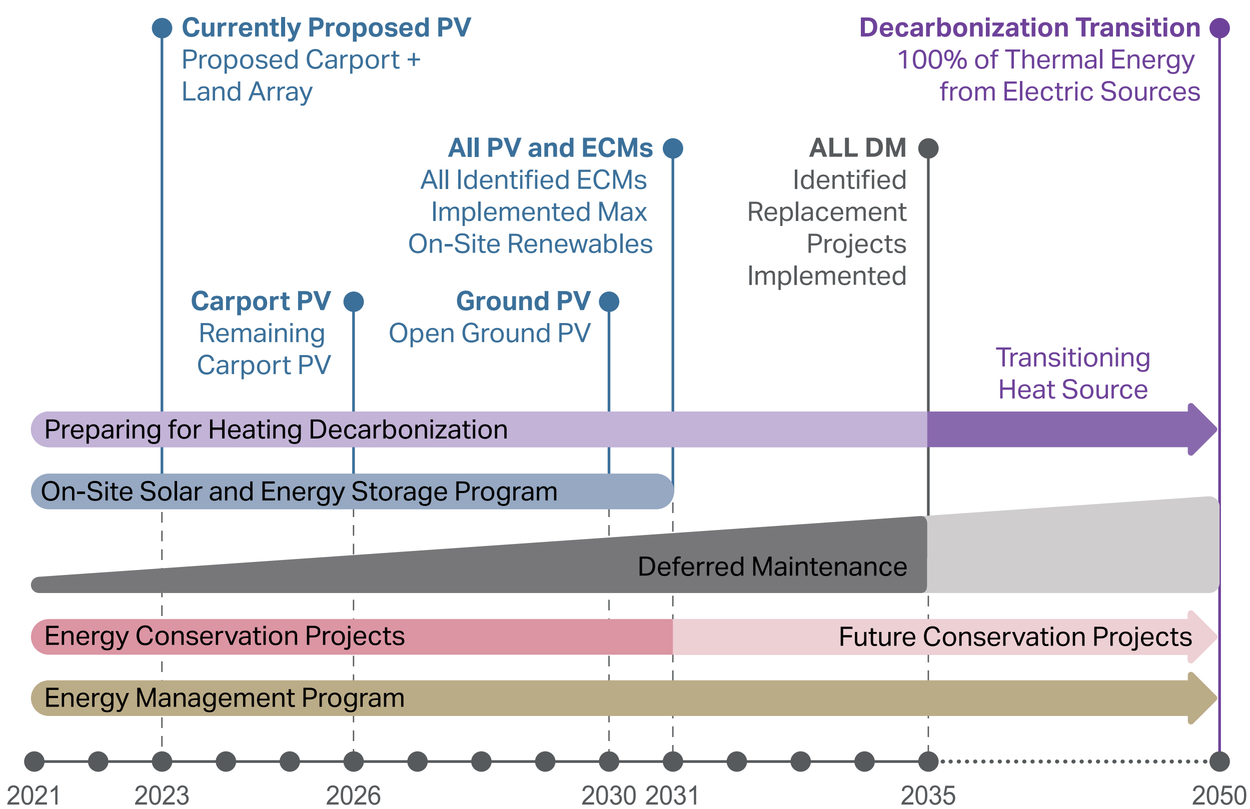
Within the context of campus growth, climate change, equipment degradation, and technology evolution, the University has developed an integrated strategy to meet the overarching energy goals that:

- Reduces energy consumption across campus
- Promotes high-performance building design
- Eliminates GHG emissions by 2050
- Enhances energy resilience of campus operations and research

This strategy is comprised of key project/program areas in conservation, management, control, and generation of energy on campus.

To best align with the University's development plans and resources, a phased implementation strategy has been developed for the key energy program elements that have a quantifiable impact on the campus' goals.

Figure 11 shows the timeline for implementation of those program elements including a tentative timeframe for transition to a decarbonized heating system on campus.



DM = Deferred Maintenance
ECM = Energy Conservation Measure
DE = District Energy

Figure 11: Roadmap Project Timeline

The deployment of energy strategies in the proposed roadmap first focuses on policy adoption, design standards updates and management program set up, then targets energy conservation, on-site generation and finally, thermal supply decarbonization.

Energy Management Program: CU Boulder will begin by expanding and formalizing its energy management program. This starts with the establishment of the EAG and ESO, the drafting and adoption of a campus-wide energy policy, and updates to the design standard. When established, the energy management program will provide support for the identification, scoping, and funding for energy projects.

Energy Conservation Projects: Once key elements of the energy management program have been put in place, CU Boulder will begin progressive implementation of energy conservation measures.

This will include the establishment of an energy auditing program to systematically identify and recommend energy conservation measures and resilience improvements. The ESO would then support the campus in the scoping, design, and implementation of recommended measures.

Deferred Maintenance: Measures that overlap with deferred maintenance such as building envelope and window upgrades are assumed to be implemented more slowly than stand-alone measures as they can be more disruptive to campus operations and are more costly to complete. The proposed roadmap assumes that an increasing amount of deferred maintenance projects that directly impact energy use can be addressed every year and help make progress toward achieving the 30 percent energy reduction target by 2035.

On-Site Solar Program: CU Boulder is estimated to have enough space on campus for the installation of 10 MW of solar PV. The roadmap recommends that the campus use these identified opportunities on rooftops, carports and open ground PV arrays to achieve its 10% on site clean energy target by 2030.

Heating Decarbonization: With the design standard updates, all new and retrofitted buildings will be set up for the transition to a lower temperature heat source or to use a decentralized electric heating source. The roadmap plans for this to be complete by 2040 at the latest, enabling the transition to a zero carbon heat source at the central plant.

Integrated Roadmap

Figure 12 shows CU Boulder's energy roadmap over the next 15 years. The projection takes into consideration:

- Planned growth
- Impact of climate change (increase in cooling demand and reduction in heating demand)
- Impact of energy cost escalation (aligned with the EIA projections)
- Change in grid power emissions factor
- Energy growth from equipment degradation
- Recommended energy efficiency and conservation measures
- Recommended on-site power generation projects
- Decarbonization of the heating system

With this roadmap CU Boulder will be able to meet and, in some cases, exceed the goals outlined in the EMP. The combination of energy efficiency projects, use of high-performance building design, and use of commissioning and other strategies to address equipment degradation can achieve a 30 percent reduction in energy use intensity by 2035 compared to the 2020 baseline. Appendix C provides a description of the methodology used for developing this integrated roadmap.

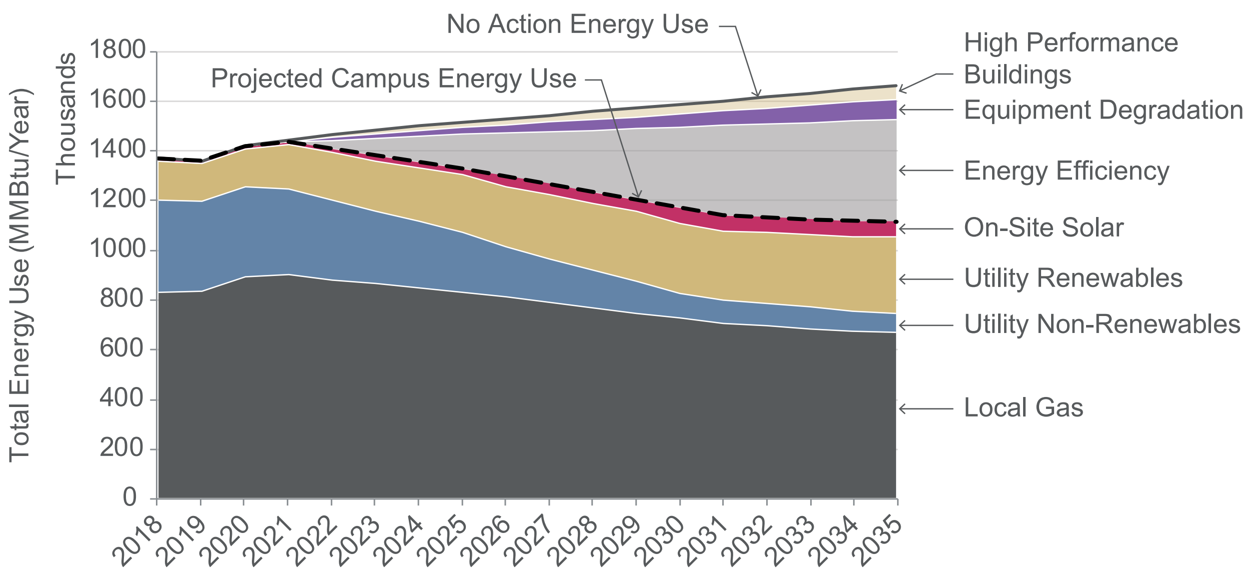


Figure 12: Integrated Roadmap

The combination of projects in addition to the utility's planned reductions in grid emissions will achieve a 59 percent reduction in energy-related emissions by 2030 compared to the 2005 baseline used in the ACUPCC. Figure 13 shows the pathway to zero carbon emissions over the next 30 years. The transition to a decarbonized heating system paired with the remaining actions outlined in the EMP will allow CU Boulder to eliminate all energy-related emissions by 2050.

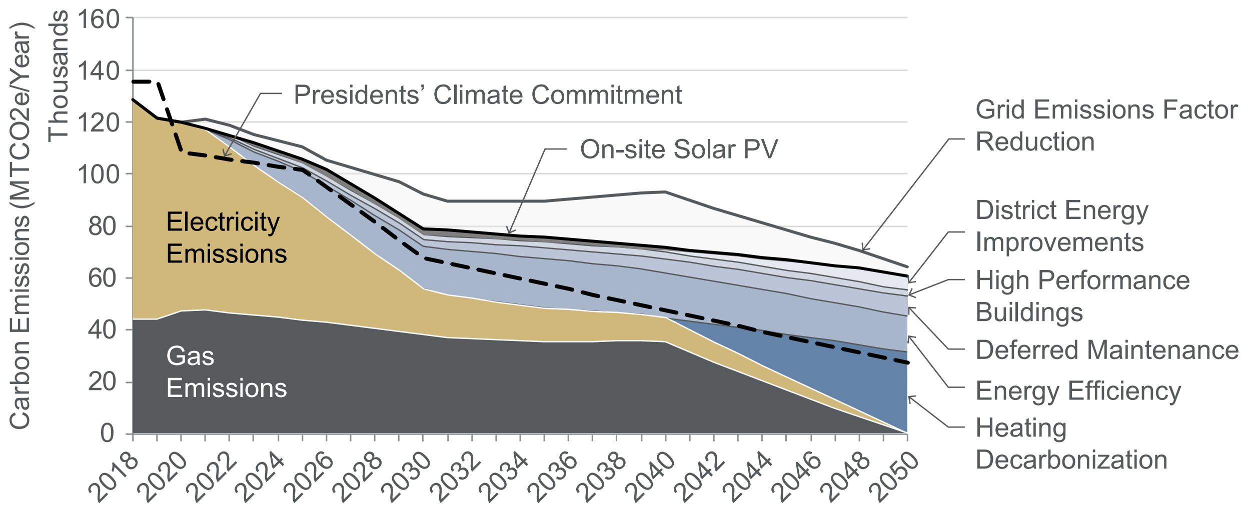


Figure 13: Energy-Related Emissions

Figure 14 shows the annual projected energy commodity cost projections compared to a 'no action' approach where the University continues its current approach. CU Boulder's roadmap to achieving its energy goals assumes that there is a consistent annual investment available to implement energy projects. With this steady rate of investment, the cumulative estimated energy cost savings amount to over $50 million before 2035. If greater levels of funding are available either through the University or through a third-party, the implementation of this roadmap can be accelerated, leading to earlier realization of the economic, resilience, and sustainability benefits of achieving its goals.

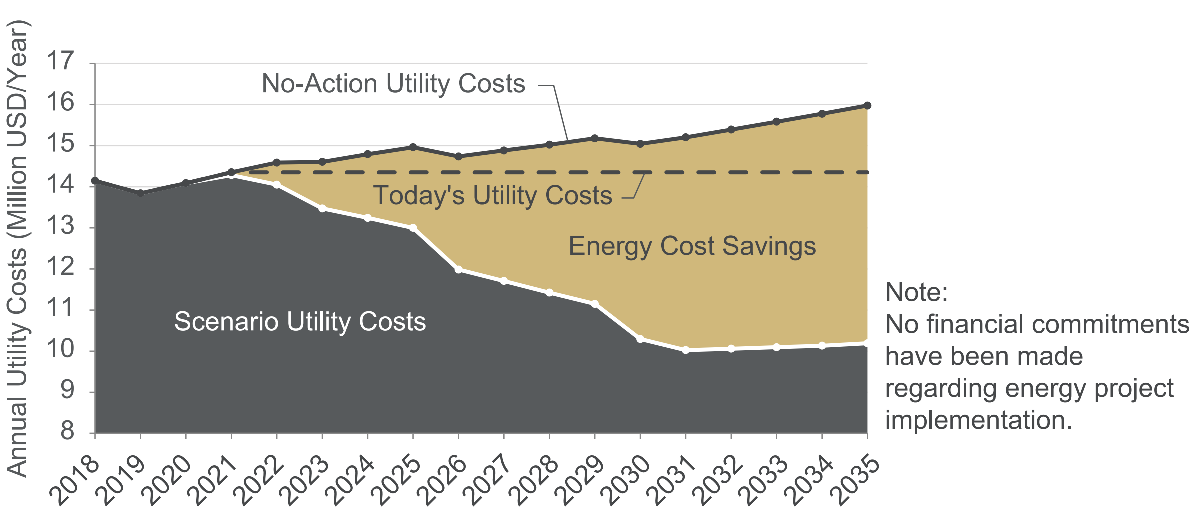


Figure 14: Utility Cost Projections

A Culture of Efficiency and Avoided Consumption through Outreach and Education

The least expensive and least carbon-intensive energy is the energy that is never produced or consumed. Cultural change through outreach and education efforts to students, faculty and staff can help reduce energy consumption through behavior modification.

An Energy and Communication Engagement Plan, developed as part of the EMP, is included in Appendix G. The plan outlines an array of approaches that the Energy Action Group (EAG) can consider for implementation with a primary focus on maximizing energy efficiency and energy conservation. It also raises the importance of awareness and education about clean energy technologies and strategies. It further outlines key actions/strategies, including policy formation; consistent and innovative education and outreach campaigns/programs; pursuit of funding opportunities; capitalizing on existing events such as the annual Sustainability Summit; and continued engagement with community partners such as Xcel Energy, NREL, as well as local, state and federal agencies.

The EAG can also support the goals and efforts of the newly formed Sustainability Council and assist in informing, supporting and prioritizing sustainability initiatives and policies to maximize impact across campus.

A Vision Forward

CU Boulder is committed to developing a more sustainable and resilient campus that will allow the university to meet its core mission; reduce life cycle costs and emissions; and ultimately, better serve its students, faculty and staff. This Energy Master Plan will ensure that the university's vision for that future will be met through a comprehensive energy program that focuses on:

1. **Increasing campus energy efficiency**
2. **Reducing facility energy emissions**
3. **Enhancing critical mission resilience**
4. **Leading in energy innovation**

The vision, goals, and strategies outlined in the EMP can only be accomplished through a deliberate and collaborative effort that will involve everyone at the university. Innovation and coordination with the broader community also will be key elements for success. The goals in this road map for CU Boulder's energy future are demanding but achievable and will entail a 30-year effort with a real focus on actions, large and small, that need to be accomplished to realize its goal of zero facilities-related carbon emissions by no later than 2050.

Solar PV on Indoor Practice Facility
Source: University of Colorado

University of Colorado
Boulder

AECOM

Appendix A: Campus Energy Management Structure

Table of Contents

This appendix provides and overview of the CU Boulder campus energy management structure. It both defines and summarizes the roles and responsibilities of the proposed campus energy teams, Energy Services Organization (ESO) and Energy Action Group (EAG) and outlines the steps required for their creation.

1. Campus Energy Teams

In accordance with the Energy Master Plan (EMP), the campus will develop an Energy Policy and Program Plan that will ensure the identified goals and timelines stated in the EMP are met for the CU Boulder Campus. To achieve the goals, all campus groups that own, operate, maintain, and support energy infrastructure shall create campus energy teams to develop unit specific energy programs, projects, initiatives, and engagement plans. Each unit will designate an individual from their energy team to represent their unit on the Energy Action Group (see Section III below).

2. Energy Services

Energy Services is the proposed campus organization suggested in the Energy Master Plan (EMP) to oversee the EMP recommendations.

A. Energy Services will facilitate the development of the Energy Action Group (EAG). The EAG is the group that will create the Campus Energy Policy that will support the approved Goals and Timelines identified in the EMP.

B. Energy Services will not have any budget authority or process approval over any other campus organization (e.g. GF, HDS, ATHL, etc.). Energy Services role and responsibility is as defined in this document with the intent to provide the specific technical and financial expertise to support the EAG members and their unit specific energy teams.

C. Role of Energy Services

    a. Management and Oversight of CU Boulder Campus Energy Portfolio in accordance with the EMP identified data collection requirements (e.g. EnergyStar Portfolio Manager, STARS, 2nd Nature, etc.). Management and oversight of all approved Energy Metrics, Initiatives, and Goals.

        i. Reporting and Analysis: Examples include, but not limited to, Energy Use Intensity (EUI) per building, Source Energy per campus, Total Energy per campus, Energy Assessments, Energy Forecasts, energy management practices, building performance score cards.

        ii. Energy Contracts and Agreements: Examples include, but not limited to, Energy Performance Contracts, Renewable Power Purchase Agreements, City of Boulder ESA, Xcel Energy ESA.

            1. Support Campus Customers that are approved to leverage 3rd Party Financing, Colorado Energy Office (CEO), or other state agency Programs, Sponsors, and/or P3 Proposals to advance the Goals identified in the EMP. Energy Services Group supports the development, provides recommendations, and manages the M&V.

D. Energy Services Staffing

    a. Existing positions: Energy Manager, Energy Data Analyst, Student 1, Student 2

3. Energy Action Group (EAG)

A recommendation of the EMP, the EAG consists of all campus wide customers and stakeholders that have direct impact on energy consumption. EAG representation [membership] is required for all campus organizations that have budgetary oversite over energy infrastructure (e.g. Building HVAC).

A. The EAG shall be tasked with the development of both the Campus Energy Policy and the resulting campus wide Energy Program.

B. The EAG shall be tasked with reviewing, recommending, and updating the Facilities Standards for Campus Energy Infrastructure (e.g. Mechanical, Electrical, Plumbing) to align with the energy goals and timelines of the EMP.

C. Energy Services will support the EAG as the central point of contact and coordination of group activities.

Figure 1 visualizes the proposed connections between thee individual campus organization's energy teams, the EAG, and the supporting ESO.

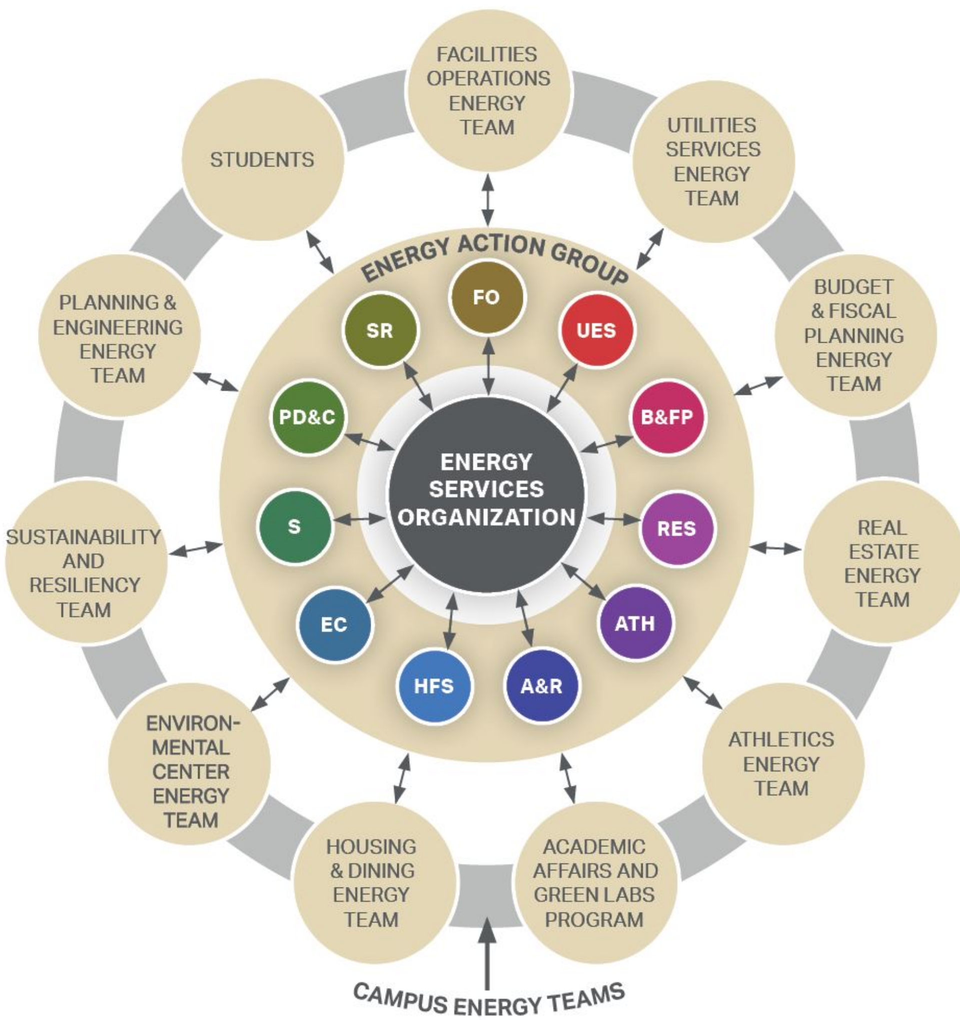


Figure 1: The Relationship Between the Campus Energy Teams, the EAG, and the ESO

4. Next Steps

A. In accordance with the recommendations of the EMP, Energy Services will guide [facilitate] the creation of the Energy Action Group and the development of an EAG Charter to identify specific member roles and responsibilities. The Charter will provide details of formal work processes and procedures for meeting schedules, project requests, review timelines, and approval guidelines/protocols to ensure EAG members support all approved energy initiatives (programs and projects).

   a. The Charter will align the set timelines of the approved EMP Goals and with each EAG members budget cycle and energy plans.

B. Energy Action Group (EAG) members: See Figure 1. Energy Services, Facilities Operations, Utility Services, Real Estate Services, Athletics, Housing & Dining Services, Environmental Center, Sustainability Office, Planning Design & Construction, Student Representatives, Academics, and Budget & Fiscal Planning Office.

   a. EAG Member [initial] Roles

      i. Energy Services:

         1. EAG Facilitator.

         2. <u>Energy Infrastructure and Engagement Projects</u>: Provide Energy Project recommendations and development to all EAG members [customers]. Support each EAG member to prioritize and optimize their established funding (deferred maintenance, capital, repair, etc) to align with and achieve the campus energy goals.

         3. <u>Energy Services</u> functions like an energy consultant service and supports customers in meeting energy goals. Energy services is funded through member utility budgets (i.e., utility rates). Therefore, all members should actively employ/consult Energy Services as needed.

         4. <u>Energy Services</u> will assist the EAG members in setting priorities for their specific Energy Programs developed by the EAG to achieve the set timelines and goals of the EMP. For example: Building assessment/audit program that is focused on achieving individual stakeholder objectives and aligned with campus overarching goals.

         5. <u>Energy Services</u> will provide the energy assessments, building energy report cards, technical support, and training to each member to ensure each members energy goals are fully supported and achievable.

            a. Types of Training / Refresher programs: Campus Goals [Policy], Building Design Intent, Optimization Applications, Facilities Standards, etc. Does not include specific OEM training.

