Colorado Mountain College

Building Carbon Neutrality Plan

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Executive Summary

Colorado Mountain College (CMC) has committed to a goal of carbon neutrality by 2050, as part of the "President's Climate Commitment" made in 2009. Carbon neutrality has been defined in this document as reducing emissions to the extent possible and then offsetting any remaining carbon emissions generated from building energy use (on-site and source emissions) and vehicle transportation with on-site renewable energy sources. Building energy related carbon emissions are the largest source of Scope 1 and 2 emissions (85%) and if these are reduced after implementing the building energy reduction plan described here, Colorado Mountain College can achieve carbon neutrality with the installation of cost efficient on-site renewable energy solutions such as solar photovoltaics (PV).

Energy Reduction Recommendations

After conducting on-site audits across seven Colorado Mountain College campuses during the week of 10/12/2015 and after reviewing existing building energy data, the following chronological strategy has been developed in order to reach carbon neutrality. Together these strategies are estimated to save Colorado Mountain College 47% of annual energy usage or 25 million kBtu/yr. The total estimated implementation cost is $5.2 million with an estimated simple payback of 6.2 years and 16% return on investment. This cost includes approximately $200,000 to Implement College Wide Energy Monitoring System, $1.7 million to Invest in Building Enclosure Commissioning and Envelope Upgrades, and $3.3 million to Implement Mechanical and Lighting System Improvements

First, Colorado Mountain College should invest in a college wide energy monitoring system to provide the proper data infrastructure, identify equipment performance problems, and track the performance of implemented solutions. Currently CMC uses Energy Navigator which shows building-level energy use and cost and is publically accessible to students, CMC employees, and the community. However, this tool does not provide the detailed equipment-level metering needed for energy efficiency measure identification and verification and not all building data is automatically transferred to Navigator. Concurrently, CMC should conduct envelope commissioning on a number of buildings to identify areas for improvement and invest in envelope upgrades. Then, with proper energy monitoring in place to provide building usage data and with tight envelopes mitigating building loads, Colorado Mountain College can focus on the most cost effective mechanical and lighting system upgrades. Finally, installing on-site Solar Photovoltaic capacity will result in CMC reach the carbon neutrality finish line while potentially creating new revenue source for the college.

Table 1 – CMC Building Energy Reduction 5 Year Plan

	2016	2017	2018	2019	2020
Implement Energy Monitoring System	■				
Building Enclosure Commissioning	■	■	■		
Mechanical and Lighting Improvements		■	■	■	■

1. **Implement College Wide Energy Monitoring System:** Without the proper data, it is difficult to make effective and meaningful decisions as they relate to building energy retrofits. An energy monitoring system with a dashboard will make building systems' operational characteristics more transparent and will give facilities personnel effective, micro level (building specific) real time data in order to ensure proper operation and to show proof of concept for projects that have been implemented.
2. **Invest in Building Enclosure Commissioning:** In cold climates especially, infiltration through building envelopes is responsible for significant heating energy losses and for occupant discomfort. Commissioning of a building's envelope identifies how leaky a building actually is and identifies areas where improvements can reap energy savings and increase occupant comfort.
3. **Implement Mechanical and Lighting System Improvements:** Investing in lighting and mechanical system upgrades will increase the effectiveness of existing systems, improving both comfort and efficiency.

On-Site Renewables with Solar Photovoltaics

4. **Install On-Site Solar Photovoltaics (PV):** Placing 5.94 MW of new PV on available building rooftops (2.56 MW) and carports over parking lots (3.38 MW) is enough for Colorado Mountain College to reach carbon neutrality, after implementing the recommended energy reduction strategies. The proposed combination of building rooftops and carports is estimated to cost $19.6 million to install enough solar PV onsite to offset building and vehicle emissions, though solar gardens may also be considered. This includes selling electricity generated directly to the utility; an alternative approach is direct consumption where PV electricity generated is supplied directly to the building first, and any access is stored in batteries or sold back to the utility. Cost-effective financing strategies, such as a Power Purchase Agreement (for which CMC has used for previous solar PV installations), should be explored because the 30% federal tax incentive for solar PV is not available to nonprofits like Colorado Mountain College.