C. EAG Listed Members:

   a. Create or develop a dedicated Energy Team for your operation to oversee the energy infrastructure and Energy Policy requirements for your work unit.

   b. Develop/update unit specific energy conservation programs and plans for incorporation with campus wide energy plan.

   c. Provide an EAG Representative.

    d. Provide priority lists and identify how the EAG can best support your initiatives.

D. EMP Engagement and Communication Planning: Engaging campus stakeholders to support the CU Boulder EMP goals through outreach programs.

    a. EAG to develop and coordinate activities to provide concise and strategic communications of the goals and timelines.

    b. Liaison with CU Boulder Strategic Relations and Communications.

    c. Establish a Green Fund for engagement, incentives, and donor strategy.

E. Chancellor's Administrative Organization (CAO) – Annual Campus Energy Report

    a. Energy Services shall be tasked with compiling, providing, and presenting an annual campus energy specific report that is authored by the Energy Action Group (EAG). Reporting the state of the campus energy based on the timelines and long-range energy performance objectives set in the Campus Energy Policy and campus energy performance goals.

Appendix B: Strategic Energy Management Framework

Table of Contents

1. Energy Management Framework

The development of an Energy Master Plan (EMP) has been undertaken for CU Boulder with the support of AECOM to define and develop a roadmap for achieving the University's energy and greenhouse gas emissions reductions, resilience, and leadership goals. The strategic energy management framework (SEMF) presented in this appendix works in tandem with the public-facing EMP to provide a comprehensive management protocol for CU Boulder that is aligned with two globally-recognized energy management programs' guidance: the National Renewable Laboratory's (NREL) Strategic Energy Management Evaluation Protocol (SEM) and the International Organization for Standardization (ISO) 50001 Energy Management Standard. The SEMF is an appendix that documents the requirements for an SEM and ISO 50001-compliant program and records where these requirements are met in the EMP and its appendices. Table 1 provides a high-level overview of the areas of overlap between the EMP and the SEM protocol and ISO 50001 standard. The yellow boxes show the common components of the management protocols, each supported by the related elements of the EMP.

Table 1: Strategic Energy Plan Component Overview

Leadership and Organizational Structure	Energy Policy and Targets	Documentation and Operational Processes	Planning and Implementation	Support and Operation	Performance Evaluation and Improvement
• Support the University in establishing roles • Assess stakeholder commitment	• Develop energy model including future growth • Establish energy goals	• Gap analysis • Advising on CU Boulder's processes	• Collect and analyze energy data • Identify opportunities • Develop roadmap for implementation	• Recommend changes to design standards	• Develop KPIs • Define roles and responsibilities • Recommend tracking and reporting improvements

1.1 NREL Strategic Energy Management Evaluation Protocol

NREL developed a SEM to provide a detailed approach for measuring energy consumption savings from energy-efficiency measures. The SEM focuses on achieving energy-efficiency improvements through systematic and planned changes and capital equipment upgrades. The protocol components and elements are closely tied to ISO 50001. Key steps to implement NREL's SEM in an organization include:

- Initial Assessment:
  - Assess whether a study focused on energy consumption or energy consumption intensity (energy consumed per floor area) is adequate for the organization
  - Verify that sufficient facility-level energy data is available to develop a baseline
- Develop Research Design:
  - Determine the organization's goals and objectives to be evaluated as part of the SEM
  - Create an energy consumption model for the study boundary (the CU Boulder campus) that includes growth
- Collect and Prepare Required Data:
  - Collect energy consumption data for all facilities in the study
  - Collect data on the organization's background, past energy audits, and information describing the organization's existing energy efforts
- Define Baseline and Reporting Periods:
  - Define the baseline and reporting periods to be used in the energy analysis
- Specify Energy Consumption Regression Model:
  - Develop a model to represent energy consumption for the facilities included in the analysis
- Fitting the Model:
  - Fit the model to the historical energy consumption data
- Estimating and Documenting Savings:
  - Use the model to estimate savings between the adjusted baseline and the metered energy consumption
  - Document assumptions used in model development
- Reporting Savings:
  - Report point estimates of program savings for the reporting period
- Measurement and Verification Methods:
  - Select and implement a measurement and verification method for measuring savings

Table 1 shows how each element of NREL SEM aligns with the EMP.

1.2 ISO 50001

The 2018 ISO 50001 Energy Management Systems – Requirements with Guidance for Use standard provides organizations with a framework for effectively and systematically managing energy. An energy management system (EnMS) integrates energy management into existing business systems, enabling organizations to better manage their energy and sustain achieved savings[1]. The key requirements of the standard include:

- Context of the Organization:
  - Study of the organizational context and identification of internal/external issues that may be an obstacle for implementation
- Leadership:
  - Establishment of a leadership team to make decisions on EnMS implementation
  - Development of an energy policy for more efficient use of energy
- Planning:
  - Establishment of objectives and targets to meet energy policy commitments
  - Utilization of data to better understand performance and make informed decisions about energy use
  - Identification of energy performance improvement opportunities
- Support:
  - Communication with organizational stakeholders to raise awareness about the energy management program
- Operation:
  - Modification of organizational design and procurement guidelines to improve energy performance
- Performance Evaluation:
  - Measurement of results associated with objectives, targets, opportunities for improvement, and action plans
  - Review of the energy policy's performance
- Improvement:
  - Continual improvement of energy management

While the ISO 50001:2018 standard does not prescribe minimum performance criteria, energy reductions, or
targets, it does require an organization to obtain and analyze data associated with energy use, efficiency, and
consumption.

Table 2 shows how each element of ISO 50001 aligns with the EMP.

[1] https://betterbuildingssolutioncenter.energy.gov/iso-50001/what-iso-50001

Table 2: NREL SEM Alignment with CU Boulder EMP

NREL SEM Component	Alignment with EMP	Reference
Initial Assessment Evaluate four key conditions are met to apply the SEM protocol: 1. The evaluation objective is estimating changes in a facility's energy consumption (savings) or energy consumption intensity (energy consumption per unit of production output or unit of floor area) from SEM activities. 2. Facility-level data on energy consumption, production output, and weather for industrial facilities or on energy consumption, weather, floor area, and occupancy or utilization for large commercial buildings are available for the baseline and reporting periods 3. Evaluators have sufficient understanding of energy consumption at the facility to construct a valid facility energy consumption model 4. Expected energy savings are sufficiently large to be detected with a statistical analysis of the available data	The EMP process meets the protocol conditions in the following ways: 1. Changes in energy consumption savings and intensity were calculated as part of the EMP 2. The data required by the SEM was available and was provided by CU Boulder 3. Representative buildings were visited and building operations personnel were interviewed to understand operations 4. Energy savings were sufficiently large to be detected	– EMP Document: Existing Energy Usage and Infrastructure Section – EMP Document: Energy Conservation and Efficiency Section
Initial Assessment Facility energy savings or changes in energy consumption intensity from SEM should be estimated by comparing the facility's metered energy consumption (or energy consumption intensity) during the reporting period with the facility's adjusted baseline during the same period—what its energy consumption (or energy consumption intensity) would have been had SEM not been implemented	Energy models of nine building types were developed as part of the EMP and calibrated using knowledge of building operations on campus and historical energy consumption data. Growth projections for each building type as well as future building energy models were used to estimate future energy consumption and the change in energy consumption and energy consumption intensity resulting from energy projects. The baseline year was selected as fiscal year 2020, and although the savings were against an adjusted baseline for future years, the preference for EMP reporting was to show savings against the actual baseline year to align with the University's goals	– Energy Modeling Appendix – Goals Appendix
Initial Assessment The adjusted baseline should be estimated using facility energy consumption data from the baseline period, which should not reflect the SEM program impacts the evaluator wishes to measure. Typically, the baseline period precedes the facility's SEM implementation.	The baseline and adjusted baselines were estimated using facility energy consumption data and incorporating future growth as applicable	– Energy Modeling Appendix

NREL SEM Component	Alignment with EMP	Reference
Develop Research Design *Evaluation goals.* Evaluators and program managers should agree on goals for the evaluation to ensure that the required data can be collected and that the evaluation answers the program administrator's research questions.	The EMP process included the development of goals with stakeholder consensus. The goals selected included GHG emissions reduction, energy intensity, and overall energy consumption reductions, and others.	– Goals Appendix
Develop Research Design *Variables necessary to model facility energy consumption, so the means to collect the required data can be put in place.* For industrial SEM programs, verifying the availability of data is an important step as some industrial utility customers may not have the data in an accessible format or may not be willing to share data on facility inputs or outputs. For commercial buildings, verifying the availability of occupancy data and the frequency of available data represents necessary steps, as occupancy can be an important explanatory variable.	A data review was conducted, and a gap analysis was provided as part of the EMP process. Sufficient data was available to conduct the analysis, but additional recommendations have been made as part of the EMP concerning how the campus can collect energy data in the future.	– EMP Document: Energy Conservation and Efficiency Section – Energy Monitoring Strategy
Develop Research Design *Required sample sizes in terms of facilities and amount of data for each facility.* The sample size calculation will depend on the program design, evaluation objectives, and frequency of available energy consumption data.	The selected sample data size for the EMP was the entire CU Boulder campus.	– EMP Document: Existing Energy Usage and Infrastructure Section
Develop Research Design *The likelihood of detecting savings at the desired levels of statistical confidence and precision for evaluations that will be performing facility-level analysis.* If there is a low probability of detecting savings using statistical analysis of facility consumption, the evaluator should consider other approaches for estimating savings, such as statistical analysis of sub-meter data.	Past energy savings studies had been conducted at the University and there was a high degree of confidence in additional evaluations to be performed at the campus level.	– EMP Document: Energy Conservation and Efficiency Section – Energy Auditing and Conservation Measures Strategy
Develop Research Design *Expectations for changes in the facility production process or input characteristics that would substantially alter facility energy consumption.* It may be necessary for evaluators to collect data on these changes to obtain an accurate estimate of savings.	Growth in campus occupied floor area and the types of facilities to be added were the two most significant factors affecting energy consumption. Both were included in the EMP analysis.	– EMP Document: Implementation Roadmap Section – Status Quo Vision for the Future Subsection – Energy Modeling Appendix
Develop Research Design As part of the research design, the evaluator also should define the energy consumption boundaries of each facility	The boundary was defined as the entire CU Boulder campus.	– EMP Document: Existing Energy Usage and Infrastructure Section

NREL SEM Component	Alignment with EMP	Reference
Develop Research Design As a facility may consume multiple types of fuels, the evaluator should identify the facility's consumption of different energy types or fuels (e.g., electricity, natural gas, fuel oil) and the types of energy consumption expected to be affected by SEM.	All energy savings were translated into the two fuels used by the campus: electricity, and natural gas. Steam and chilled water on Main Campus were not considered as fuels but any savings associated with reduction in consumption of these two resources was translated into a fuel savings and considered in the EMP.	– EMP Document: Energy Conservation and Efficiency Section
Develop Research Design During development of the research design, evaluators should conduct a statistical power analysis to determine the study's likelihood of detecting the expected savings. The probability of detecting savings is known as the statistical power of the study and is a function of the following: - The expected SEM savings as a percent of consumption; - The variability of facility energy, as measured by the coefficient of variation (CV) of facility energy consumption; - The probability of concluding savings occur when there are none (also known as the probability of making a type I error and the statistical significance level) - The number of energy consumption observations for the baseline and reporting period; - The correlation of facility energy consumption over time	The parametric nature of the EMP modeling process intrinsically made assumptions on the potential savings that looked to quantify the overall opportunity rather than capture the uncertainty / variability of savings in each individual building. While it did capture sensitivity to overarching factors such as energy cost, or equipment degradation, building-level variability was not reflected (beyond building-type). As the energy management program is rolled-out, and the opportunity evaluation looks to identify specific building applications, this process will become important to refine expectations and validate project implementation.	– Energy Modeling Appendix
Collect and Prepare Required Data Evaluators should collect data on energy consumption during the SEM baseline and reporting periods for all the energy types the SEM program will evaluate. The evaluator should collect these data from the utility supplier or the program administrator.	Energy consumption data was collected for all facilities as well as the district energy plants at the beginning of the EMP process from the University.	– Energy Modeling Appendix
Collect and Prepare Required Data Evaluators should collect data on the principal drivers of facility energy consumption. In industrial facilities, the principal energy consumption drivers typically will be production outputs and weather. In commercial buildings, the principal drivers most likely will be occupancy and weather. In commercial buildings such as offices, space conditioning usually is the single largest energy end use, accounting for over 40% of total building consumption.	Weather data was collected from publicly available weather files. Other variables affecting energy consumption were collected through site visits of representative facilities and interviews with CU Boulder personnel.	– Energy Modeling Appendix
Collect and Prepare Required Data Collect data: Company Background.	Data was collected on CU Boulder's background and historical energy consumption. The University's growth plans and factors affecting energy consumption (for example, focus	– Energy Modeling Appendix

NREL SEM Component	Alignment with EMP	Reference
	on research activities) were discussed throughout the EMP process and included in the analysis.	
<u>Collect and Prepare Required Data</u> Collect data: Facility background, including location, building type, outputs for industrial sites, occupants for commercial buildings, and any changes in facility operations.	Facility data, including location, building type, floor area, and others was provided by CU Boulder.	– N/A
<u>Collect and Prepare Required Data</u> Collect data: Descriptions of key drivers of energy consumption.	Growth in campus occupied floor area and the types of facilities to be added were the two most significant factors affecting energy consumption. Both were included in the EMP analysis.	– EMP Document: Implementation Roadmap Section – Status Quo Vision for the Future Subsection
<u>Collect and Prepare Required Data</u> Collect data: Results of any facility energy efficiency opportunity assessments or audits.	Previous facility energy efficiency opportunity assessments and audits were provided by CU Boulder and included in the EMP analysis.	– Energy Modeling Appendix
<u>Collect and Prepare Required Data</u> Collect data: SEM program implementation start and end dates, and the expected energy savings.	The expected energy savings were calculated as part of the EMP analysis and provided to CU Boulder. The program implementation start and end dates are to be decided by CU Boulder, but the program is expected to start in FY2022.	– Energy Modeling Appendix
<u>Collect and Prepare Required Data</u> Collect data: Description of SEM facility boundaries, program design, objectives, and milestones.	Objectives and milestones have been described in the EMP goals.	– Goals Appendix – Introductions to the Energy Conservation and Efficiency, Greenhouse Gas Emissions Reduction, Energy Resilience, and Regional and Industry Leadership Sections for goals and metrics to be tracked
<u>Collect and Prepare Required Data</u> Collect data: Description of the facility-level SEM framework, including implementation details of relevant SEM elements (e.g., energy policy, type and scope of trainings, and process for measuring energy performance improvement).	The relevant SEM elements mentioned have been included and described as strategies in the EMP, including timeframes and responsible parties for implementation.	– EMP Document: Energy Conservation and Efficiency Section Strategies
<u>Collect and Prepare Required Data</u> Collect data: Descriptions of SEM energy efficiency measures and activities.	Energy efficiency opportunities, measures, and activities have been described as strategies in the EMP.	– EMP Document: Energy Conservation and Efficiency Section Strategies
<u>Collect and Prepare Required Data</u> Collect data: Descriptions of other energy efficiency capital and retrofit projects, including detailed measurement and	Description of other energy efficiency capital and retrofit efforts, such as addressing deferred maintenance, have been included in the EMP. M&V documentation is to be collected and maintained by CU Boulder.	– EMP Document: Background Section – Integration with Campus Initiatives Section

NREL SEM Component	Alignment with EMP	Reference
verification (M&V) documentation implemented during the baseline or reporting period.		– EMP Document: Energy Conservation and Efficiency Section – Deferred Maintenance Strategy – EMP Document: Energy Conservation and Efficiency Section – Energy Management Program Reporting Strategy
<u>Collect and Prepare Required Data</u> Collect data: Descriptions of any changes in facility or building operations and maintenance, unrelated to the SEM program during the baseline and reporting periods.	Growth in campus occupied floor area and the types of facilities to be added were the two most significant factors affecting energy consumption. Both were included in the EMP analysis.	– EMP Document: Implementation Roadmap Section – Status Quo Vision for the Future Subsection
<u>Collect and Prepare Required Data</u> Collect data: Descriptions of SEM and capital project energy savings estimations, and assumptions used in those estimations.	Energy savings estimations and assumptions used in those calculations have been provided as supporting documentation to the EMP.	– Energy Modeling Appendix
<u>Collect and Prepare Required Data</u> After reviewing SEM documentation, the evaluator may have outstanding questions about the facility's operations, energy consumption, or SEM activities. For example, the evaluator may be unclear about the implementation date of a particular SEM activity or a change in facility operations.	Multiple focus sessions were conducted with several campus stakeholders to discuss the goals of the EMP and address any outstanding questions that could help the EMP analysis.	– Goals Appendix
<u>Define Baseline and Reporting Periods</u> The baseline period should be sufficiently long to cover the range of operating conditions that the facility experienced prior to SEM implementation and to provide enough data to precisely estimate the coefficients of the energy consumption regression. This protocol recommends collection of a full year of baseline data. A full year is usually sufficient to capture any changes in energy consumption related to weather, seasonal market demand for facility output, and facility closures and schedules.	The baseline period is the Fiscal Year 2020. A full year of energy consumption data was used. There are several reporting periods which are aligned with the university's goals, i.e., 2025, 2030, 2035, 2050. However, it was a recommendation in the EMP that the M&V program be developed annually by CU Boulder track performance.	– Energy Modeling Appendix – introductions to the Energy Conservation and Efficiency, Greenhouse Gas Emissions Reduction, Energy Resilience, and Regional and Industry Leadership Sections for goals and metrics to be tracked
<u>Define Baseline and Reporting Periods</u> An important issue for programs running for longer than one year concerns the validity of the original baseline. This protocol recommends that evaluators maintain the original facility baseline as long as the baseline remains valid. Specifically, evaluators should continue to use the original	Fiscal Year 2020 will remain the baseline and is what was used in the EMP analysis and roadmap development.	– Energy Modeling Appendix

NREL SEM Component	Alignment with EMP	Reference
baseline if the baseline and reporting periods have similar operating conditions, not counting SEM program effects.		
Specify Energy Consumption Regression Model The model-dependent variable either will be facility energy consumption per unit of time (e.g., day, week, month) or facility energy consumption intensity per unit of time. In industrial facilities, energy consumption intensity is usually defined in relation to output, whereas energy consumption intensity in large commercial buildings is usually defined in relation to floor area.	Both energy consumption per year and energy use intensity in a given year are key metrics in the EMP analysis and are recommended for continuous tracking as part of the strategies outlined in the EMP.	– Introductions to the Energy Conservation and Efficiency, Greenhouse Gas Emissions Reduction for goals and metrics to be tracked – Energy Goals Appendix
Specify Energy Consumption Regression Model The energy consumption regression model specification should be determined on the basis of engineering knowledge about the facility's energy consumption and statistical diagnostics and testing.	Energy consumption models were created using energy simulation software which is industry-accepted, and the models were calibrated to align with each facility type's operational profile and energy consumption.	– Energy Modeling Appendix
Specify Energy Consumption Regression Model Specifying the model also requires making assumptions about the properties of the error term. The error term represents influence of unobserved factors on a facility's energy consumption. These assumptions help determine the approach for estimating the model.	It was assumed that a difference of up to 10% in either direction between the model and the historical energy data would be acceptable.	– N/A
Fitting the Model After estimating the energy consumption model, the evaluator should assess the model's fit and conduct tests of key model assumptions. When beginning testing, the evaluator should first plot the model residuals, looking for anomalous patterns suggesting omitted variables, auto-correlated errors, or heteroscedastic errors. The evaluator should also inspect the model coefficient of determination (R2), the regression F statistic, and the signs and statistical significance of the coefficients. The model R2 indicates the amount of variation in the dependent variable explained by the model-independent variables.	Models were calibrated against historical consumption data and the final modeled consumption output was within 1% and 5% of the historical electricity and natural gas consumption respectively.	– Energy Modeling Appendix
Estimating and Documenting Savings The evaluator should use the estimated regression to estimate the adjusted baseline and then to estimate savings as the difference between the adjusted baseline and metered energy consumption.	The model developed as part of the EMP was used to estimate future energy consumption in a 'business as usual' scenario, i.e., a scenario where the University's planned growth occurred and an energy management program was not implemented. Savings were estimated and discussed against this future projection when setting goals, but it was	– Energy Modeling Appendix – EMP Document: Implementation Roadmap

NREL SEM Component	Alignment with EMP	Reference
	decided by CU Boulder stakeholders that the final energy conservation goals should be measured against the FY20 baseline. Projected savings and performance against the goals were documented in the EMP.	
Estimating and Documenting Savings This protocol focuses on estimating overall energy savings from SEM activities, whether from OM&B measures or from capital and retrofit projects. However, as implementation of OM&B measures is an integral component and defining feature of SEM programs, program administrators and regulators may ask for a separate estimate of OM&B savings. Also, other utility programs may claim savings from capital projects, requiring evaluators to obtain a separate estimate of the remaining OM&B savings.	Savings from deferred maintenance activities were included in the EMP.	– Energy Modeling Appendix
Reporting Savings Evaluators should report point estimates of SEM program savings for the reporting period and standard errors or confidence intervals to indicate the program savings uncertainty. Depending on the evaluation objectives and research design, evaluators may also want to report savings estimates for individual facilities. Savings should be reported in units of energy and in a percentage of the adjusted baseline.	The EMP reports energy consumption and energy use intensity savings as a percentage compared to the baseline for all the goal years.	– Introductions to the Energy Conservation and Efficiency, Greenhouse Gas Emissions Reduction for goals and metrics to be tracked – Energy Goals Appendix
Selecting a Measurement and Verification Method This protocol recommends statistical analysis of facility energy consumption for estimating SEM program savings. This section presents five regression-based methods for estimating SEM savings: - Forecast models - Pre-post models - Normal operating conditions models - Backcast models - Panel models.	CU Boulder will select a measurement and verification method for its future estimations of actual energy savings.	– EMP Document: Energy Conservation and Efficiency Section – Energy Monitoring and Energy Management Program Reporting Strategy

Table 3: ISO 50001 Alignment with CU Boulder EMP

ISO 50001 Requirement	Alignment with EMP	Reference
Context of the Organization Identify and record internal/external issues that may be an obstacle for certification	Information collected through multiple workshops and dedicated focus sessions with various stakeholder groups to assess barriers for implementation of a strategic energy management program. Key issues include: - Validity of existing goals: goals were reviewed as part of EMP process to ensure they were valid and ambitious yet achievable - Organizational structure: people and groups within the organization responsible for implementing energy management projects - Funding: budgetary constraints created by the COVID-19 pandemic and other campus needs, such as deferred maintenance	– Identified as part of EMP development process
Context of the Organization Identify People and Legal Requirements affecting the EnMS, including interested parties and their needs and expectations as well as Legal Requirements related to energy	Stakeholder groups were identified early in the process and include: - Utility and Energy Services - Budget & Fiscal Planning - Real Estate Services - Athletics - Academics and Research - Housing Facilities Services - Environmental Center - Sustainability - Planning, Design and Construction - Students	– EMP Document: CU Boulder's Energy Planning Process Section – Stakeholder Engagement Subsection
Context of the Organization Implement a process to periodically evaluate compliance with People and Legal Requirements identified	One of the strategies recommended in the EMP is a periodic (every 5 years) revision of the document	– EMP Document: Regional and Industry Leadership Section - Periodic Energy Master Plan Validation Strategy
Context of the Organization Identify the scope and boundaries of the EnMS based on strategic issues and Requirements	The following scope and boundaries were identified throughout the process: - Include the entire campus - Consider the different stakeholders and their needs/financing mechanisms and opportunities	– EMP Document: CU Boulder's Energy Planning Process Section – Stakeholder Engagement Subsection – EMP Document: Existing Energy Usage and Infrastructure Section
Leadership Identify top management ('leadership') team to make decisions on the EnMS, including Top Management and Energy Representatives	An Energy Action Group was defined as part of the EMP process. This group will report to a Sustainability Council which include executive leadership representation.	– EMP Document: Stakeholder Engagement Section – Energy Action Group and Energy Services Organization Subsections
Leadership Management Commitment: Identify business drivers and benefits applicable to the organization, management roles and	All these elements are identified in the EMP document	– EMP Document: Background Section