Table 2 – Possible PV Installation Schedule

	2016	2017	2018	2019	2020	2021+
PV Installation (kW)	300	400	530	710	940	3,060
PV Installation Cost ($ in 1000s)	900	1,200	1,600	2,120	2,970	10,730

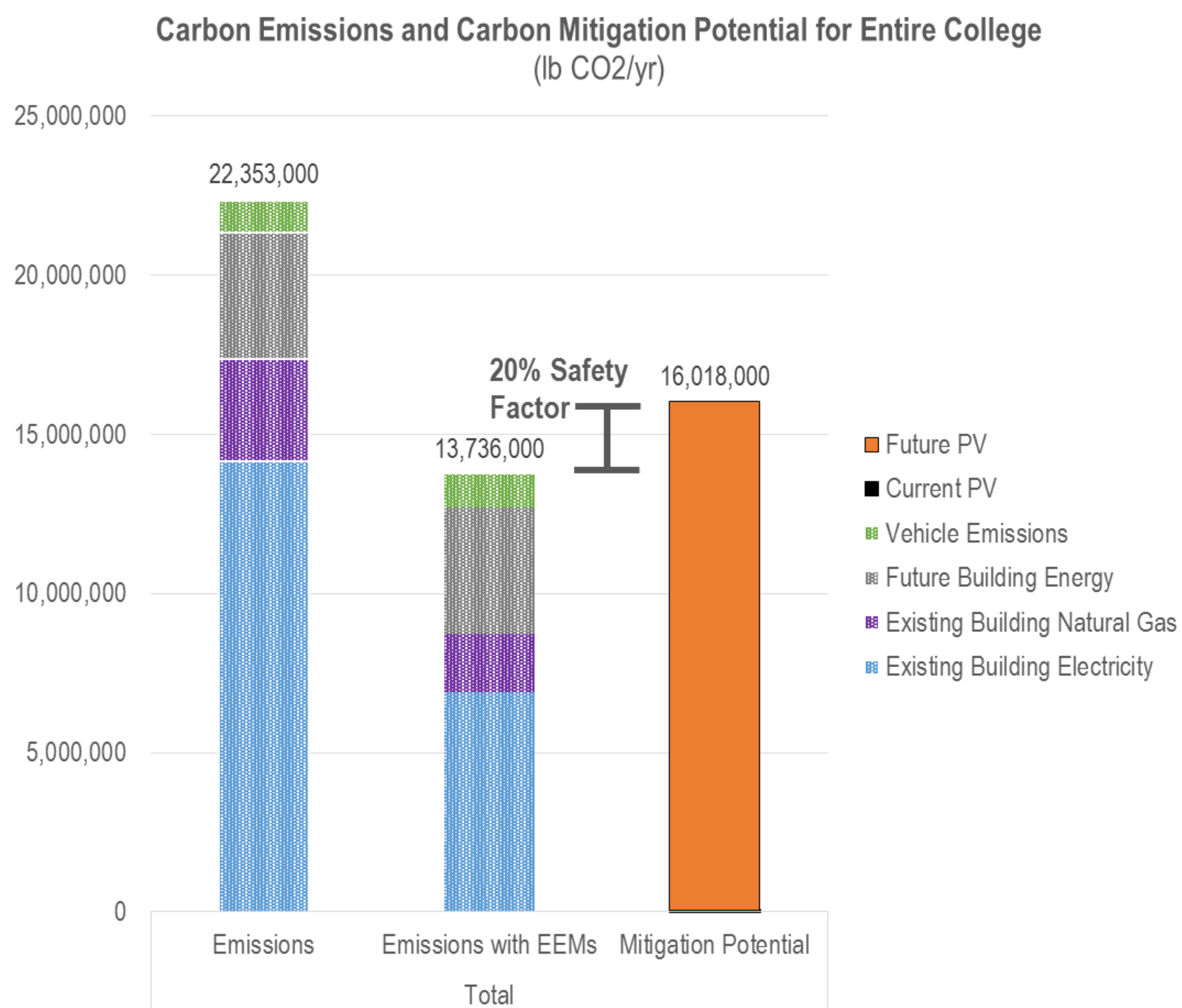

Figure 1 – CMC Carbon Emissions and Mitigation Potential[1]

Energy Reduction Plan

One of the greatest opportunities for significant reduction in energy, cost and GHG emissions identified is to control off-hours energy usage. Off-hours energy usage is defined as the energy used by a building when it is not occupied.

Table 3 summarizes the estimated impact of off-hours energy usage, or the energy consumed during hours that the building is not occupied.

Table 3 – Colorado Mountain College Time of Use Energy Breakdown

Building Name	Campus	Total Load Annual Energy (kBTU/yr)	Average Electrical Base Load (kW)	Average Gas Base Load (Therm/hr)	Base Load Annual Energy (kBtu/yr)	% Total (Base/Total)
Academic Bldg	Alpine (Steamboat)	4,950,000	47	1	764,000	15%
Building	Edwards	6,670,000	35	3	1,531,000	23%
Calaway Academic	Roaring Fork	2,780,000	72	-	893,000	32%
Hill Hall	Alpine (Steamboat)	3,800,000	32	2	1,124,000	30%
Breckenridge	Summit	3,840,000	23	1	534,000	14%
College Center	Roaring Fork	1,910,000	33	-	415,000	22%
Bristol Hall	Alpine (Steamboat)	2,860,000	25	2	920,000	32%
Encana Academic	Rifle	1,890,000	30	1	617,000	33%
Sopris Hall	Roaring Fork	1,520,000	43	-	540,000	35%
Glenwood Center	Roaring Fork	1,460,000	23	0	351,000	24%
College Center	Leadville	1,950,000	2	1	512,000	26%
New Discovery	Leadville	2,420,000	20	2	857,000	35%
Quigley Library	Roaring Fork	980,000	13	-	166,000	17%
Library	Leadville	2,290,000	7	2	819,000	36%
Dillon Center	Summit	1,270,000	15	1	400,000	31%
Climax Building	Leadville	1,590,000	7	1	454,000	28%
Total		42,180,000			10,897,000	26%

(1) Average electrical and average gas base loads were calculated by observing week long trends of electricity draw and gas for the first weeks of December, August, and April from the Building Energy Navigator. The constant load in each of these trends was averaged to arrive at the "Average Base Load".
(2) Only buildings with data available on the Building Energy Navigator are included in this table.

The following strategies laid out in this report are aimed at first mitigating the base load and then employing efficient technologies to reduce the total load.

[1] Carbon emission factors of electricity from the WECC Rockies Grid is 0.56 lb. CO2/kBtu (1,897 lb. CO2/MWh) and carbon emissions from natural gas combustion is 0.12 lb. CO2/kBtu (53.06 kg CO2/mmBtu).

Building Prioritization

It likely may not be feasible to retrofit every one of the buildings in the Colorado Mountain College portfolio in the next 5-10 years without external financing sources. External financing could allow for energy efficiency projects to be implemented faster and at a greater scale. However, if CMC must prioritize building to work on first, the list below is a suggested set of buildings to prioritize. In this list, residential campuses are prioritized because (a) the centrality of multiple buildings will facilitate an "economy of scale" cost benefit more readily than satellite campuses and (b) at residential campuses, student residents can be utilized in order to help ensure the performance of building energy efficiency solutions.

Prioritized Buildings[2]

Leadville Campus (12,600,000 kBtu/yr, 110 kBtu/sf/yr Site EUI[3])

- College Center, Library, Climax Building, Residence Hall, New Discovery, Crown Point

Spring Valley Campus (14,700,000 kBtu/yr, 82 kBtu/sf/yr Site EUI[4])

- Calaway Academic, College Center, Quigley Library Sopris Hall

Steamboat Campus (11,600,000 kBtu/yr, 72 kBtu/sf/yr Site EUI)

- Hill Hall, Academic Building, Bristol Hall

Edwards Building (6,600,000 kBtu/yr, 104 kBtu/sf/yr Site EUI)

Summit Breckenridge (3,800,000 kBtu/yr, 104 kBtu/sf/yr Site EUI)

Aspen Morgridge Center (2,000,000 kBtu/yr, 59 kBtu/sf/yr Site EUI)

The annual energy consumption responsible from this list of prioritized buildings accounts for 80% of the total Colorado Mountain College energy.[5]

[2] Buildings are grouped by campus, and then listed in order of priority within each campus. Priority is based on building EUI, building total energy use, and building floor area.