ISO 50001 Requirement	Alignment with EMP	Reference
responsibilities, and develop a document establishing the commitment to energy performance		
Leadership Energy Policy: Develop an energy policy statement that is approved by top management and communicated across the organization	The EMP outlines the goals, metrics, and timeframes the University will strive to achieve as part of its energy management program. In addition, a strategy recommending the development of a comprehensive energy policy for the University that guides how the buildings are designed and operated was included in the EMP.	– EMP Document: Goals and objectives outlined throughout. – Goals Appendix – EMP Document: Energy Conservation and Efficiency Section – Campus Energy Policy Strategy
Leadership Energy Team and Resources: Form an energy team with authority to oversee the EnMS and outline roles and responsibilities	An Energy Services Organization was defined as part of the EMP. This group will has specific roles and responsibilities designed to help push the University's energy management efforts forward	– EMP Document: Stakeholder Engagement Section – Energy Action Group and Energy Services Organization Subsections
Planning Risks to EnMS Success: Identify strategic risks to the intended outcomes of EnMS and plan and implement actions to address them	Risks to the achievement of EMP goals were described throughout the development process and evaluated quantitatively in the form of a sensitivity analysis. Risks included: cost of measures, cost of energy commodities, availability of funding variability in grid GHG emissions factors, and others	– Energy Modeling Appendix
Planning Energy Data Collection and Analysis: Identify energy sources and energy uses, have a data collection plan in place, and collect related energy and relevant variable data.	Data on energy consumption, building operations, energy sources, etc. was collected to inform the EMP. Energy data was primarily sourced through EnergyCAP and utility bills from district energy plants. The EMP has recommended the development of an updated data collection plan and system to effectively meet the goals of the proposed energy management program	– EMP Document: Energy Monitoring Strategy
Planning Significant Energy Uses (SEUs): Identify the most significant energy uses, monitor their relevant variables and energy performance, and develop and implement a process to review and update SEU data	Information on significant energy uses was collected through site visits, personnel interviews, and review of available energy use data.	– Energy Modeling Appendix – Benchmarking Appendix
Improvement Opportunities: Identify and prioritize energy performance improvement opportunities and have processes in place to update them	Improvement opportunities in terms of energy conservation, improved performance for future buildings, on-site renewable generation, decarbonization of the heating system, and others were evaluated as part of the EMP. It is recommended as part of the EMP that these analyses as well as the EMP itself be updated regularly	– Energy Modeling Appendix – Opportunities and strategies are included and described throughout the EMP Document
Planning Energy Performance Indicators and Energy Baselines: Identify energy performance indicators and energy baselines to measure and monitor our energy performance and demonstrate energy performance improvement	Energy performance indicators such as total annual energy consumption and energy use intensity were identified as key performance indicators for energy use at the University and used throughout the EMP	– Goals Appendix – EMP Document: Energy Conservation and Efficiency, Greenhouse Gas Emissions Reduction, Energy Resilience, Regional and Industry Leadership Sections

ISO 50001 Requirement	Alignment with EMP	Reference
Planning Objectives and Targets: Establish energy objectives and targets and obtain top management's approval. Communicate these to the organization	Objectives and targets were identified and validated by CU Boulder stakeholders. The goals and metrics used to track performance were approved by campus leadership	– - Goals Appendix
Planning Action Plans for Continual Improvement: Select projects for implementation identified as 'Improvement Opportunities' and develop plans for implementation	The EMP outlines several strategies for continual improvement of energy performance on campus	– Opportunities and strategies are included and described throughout the EMP Document – EMP Document: Energy Conservation and Efficiency, Greenhouse Gas Emissions Reduction, Energy Resilience, Regional and Industry Leadership Sections – Implementation Roadmap Subsections – EMP Document: Implementation Roadmap Section
Support Competence and Training: Provide training to personnel whose work affects the organization's energy performance and energy management system.	Providing training to personnel has been included as a strategy in the EMP	– EMP Document: Energy Conservation and Efficiency Section – Staff Development Strategy
Support Awareness and Communication: Ensure personnel and on-site contractors are aware of the organization's energy policy and their energy-related roles and responsibilities	Engagement and communication with campus stakeholders has been included as a strategy in the EMP and an Engagement and Communication plan has been developed	– EMP Document: Energy Conservation and Efficiency Section – Engagement and Education – EMP Document: Stakeholder Engagement Section – Engagement and Communication Plan
Support Documenting the EnMS: Ensure the EnMS includes the documented information suggested by the ISO 50001 guidance as well as other information that ensures EnMS effectiveness and demonstrates energy performance improvement	The EMP recommended a strategy to update the energy management system used by CU Boulder to track its energy performance. CU Boulder will have to select the future energy management system and ensure that it includes all appropriate documentation	– EMP Document: Energy Conservation and Efficiency Section – Energy Monitoring and Energy Management Program Reporting Strategies
Operation Operational Controls: Plan and control the processes related to the SEUs and set operations and maintenance criteria where there are risks of significant deviations in energy performance	CU Boulder has strategies in place to identify and manage SEUs. However, the EMP includes recommendations for energy data management and tracking to help the University enhance its data collection processes and quickly identify deviances in SEU performance	– EMP Document: Energy Conservation and Efficiency Section – Energy Monitoring, Energy Management Program Reporting, and Campus Building Operation Standards Strategies

ISO 50001 Requirement	Alignment with EMP	Reference
Operation Energy Considerations in Design: Identify the sites, equipment, systems, and processes that can have significant impact on energy performance and incorporate energy performance considerations in specification, design, and procurement opportunities where applicable	These types of sites, equipment, systems, and processes have been identified and improvements have been recommended in the form of strategies within the EMP	– EMP Document: Energy Conservation and Efficiency Section – Energy Performance Design Targets, Performance-Focused Design Process, and Space Optimization Strategies
Operation Energy Considerations in Procurement: Evaluate the organization's procurement processes for items that can significantly impact performance. For purchases related to SEUs identify and communicate energy performance-related requirements. Develop life cycle criteria for specific types of procurement activities	CU Boulder has strategies in place to ensure procurement of energy-efficient technology wherever there's a potential impact to energy consumption	– N/A
Performance Evaluation Monitoring and Measurement of the EnMS: Determine what data or information is needed to establish trends in EnMS performance, including trends on non-conformities, corrective actions, internal and external audits, and evaluations of compliance.	The key metrics to evaluate performance against CU Boulder's goals have been included in the EMP. Establishing the actions related to non-conformance, corrective actions, frequency and type of internal and external audits, and evaluations of compliance would be part of CU Boulder's responsibility	– Introductions to the Energy Conservation and Efficiency, Greenhouse Gas Emissions Reduction, Energy Resilience, and Regional and Industry Leadership Sections for goals and metrics to be tracked – EMP Document: Energy Conservation and Efficiency Section – Energy Monitoring and Energy Management Program Reporting Strategies
Performance Evaluation Monitoring and Measurement of Energy Performance Improvement: Monitor and measure key characteristics of processes that affect energy performance. Identify the methods used, the frequency of measurement, and the process for analyzing results.	The EMP recommended a strategy to update the energy management system used by CU Boulder to track its energy performance. CU Boulder will have to select the future energy management system and establish its own methods, frequency of measurement, and processes	– EMP Document: Energy Conservation and Efficiency Section – Energy Monitoring and Energy Management Program Reporting Strategies
Performance Evaluation Internal Audit: Conduct internal audits of the EnMS at specified intervals and report the results to relevant management	An Energy Services Organization and Energy Action Group was developed as part of the EMP. These groups will be responsible for reporting on the progress of the energy management program to CU Boulder leadership. It is recommended the reporting be conducted on, at a minimum, an annual basis	– EMP Document: Stakeholder Engagement Section – Energy Action Group and Energy Services Organization Subsections
Performance Evaluation Management Review: Top management periodically reviews the EnMS and the organization's energy performance to ensure its continuing suitability, adequacy, and effectiveness	An Energy Services Organization and Energy Action Group was developed as part of the EMP. These groups will be responsible for reporting on the progress of the energy management program to CU Boulder leadership. It is recommended the reporting be conducted on, at a minimum, an annual basis	– EMP Document: Stakeholder Engagement Section – Energy Action Group and Energy Services Organization Subsections

ISO 50001 Requirement	Alignment with EMP	Reference
<u>Improvement</u> Corrective Actions: Identify nonconformities and other problems in the EnMS and take appropriate corrective action	Through the establishment of an Energy Services Organization and an Energy Action Group that will be responsible for the implementation of CU Boulder's energy management program, the University will be able to periodically assess its performance against the established goals and take the appropriate corrective actions	– EMP Document: Stakeholder Engagement Section – Energy Action Group and Energy Services Organization Subsections
<u>Improvement</u> Continual Improvement: Ensure that processes are in place for reviewing and updating specific parts of the EnMS on a regular basis to improve the suitability, adequacy, and effectiveness of the system.	The Energy Services Organization developed as part of the EMP in collaboration with the University's Sustainability department will be responsible for ensuring the energy management program is on track and for continuously identifying and implementing improvement opportunities	– EMP Document: Stakeholder Engagement Section – Energy Action Group and Energy Services Organization Subsections

Appendix C: Energy Modeling and Strategy Evaluation Process

Table of Contents

This appendix outlines the process and assumptions used in creating an energy demand model for CU Boulder, quantifying the savings potential from energy strategies, and the use of the Rosetta methodology to develop a feasible roadmap for implementing energy strategies at the University.

1. Energy Demand Assessment

The first step in the development of the Energy Master Plan (EMP) was to understand how CU Boulder uses energy. An energy model of the campus was developed to provide an in-depth understanding of energy demand and provide a strong evidence base for the energy conservation, district energy, renewable energy, and other energy management recommendations included in the EMP.

1.1 Energy Modeling Methodology

The basis of the campus-wide energy model developed for the EMP was building-level energy models scaled to the entire campus. CU Boulder is comprised of nearly 400 facilities ranging in size and use types. These facilities were consolidated into nine common facility types that were modeled to provide a representation of energy use on campus. The nine types of facilities modeled included: Dining, Healthcare, Housing, Learning, Library, Office, Other, Recreation, and Research. These facility types were selected to align with the American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE) Standard 100 – Energy Efficiency in Existing Buildings, which is used by the energy team on campus to classify facilities and benchmark their performance. Each facility was assigned one of these categories using data provided by the University. Energy models for each of these facility types was undertaken using IES<VE> software which allows detailed modeling of energy end-use demands and provides results calculated on an hourly basis. Data collected from existing reports and on-site walk-throughs, including limited construction and operational information, was input into the model and the annual energy performance was simulated using local typical meteorological year weather data.

1.2 Calibration

To obtain the most accurate representation of energy use on campus, the energy models developed were calibrated to align with the monthly and annual electricity and natural gas consumption data provided by the University or otherwise obtained from the University's energy billing system, EnergyCAP. For buildings on Main Campus the heating and cooling demands were calibrated using steam and chilled water supply trend data for the campus' West District Energy Plant (WDEP) and East District Energy Plant (EDEP).

The first step in the calibration process was to compare the modeled profiles with the measured data. The measured data provided was sufficiently granular to determine the total electricity, natural gas, steam, and chilled water demand by building type which helped identify focus areas for calibration. The initial modeled results showed approximately 30 percent less steam and chilled water demand for the Main Campus than the measured data, and there were variances in the electricity and natural gas consumption values for each building type. The measured steam and chilled water demands for the Main Campus showed higher baseload demands year-round than what was predicted by the models, which indicated that buildings on campus typically operate with higher internal loads and for longer periods than expected. Building types like Learning, Office, and Research were found to have the largest differences between the modeled and measured data so they were the initial focus of the calibration.

The first end-uses to be modified through extended operating schedules and increased loads were the Lighting and Plug Loads since these tend to have the highest variability. Gas equipment loads were added to the Research building type to account for natural gas loads, and gas demands were increased for the Dining building type to better align with measured data. Once these end-uses had been modified and the modeled electricity and natural gas consumption at the building-level was corrected, the heating and cooling demands were calibrated to the measured data for the Main Campus. The calibrated models were applied parametrically to the square footage of each of the building types across campus, and the resulting modeled energy consumption was compared with the Fiscal Year (FY) 2020 which was being used as a baseline. The modeled total natural gas and electricity consumptions were within 1 percent and 5 percent respectively when compared to the measured FY20 baseline.

The results of the calibrated energy modeling are shown in Figure 1 and Figure 2. The primary energy end use on campus is heating, and the receptacle loads from research and educational equipment are also relatively large.

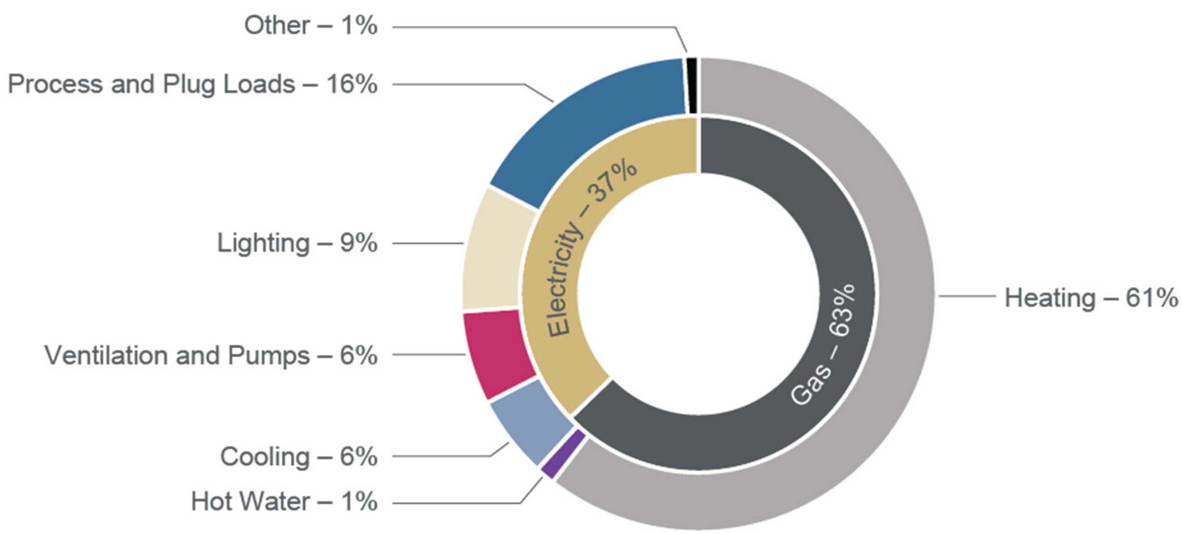


Figure 1: Energy Demand at CU Boulder by End-Use

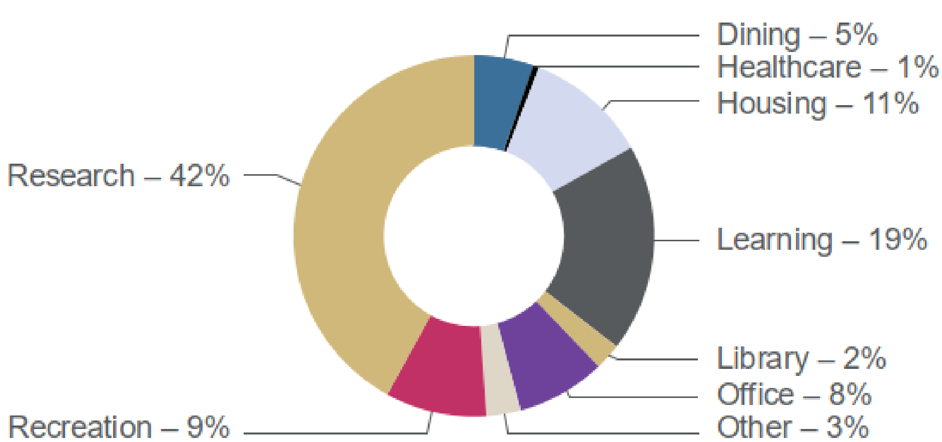


Figure 2: Energy Use by Facility Type

The cost and peak electricity demand for the Main Campus were also checked against measured data to confirm the validity of the calibration. Figure 3 shows the comparison between the modeled and measured electricity peak demand and cost for the Main Campus. The measured demand peaked at 21 MW in September, whereas the modeled demand peaked in July at 20.4 MW. However, the overall modeled cost of electricity is within 5 percent of the measured cost. These results showed that the models were sufficiently calibrated for the purposes of analyzing energy strategies.

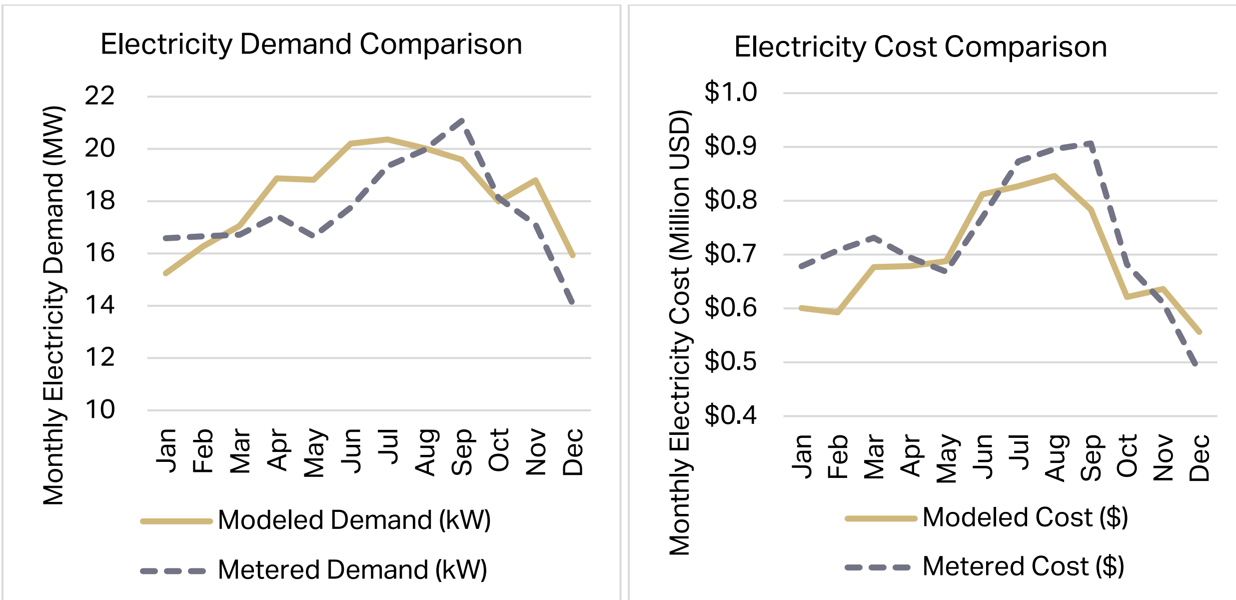


Figure 3: Comparison of Measured and Modeled Electricity Demand and Cost for the Main Campus

1.3 Modeling Future Energy Use

A key driving factor of CU Boulder's energy consumption is the amount of occupied square footage and the types of facilities being used. The Strategic Facilities Visioning effort and the Campus Master Plan project a net growth of nearly 3 million assignable square feet (ASF) over the next thirty years. At an estimated ratio of 1.54 gross square feet (GSF) to ASF, this represents a net addition of 4.2 million GSF to the campus, with slightly over 40 percent of that corresponding to Research facilities.

To model future energy demand for the campus, the calibrated models representing the existing facilities were updated to match the construction and energy code that was most likely to be applicable in the near term, the 2018 International Energy Conservation Code (IECC). Key elements of the models were updated, including envelope performance parameters and components of the modeled Heating, Ventilation, and Air Conditioning (HVAC) systems. Although it is likely that future energy codes will become more stringent and require better performance than what is mandated by the 2018 IECC, no further energy savings were assumed from what was modeled to provide conservative estimates. The future energy models also take into consideration that the operation of future facilities is likely to resemble the typical operations of those facility types more closely and not the extended operations of existing buildings on campus. Table 1 shows a comparison of modeled energy end-use demands for existing and future buildings. Note that these are energy demands or loads, not actual fuel consumption.

Table 1: Comparison of Modeled Energy Demand Intensity (kBtu/SF) by End Use for Existing and Future Buildings[1]

Building Type	Model Type	Interior Lighting	Receptacle Equipment	Space Heating	Service Water Heating	Space Cooling	Heat Rejection	Interior Fans	Exhaust Fans	Pumps	Gas Equipment
Dining	Existing Building	21	14.7	41	6.2	11.3	6.9	2.8	-	0.3	8.3
	Future Building	9.7	14.7	20.5	6.2	11.3	6.9	2.8	-	0.3	8.3
Healthcare	Existing Building	11.2	12.5	67.4	-	37.4	-	2.8	-	0.3	-
	Future Building	11.2	12.5	46.6	-	37.4	-	2.8	-	0.3	-
Housing[2]	Existing Building	5.2	11.9	51	7.2	10	-	1.2	-	0.1	0.6
	Future Building	5.2	11.9	19.4	7.2	10	-	1.2	-	0.1	0.6
Learning	Existing Building	16.9	14.2	72.2	-	34.4	0.3	3	-	0.2	0.2
	Future Building	13.7	14.2	21.5	-	34.4	0.3	3	-	0.2	0.2
Library	Existing Building	17.8	6.8	40	-	34.1	-	2.5	-	0.3	-
	Future Building	11.7	6.8	17	-	34.1	-	2.5	-	0.3	-
Other[3]	Existing Building	10	2	779	-	814.7	0.5	0.3	-	0.2	-
	Future Building	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Office	Existing Building	12.7	16.3	60.7	-	28.1	0.2	2.3	-	0.3	10.8
	Future Building	9	16.3	12.9	-	28.1	0.2	2.3	-	0.3	-
Recreation	Existing Building	8.8	3.8	48.3	-	5.3	-	2.5	-	0.3	1.2
	Future Building	5.5	3.8	29	-	5.3	-	2.5	-	0.3	1.2
Research	Existing Building	10.2	32.5	113.4	-	51.1	-	9.5	5.3	5.6	0.2
	Future Building	10.2	32.5	39.7	-	51.1	-	9.5	5.3	5.6	0.2

[1] The values shown for existing buildings are the modeled end use demands after calibration. They are intended to be a representative values for a given building typology and may vary between individual buildings

[2] Existing Housing buildings do not typically have cooling, but the energy demand showed accounts for those that do. Future Housing buildings are expected to have cooling

[3] The Other building typology includes buildings such as storage buildings, steam conversion sheds, grounds buildings, the district energy plants, and others. End-use intensities may appear high due to the small footprint occupied by these buildings. No growth is expected in this building category

1.4 Factors Impacting Future Energy Use

In addition to area growth, two other factors were understood to have a potential impact on future energy demand: climate change, and equipment degradation.

1.4.1 Climate Change

The future projections for energy use must take into consideration the rapidly increasing impact of climate change on the local environment. Modeling of climate change in Boulder suggests that, by 2050, annual cooling energy use is likely to increase by 10 percent while heating energy use will decrease by 8 percent. This overall change in energy consumption was translated in an annual percentage increase and included in the future energy modeling

1.4.2 Equipment Degradation

As with most equipment, building and energy systems experience reductions in performance efficiency throughout their lifespan. This performance degradation reveals itself as an increase in energy consumption for that system or building. This can be exacerbated without effective equipment monitoring, assessment, or ongoing commissioning. A degradation of 0.5 percent annual increase was included in the campus energy growth. It was assumed that implementing an effective deferred maintenance program could offset the effects of degradation.