[3] EUI = energy use intensity in units of kBtu/sf/yr.

[4] The EUI of Spring Valley was calculated by adding the "Spring Valley Main Campus Gas" total to the individual building electric energy totals.

[5] This figure is calculated using a total Colorado Mountain College Campus energy consumption of 58,000,000 kBtu/yr.

1. Implement College Wide Energy Monitoring System and Project Financial Performance Database

An energy monitoring system actively tracks the energy using components of a building. This could encompass everything from the whole building electrical meter to metering everything at the individual equipment level.

Part A: Energy Monitoring System

System Description

An energy monitoring system would work in conjunction with the existing building energy management system and is made-up of the following components shown in Figure 2:

(1) **Sensors** – records variables to be tracked, this is usually electrical power (kW), gas consumption (Btu/h), or load (Btu/h)
(2) **System Gateway** – transcribes sensor data onto common platform and puts data online, to be stored in off-site servers owned by vendor
(3) **Off-Site Servers ("The Cloud") –** stores all automatically trended data
(4) **Front-End Dashboard Software –** presents all data in visible format accessed by users

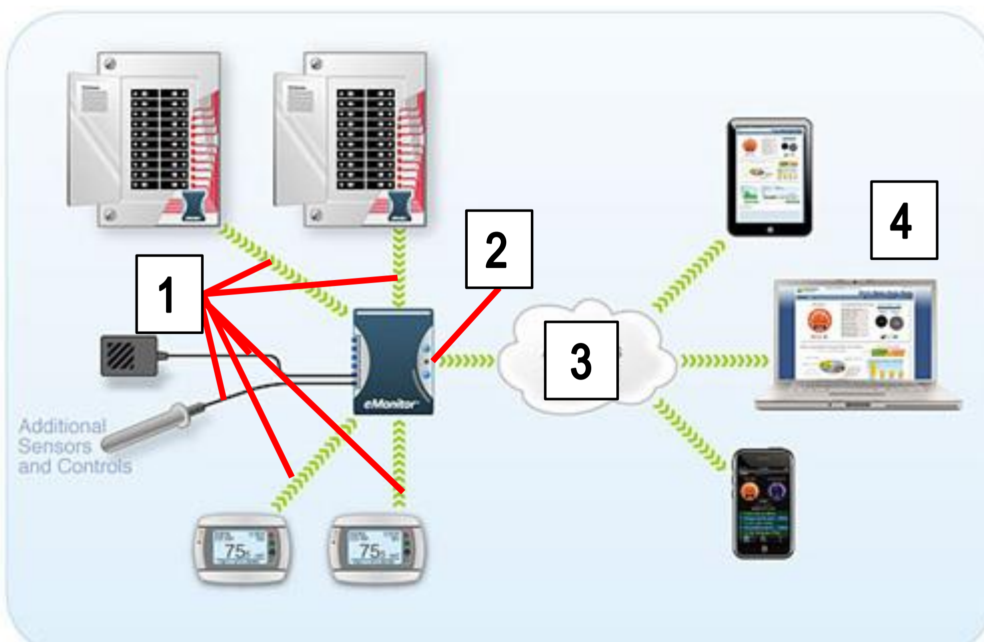

Figure 2 – Example Energy Monitoring System Diagram

(1) Sensors (2) System Gateway (3) Off-site Servers (4) Front End Dashboard Software

System Functionality

The "Front End Dashboards" of these systems consolidate all of the data and present a usable summary of a building's energy use characteristics at the equipment-level. Typically this involves:

(1) Energy Use Breakdown – % HVAC, % Lighting, % Plug Load
(2) Energy Use Trends – interval data showing what equipment is using energy and when