1.5 Assumptions and Factors Impacting Energy Use

Key assumptions used in the energy modeling and calibration process include:

- Buildings were assigned a single building type for modeling purposes aligned with the types assigned by the energy team in their energy performance tracking documents. In practice buildings may be composed of two or more types.
- Data provided by the University was used to calculate average efficiencies for the steam and chilled water district energy systems on Main Campus. These efficiencies were used in calculating the fuel required to provide heating and cooling to plant-tied buildings on main campus. The following efficiencies were used:
    - The steam system overall efficiency was estimated at 86 percent
    - The chilled water system overall coefficient of performance was estimated at 4
- In 2019 and parts of 2020 the campus energy team noticed discrepancies between the amount of gas consumption measured at the district plants and the amount of gas actually transported to campus by Xcel Energy, with the latter being smaller. At the guidance of the University the EMP analysis used the steam demand from 2018 as the basis for model calibration since the data from that year was more accurate.

Several factors were identified as having the potential to impact future energy use and were included in the future energy demand projections.

2. Leveraging Rosetta

Rosetta™ is a methodology – a combination of a web-based analytics platform, workshops, gameboarding, and the ideas of many experienced professionals, both at the client and AECOM levels – that results in a consensus-built roadmap to achieve energy performance goals. The Rosetta web-based analytics platform uses parametric (industry benchmarks and simulated); audited (from inspection of the site); and real utility data to model future scenarios.

2.1 Creating a Digital Twin

The Rosetta analytics platform leverages the concept of a digital twin, which allows a large and complex campus like CU Boulder to be represented through energy models on the Rosetta platform. To create a digital twin for the CU Boulder campus, the energy models developed as part of the energy demand assessment were replicated in Rosetta. These models were then applied and scaled to the building types located in different areas or 'districts' of the campus (e.g., Main Campus, East Campus). For buildings located on main campus, a virtual district energy plant was created to represent the WDEP and EDEP serving that area of the campus. The future energy demand was also accounted for by adding the planned growth for each facility type and using the future building energy models to assess the demand. Additional project parameters such as project location, utility rate structures, and electrical grid emissions factors were also introduced.

Once all the buildings had been created, a process of calibration was conducted for existing buildings to ensure alignment with measured energy consumption. Figure 4 is a chart from Rosetta showing the resulting hourly energy demand of the existing campus by end use. By applying equipment efficiencies Rosetta also generated an hourly demand for electricity and natural gas as shown in Figure 5.

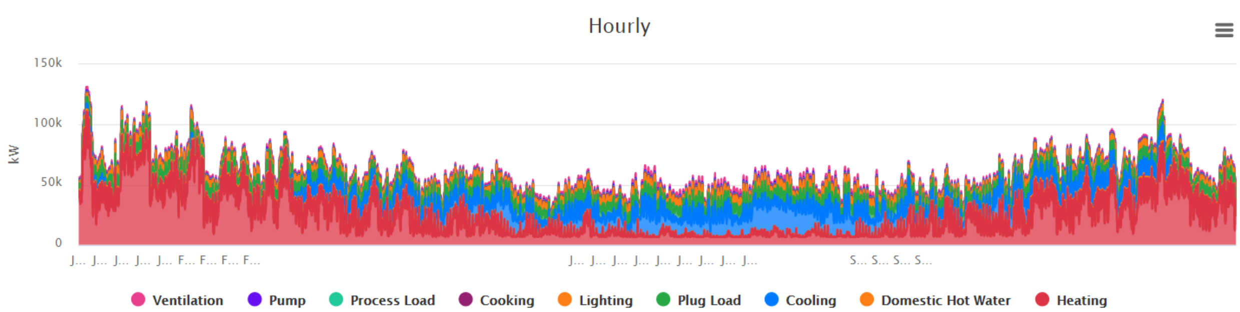


Figure 4: CU Boulder Hourly Energy Demand Output from Rosetta

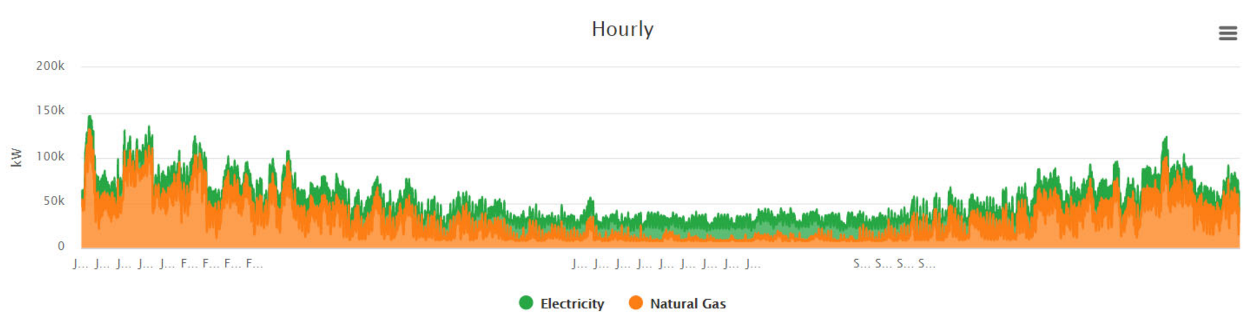


Figure 5: CU Boulder Hourly Fuel Demand Output from Rosetta

Rosetta also provides other useful outputs and visualizations that were used to identify potential areas of focus for energy performance improvements. As shown in Figure 6 through a ranking of the top energy users on campus, 41 percent of the University's gross floor area uses nearly 60 percent of the total energy. This includes research buildings on both the Main and East Campus, as well as Learning facilities on the Main Campus.

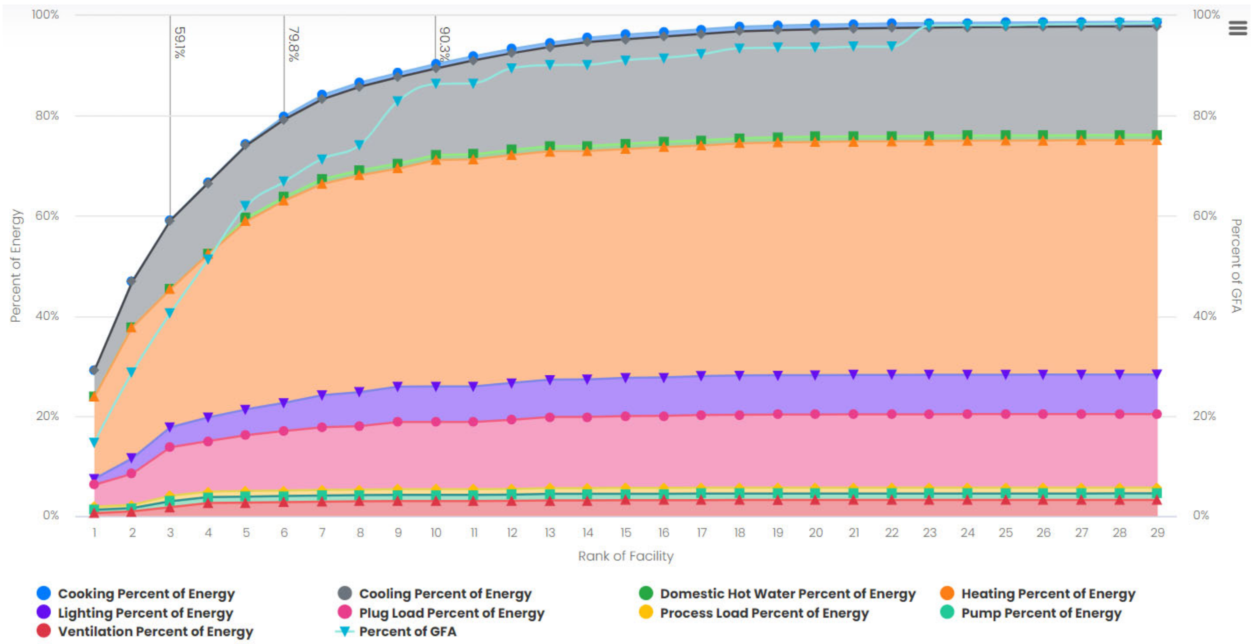


Figure 6: CU Boulder Top Ranked Energy Users

3. Measure Evaluation and Integration

The EMP evaluated the techno-economic viability of implementing a variety of measures to help CU Boulder achieve its energy and greenhouse gas emissions goals. Each measure was evaluated based on performance metrics that included energy reduction, emissions reduction, on-site energy generation, capital expenditure, and cost savings.

3.1 Energy Commodity Costs

Electricity and natural gas are provided to CU Boulder by Xcel, the local utility, but managed internally by the Utilities and Energy Services (UES) group. UES is responsible for the design, operation, maintenance, and repair of the campus's energy generation and distribution infrastructure for services like electricity, steam, and chilled water. UES purchases electricity and natural gas from Xcel to provide these services at Xcel's prices (commodity rates), and bills campus customers adjusted rates to account for operation and maintenance costs (all-in rates). It was assumed that labor, maintenance, and other operational costs not related to the energy commodities would not be significantly impacted by energy conservation measures; therefore, cost savings calculations in the EMP were conducted using commodity rates instead of all-in rates. Table 2 shows the commodity rates used in the analysis of EMP strategies.

Table 2: Commodity Rates Used in Analysis

Fuel	FY20 Commodity Rate
Electricity	7.5 cents / kWh
Natural Gas	32.5 cents / therm

3.2 Energy Conservation

CU Boulder has worked with external organizations like Xcel and other consultants to conduct energy audits of some of its facilities and identify energy conservation opportunities. Energy audits conducted at over 25 of the most energy-intensive buildings on campus identified potential projects such as lighting upgrades, retro-commissioning, HVAC upgrades, and operational improvements that could save the campus close to $1.8 million in annual energy costs. Leveraging these energy audits, knowledge of the campus, and facility walk-throughs, AECOM developed a comprehensive list of potential energy conservation measures (ECM) that could be implemented on campus. The energy savings from these measures were extrapolated across the campus to assess the true scale of the energy conservation opportunity.

The first step in the development of the ECM for the campus was the development of an estimate of potential savings by energy end-use demand (e.g., lighting, cooling, heating) for each strategy and building type. Table 3 shows an example of the percentage energy savings by end use for the Commissioning ECM for the Dining facility type.

Table 3: Example Energy Savings by End Use for Dining Facilities – Commissioning ECM

Energy End-Use	Percentage Energy Savings
Cooling	7%
Domestic Hot Water	5%
Heating	7%
Pumps	3%
Ventilation	3%

The percentage energy savings by end use were adjusted by an applicability factor for each building type. The applicability factor is a measure of how applicable a given ECM is for a specific type of building and is measured in terms of percentage of total building area. The applicability factors for each building type were determined based on information collected through past energy audits, facility walkthroughs, and information gathered from stakeholders. Table 4 shows the applicability factors used for each ECM.

Table 4: Applicability Factors by ECM

	Dining	Healthcare	Housing	Learning	Library	Office	Other	Recreation	Research
Building Envelope Upgrades	50%	50%	50%	50%	50%	50%	50%	50%	50%
Commissioning	100%	100%	100%	100%	100%	100%	100%	100%	100%
Energy Recovery	25%	100%	25%	100%	100%	100%	100%	100%	25%
Fume Hood Controls	0%	0%	0%	0%	0%	0%	0%	0%	30%
HVAC Control Upgrades	50%	100%	50%	100%	100%	100%	100%	100%	15%
Lighting Daylight Controls	30%	100%	30%	100%	100%	100%	100%	100%	100%
Lighting Occupancy Sensors	25%	100%	25%	100%	100%	100%	100%	100%	100%
Lighting Upgrades	35%	100%	35%	100%	100%	100%	100%	100%	100%
Piping and Equipment Insulation	50%	100%	50%	100%	100%	100%	100%	100%	25%
Temperature Setbacks	15%	100%	15%	100%	100%	100%	100%	100%	25%
Ventilation Upgrades	20%	100%	20%	100%	100%	100%	100%	100%	15%
Weatherization	50%	100%	50%	100%	100%	100%	100%	100%	100%
Window Upgrades	50%	50%	50%	50%	50%	50%	50%	50%	50%

The energy demands by end use for each facility type were estimated as part of the energy modeling process. The percentage energy savings by end use for each facility type was applied to each of the calculated energy end use demands and adjusted by an applicability factor as well as an interactivity factor. The interactivity factor is used to account for synergies between measures and was calculated for each building and energy end-use type individually. The example below illustrates the calculation of interactivity factors:

- Measure 1 and Measure 2 save 10 percent and 15 percent respectively in lighting energy demand. After the application of Measure 1, only 90 percent of the lighting energy demand remains. Measure 2 will then save 15 percent of the remaining 90 percent of the lighting energy demand, resulting in a total savings of 23.5 percent of the lighting energy demand. If interactivity had not been considered, the implementation of these two measures would save 25 percent of the lighting energy demand. The interactivity factor is then calculated by dividing the actual savings, 23.5 percent, by the theoretical savings, 25 percent, for an interactivity factor of 94 percent. Therefore, the interactivity factor ensures that savings are not overestimated.

Table 5 shows an example of the resulting energy savings for the Commissioning ECM for the Dining facility type.

Table 5: Example Energy Savings for Dining Facilities – Commissioning ECM

Energy End-Use	Percentage Energy Savings	Baseline Electricity Use (kBtu/Year)	Baseline Gas Use (kBtu/Year)	Interactivity Factor	Electricity Savings (kBtu/Year)	Gas Savings (kBtu/Year)
Cooling	7%	1,406,710	NA	86%	85,067	NA
Domestic Hot Water	5%	NA	5,087,749	100%	NA	253,231
Heating	7%	NA	33,425,761	89%	NA	2,077,109
Pumps	3%	225,236	NA	93%	6,298	NA
Ventilation	3%	1,926,625	NA	92%	53,172	NA

A cost per square foot for the implementation of each measure at the different building types was developed using data from CU Boulder energy audits and validated by AECOM's energy project development experts. These costs were applied to the applicable area (as given by the applicability factor) for each ECM to arrive at a total cost per measure. Table 6 shows the cost per square foot for each measure.

Table 6: ECM Cost per Square Foot

	Dining	Healthcare	Housing	Learning	Library	Office	Other	Recreation	Research
Building Envelope Upgrades	$0.7	$1.4	$0.7	$0.7	$0.7	$0.7	$0.7	$0.9	$1.4
Commissioning	$0.1	$0.2	$0.1	$0.1	$0.1	$0.1	$0.1	$0.1	$0.2
Energy Recovery	$1.0	$2.1	$1.0	$1.0	$1.0	$1.0	$1.0	$1.3	$2.1
Fume Hood Controls	$0.5	$1.2	$1.2	$1.2	$1.2	$1.2	$1.2	$1.2	$1.2
HVAC Control Upgrades	$1.0	$2.1	$1.0	$1.0	$1.0	$1.0	$1.0	$1.3	$2.1
Lighting Daylight Controls	$0.8	$1.7	$0.8	$0.8	$0.8	$0.8	$0.8	$1.1	$1.7
Lighting Occupancy Sensors	$0.7	$1.4	$0.7	$0.7	$0.7	$0.7	$0.7	$0.9	$1.4
Lighting Upgrades	$0.4	$0.8	$0.4	$0.4	$0.4	$0.4	$0.4	$0.5	$0.8
Piping and Equipment Insulation	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Temperature Setbacks	$0.2	$0.2	$0.2	$0.2	$0.2	$0.2	$0.2	$0.2	$0.2
Ventilation Upgrades	$1.0	$2.1	$1.0	$1.0	$1.0	$1.0	$1.0	$1.3	$2.1
Weatherization	$0.2	$0.2	$0.2	$0.2	$0.2	$0.2	$0.2	$0.2	$0.2
Window Upgrades	$5.4	$10.7	$5.4	$5.4	$5.4	$5.4	$5.4	$7.0	$10.7

Throughout the development of the EMP, AECOM has worked with CU Boulder to validate that the correct level of savings potential has been captured and that the opportunity is not being overestimated.

Table 7 shows the total savings from the implementation of energy conservation measures across campus. Energy cost savings were calculated using FY 2020 commodity costs for electricity and natural gas.

Table 7: Savings and Costs from Energy Conservation Measures

	Electricity Savings (kBtu)	Gas Savings (kBtu)	Electricity Cost Savings ($)	Gas Cost Savings ($)	Total Cost Savings ($)	Capital Cost ($)	Payback
Building Envelope Upgrades[2]	4,796,501	35,348,692	103,844	114,883	218,727	579,000	26.5
Commissioning	6,396,729	49,742,216	138,489	161,662	300,151	1,660,000	6
Energy Recovery[2]	3,931,638	29,838,657	85,120	96,976	182,096	1,718,000	94
Fume Hood Controls	4,828,515	4,271,422	104,537	13,882	118,419	4,050,000	34
HVAC Control Upgrades[3]	5,684,301	38,464,691	123,065	125,010	248,075	8,590,000	69
Lighting Daylight Controls[1]	23,783,930	(17,837,468)	514,922	(57,972)	456,950	13,730,000	30
Lighting Occupancy Sensors[1]	22,665,647	(17,596,629)	490,711	(57,189)	433,522	11,690,000	27
Lighting Upgrades[1]	33,914,677	(18,078,308)	734,253	(58,754)	675,498	6,470,000	10
Piping and Equipment Insulation	-	4,156,717	-	13,509	13,509	430,000	32
Temperature Setbacks	6,677,850	35,692,728	144,575	116,001	260,577	1,910,000	7
Ventilation Upgrades[2]	2,403,191	16,823,955	52,029	54,678	106,707	1,718,000	161
Weatherization	3,204,640	35,348,692	69,380	114,883	184,264	2,540,000	14
Window Upgrades[2]	5,110,689	35,348,692	110,646	114,883	225,530	4,445,000	197
Total	123,398,307	231,524,054	2,671,573	752,453	3,424,026	144,260,000	42

[1] Lighting measures increase demand for heating by reducing internal space loads
[2] The implementation costs for these measures were reduced by 90% because they are aligned with the deferred maintenance program.

[3] The implementation costs for this measure were reduced by 50% because they are aligned with the deferred maintenance program.

In addition to building-level opportunities, the University will likely have opportunities to improve the performance of the district energy system as the system ages and becomes less efficient.

3.3 District Energy Decarbonization

The two district energy plants that serve CU Boulder's Main Campus consume 48 percent of the University's total energy consumption. Additional buildings are expected to be added onto the plant system as the campus grows, and this will further increase the amount of energy consumed by the plants. Decarbonizing CU Boulder's heating system will be fundamental to meeting the University's existing greenhouse gas emissions reduction goals and eliminating energy-related emissions on campus. A crucial step in heating system decarbonization will be the conversion of the existing steam system into a lower temperature hot water system that can leverage alternate sources of heat. The potential energy savings from a steam to hot water conversion on Main Campus were evaluated—taking into consideration the current length of the system, operating temperatures, and heating source efficiencies— and included in the EMP analysis.

Table 8: Savings from Steam to Hot Water Conversion

Baseline Steam Load (MMBtu/Year)	Baseline Total Gas Consumption (MMBtu/Year)	Baseline Total Gas Cost ($/Year)	Load Savings from Conversion (%)	Hot Water Load (MMBtu/Year)	Gas Consumption Savings (MMBtu/Year)	Gas Cost Savings ($/Year)
630,000	889,500	$2.9 Million	7.7%	559,000	102,000	331,500

3.4 Energy Generation

To identify the optimal blend of alternative energy generation options that offers the greatest potential for simultaneous energy cost reduction, greenhouse gas (GHG emissions reduction, and resilience for the CU Boulder campus, the University conducted studies of the renewable energy and storage potential on its campus that were incorporated into the EMP.

3.4.1 Solar PV

CU Boulder has worked with external parties like Ameresco and NREL to assess the potential for installing additional solar photovoltaic (PV systems on its campus. The Boulder Energy Planning Assessment Using ReOpt conducted by NREL in 2018 found the campus to have capacity for approximately 4.9 megawatts direct current (MW-DC of rooftop PV, 3.2 MW-DC of open ground PV, and 4.2 MW-DC of carport PV. The available rooftop PV capacity was refined in 2019 through a Flat Roof study conducted by Ameresco, which evaluated 372 potential locations for PV and found that only 32 sites were viable. The rooftop PV potential found by the Flat Roof study was approximately 2.8 MW-DC. During the EMP process CU Boulder also identified an additional ~2 MW-DC of PV potential at Research Lab #2 (RL2, which was a planned project that has not yet been implemented.

AECOM validated the PV potential and used typical generation values for the University's existing PV assets to determine the potential annual energy generation from new systems. An industry-accepted cost for installing PV in the Colorado region of $1.5/Watt-DC was applied to the systems to estimate capital expenditure. Annual energy cost savings were estimated using typical electricity commodity costs for the campus.

Table 9: Savings from Solar PV Projects

System	Potential Capacity (MW-DC)	Annual Energy Generation (kWh/Year)	Annual Electricity Cost Savings ($/Year)	Capital Cost ($)
Potential - RL2 Carports and Land Array	1,984	2,420,000	181,500	2,976,000
Potential - Flat Roof	2,825	3,450,000	258,750	4,237,500
Potential - Open Ground	3,220	3,930,000	294,750	4,830,000
Potential - Carport	4,200	5,120,000	384,000	6,300,000

3.4.2 Battery Energy Storage

With decreasing costs, and increasing reliability, peak energy costs, and incentives, battery energy storage (BES viability has greatly increased over the past few years. To assess the potential for the use of BES for demand management at CU Boulder, the existing and modelled future projected electrical demand profiles were evaluated using Rosetta's optimizer and validated using Geli's ESyst optimizer[1].

Hourly electrical interval data was used as the basis of this analysis. Existing measured data was accentuated with the energy models developed to quantify the growth on campus. This was combined with solar generation estimates to identity the following demand scenarios for which BES was assessed:

- Existing (2019) demand profile
- 2030 profile (no additional solar)
- 2030 profile (10 MW solar)
- 2048 profile (10 MW solar)

Figure 7 provides a graphic view of the hourly demand data both in 2019 and in 2030 if 10 MW solar is installed on the campus. The impact of the solar generation is clearly visible as reduced daytime demand. BES is typically more beneficial for demand management when there are sharper 'peaks' in demand, as a greater reduction in max demand can be achieved with a smaller capacity battery.

[1] Geli's ESyst, https://esyst.geli.net/#!/login

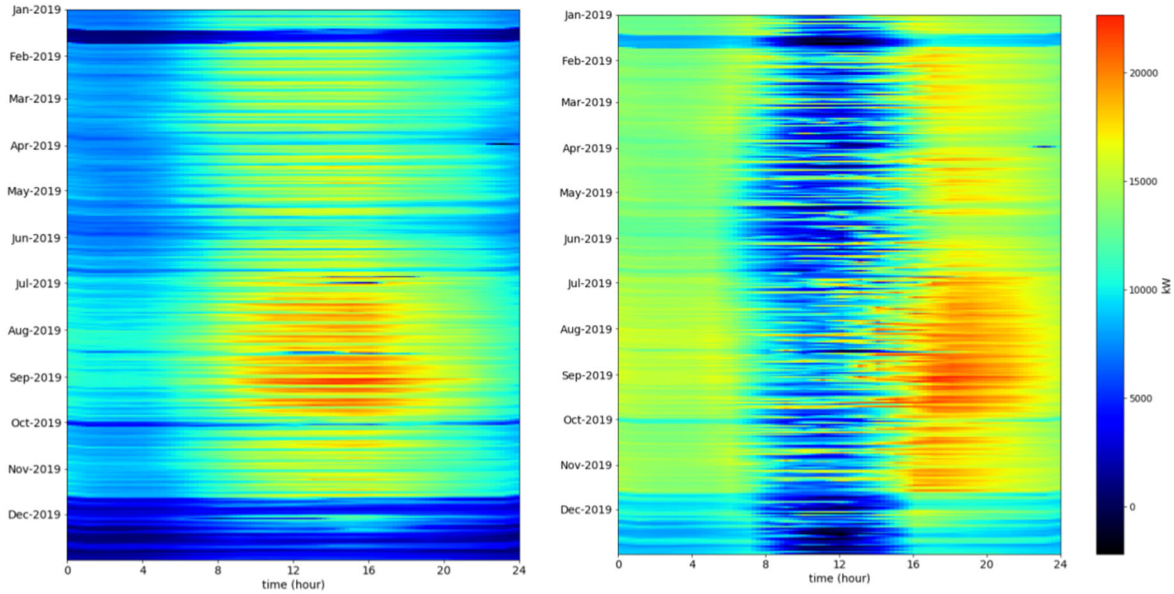


Figure 7: Snapshot from Esyst Displaying the Existing Demand Profile (Left) and a Projected 2030 Profile with 10 MW Solar (Right)

For each of these scenarios, BES sizes were evaluated from 1 MWh to 8 MWh in 1 MWh increments to identify the optimal size for utility savings and return on investment. Figure 8 is a screenshot from Rosetta showing monthly peak-day operation of a 4 MWh battery modeled on projected campus 2030 demand profile with 10 MW of installed solar capacity.

Table 10 summarizes the results of the analysis.

Table 10: Summary of BES Analysis

Configuration	Size with highest NPV	Annual Savings ($)	NPV ($)	IRR (%)	Simple Payback (years)
Existing Main Campus	2,000 kWh	152,000	818,000	11	8.1
+ Future Growth (2030)	2,000 kWh	151,000	811,000	11	8.1
+ Future Growth (2030) + Solar	4,000 kWh	365,000	2,580,000	14	6.8
+ Future Growth (2048)	3,000 kWh	221,000	1,280,000	10	8.3
+ Future Growth (2048) + Solar	5,000 kWh	470,000	3,450,000	15	6.6

The assumptions used in the analysis included:

- Cost of BES: $ 700 / kWh, installed
- Roundtrip efficiency of the BES: 95 percent
- There are no changes to the utility rate schedule that CU Boulder currently uses with one caveat – that there would be no standby charge on installed capacity

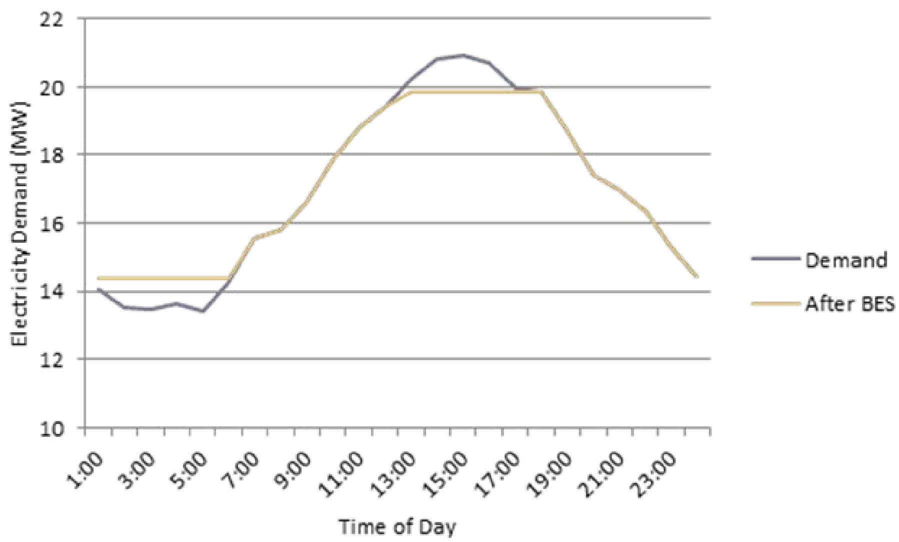


Figure 8: Analysis Showing 2030 Demand Profile Before and After 4 MWh BES on the Annual Peak Day

Figure 9 shows the modeled optimal capacity for demand management for the existing demand profile, in 2030, and in 2050 both with and without onsite solar. The modeled optimal size for the existing profile is 2 MWh both with and without solar, in 2030 that changes to 4 MWh with solar, and in 2050 increases to 5 MWh with solar and 3 MWh without.

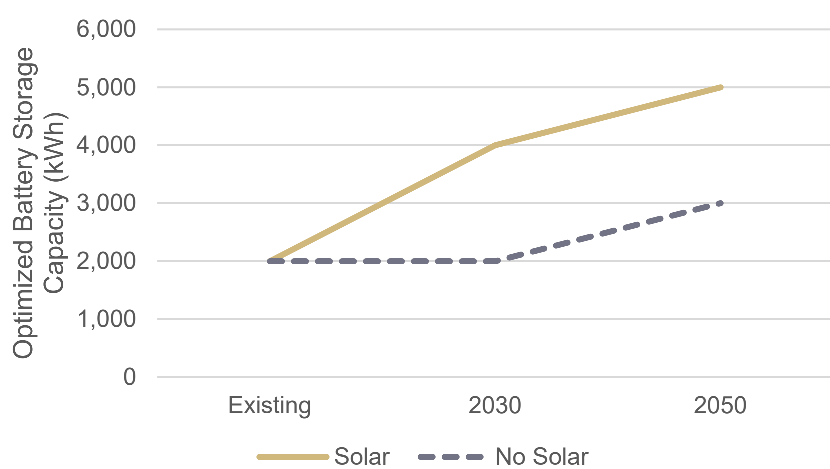


Figure 9: Optimal BES Size for Demand Management in 2030 and 2050

The assessment of BES for demand management at CU Boulder echoed previous analysis on the site and suggested that there is a strong financial case for installation on the campus grid with the current rate structure. However, this business case is eliminated if the campus is subjected to a stand-by charge, relative to the installed BES capacity. The recommended path forward is to investigate, through discussions with Xcel, if a standby charge will be applied, and if not, that steps be taken to further this analysis and progress towards the installation of a BES on the campus.

3.4.3 Combined Heat and Power

CU Boulder owns a combined heat and power (cogen plant tied to the WDEP that has capacity (33 MW which is more than enough to power to peak demand the campus grid. The plant is currently only operated when economically viable —which is a small portion of the year— despite being more efficient from an emissions perspective than purchasing electricity from Xcel. The grid emissions factor is expected to progressively decrease as Xcel makes progress towards reducing emissions on its Colorado electricity grid by 80 percent from 2005 levels by 2030.

An analysis of the cogen emissions factor was undertaken to advise upon when, based on current grid GHG factor projections, that the cogen would start having a negative impact on the University's overall emissions. The GHG factor (MTCO2e/MMBtu for the generated electricity was calculated assuming that all cogen heat would be utilized and offset gas used in district plant boilers (86 percent. Cogen electrical and thermal efficiency was assumed to be 30 percent and 45 percent respectively.

The analysis estimated that the carbon emissions factor from producing electricity with the cogen is approximately 0.263 MTCO2e/MMBtu. The emissions factor of the Xcel electricity in 2020 was approximately 0.481 MTCO2e/MMBtu, and thus, running the cogen is currently around 40% 'cleaner' than using the grid electricity. Based on a linear extrapolation of Xcel emissions factor from current rates to 80 percent clean energy by 2030, the cogen electricity GHG factor will continue to be lower than electricity produced using the local grid until approximately 2027.

3.5 High Performance Buildings

CU Boulder currently uses sustainability certification to guide building design and construction by requiring all new buildings to achieve Leadership in Energy and Environmental Design (LEED Gold certification or better under the LEED version 4 rating systems for Building Design and Construction (LEEDv4 BD+C. This requirement stems from the High-Performance Certification Program mandated by the State of Colorado, which includes a provision to meet the 2018 IECC standard. AECOM evaluated the impact of pursuing a building performance standard more stringent than the 2018 IECC standard that was assumed to be applicable to future buildings (See Section 0 on future energy demand. Leveraging AECOM's energy simulation expertise, a 30 percent reduction for each energy end-use demand was applied to the future building energy models to account for improved performance.

3.6 Strategy Integration

The analyzed measures were integrated into Rosetta to allow for a campus-level analysis and the development of implementation scenarios. Measures that reduce energy demand, such as energy conservation, high-performance building construction, and steam to hot water conversion, were created in Rosetta for each applicable building type were assigned a percentage savings by energy end-use. Solar PV and battery energy storage were added as energy supply systems that could be applied at a campus level when economically viable. Each of these measures was evaluated independently and later combined into scenarios to determine the optimal combination of projects and timelines that would help the campus achieve its goals.

3.6.1 Rosetta Scenario Development

Rosetta was used to rapidly test several combinations of measures to identify the optimized set that would be most impactful yet cost-effective in helping the campus meet its goals. This measure set is developed through Rosetta's built-in optimizer engine, which conducts a dynamic optimization of all the possible combinations of measures considering the project's constraints and the preferred outcome of the optimization. The constraints used by the optimizer are tied to the overall project's goals and can range from an annual limit on capital expenditure (CAPEX, to an energy use intensity reduction goal, or to a carbon emissions reduction goal. The main constraints used for the CU Boulder optimization were the University's carbon reduction goals as described in the Goals Appendix and varying levels of capital investment. Rosetta allows the user to select the preferred outcome of the optimization by selecting one of four available optimizer goals that guide the optimization process while still meeting other project constraints:

- Minimize Capital Cost: this goal is used to develop a set of strategies that results in the lowest investment cost.
- Maximize Annual Energy Consumption Reduction: this goal is used to select the combination of strategies that results in the highest possible annual energy consumption savings.
- Maximize Annual Energy Cost Reduction: this goal seeks to maximize the amount of annual energy cost savings that can be achieved through strategy implementation.
- Maximize Resilience Score Improvement: this goal is applicable if the Rosetta project has a resilience score and the measures input in the project have a resilience impact. This feature was not used for CU Boulder.

A total of five scenarios were evaluated using the previously mentioned constraints and the Maximize Annual Energy Consumption Reduction Goal. The scenarios analyzed focused on a 15-year timeframe (ending in year 2035) at the request of CU Boulder to provide an actionable, near-term implementation roadmap. The performance of each scenario was evaluated using the following quantitative and qualitative criteria:

<u>Quantitative</u>

- Fiscal Year (FY) 2035 Annual Energy Savings: percentage energy savings achieved in FY 2035 by the implementation of measures selected in the scenario, compared to the projected energy consumption for the same year in a 'Business as Usual' (BAU) scenario where no energy conservation measures are implemented.
- FY 2035 Annual Cost Savings: annual cost savings achieved in FY 2035 by the implementation of measures selected in the scenario, compared to the projected energy costs in a BAU scenario in the same year where no energy conservation measures are implemented.
- FY 2035 GHG Emissions Savings: percentage savings in energy-related greenhouse gas emissions achieved in FY 2035 by the implementation of measures selected in the scenario,

compared to the baseline calendar year 2005 baseline established in the University's existing GHG emissions reduction goals.

- FY 2035 Percent New On-Site Renewables: percentage of total campus electricity supplied by on-site renewable energy systems in FY 2035 achieved by the implementation of renewable energy measures selected in the scenario.
- FY 2035 Cumulative Cost Savings: total cumulative energy cost savings over the scenario timeframe calculated as the sum of year-on-year energy cost savings.
- CAPEX: capital costs required to implement the measures selected in the scenario.
- Simple Payback: years required to recover the scenario's CAPEX using the FY35 annual energy cost savings as the savings value.

Qualitative

- Constructability: large infrastructure improvements can disrupt operations for long periods of time. A more gradual implementation of projects on campus minimizes disruptions to the University's operations.
- Flexibility: CU Boulder is an institution with a dynamic mission, and it needs the ability to modify its infrastructure to adapt to changing needs.

Table 11 shows the metrics obtained from the scenario analysis.

Table 11: Scenario Analysis Results

Scenario	FY35 Energy Savings (%)	FY35 Annual Cost Savings ($/year)	FY 35 GHG Savings (%)	FY35 Percent New On-Site Renewables (%)	FY 35 Cumulative Cost Savings ($)	CAPEX ($)	Simple Payback (Years)
1: Low Annual Investment ($500k/year)	4.5%	$1.3M	47%	0%	$13.2M	$6.7M	5.1
2: Medium Annual Investment ($2M/year)	22%	$6.15M	56%	0%	$52.3M	$26.8M	4.4
3: High Annual Investment ($10M/year)	37%	$10.8M	65%	14%	$100M	$132.7	12.3
4: Phased Large Investment ($50M every 5 years)	38%	$10.9M	66%	14%	$88M	$150M	13.7
5: Early Max Investment ($150M+ after 2024)	43%	$11.4M	69%	14%	$122.5M	$330M	28.9

The results of this analysis were used as a basis for selection of the preferred implementation roadmap for the campus.

4. Final Roadmap Development

Based on the feedback received on the proposed scenarios, the roadmap timelines shown in Figure 10 were selected for each of the energy strategy areas.

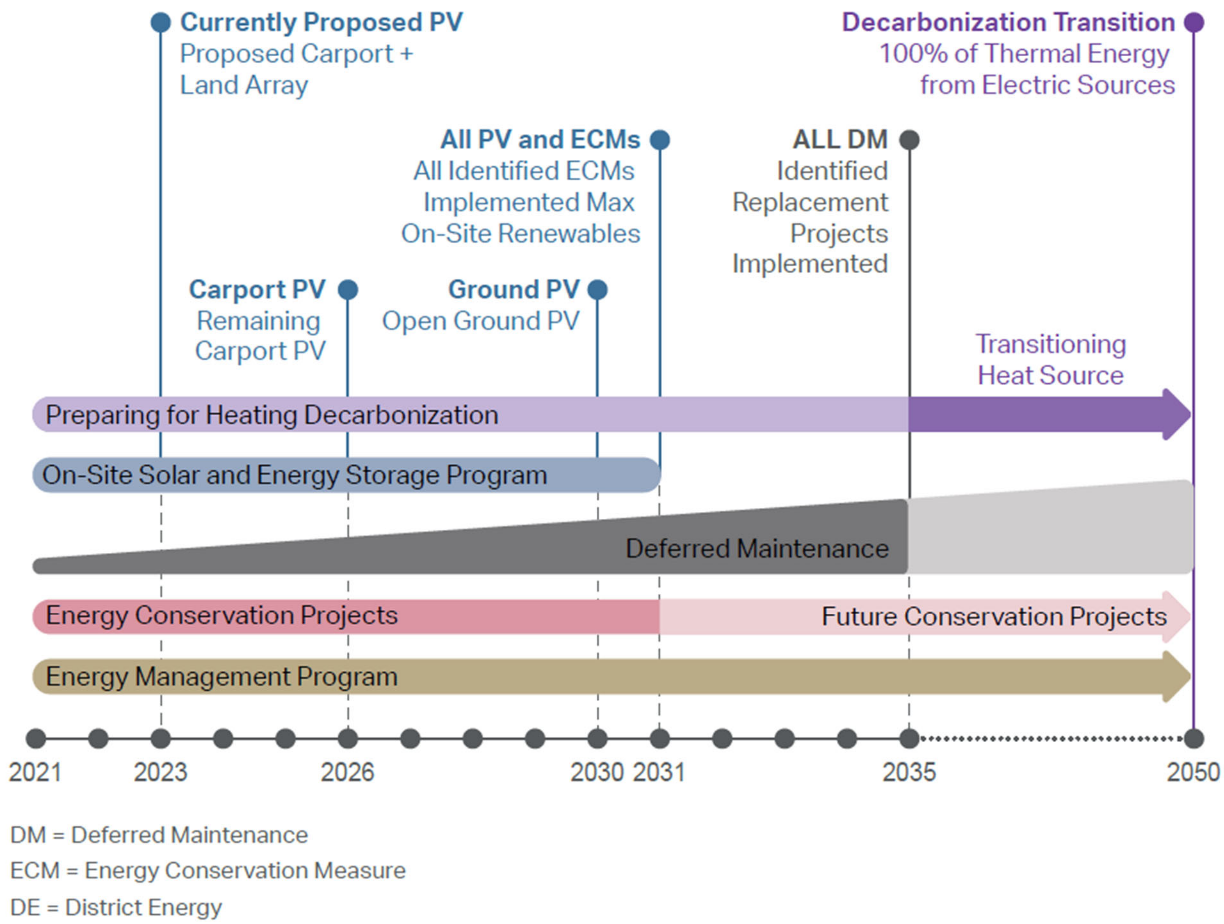


Figure 10: Roadmap Project Timeline

The deployment of energy strategies in the proposed roadmap is distributed as follows:

- Energy Management Program: Following the completion of the EMP in 2021, CU Boulder will begin expanding and formalizing its energy management program. This will include the following short-term (0-3 years) actions:
  - The establishment of the Energy Services Organization (ESO) and Energy Action Group (EAG)
  - The publication of a campus-wide energy policy that includes the following:
    -The development of benchmark-based building performance standards to identify and prioritize under-performing buildings
    - -The development of periodic review and reporting of the outcomes of the energy management program

- Energy Conservation Projects: Once key elements of the energy management program have been put in place, CU Boulder will begin the progressive implementation of the energy conservation measures identified in the EMP. This will include the following short-term actions:
    - The development of energy performance benchmarks for campus buildings. This will help identify under-performers that should be prioritized for energy conservation projects.
    - The implementation of energy conservation measures that have been previously identified through energy audits.
    - The expansion of the energy auditing program to identify additional cost-effective energy conservation measures, particularly for buildings that are not meeting their benchmarks.

  The final roadmap presented in the EMP assumes progressive implementation of all available energy conservation measures, starting with those that are most cost-effective and completing the implementation of all measures by 2035. Measures with a deferred maintenance component are assumed to be implemented more slowly than stand-alone, cost-effective energy conservation measures, which are assumed to be fully in place by 2031.
- Deferred Maintenance: CU Boulder has a significant deferred maintenance backlog that it is working to address. The proposed roadmap assumes that sufficient deferred maintenance projects can be addressed every year to prevent energy demand increases resulting from equipment degradation.
- On-Site Solar Program: CU Boulder is estimated to have enough space on campus for the installation of 13 MW-DC of solar PV. The roadmap assumes progressive installation of rooftop PV (max of 2.8 MW-DC installed by 2031), with RL2 PV installed in 2023 (~1.9 MW-DC), carport PV installed in 2026 (4.2 MW-DC), and open ground PV installed 2030 (~3.2 MW-DC)
- Decarbonization: Building heating is currently responsible for nearly 40 percent of the campus facility based GHG emissions. CU Boulder recognizes that heating-related fossil fuel consumption is its largest source of emissions and also its most significant challenge in eliminating energy-related emissions for the campus. Although energy savings from decarbonization have not been included in the near-term implementation roadmap for the campus, activities to drive the transition away from the use of fossil fuels have to begin as soon as possible to enable the transition to a fully electrified heating system. Enabling activities include updating design standards to allow HVAC systems to be steam and hot water capable, future proofing the East Campus and other areas of campus to allow for a conversion to a district-based energy system, studies to identify applicable technologies for decarbonization, and others.

Figure 11 shows CU Boulder’s integrated energy roadmap over the next 15 years resulting from the phased implementation of the proposed energy projects.

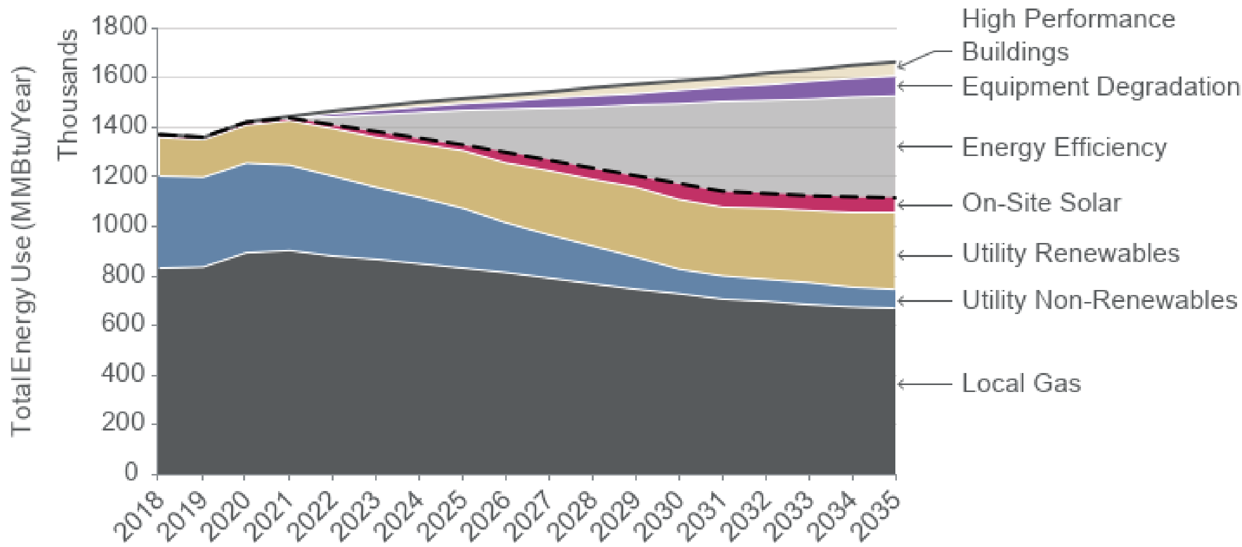


Figure 11: Integrated Roadmap

With this roadmap CU Boulder will be able to meet and, in some cases, exceed the goals outlined in the EMP. This combination of projects in addition to the utility's planned reductions in grid emissions will achieve a 59 percent reduction in energy-related emissions by 2030 compared to the 2005 baseline. Figure 12 shows the result of project implementation over the next 30 years.