The main benefits of an energy end use monitoring system, which are not offered by the existing Energy Navigator system, are listed below:

(a) Makes the operational characteristics of building systems (HVAC equipment, lighting, plug loads) transparent so that facilities operators and occupants can identify energy efficiency projects and verify improved performance after energy efficiency projects are implemented.
(b) Compares the energy performance of buildings across a portfolio to identify the greatest opportunities. For example, the energy use of buildings at Leadville, Steamboat, Spring Valley, and other satellite campuses can be compared against each other under one screen.
(c) Tracks financial performance of energy efficiency projects so that successful projects have the data to support further implementation across the campus.

One of the main benefits of the existing Energy Navigator system are its easy public accessibility by interested parties such as students.

For Colorado Mountain College, an energy monitoring system could replace and/or complement existing processes and centralize the data in one area accessible by all desired parties. Specifically, there are two processes / workflows that the CMC facilities staff utilize which will become automated and more robust with the addition of an Energy Monitoring System.

A. "Building Energy Navigator" – provides trended whole building electrical and gas usage, with some data inputted automatically and some data inputted manually. The energy monitoring system recommended automatically updates all data, is designed to accept many data points, and has the software to consolidate the data into usual visualizations. The main difference between the Building Energy Navigator and the recommended energy monitoring system is the granularity of data that is feasible with the addition of an energy monitoring system.
B. "Energy Management Project Tracking" worksheet – provides a summary of the annual energy consumption for all Colorado Mountain College campuses, tracks the implementation of projects, and has a 'payback template' to estimate the economic success of projects. The energy monitoring system recommended will automatically track and record the performance of all buildings connected, comparing them against each other to identify where problem areas lie. In addition, the recommended system offers modules to input and track the financial success of energy efficiency projects.

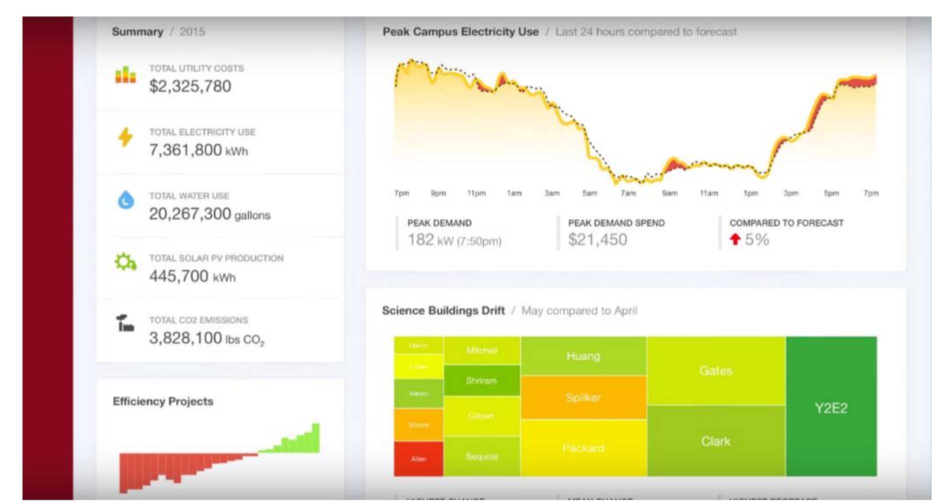

Figure 3 – Example Energy Monitoring Dashboard Front-End (Lucid Building OS Front-End is used in this example)

(1) This particular screenshot of the Lucid Building OS Front-End displays relevant totals for a portfolio of buildings. These include (a) total portfolio energy usage and cost (left side of screenshot), (b) trended data updated automatically (middle top of screenshot), (c) representation of energy use by specific building (middle bottom of screenshot, green / yellow / red blocks).