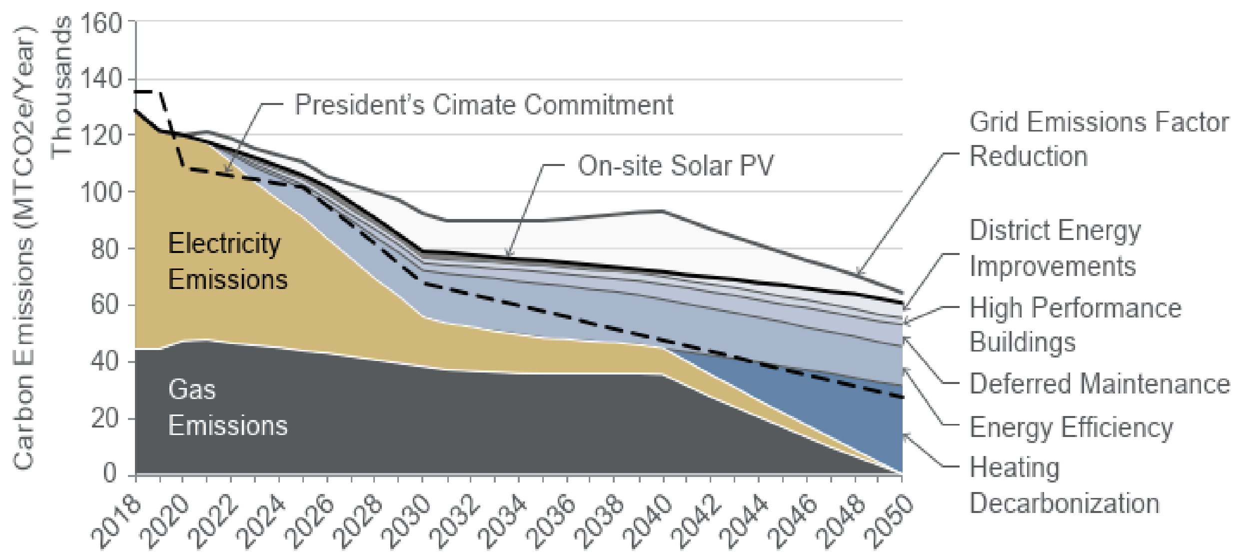


Figure 12: Energy-Related Emissions

4.1 Sensitivity Analysis

The proposed phasing of project implementation was selected to provide a cost-effective roadmap that met CU Boulder's energy conservation, GHG emissions, and resilience goals. The sensitivity of the proposed roadmap to changes in external and internal factors was evaluated as part of the EMP analysis. The factors studied included:

- Measure Cost: the capital cost of the proposed energy measures can vary significantly depending on factors like construction difficulty, implementation timeframe, and vendor. This factor could impact the cost-effectiveness of the roadmap.
- Discount Rate: the internal discount rate used by the campus in its financial analyses. This factor could impact the cost-effectiveness of the roadmap.
- Xcel Grid Emissions Factor: the emissions factor associated with purchasing units of electricity from the local utility, Xcel. The utility plans to reduce its emissions in the Colorado grid by 80 percent from 2005 levels by 2030. Although Xcel meeting its targets would go a long way to reducing emissions for CU Boulder, the University cannot rely exclusively on those efforts since it is possible that the targets may not be met. This factor could impact the University's ability to meet its emissions reduction goals.
- High Performance Buildings: high performance buildings were assumed to perform 30 percent better than future building code requires. It is possible that future buildings could be built to a more or less strict performance standard than what was studied. This factor could impact the University's ability to meet its energy conservation and emissions reduction goals.
- Electricity Rate: The cost of the electricity commodity may vary over the timeframe studied in the roadmap. This factor could impact the cost-effectiveness of the roadmap.
- Gas Rate: The cost of the gas commodity may vary over the timeframe studied in the roadmap. This factor could impact the cost-effectiveness of the roadmap.
- Equipment Degradation: equipment may degrade more or less significant than originally assumed. This factor could impact the University's ability to meet its energy conservation and emissions reduction goals.

Table 12 shows the baseline values used in the roadmap for each of these factors and the lower and upper bounds that were tested as part of the sensitivity analysis. A red arrow indicates that the factor adversely impacts the roadmap in terms of likelihood of meeting CU Boulder's goals, while a green arrow indicates a positive impact.

Table 12: Sensitivity Factors and Impact on Roadmap

Parameter	Proposed	Lower Boundary	Upper Boundary
Measure Cost	No added soft costs	30% added soft costs	No added soft costs
Discount Rate	6%	5%	8%
Xcel Emissions Factor	55% Renewable 2026 80% Clean Energy 2030	50% Renewable 2026 60% Renewable 2030	55% Renewable 2026 80% Renewable 2030
High Performance Buildings	30% Improvement on Code	15% Improvement on Code	40% Improvement on Code
Electricity Rate	0.6% Increase by 2050	$2c Lower by 2050	$5c Higher by 2050
Gas Rate	0.9% Increase by 2050	$2c Lower by 2050	$5c Higher by 2050
Equipment Degradation	0.5% Annually	1% Annually	0.25% Annually

Table 13 shows how the proposed roadmap tested using the lower and upper boundary values performs against CU Boulder's goals.

Table 13: Sensitivity Analysis Results

Parameter	Targets	Proposed	Lower Boundary	Upper Boundary
EUI Reduction from 2020 (%)	• 5% by 2025 • 15% by 2030 • 30% by 205	All targets achieved	Targets should be achieved	All targets achieved
GHG Reduction from 2005 (%)	• 25% by 2025 • 50% by 2030 • 100% by 2050	All targets achieved	No targets achieved	All targets achieved
Total Investment ($)	NA	$78M	$52M	$78M
Simple Payback	NA	23	34	11
IRR (%)	NA	5.7%	5.1%	9.1%
NPV ($)	NA	($1.5M)	($6M)	$24M

Appendix D: Goals Summary

Table of Contents

1. Overview

An essential component of a successful energy program is the setting of goals and associated metrics to serve as a reference point in strategy identification, deployment, and reporting. This memo summarizes the draft set of energy performance and resilience goals that were proposed to be included in in University of Colorado Boulder's (CU Boulder) Energy Master Plan (EMP) and were used as the starting point for energy modeling analyses.

The goals and metrics are a direct outcome of the goal-setting workshop on September 29, 2020 and further analysis and stakeholder input over the course of the EMP development. This effort also identified goals and targets that are deemed to be valuable for the energy program to track but will not necessarily be reported as part of the EMP.

The University is looking to establish a clear set of overarching goals focused on drastically reducing its impact on the environment while continuing to meet its mission requirements. Goals were proposed in energy conservation, clean energy, greenhouse gas (GHG) emissions reduction, energy resilience, and leadership; summarized in Table 1. Projects and strategies that are proposed to achieve these goals are required to be evaluated for their cost performance to ensure that investments are financially sustainable and aligned with the University's capital plan.

Table 1: Summary of EMP Goals

Goal	Target	Description
Increase Campus Energy Efficiency (Reduce energy use intensity by an average of 2% per year)	Energy use intensity (EUI) reduction: • 5% reduction by 2025 • 15% reduction by 2030 • 30% reduction by 2035 From FY20 baseline – calculated as a weighted average of building typology	Commit first to minimizing campus energy consumption, meeting ambitious benchmarks for both existing and new facilities, and avoiding additional consumption where possible through optimized use of space and infrastructure and engaging the campus community in a culture of energy conservation.
Reduce Campus Facility Energy Emissions **(Target zero energy emissions by 2050)**	Emissions reduction (from CY05 baseline) • 25% by 2025 • 50% by 2030 • 100% by 2050 Electricity from clean sources: • 50% by 2025 • 80% by 2030 (including 10% on-site renewable) • 100% by 2050	Decarbonize campus facility-tied energy use by 2050 through transition to clean thermal energy and implementation of a financially viable mix of on-site and regional clean electricity.
Maximize Critical Mission Resilience		Enhance energy resilience for mission critical facilities, research, and operations.
Lead in Energy Innovation		Establish CU Boulder as a world-leading, living, learning laboratory focused on collaboration between students, faculty, staff, and the community through research and deployment of innovative energy solutions with a positive global impact.

2. Context & Existing Goals

The development of energy performance and resilience goals is a critical stage of the EMP process as they will be the guiding force behind investment of time and resources into CU Boulder's energy program. It is therefore also critical that these goals are appropriate for CU Boulder and reflective of the university's reputation as a leader in environmental stewardship. The criteria for the goals selected for the EMP are that they are ambitious yet achievable, supported by a strong evidence base, representative of the interests of all stakeholders, and will be supported by leadership,

Six focus areas were considered for goal setting to effectively represent the breadth of the energy program. These include energy use, energy cost, GHG emissions, clean energy, energy resilience, and energy leadership. For each focus area, stakeholders were asked to consider if there should be a goal in this area, if an existing goal is still appropriate, to what level of ambition CU Boulder should strive for, and how it should be measured. Target setting, where applicable, was supported by preliminary analysis of strategy potential and considered the envisioned growth the campus mission. CU Boulder's existing energy goals are summarized in Table 2 along with their 'status', an indication if the goal is on track to be achieved (Y) or not (N).

Table 2: Existing Goals at CU Boulder

Goal Area	Goal Source	Goal	Status
Energy Use	Colorado Executive Order D 2019 016 (EOD 2019)	Reduce energy consumption per square foot by at least 15% by the end of fiscal year (FY) 2022-2023 (normalized for weather), using FY 2014-2015 as a baseline.	N
	CU Boulder 2011 Master Plan	Meter all individual buildings for electricity, gas, steam, and chilled water by FY 2020.	Y
Clean and Renewable Energy	Federal Requirement	At least 10% of the campus' total electric and thermal energy will be from renewable and alternative sources by FY 2017, working towards 25% by FY 2025.	N
	Federal Requirement	At least 10% of the campus' total electric energy will be from a renewable source by FY 2017, working towards 30% by FY 2025.	N
	EOD 2019	State agencies to increase percentage of renewable electricity consumed or purchased by state facilities to 5% by FY 2022-2023. Such increase will be in addition to the renewable energy provided by the utility as part of the overall power mix.	Y
	EOD 2019	Renewable energy installations will include energy storage if feasible and cost-effective.	N
Greenhouse Gas Emissions	President's Climate Commitment (PCC)	20% reduction by 2020 from CY 2005 baseline.	N
	Supporting Clean Energy Executive Order	26% reduction by 2025 from CY 2005 baseline.	N
	PCC	50% reduction by 2030 from CY 2005 baseline.	N
	PCC	80% reduction by 2050 from CY 2005 baseline.	N
	EO	10% reduction by FY 2022-2023 from FY 2014-2015.	N

N - Goal not on track to be achieved, Y - Goal on track to be achieved

Due to the evolving mission of the university (growth in research which is more energy intensive) and physical constraints for on-site renewable energy, many of these existing goals are no longer valid or are considered unachievable for CU Boulder. Additional metrics as well as target revisions have been identified for CU Boulder to track and report internally to inform decision making and ensure positive progress is being made toward its goals.

3. Focus Area Goals

Following the goals workshop with CU Boulder stakeholders, goals are set in five of the six focus areas. Each is summarized in this section with a description, related key performance indicators, tracking method and target year.

3.1 Energy Conservation

Overview

The first steps towards an effective and comprehensive energy strategy are to minimize demand through conservation measures and to utilize energy in the most efficient manner possible. This goal is to reduce annual energy use, the combined fuel (electricity and natural gas) consumption, and therefore associated cost and GHG emissions. This can be achieved through improvements to existing buildings or enhanced performance requirements on new construction and renovation.

Reducing energy use has direct positive impact on GHG emissions, operational costs, and can enhance resilience by reducing the load that needs to be supported.

Metrics

To track the performance of energy conservation efforts, three EUI metrics will be used to measure progress toward the reduction goals.

- Energy use (thousand British thermal units (kBtu)) per square foot of the overall campus portfolio (weighted average of building types)
- Energy use (kBtu) per square foot of each distinct building type
- Total energy consumption of the campus (kBtu/year)
- Total energy consumption (kBtu) for each building typology and customer group
- Total space (in square feet) of each building typology and customer group
- Annual performance scorecard for each building on campus to be distributed to relevant customers

The energy use per square foot per building type metric will used to measure year-on-year change in comparison to the FY20 baseline year. The other metrics will be tracked for internal reporting.

Table 3: Energy Conservation Targets

Energy Use Intensity Reduction	Target Year	Timeframe
5%	2025	Short-term
15%	2030	Medium-term
30%	2035	Long-term

Calculation and Reporting Methodology

EUI is a metric designed to normalize energy use measurement across scale and type of building for performance assessment. It is calculated, as defined by the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE)[1], by dividing the total energy consumed by the building in one year (measured in kBtu) by the total gross floor area of the building. CU Boulder currently tracks individual building-level EUI performance across its portfolio.

It is noted that campus-wide EUI is most simply calculated by scaling up the ASHRAE building-level calculation to the whole campus – dividing total campus energy use by the total floor area. However, the University's mission is rapidly evolving with an increasing commitment to research (which has more intense energy use requirements) and is facing significant uncertainty on post-pandemic operations, meaning that this simple scaling would not accurately capture performance trends. A flexible calculation methodology for campus-wide EUI is therefore proposed whereby building-level EUI will be calculated in line with the ASHRAE definition at a building typology-level with the aggregate campus performance calculated by an energy-use-weighted average of each building type's individual performance.

Performance will be tracked against these goals on an annual basis by interpolating between targets stated in Table 3.

3.2 Greenhouse Gas Emissions Reduction

Overview

GHG emissions are the predominant metric for determining the negative environmental impact of facility operations. Reductions in GHG can be achieved through a combination of energy conservation and clean energy generation strategies. This goal is to minimize the GHG emissions associated with university facility operations and is supported by those outlined in Energy Conservation and Clean Energy.

Metrics

To track the performance of GHG emissions reduction efforts, the following three metrics will be used:

- Total metric tons of carbon dioxide equivalent (MTCO2e) associated with campus energy use
- Percent emissions reduction from Fiscal Year (FY) 2005 levels

[1] https://www.energystar.gov/buildings/facility-owners-and-managers/existing-buildings/use-portfolio-manager/understand-metrics/what-energy

- Metric tons of carbon dioxide equivalent (MTCO2e) per square foot (SF) of the over-all campus portfolio

The total metric tons metric will used to measure year-on-year change in comparison to the FY05 baseline year. The targets in Table 4 align with CU Boulder's existing President's Climate Commitment. CU Boulder is setting a long-term goal of emissions elimination by 2050. The greatest technical challenge in striving to transition to clean energy is likely to be in replacing fossil fuels for heat generation. The university will focus its efforts on decarbonization of the heating system in support of these clean energy and GHG reduction goals. Elimination of emissions means that no fossil fuel will be used on campus and therefore offsets will not aid in the achievement of this goal.

Table 4: GHG Reduction Targets

GHG Emissions Reduction	Target Year	Timeframe
25%	2025	Short-term
50%	2030	Medium-term
100%	2050	Long-term

Calculation and Reporting Methodology

The energy-related GHG emissions are calculated by applying the annual reported GHG emissions factor of the off-campus utility provider (electricity, natural gas, and any other applicable fuels). The targets are set as percentage reduction in absolute carbon emissions as aligned with the President's Climate Commitment however campus-wide GHG-emission intensity will also be calculated and reported on an annual basis.

3.3 Clean Energy

Overview

The transition of energy fuel source from fossil fuels to renewable energy equates to reduced GHG emissions, operational costs, and when on-site, an invaluable source of power for resilience. CU Boulder's local utility provider, Xcel Energy, is rapidly transitioning to renewable power across its generation assets and has set an ambitious goal of 80 percent renewable by 2030 and 100% by 2050. CU's clean electricity target is aligned with Xcel's goal but builds upon it with the addition of an on-site renewable energy goal. An on-site target has been established which is representative of the maximum technically feasible capacity for solar photovoltaic or PV systems on the campus.

Metrics

CU Boulder's progress towards meeting this goal is the percentage of its energy supply portfolio that comes from renewable sources, both on-site and off-site utilities. The metrics that will be monitored include:

- Percent of electricity generated by on-site renewable energy sources.
- Percent of energy generated by on-site renewable energy sources.
- Total percent of energy demand met by renewable sources (including off-site).

Table 5: Clean Energy Targets

% of Renewable Electricity	Target Year	Timeframe
50%	2025	Short-term
80% (10% on-site)	2030	Medium-term
100%	2050	Long-term

Calculation and Reporting Methodology

The contribution of clean energy to the CU Boulder campus is calculated by dividing the total generated renewable electricity by the total consumption of electricity. This has two components, 1) grid purchased energy – the renewable fraction of which is reported by the off-site utility, and 2) on-site renewable energy generation. CU Boulder will combine these in the calculation of the campus annual renewable electricity fraction.

3.4 Energy Resilience

Overview

Energy resilience is the ability of energy systems to prepare for and adapt to changing conditions and withstand and
recover rapidly from disruptions. For CU Boulder, energy resilience is critical for meeting its mission requirements in providing adequate service to research and other essential campus functions. To achieve this, CU Boulder will establish a minimum set of mission-tied resilience requirements for systems in both existing and new construction.

Metrics

In order to communicate CU Boulder's commitment to energy resilience, the EMP will include statements of priorities and approach. These include:

- Statement outlining focus on certain buildings / missions
- Striving for zero outages of critical systems
- Space optimization – ensuring missions/people are signed to space that will adequately support their needs
- Implementing minimum resilience requirements into new construction and renovation projects

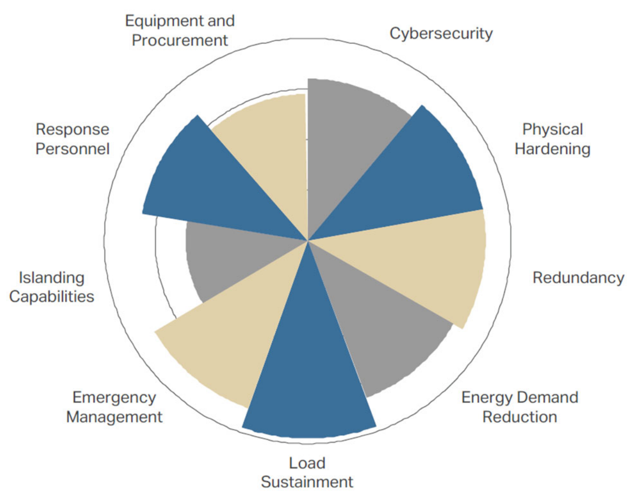
An explicit focus on energy resilience within an energy plan is a relatively new consideration and a standard protocol for the valuing of resilience has yet to be established. The following metrics will also be captured where possible to communicate the wider value of energy resilience benefits:

- Outage Time: time in minutes or hours where critical systems have experienced a critical resource outage, including power, natural gas, heating, cooling, and water.
- Monetary Cost of Lost Research: monetary value lost per time period of resource outage for research activities, calculated based on the quantifiable value of existing research samples and

data (where available) or on the grant value lost. Reported in terms of $/time period ($/hour or $/day).

- Monetary Cost of Lost Housing Services: monetary value lost per time period of resource outage for housing and dining activities, including summer activities such as conference hosting. Reported in terms of $/time period ($/hour or $/day)
- Brand Impact: resource outages that impact research activities can have a negative effect on CU Boulder's reputation as a research institution by signaling that the University does not have reliable energy resources. Reported in terms of negative, positive, or neutral impact.
- Service Assurance: The number of hours for which the building can continue its operations in the event of grid power, heating, or cooling outages at varying levels of service

As part of the EMP process, CU Boulder identified the attributes that constitute its definition of energy resilience. These attributes will be considered when evaluating potential new energy projects for their ability to positively improve the campus's energy resilience posture. Figure 1 summarizes these attributes and their relative weighting to CU Boulder. More details on the definition of resilience for CU Boulder can be found in Appendix E Definition of Energy Resilience.



Attributes in the chart to the left are sized by their relative weighting to CU Boulder. For example, a larger wedge (Load Sustainment) has a greater weight than a smaller wedge (Islanding Capabilities).

Figure 1: Energy Resilience Attributes

3.5 Leadership

Overview

CU Boulder's mission is not limited to changing its own campus for the better. As a regional leader in sustainability, the university is both responsible and privileged to lead those in its sphere of influence through knowledge sharing, best practices, and lessons learned. It is also uniquely placed to be a hub for knowledge sharing, the practical testing of new technologies, and developing energy management approaches. As a living laboratory, CU Boulder will lead and partner with campus stakeholders, researchers, students, and academic colleagues to drive forward development in resilience and fossil free solutions to our current and future energy challenges.

Metrics

Like energy resilience, Leadership commitment is perhaps better expressed as statements of intent than metrics. These include:

1. Establish partnerships with local/regional agencies, research, and faculty for knowledge sharing and development opportunities.
2. Create a model for University collaboration with industry with intention of fostering innovation.
3. Establish an outreach program to the community focused around education in energy and sustainability There may be opportunity to track certain engagements such as percent of new construction projects with technical network input, number of members of a technical practice network, number of related publications, or the number of community events hosted. The appropriate metrics may be identified as the programs/networks are established.

There may be opportunity to track certain engagements such as percent of new construction projects with technical network input, number of members of a technical practice network, number of related publications, or the number of community events hosted. The appropriate metrics may be identified as the programs / networks are established.

Appendix E: Definition of Energy Resilience

Table of Contents

1. Objective

The primary objective of this memo is to provide a definition of resilience for the University of Colorado Boulder (CU Boulder) based on the outcomes of the Energy Master Plan (EMP) Workshop 2: Defining Resilience, conducted on March 12, 2020.

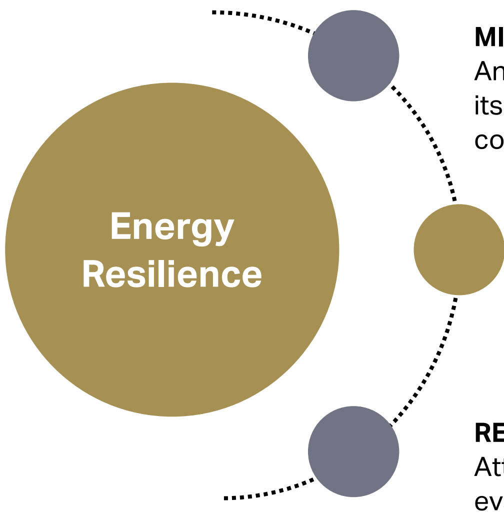
2. Definition of Resilience

AECOM conducted a workshop with CU Boulder stakeholders on March 12, 2020 with the goal of defining energy resilience for the University. Although the terms 'resilience' and 'resiliency' are often used interchangeably, a poll conducted during the workshop showed that 82percent of attendees favor the use of the term resilience over resiliency. Based on feedback obtained during the workshop, energy resilience for CU Boulder can be defined as shown in Figure 1.

Figure 1: Definition of Resilience for the University of Colorado Boulder

Energy resilience is the ability of energy systems to prepare for and adapt to changing conditions and withstand and recover rapidly from disruptions.

When establishing a framework for the assessment of energy resilience, the components of this definition are broken down into those shown in Figure 2.



MISSION NEEDS
Anything that is needed by an organization to accomplish its mission. This can include equipment, personnel, communications, backup power, and others.

RESOURCES & SUPPORTING INFRASTRUCTURE
Resources such as power, heat, cooling, and water may be required to support mission needs. The infrastructure supporting these resources must also be considered.

RESILIENCE ATTRIBUTES
Attributes are characteristics that help an organization evaluate its performance against resilience goals. Resilience attributes can help target investments by providing a framework for prioritizing projects.

Figure 2: Components of Energy Resilience

Each of these components can be defined in further detail within the context of CU Boulder.

2.1 Mission Needs and Supporting Infrastructure

A mission at CU Boulder is defined as an organization or stakeholder that conducts a specific type of activity on campus. Major missions at the University include the following:

1. Administrative
2. Athletics
3. Campus Life
4. Community
5. Cultural
6. Housing and Dining
7. Learning
8. Research
9. Other

Mission needs are met by energy resources such power, heating, cooling, and water which are in turn supported by the campus' energy infrastructure networks. The needs of each mission are unique and have varying resource requirements that cover three different levels of quality and availability:

1. Uninterruptable: resource must always be available at a high-quality level to prevent disruption to the mission (e.g., power that is continuously available without dips or surges; continuous cooling capable of maintaining specific environmental conditions)
2. Essential: resource must generally be available, but limited downtimes are allowed. The acceptable amount of resource downtime varies by mission and resource quality is not critical

(e.g., power, heating, or cooling outages are acceptable up to a certain duration; power can have dips or surges)

3. Non-essential: resource downtimes do not have major implications for the mission.

Stakeholder discussions held during the workshop resource requirement levels for each type of mission as shown in Table 1.

Table 1: Mission Needs

Campus Building Type	Power	Heat	Cool	Water
Administrative	Non-essential	Non-essential	Non-essential	Non-essential
Athletics	**Essential**	Non-essential	Non-essential	**Essential**
Campus Life	Non-essential	Non-essential	Non-essential	Non-essential
Community	Non-essential	Non-essential	Non-essential	Non-essential
Cultural	Non-essential	Non-essential	Non-essential	Non-essential
Housing & Dining	**Essential**	**Essential**	Non-essential	**Essential**
Learning	Non-essential	Non-essential	Non-essential	Non-essential
Research	Non-essential	Non-essential	Non-essential	Non-essential
Other	**Uninterruptible**	**Essential**	**Uninterruptible**	**Essential**

Research was identified as one of the most critical missions on campus, requiring uninterruptible power and cooling to ensure valuable research samples and information can be preserved during an emergency. Housing & Dining services was highlighted as having essential resource requirements for facilities such as graduate family housing while Athletics was identified as a mission that has essential needs during events but flexibility at other times.

2.2 Energy Resilience Attributes

Attributes are the characteristics of energy resilience that can be used to assess the extent to which supporting infrastructure is meeting mission needs and can be grouped into categories depending on their impact. The categories of energy resilience attributes are defined below:

- Robustness: the extent to which supporting infrastructure is hardened and physically protected against threats
- Resourcefulness: the diversity in energy resource supply sources and distribution paths as well as the system's capacity for sustaining critical loads
- Response: the ability of energy systems and staff to respond to an ongoing threat or event
- Recovery: the ability of energy systems and staff to recover once an event has occurred and to return activities to their previous state

Table 2 shows the categories and definitions of energy resilience attributes for CU boulder.

Table 2: Definition of Energy Resilience Attributes

Categories	Attribute	Attribute Qualities
Robustness	Cybersecurity of Energy Systems	Protection in place for energy systems (e.g., HVAC controls, centralized monitoring) to resist a cyber attack
	Physical Hardening	Protection of energy infrastructure (e.g., electrical supply lines and switch stations, district heating plants and pipes) from threats such as flooding, fire, and strong winds
Resourcefulness	Redundant Supply Paths	Separated supply paths to minimize the system infrastructure's vulnerability to the same local threat (e.g., having multiple electrical supply lines from the same source routed through the north and south of campus respectively)
	Energy Source Diversity	Alternative energy sources to provide energy supply redundancy in case one or more sources are affected by threats (e.g., having electrical feeders that are supplied electricity from alternate power generation sources, having local energy generation)
	Energy Demand Reduction	Conservation and management of energy use to reduce the requirement for critical backup capacity and increase outage sustainment time
	Load Sustainment Capacity	Ability to maintain energy supply to critical demand from on-site sources. Includes power generation, fuel storage, controls, and infrastructure
Response	Emergency Management Protocols	Level of emergency response planning and personnel training (e.g., response protocols for campus personnel in different threat scenarios, accessibility to critical infrastructure for repair teams)
	Islanding Capabilities, Analytics and Controls	Automation of backup systems, predicting threats, performance indicators to support response efforts
Recovery	Availability of Personnel for Assessment and Repair	Ability to access staff (be it University, contractor, or local specialists) of appropriate expertise for damage assessment and repair
	Equipment, Parts and Procurement	Ensuring replacement critical equipment and parts are available. Also includes standardization of components and secured procurement practices

In a survey sent out as part of the Defining Resilience workshop, campus stakeholders identified the following four attributes as the most critical:

1. Physical hardening
2. Availability of personnel for assessment and repair
3. Emergency management protocols
4. Equipment, parts, and procurement

Most of these attributes are aligned with the Response and Recovery attribute categories, suggesting that CU Boulder wants to take a proactive approach in planning for and responding to threat events. This type of approach to energy resilience is suitable for missions such as Learning or Athletics that can tolerate downtime in the availability of energy resources. Other stakeholder groups such as Research and in some instances, Housing & Dining, require a higher level of resource quality and availability and place more value in the Resourcefulness attribute category.

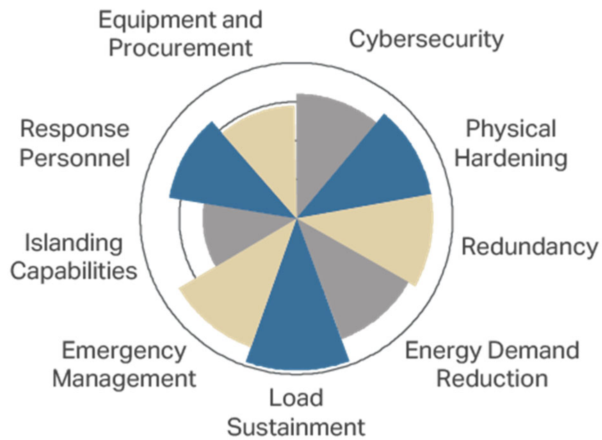
3. Energy Resilience and the Energy Master Plan

One of the objectives of the EMP is to provide CU Boulder with energy resilience recommendations as it relates to campus energy purchase, generation, and distribution as well as the organization and infrastructural support of critical equipment resources in campus buildings. This objective is part of a larger overarching task to provide CU Boulder with an implementation roadmap of strategies that will improve energy performance and help the University achieve its sustainability and greenhouse gas emissions goals.

3.1 Goal Setting and Strategy Assessment

To ensure that resilience is properly considered throughout the EMP, each strategy will be evaluated not only for its potential to improve energy performance and its financial viability but also for its impact on campus energy resilience. The energy resilience impact of each strategy will be assessed based on the resilience attributes it contributes to and documented in the form of a resilience scorecard similar to that shown in Figure 3. The weighting of the scorecard for CU is tailored based upon the order of priority from stakeholders. If a strategy contributes to high-priority attributes it will be highlighted as having a greater impact on the campus' overall energy resilience strategy.

Figure 3: Sample Attribute Scorecard



Achieving a specific score on the scorecard is being considered as a metric for setting and tracking measurable campus energy resilience goals.

3.2 Communicating the Value of Energy Resilience

An explicit focus on energy resilience within an energy plan is a relatively new consideration and a standard protocol for the valuing of resilience has yet to be established. As such, this effort looks to determine agreed-upon terminology and metrics for communicating the value of resilience across a wider stakeholder group in a matter that resonates most strongly. The EMP working group proposes the following metrics for use where applicable in the energy master plan and wider communication of energy resilience benefits:

- Monetary Cost of Lost Research: monetary value lost per time period of resource outage for research activities, calculated based on the quantifiable value of existing research samples and data (where available) or on the grant value lost. Reported in terms of $/time period ($/hour or $/day).
- Monetary Cost of Lost Housing Services: monetary value lost per time period of resource outage for housing and dining activities, including summer activities such as conference hosting. Reported in terms of $/time period ($/hour or $/day)
- Brand Impact: resource outages that impact research activities can have a negative effect on CU Boulder's reputation as a research institution by signaling that the University does not have reliable energy resources. Reported in terms of negative, positive, or neutral impact.
- Class Time Impact: lost student class hours associated with a resource outage. Reported as # of lost hours or percent of total class time.
- Avoided Cost of Natural Hazard Mitigation: cost avoided per dollar invested in natural hazard mitigation strategies calculated based on studies from known organizations such as the National Institute of Building Sciences. Reported in terms of dollar cost avoided per dollar cost invested.

Where these metrics can be effectively quantified and allocated to specific strategies, they will be incorporated into the financial assessment and impact the project viability and therefore if it is recommended for implementation.

Appendix F: Benchmarking Data

The following data shows the comparison between the actual annual energy use intensity (EUI) of each building on the CU Boulder campus compared to its corresponding the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) benchmark and the average campus EUI buildings of the same type.

EUI is provided in units of kBtu per square foot (kBtu/SF) and in terms of fuel consumption, i.e., the sum of the electricity and natural gas consumed by the building in addition to the fuel required to supply steam and chilled water to the building, where applicable. The fuel required for steam and chilled water was calculated applying an 86 percent efficiency to the steam demand for the building, and a coefficient of performance (COP) of 4 to the chilled water demand for the building to reflect the operational efficiency of the district energy plants. The efficiency and COP were determined as part of the energy modeling process; see the Energy Modeling Appendix for reference. These EUIs were averaged by building type to obtain the average benchmark for comparison. The ASHRAE benchmarks were obtained from the ASHRAE 100 standard.

Table 1: Building Energy Use Intensity and Benchmark Comparison

Building Name	Building Type	FY19 Fuel Use (kBtu)	Floor Area (SF)	Fuel-Based EUI (kBtu/SF)	ASHRAE Benchmark	Fuel-based EUI vs ASHRAE Benchmark	Average Benchmark	Fuel-Based EUI vs Average Benchmark
1135 BROADWAY (1135BRD)	Learning	885,967	18,548	48	65	-27%	121	-61%
ADEN HALL (ADEN)	Housing	1,886,943	26,942	70	55	27%	58	22%
AEROSPACE ENGINEERING SCIENCES (AERO)	Research	15,315,326	184,917	83	187	-56%	152	-46%
KOENIG ALUMNI CENTER (ALUM)	Office	806,242	8,263	98	48	103%	81	20%
ANDREWS HALL (ANDS)	Housing	4,688,641	61,828	76	55	38%	58	32%
ADMINISTRATIVE AND RESEARCH CENTER- EAST CAMPUS (ARCE)	Office	5,954,391	186,279	32	48	-33%	81	-61%
ASTROPHYSICAL RESEARCH LABORATORY (ARL)	Research	9,832,707	36,375	270	187	45%	152	78%
ARMORY (ARMR)	Learning	1,857,890	24,976	74	65	14%	121	-38%
ARNETT HALL (ARNT)	Housing	6,832,778	61,577	111	55	102%	58	93%
ATHENS NORTH COURT (ATHN)	Housing	937,322	47,916	20	55	-64%	58	-66%
ROSER ATLAS CENTER (ATLS)	Research	4,630,686	70,991	65	187	-65%	152	-57%
BEAR CREEK APT B (BCAPB)	Housing	9,716,330	190,887	51	55	-7%	58	-12%
BENSON EARTH SCIENCES BUILDING (BESC)	Learning	16,506,815	89,019	185	65	185%	121	53%
JENNIE SMOLY CARUTHERS BIOTECHNOLOGY BUILDING (BIOT)	Research	32,036,578	415,809	77	187	-59%	152	-49%
BAKER HALL (BKER)	Housing	5,086,387	113,237	45	55	-18%	58	-22%
BRACKETT HALL (BRKT)	Housing	3,487,709	26,901	130	55	136%	58	125%
BUCKINGHAM HALL (BUCK)	Housing	5,290,249	60,224	88	55	60%	58	53%
CENTER FOR COMMUNITY (C4C)	Dining	29,543,690	317,182	93	72	29%	116	-20%

Table 1: Building Energy Use Intensity and Benchmark Comparison (Continued)

Building Name	Building Type	FY19 Fuel Use (kBtu)	Floor Area (SF)	Fuel-Based EUI (kBtu/SF)	ASHRAE Benchmark	Fuel-based EUI vs ASHRAE Benchmark	Average Benchmark	Fuel-Based EUI vs Average Benchmark
CARLSON GYMNASIUM (CARL)	Learning	9,809,583	52,641	186	65	187%	121	54%
CENTER FOR ASIAN STUDIES (CAS)	Office	245,268	5,942	41	48	-14%	81	-49%
CENTER FOR ACADEMIC SUCCESS AND ENGAGEMENT (CASE)	Office	16,770,847	107,797	156	48	224%	81	92%
CONTINUING EDUCATION CENTER (CEDU)	Office	1,376,971	19,350	71	48	48%	81	-12%
CRISTOL CHEMISTRY & BIOCHEMISTRY BUILDING (CHEM)	Research	36,054,439	147,613	244	187	31%	152	60%
CHEYENNE ARAPAHO HALL (CHEY)	Housing	8,458,932	108,963	78	55	41%	58	35%
CHAMPIONS CENTER (CHMP)	Office	25,772,873	231,121	112	48	132%	81	38%
CENTER FOR INNOVATION & CREATIVITY (CINC)	Office	5,293,745	88,757	60	48	24%	81	-26%
CIRES COOPERATIVE INSTITUTE FOR RESEARCH IN ENVIRONMENTAL SCIENCES (CIRE)	Research	4,835,824	25,445	190	187	2%	152	25%
COCKERELL HALL (CKRL)	Housing	1,809,779	25,373	71	55	30%	58	24%
CLARE SMALL ARTS & SCIENCES (CLRE)	Learning	5,127,898	43,251	119	65	82%	121	-2%
UNIVERSITY CLUB (CLUB)	Recreation	2,112,407	27,266	77	28	177%	76	2%
COMPUTING CENTER (COMP)	Research	7,205,887	27,546	262	187	40%	152	72%
GATES WOODRUFF WOMEN'S STUDIES COTTAGE (COTT)	Learning	123,237	5,228	24	65	-64%	121	-81%
COLORADO POND PUMP STATION (CPMP)	Other	398,673	478	834	30	2680%	946	-12%
CROSMAN HALL (CROS)	Housing	2,831,854	25,936	109	55	99%	58	90%
CU CHILDREN'S CENTER (DACR)	Recreation	294,535	8,348	35	28	26%	76	-54%
DAL WARD ATHLETIC CENTER (DALW)	Recreation	11,237,160	100,727	112	28	298%	76	46%
DUANE D-WING (DDW)	Research	13,945,040	31,422	444	187	137%	152	192%
DENISON ARTS & SCIENCES BUILDING (DEN)	Learning	1,015,022	5,471	186	65	185%	121	53%
GALLOGLY DISCOVERY LEARNING CENTER (DLC)	Research	4,723,033	48,616	97	187	-48%	152	-36%
DARLEY TOWERS TOTAL	Housing	8,225,141	122,957	67	55	22%	58	16%
DUANE PHYSICS (DUAN)	Research	21,832,817	186,828	117	187	-38%	152	-23%
ENGINEERING COMPLEX	Learning	89,323,093	584,299	153	65	135%	121	26%
ECONOMICS BUILDING (ECON)	Learning	3,354,344	29,605	113	65	74%	121	-6%
EDUCATION BUILDING (EDUC)	Learning	10,402,725	46,496	224	65	244%	121	85%
ENVIRONMENTAL HEALTH & SAFETY (EHSC)	Office	4,359,930	22,271	196	48	308%	81	142%
EKELEY SCIENCES BUILDING (EKLC)	Research	45,621,256	133,136	343	187	83%	152	125%
ENVIRONMENTAL DESIGN BUILDING (ENVD)	Learning	13,816,046	60,411	229	65	252%	121	89%
CU EVENTS CENTER (EVNT)	Recreation	10,533,381	202,321	52	28	86%	76	-32%
BALCH FIELDHOUSE COMPLEX (FH)	Recreation	10,212,864	69,154	148	28	427%	76	94%
BALCH FIELDHOUSE PRESSBOX (FHPB)	Recreation	1,406,567	20,406	69	28	146%	76	-10%
FISKE PLANETARIUM & SCIENCE CENTER (FISK)	Office	2,192,490	16,768	131	48	172%	81	61%

Table 1: Building Energy Use Intensity and Benchmark Comparison (Continued)

Building Name	Building Type	FY19 Fuel Use (kBtu)	Floor Area (SF)	Fuel-Based EUI (kBtu/SF)	ASHRAE Benchmark	Fuel-based EUI vs ASHRAE Benchmark	Average Benchmark	Fuel-Based EUI vs Average Benchmark
FLEMING BUILDING (FLMG)	Learning	5,667,172	125,336	45	65	-30%	121	-63%
ARTS & SCIENCES FINANCE AND PAYROLL ADMINISTRATION (FPA)	Office	525,769	8,754	60	48	25%	81	-26%
FARRAND HALL (FRND)	Housing	18,597,125	132,553	140	55	155%	58	144%
GREENHOUSE NO 1 AT MACKY (GH-1)	Learning	433,256	3,299	131	65	102%	121	9%
RESEARCH PARK GREENHOUSE (GH-3)	Learning	3,087,751	10,324	299	65	360%	121	147%
GOLD BIOSCIENCES BUILDING (GOLD)	Research	50,426,807	132,641	380	187	103%	152	150%
GROUNDS AND RECYCLING OPERATIONS CENTER (GROC)	Office	2,505,159	19,318	130	48	170%	81	60%
GUGGENHEIM GEOGRAPHY BUILDING (GUGG)	Learning	1,419,145	22,909	62	65	-5%	121	-49%
1330/1332 GRANDVIEW (GVAS)	Office	165,426	1,776	93	48	94%	81	15%
HALE SCIENCE BUILDING (HALE)	Research	4,134,663	41,658	99	187	-47%	152	-35%
HENDERSON BUILDING (MUSEUM)	Library	2,420,943	31,237	78	64	21%	83	-7%
HOUSING & DINING SERVICES FACILITES OPERATIONS (HFOC)	Office	3,088,879	38,581	80	48	67%	81	-1%
HALLETT HALL (HLET)	Housing	8,373,055	93,086	90	55	64%	58	56%
HELLEMS ARTS & SCIENCES BUILDING (HLMS)	Learning	16,186,364	111,551	145	65	123%	121	20%
HIGH PERFORMANCE COMPUTING FACILITY (HPCF)	Research	5,725,459	2,312	2,476	187	1224%	152	1527%
HOUSING SYSTEM SERVICE CENTER (HSSC)	Office	754,167	37,996	20	48	-59%	81	-76%
INSTITUTE FOR BEHAVIORAL GENETICS (IBG)	Office	2,961,324	25,616	116	48	141%	81	43%
INSTITUTE OF BEHAVIORAL SCIENCE (IBS)	Office	2,418,466	55,821	43	48	-10%	81	-47%
INSTITUTE OF BEHAVIORAL SCIENCE NO 2 (IBS2)	Office	720	6,040	0	48	-100%	81	-100%
COLLEGE OF MEDIA, COMMUNICATION AND INFORMATION DEPARTMENT OF INFORMATION SCIENCE (INFO)	Learning	2,502,294	16,773	149	65	130%	121	23%
INDOOR PRACTICE FACILITY (IPRC)	Recreation	2,711,422	326,719	8	28	-70%	76	-89%
DRESCHER UNDERGRADUATE ENGINEERING INTEGRATED TEACHING AND LEARNING LAB (ITLL)	Research	5,073,417	36,322	140	187	-25%	152	-8%
JILA (JILA)	Research	13,882,019	161,078	86	187	-54%	152	-43%
KITTREDGE WEST HALL (KITW)	Housing	4,251,699	73,809	58	55	5%	58	0%
KOELBEL BUILDING - LEEDS SCHOOL OF BUSINESS (KOBL)	Learning	12,468,601	165,660	75	65	16%	121	-38%
KETCHUM ARTS & SCIENCES BUILDING (KTCH)	Learning	2,500,973	57,264	44	65	-33%	121	-64%
KVCU RADIO TOWER (KVCU)	Other	407,248	128	3,182	30	10505%	946	236%
LESSER HOUSE (LESS)	Learning	109,234	3,427	32	65	-51%	121	-74%
NORLIN LIBRARY (LIBR)	Library	27,196,077	325,670	84	64	30%	83	1%
LIBBY HALL (LIBY)	Housing	9,817,211	109,309	90	55	63%	58	56%
LITMAN RESEARCH LAB (RL1) (LITR)	Research	1,321,663	53,923	25	187	-87%	152	-84%
LIFE SCIENCE RESEARCH LAB (RL4) (LSRL)	Research	2,512,759	11,980	210	187	12%	152	38%
LASP SPACE TECHNOLOGY RESEARCH CENTER (LSTR)	Research	11,751,764	117,377	100	187	-46%	152	-34%

Table 1: Building Energy Use Intensity and Benchmark Comparison (Continued)

Building Name	Building Type	FY19 Fuel Use (kBtu)	Floor Area (SF)	Fuel-Based EUI (kBtu/SF)	ASHRAE Benchmark	Fuel-based EUI vs ASHRAE Benchmark	Average Benchmark	Fuel-Based EUI vs Average Benchmark
OLD MAIN (MAIN)	Office	2,648,337	25,160	105	48	119%	81	30%
MATHEMATICS BUILDING (MATH)	Learning	5,587,997	58,982	95	65	46%	121	-22%
MACKY AUDITORIUM (MCKY)	Recreation	8,002,371	88,374	91	28	223%	76	19%
BRUCE CURTIS BUILDING (MCOL)	Learning	5,412,887	43,409	125	65	92%	121	3%
MCKENNA LANGUAGES BUILDING (MKNA)	Learning	760,512	22,668	34	65	-48%	121	-72%
MARINE STREET SCIENCE CENTER (RL6) (MSSC)	Research	3,666,141	51,841	71	187	-62%	152	-54%
MUENZINGER PSYCHOLOGY & BIOPSYCHOLOGY BUILDING (MUEN)	Research	25,279,431	151,418	167	187	-11%	152	10%
IMIG MUSIC BUILDING (MUS)	Research	13,751,811	102,123	135	187	-28%	152	-12%
NEW PHYSICS LABORATORY (NPL)	Research	2,524,629	27,538	92	187	-51%	152	-40%
ARTS & SCIENCES OFFICE BUILDING 1 (OB1)	Office	569,698	8,676	66	48	37%	81	-19%
SOMMERS-BAUSCH OBSERVATORY (OBSV)	Office	211,009	8,306	25	48	-47%	81	-69%
POLICE & PARKING SERVICES CENTER (PDPS)	Office	2,993,034	31,987	94	48	95%	81	15%
PAGE FOUNDATION CENTER (PFDC)	Office	793,417	10,277	77	48	61%	81	-5%
PORTER BIOSCIENCES (PORT)	Research	42,170,379	106,967	394	187	111%	152	159%
RAMALEY BIOLOGY BUILDING (RAMY)	Research	31,172,800	137,061	227	187	22%	152	49%
STUDENT RECREATION CENTER (REC)	Recreation	24,612,089	320,531	77	28	174%	76	1%
REED HALL (REED)	Housing	2,619,352	25,683	102	55	85%	58	77%
REGENT ADMINISTRATIVE CENTER (RGNT)	Office	10,825,713	86,947	125	48	159%	81	54%
RESEARCH LAB NO 2 (RL2)	Office	1,713,703	76,854	22	48	-54%	81	-72%
RESEARCH PARK PUMP STATION (RPMP)	Other	319,884	295	1,084	30	3515%	946	15%
SUSTAINABILTY ENERGY AND ENVIRONMENT COMMUNITY (SEEC)	Research	14,147,988	292,287	48	187	-74%	152	-68%
SUSTAINABILTY ENERGY AND ENVIRONMENT LABORATORY (SEEL)	Research	9,632,843	142,343	68	187	-64%	152	-56%
SPEECH LANGUAGE AND HEARING SCIENCES (SLHS)	Office	813,582	22,558	36	48	-25%	81	-56%
SOCCER LOCKER ROOM (SLKR)	Recreation	60,490	2,275	27	28	-5%	76	-65%
SMITH HALL (SMTH)	Housing	6,782,048	96,667	70	55	28%	58	22%
SPACE SCIENCE BUILDING (SPSC)	Research	19,413,014	100,036	194	187	4%	152	28%
STADIUM BUILDING (STAD)	Research	17,883,996	149,065	120	187	-36%	152	-21%
STEARNS TOWERS TOTAL	Housing	19,845,297	249,440	80	55	45%	58	38%
STADIUM SKY BOX (STSB)	Recreation	15,029,499	114,864	131	28	367%	76	72%
SEWALL HALL (SWLL)	Housing	11,728,396	98,128	120	55	117%	58	108%
TELECOM EQUIPMENT BUILDING SMILEY COURT (TB16)	Other	98,536	131	752	30	2407%	946	-20%
UNIVERSITY ADMINISTRATIVE CENTER ANNEX (TB19)	Office	121,149	2,077	58	48	22%	81	-28%
FAMILY HOUSING EXPANSION (141) (TB34)	Housing	18,200	660	28	55	-50%	58	-52%
STEAM CONVERSION SHED (TB49)	Other	21,387,058	1,688	12,670	30	42134%	946	1239%

Table 1: Building Energy Use Intensity and Benchmark Comparison (Continued)

Building Name	Building Type	FY19 Fuel Use (kBtu)	Floor Area (SF)	Fuel-Based EUI (kBtu/SF)	ASHRAE Benchmark	Fuel-based EUI vs ASHRAE Benchmark	Average Benchmark	Fuel-Based EUI vs Average Benchmark
PRACTICE FOOTBALL FIELD BUILDING (TB55)	Recreation	315,990	289	1,093	28	3805%	76	1334%
TEMPORARY BUILDING 65 (TB65)	Office	159,253	2,923	54	48	14%	81	-33%
FAMILY HOUSING COMMUNITY CENTER (TB68)	Housing	140,448	2,259	62	55	13%	58	8%
TEMPORARY BUILDING 72 (TB72)	Other	34,319	16,576	2	30	-93%	946	-100%
TEMPORARY BUILDING 82 (TB82)	Office	234,773	4,435	53	48	10%	81	-35%
POTTS FIELD TRACK STORAGE (TB83)	Recreation	57,842	1,285	45	28	61%	76	-41%
BRYAN BENJAMIN SAX SKI TEAM BUILDNG (TB84)	Recreation	202,981	3,517	58	28	106%	76	-24%
TEMPORARY BUILDING 88 (TB88)	Office	159,439	3,193	50	48	4%	81	-38%
TEMPORARY BUILDING 93 (TB93)	Office	180,411	3,081	59	48	22%	81	-28%
TEMPORARY BUILDING 97 (TB97)	Office	206,838	3,886	53	48	11%	81	-34%
UNIVERSITY THEATRE (THTR)	Recreation	22,711,913	70,796	321	28	1046%	76	321%
TRANSPORTATION CENTER AND ANNEX (TRAN)	Office	504,384	9,349	54	48	12%	81	-33%
UNIVERSITY ADMINISTRATIVE CENTER (UCTR)	Office	872,245	15,091	58	48	20%	81	-29%
UNIVERSITY MEMORIAL CENTER (UMC)	Dining	29,298,442	254,241	115	72	60%	116	-1%
UNIVERSITY RESIDENCE (URES)	Housing	584,554	11,054	53	55	-4%	58	-8%
VISUAL ARTS COMPLEX (VAC)	Research	37,546,192	179,809	209	187	12%	152	37%
VARSITY LAKE PUMP STATION (VPMP)	Other	291,833	401	728	30	2326%	946	-23%
WARDENBURG STUDENT HEALTH CENTER (WARD)	Healthcare	6,350,014	55,965	113	45	152%	113	0%
WOODBURY ARTS & SCIENCES BUILDING (WDBY)	Learning	8,902,703	12,937	688	65	959%	121	469%
WEBER HALL (WEB)	Housing	12,239,647	190,869	64	55	17%	58	11%
2860 WILDERNESS PLACE (WILD)	Research	7,067,882	63,190	112	187	-40%	152	-27%
WIND TUNNEL (WIND)	Research	229,717	3,469	66	187	-65%	152	-56%
WOLF LAW BUILDING (WLAW)	Learning	10,496,160	183,608	57	65	-12%	121	-53%
WILLARD HALL (WLRD)	Housing	5,667,440	89,932	63	55	15%	58	9%
WILLIAMS VILLAGE DINING AND COMMUNITY COMMONS (WVC)	Dining	21,427,077	114,917	186	72	159%	116	60%
WILLIAMS VILLAGE EAST (WVE)	Housing	14,794,115	188,845	78	55	42%	58	36%
WILLIAMS VILLAGE HEATING PLANT (WVHP)	Other	3,776,461	8,277	456	30	1421%	946	-52%
WILLIAMS VILLAGE NORTH (WVN)	Housing	9,685,612	142,693	68	55	23%	58	18%
WILLIAMS VILLAGE PUMPHOUSE (WVPH)	Other	181,866	456	399	30	1229%	946	-58%
WILLIAMS VILLAGE RECREATION CENTER (WVRC)	Recreation	964,956	11,035	87	28	212%	76	15%

Appendix G: Communication and Engagement Plan

Table of Contents

1. Introduction

Meaningful campus-wide engagement and communication are critical components of the Energy Master Plan (EMP), benefitting campus cultural shifts and changes in practices leading to energy savings; but most importantly, helping to avoids consumption. Engagement programs that help avoid consumption and provide behavior modification are inexpensive compared to infrastructure and system investments that enable consumption to take place, and then needing to address that consumption through clean energy sources or technologies to make buildings more efficient—although these are important energy strategies. This Energy Communication and Engagement Plan (Plan) recommends elevating campus energy engagement programs with historically bottom-up approaches to programs that receive increased leadership support, attention, and integration into wider campus processes to maximize positive impact. In addition to energy efficiency, this Plan also targets raising awareness and education regarding clean energy strategies and technologies.

2. Implementation Team

The proposed integrated EMP roadmap involves the creation and chartering of the Energy Action Group (EAG) and the Energy Service Organization (ESO). The EAG will consist of leadership, including campus-wide customers and stakeholders that have direct impact on energy consumption, and thus have the power to influence it. The ESO will support the EAG and oversee implementation of actions and provide technical experience to support an ongoing energy management program. The EAG and the ESO will support the newly formed Sustainability Council and the Sustainability Communication Group (coordinated by the Research and Innovation Office) that will serve as a hub to help ensure cohesion and brand identity in communicating messages regarding energy conservation, resilience, and how individuals can engage.

Figure 1: Components of the Implementation Team

The adoption of the EMP goals and the proposed campus energy policy will empower the EAG to implement strategies, including those that can only be realized through enhancing campus stakeholder engagement and outreach. To target effective outreach, this Plan has been developed in support of the actions laid out in the EMP with mechanisms targeting energy conservation, avoided consumption, and clean energy strategies for a wide target audience, including students, faculty, research, campus leadership, staff, alumni, visitors, and campus institutions. The opportunity to align and combine the Plan with the EMP creates a powerful system to become a change agent to communicate effectively and with a united voice to empower CU Boulder to achieve ambitious energy and decarbonization goals.

3. Communication and Engagement Plan Components

This Plan has four major components: System Changes, Awareness Campaign, University Engagement, and Partner Engagement, as described below.

1. System Changes— System Changes play a critical role because of their large scale, university-wide impact. For example, creation and implementation of institutional policies related to the research enterprise, human resources, and space optimization. In addition to policy, System Changes can also include process changes and updates to current campus systems to integrate energy efficiency and space efficiency into the campus culture, various campus processes (involving faculty, staff, and students), and campus decision-making. For example, campus culture can be influenced through efforts connected to the hiring, onboarding, training, and employee evaluation process. Research spaces that are known to be energy intensive could implement system changes that promote a shared research equipment culture among scientists that benefits utilities savings and efficiency for both laboratory space and infrastructure. Regarding campus buildings, efforts could include those that lead to optimized use of existing building space and infrastructure, because it has been frequently said in the EMP process by CU Boulder leadership: "The most energy efficient building we have is one we don't need to build." Furthermore, a System Change recommendation of this plan is elevating campus energy engagement programs with historically bottom-up approaches to programs that receive increased leadership support, attention, and integration into wider campus processes to maximize their positive impact.

2. Awareness Campaign—The Awareness Campaign leverages knowledge-sharing tactics to raise the visibility of energy initiatives, disseminate information, and support the culture of energy sustainability. We recommend that an Awareness Campaign develop a unified brand that is then disseminated through various methods. The Awareness Campaign components include student and employee orientation, dashboards and interactive displays, social media tool kits and posters, newsletters, and fact sheet emails. These actions/strategies also include building on awareness campaign successes of the Green Labs toolkit, as well as other Environmental Center and campus programs, including digital content, posters, signs, and newsletters updates that are managed and regularly updated and maintained.

3. University Engagement—University Engagement—University Engagement includes activities and events targeted toward CU Boulder students, faculty, and staff, such as competitions, awards, incentives, conferences/symposiums, and summits such as the Sustainability Summit on Earth Day. These events will be coordinated by various campus engagement programs with the recommendation that the Sustainability Communication Group collaborate with engagement programs to help publicize and report on engagement activities.

4. Partner Engagement—Partner Engagement is communication and engagement with external stakeholders such as utility providers (i.e., Xcel), the City of Boulder, State of Colorado representatives, and organizations like the National Renewable Energy Laboratory. Activities and events with external partners include conferences/symposiums and community-wide events and will also be coordinated with the Sustainability Communication Group.

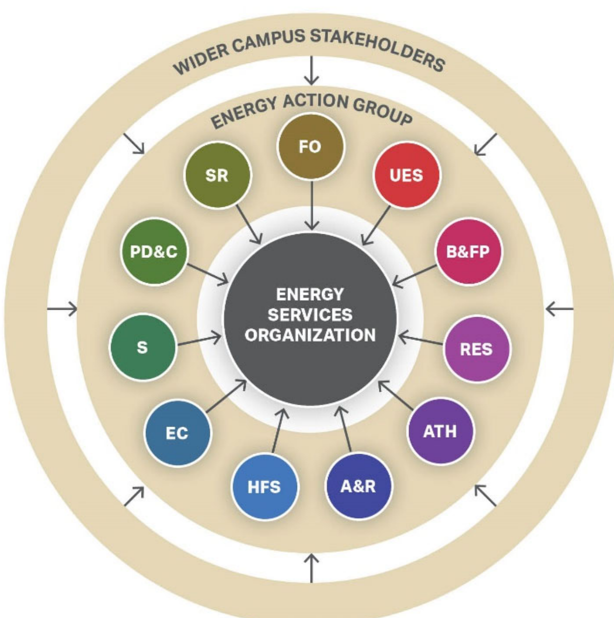
The Communication and Engagement Plan identifies actions and strategies for implementation in each of the four areas described above. Case studies are provided to share best practices related to a specific strategy. A suggested schedule for implementation is provided that should be updated regularly by the Sustainability Communication Group, supported by the EAG and ESO. This Plan evaluates and recommends improvements to current communication, outreach, and campus processes related to students, staff, and faculty that impact the ability to engage the CU Boulder's campus community and succeed with actions towards reaching the EMP energy goals.

4. Communication and Engagement Plan Methodology

The Plan methodology includes performing a gap analysis by identifying what CU Boulder is doing and not doing in terms of engagement; identifies actions/strategies; and showcases best practices at CU Boulder and at other institutions in the form of case studies. Recommended actions/strategies target co-benefits such as achieving energy conservation and energy resilience for the campus.

5. Stakeholder Groups

As described earlier, two groups are focused on energy and implementing the EMP—the ESO and the EAG. Diverse campus-wide stakeholders comprise the ESO as illustrated below.



Legend
Energy Action Group (EAG)
Energy Services Organization (ESO)
Facilities Operations (FO)
Utility and Energy Services (UES)
Budget and Fiscal Planning (B&FP)
Real Estate Services (RES)
Athletics (ATH)
Academics and Research (A&R)
Housing Facilities Services (HFS)
Environmental Center (EC)
Sustainability (S)
Planning, Design, and Construction (PD&C)
Student Representatives (SR)

Figure 2: The Role Relationship Between the ESO, EAG, and Wider Campus Stakeholders

6. Target Audience

The target audience for the Plan includes:

- Student groups and student body
- Faculty, research, and staff
- CU Boulder leadership and staff
- Campus institutions
- Donors and alumni
- Visitors

Case Study – UC Berkeley is effectively **disseminating energy information**. An "Energy Liaison" was appointed from each operating unit to manage energy use coordination. Facility managers were trained and engaged. Deans/directors received monthly energy performance and trends reports to disseminate information
UC Berkeley: Energy Savings Through Campus and Occupant Engagement [1]

7. Actions/Strategies

Actions and strategies are described for each focus area along with relevant case studies.

7.1 System Changes

The following actions are identified to address system changes for the biggest impacts related to energy and space efficiency. It is recommended that upon initiation, the EAG work with the Provost and Chief Operating Officer to institutionalize energy policies for University-wide implementation.

System Changes	
	Actions/Strategies:
A	Update policies related to the hiring, onboarding, training, and employee evaluation process
B	Incorporate efficient energy and space utilization in the annual employee orientation
C	Update policies integrating energy efficiency and space efficiency into the campus culture
D	Update policies for optimized use of existing building space and infrastructure
E	For research spaces that are known to be energy intensive, implement system changes that promote a shared research equipment culture among scientists that benefits utilities savings and efficiency for both laboratory space and infrastructure
F	Engage University leadership to support engagement programs

[1] https://betterbuildingssolutioncenter.energy.gov/implementation-models/uc-berkeley-energy-savings-through-campus-and-occupant-engagement

System Changes Case Studies:

CU Boulder Green Labs effectively has incorporated **system changes**, including best in class/best practice information sharing and engagement at CU Boulder. Green Labs needs additional empowerment, resources, and direction/policy to serve as a model for the campus. Outreach materials developed by Green Labs includes context materials, posters, presentations, and archived newsletters Outreach Materials by Green Labs [1]

Bring Efficiency To Research (BETR) Grants connects efficiency expectations and sustainability to the funding of research leading to advances in sustainable practices in research, the efficient use of resources, and optimizing spending by reducing the direct and overhead costs of research BETR Grants [2]

In addition to creating the actions/strategies identified previously, it is recommended to use the following methods to bolster system wide policies:

EAG Ambassadors: Assign members from the EAG to provide quarterly updates to the Centers, Research Institutes and Initiatives, Student Government, and Faculty Senate on EMP policies for system scale impact. As the EAG is formalized with the authority and responsibility to implement the EMP, it is recommended that the EAG decide which groups should receive consistent reporting. It is also recommended that an EAG member be assigned to each group to create a consistent EAG liaison.

Employee Hiring and Onboarding: In collaboration with the Chief Human Resources Officer and team, the EAG should develop a strategic communication framework that integrates into the recruiting, hiring, and onboarding process. For example, outcomes of the Employee Hiring and Onboarding work stream could be to include information about energy policies and sustainability initiatives in the job description, interview, and offer letter. Other areas include energy efficiency and sustainability training in a module of standard employee onboarding and annual retraining. A formalized structure would drive the culture of energy efficiency and sustainability, while enabling employees to increase participation in these initiatives through program development and action groups.

7.2 Awareness Campaign

The following are identified actions/strategies comprising a large-scale Awareness Campaign designed for knowledge sharing and promoting the on-campus and online culture for energy efficiency and implementation of the EMP. The Awareness Campaign develops consistent brand identity through the Sustainability Communication Group. The Awareness Campaign actions/strategies are best combined with events and activities found in University Engagement.

[1] https://www.colorado.edu/ecenter/greenlabs/outreach-materials

[2] https://betrgrants.weebly.com/

Awareness Campaign	
	Actions/Strategies:
A	Dashboards and Interactive displays
B	Student and Employee Orientation
C	Centralized Website/ One-Stop-Digital-Shop (see following page for description)
D	Social Media Tool Kit and consistent brand development
E	Branded Posters
F	Digital Newsletters and Fact Sheet Emails
G	Sustainable Map and Campus Tour

Awareness Campaign Case Studies:

Study by Western Michigan University sharing **dashboard effect research**: College campus that had dashboards in each dorm in conjunction with a competition saw energy reduce by 55 percent over 7 weeks. Energy use continued in a downward trend after study. The Student Union (Bernhard Center) saw "significant" decline in energy use after dashboard instillation (ongoing reporting is needed, because this tends to taper off over time)
The Effects of Energy Dashboards and Competition Programming on Electricity Consumption [1]

Swarthmore College utilized **posters and signage** to turn off lights and unplug electronic devices, which—in conjunction with LED installation, timers, and other efficiency upgrades—saw a reduction of 13.25 percent Swarthmore College OP-5: Building Energy Efficiency [2]

George Washington University provided bi-weekly newsletters, signage, and a sustainability map (distributed at events); **green tours and sustainability were incorporated in student and visitor tours** George Washington University EN-4: Outreach Materials and Publications [3]

The following activities are designed to bolster awareness:

Dashboards and Interactive Displays
Centrally placed dashboards are standard best practice across top energy-conscious institutions. This can include placing QR codes in buildings to link to performance reporting. Content and locations need to be accessible.

Student and Employee Orientation: Incorporate sustainability and energy efficiency into orientation and annual employee training. This will reinforce energy messaging on a yearly basis.

Centralized Website/One-Stop-Digital-Shop: create a CU Boulder "one-stop-digital-shop" for University-wide awareness, promotion, and monitoring of energy efficiency and sustainability initiatives. Although all materials do not need to be housed on the same web portal, links should be provided. The Digital One-Stop could be synced to push content out to social media channels.

Social Media Tool Kit: Develop a social media tool kit designed to provide consistent social media strategies for Facebook, Twitter, and Instagram that link targeted populations with EMP initiatives.

[1] https://wmich.edu/sites/default/files/attachments/u159/2015/Energy%20Dashboard%20Final%20Report.pdf

[2] https://reports.aashe.org/institutions/swarthmore-college-pa/report/2020-03-06/OP/energy/OP-5/

[3] https://reports.aashe.org/institutions/george-washington-university-dc/report/2020-03-05/EN/campus-engagement/EN-4/

Branded Posters, Newsletters, Fact Sheet Emails: For all printed and digital information, the goal is to communicate CU Boulder's goals and commitments to make sure they are widely recognized and understood. Branded topics can include awareness of "behind the scenes" action, awareness of everyday actions (turning off lights, recommended thermostat temperatures, vampire energy, and other behavioral changes to participate in or lead. It is recommended that this content be coordinated with launches of programs, competitions, and events on a regular basis (e.g., quarterly).

Sustainable Map and Campus Tour: A Sustainable Map can provide self-guided information on campus. Expand campus tour content for students/visitors to include sustainability components. In addition, a guided "green tour" can be an option for students/visitors and the community.

7.3 University Engagement

The following actions/strategies are identified to address University Engagement for the biggest impacts related to energy and space efficiency, as well as overall awareness and education related to clean energy and energy resilience. These actions/strategies include activities, events/challenges, and classes.

University Engagement	
	Actions/Strategies:
A	Competitions with incentives
B	Gamification of energy efficiency with initiatives
C	Award opportunities
D	Conferences/symposiums
E	Quarterly updates from EAG Ambassadors to students, faculty, and staff
F	Expand energy and sustainability classes/curriculum
G	Expand energy awareness

University Engagement Case Studies:

Harvard Shut the Sash ongoing monthly competition to encourage researchers to close fume hoods, encompassing 19 labs and over 350 researchers. Winner gets a pizza party, bi-annual larger celebrations. Resulted in 30 percent reduction in fume hood exhaust levels, annual savings of $240,000, and 300 metric tons of greenhouse gas emissions
Shut the Sash Program [1]

UC Berkeley "MyPower" Resource Center, was set up to provide free **energy-saving tools and tips**, includingresourcesspecific energy-intensive space. Engaged student groups and university to workon and implement various energy projects myPower.[2] In addition, personal awarenesson individualcarbon footprint and sustainability can be found on the **CoolClimate Calculator** CoolClimate Network[3]

Suggestions to bolster University Engagement are discussed in further detail in the following paragraphs.

1 https://green.harvard.edu/programs/green-labs/shut-sash-program

2 https://sustainability.berkeley.edu/mypower

3 https://coolclimate.berkeley.edu/calculator

Competitions and Gamification of energy efficiency: Completions or development of games related to energy efficiency should be used in conjunction with the Awareness Campaign and incentives tied to performance, along with social media outreach. Gamification could include a QR Code scavenger hunt with prizes to find all the signs around campus to learn about energy conservation measures and renewable energy. Sub-metering in campus locations will need to occur to equip resident hall competitions. The EPA website and other institutions have resources to support hosting energy efficiency completions and energy treasure hunts.

Energy and Sustainability Classes: CU Boulder has significant coursework related to energy, sustainability, and environmental issues. Expanding these classes, summarizing all resources in a centralized website, and/or the one-stop-digital-shop is needed. Curriculum can be provided in tandem with energy competitions or larger campus engagement events.

Energy Awareness: Do-it-yourself resources for personal energy conservation education and awareness can be tied to sustainability campaigns and a centralized website with resources such as carbon footprint calculators and action steps to reduce consumption and energy efficiency awareness programs for existing and new students, faculty, and staff.

Coordinated Energy Awareness and Events: Targeted energy awareness events on campus should be coordinated with a larger schedule developed by the EAG or ESO. Energy months could be April (in association with Earth Day) and October (after students move in and National Energy Awareness month). Activities, competitions, and awards should be in conjunction with targeted outreach and energy initiatives. Student competitions could include engineering pilot projects, architectural passive solar design, and others.

Quarterly Updates from EAG Ambassadors: Regular and consistent updates need to occur through existing networks such as the CU Boulder Green Labs, residential hall Eco-Leaders for peer-to-peer education to occur, and other networks such as the Green Office Program.

7.4 Partner Engagement

The following actions/strategies are identified to address Partner Engagement for the biggest impacts related to energy and space efficiency, as well as overall awareness and education related to clean energy and energy resilience. This topic focusses on internal and external partnerships.

Partner Engagement	
	Actions/Strategies:
A	Establish a working group to leverage student and faculty expertise to support the EAG
B	Establish an energy-focused University Technical Practice Network to ask act as a hub for students, faculty, staff, and partners
C	Ongoing coordination with utility providers such as Xcel
D	Ongoing coordination with City of Boulder Representatives
E	Ongoing coordination with State Representatives
F	Leverage resources and relationships with NREL, RMI, and other energy organizations

UCLA's Sustainable LA Grand Challenge: Connects scholars and partners in Los Angeles to solve energy and sustainability challenges; targeting transforming Los Angeles through **cutting-edge research** Sustainable LA [1]

Stanford Energy Corporate Affiliates emphasizes private sector interactions, fosters cutting-edge energy research and provides sustainable support for academic institutions. Stanford Energy Corporate Affiliates [2] In addition, the **Stanford Strategic Energy Alliance** provides a vehicle for large global companies to form **research and educational relationships** with Stanford targeting a low carbon energy future Stanford Energy Strategic Energy Alliance [3]

MIT's world-class research teams link with innovators in industry and government to address energy challenge and move **solutions into the marketplace** through MITei MIT Energy Initiative [4]

Working Group to support the EAG: A working group of students and faculty should be developed to meet regularly with EAG Ambassadors to provide partnerships and expertise to solve energy challenges, create learning living-laboratory opportunities for students, and leverage resources.

Partnership Opportunities: Many academic institutions have organizations to link the private sector, government, and academia to address energy efficiency and decarbonization; CU Boulder's partnership with the National Renewable Energy Laboratory (RASEI) is an example. Partnership opportunities with private-sector companies can be expanded at CU Boulder. Furthermore, ongoing partnerships with the City of Boulder and State of Colorado representatives can be formalized through the EAG and Sustainability Council.

8. Communication and Engagement Schedule

A detailed communication and engagement schedule should be developed with the EAG, ESO, and the Sustainability Communication Group. The actions/strategies identified include the following suggested schedule:

- Quarterly presentations/briefings by the EAG to various groups
- October and April energy months with associated events and activities
- Student-run events targeted in energy months, and potentially year-round
- Ongoing monthly programs
- Regular and consistent updates/refresh of posters on campus
- Regular and consistent updates to website coordinated with social media blasts

1 https://grandchallenges.ucla.edu/sustainable-la/

2 https://seca.stanford.edu/

3 https://energy.stanford.edu/strategic-energy-alliance

4 https://energy.mit.edu/membership/#about

9. Next Steps

After approval of the EMP and formation of the EAG and the ESO, the EAG will confirm and update actions/strategies suggested in this Plan. The EAG will meet with the Sustainability Communication Group to formalize communication and engagement. The following steps are suggested:

- Kick-off and ongoing coordination with Sustainability Communication Group
- Develop policies for System Changes for communication and engagement
- Confirm "Energy Months" on campus and other important campus events/activities
- Confirm actions/strategies for communication and engagement
- Confirm schedule for actions/strategies
- EAG to identify resources in coordination with Sustainability Council for implementation
- Engage departments and student groups for relevant projects and communication/engagement activities
- Update the Communication and Engagement Plan on a regular basis—preferably every 6 to 12 months—because the Plan should serve as a living resource