Data Granularity

The key feature of an energy monitoring system is its ability to granulate the energy end use of a particular building. For example, a typical energy monitoring system will be set up so that facilities staff can identify what equipment is using the most energy and when specific equipment energy is being used. It is recommended that, at a minimum, the following building end-uses should be separated and tracked on the system and data recorded at 5-minute intervals or less to allow for sufficient visibility into equipment performance:

1. Total Building Electricity
2. Total Building Gas
3. HVAC Electricity (large equipment should be prioritized)
   - Ex) Chillers, Pumps, Large Fans, Package Units, and Fan Coil Units (individual smaller units can be combined onto a meter)
4. HVAC Gas
5. Lighting
6. Plug Loads (total plug load energy can be calculated by subtracting submeters of the above equipment from the total building electricity use)

System Cost

Depending on the infrastructure already in place at a building, recording these data points can happen at little to no cost. However, it is likely that additional electrical / gas meters need to be installed in order to capture the proper granularity. For electrical meters, there is a company called eGauge local to Colorado which makes affordable electrical meters (~$500 per meter).

Identified energy monitoring vendors have a similar pricing model in that the price to implement a system is broken into two components:

1. **Implementation** - cost to install necessary sensors and consolidate data streams onto a common platform
   a. *Fee Range:* $5,000 - $10,000 per building (includes materials and labor)
2. **Annual Fee** – cost to maintain front-end software license, pays for remote upkeep and software updates
   a. *Fee Range:* $2,000 / yr - $4,000 / yr per building OR $15,000 / yr - $30,000 / yr per portfolio of buildings (e.g. ~20 buildings)

Costs will be highly dependent on the actual parameters of a specific project; these costs are meant to give a range of expected costs based on actual implementation costs. Colorado Mountain College should send out Request for Proposals (RFPs) to vendors listed below in order to get actual costs.

Three vendors – Lucid, Schneider Electric, and Switch Automation have been identified and offer the capabilities recommended for Colorado Mountain College (**Error! Reference source not found.**).

Table 4 – Energy Monitoring System Vendors

Vendor / System	Advantages	Disadavantages	Contact Info
Lucid: BuildingOS	Attractive data visualizations, user friendly interface, utilizes electrical meters from company in Colorado (eGuage)	Only a software company; has partnerships with sensor companies and contractors to physically implement equipment	Cole Schoolland cole@luciddg.com (510) 907 - 0400
Schneider Electric: Facilities Insight	A "turn-key" solution - offers both the software and sensors (electrical) necessary to operate system.	A new product offering from Schneider among many other product offerings by Schneider, could receive less attention as result	Laura Perek laura.perek@schneider-electric.com (619) 873 - 6123
Switch Automation	Comprehensive system offering ability to control data points in addition to monitoring them	Robustness of system makes smaller scale implementations less feasbible.	Darlene Bereznicki dbereznicki@switchautomation.com (415) 712 5853

Utilizing the Data

Identify Proper Scheduling

A significant strength of an energy monitoring system is its ability to identify systems with improper scheduling, or systems that stay ON when they should be OFF. This is a simple, yet powerful, functionality that will allow facilities staff to identify areas where energy is being wasted, and to ensure that solutions implemented to fix this actually work and stay working over time.

Student Involvement

As a college campus, Colorado Mountain College has a unique opportunity to engage their students using the transparency of data that an equipment monitoring system offers. Many issues that an equipment monitoring system uncover are easy fixes (e.g. lights staying ON), that can be identified and fixed by students if empowered with the data.

A student intern could be responsible for reviewing the dashboard trend data on a regular (daily or weekly) basis to help facility staff verify equipment is operating properly and also identify equipment that may not be properly scheduled.

Having an easy to understand equipment energy trend dashboard also helps students succeed in energy-reduction activities like dorm competitions.

Third Party Building Energy Engineers Consultants

Throughout the course of a year, data could periodically be analyzed in detail by engineers qualified to make recommendations on larger equipment and larger systems. This would make the most sense after a year's worth of complete data has accrued. The data will give an engineer valuable insight into how the existing building is actually operated (e.g. actual heating / cooling loads, efficiencies, controls operations, and granulized energy use data), with which he or she can (a) suggest the most relevant and effective solution and (b) perform a very accurate life cycle cost analysis to illustrate the feasibility of a suggested project. This scope of work could potentially be completed by CLEER, with which CMC has an existing contract to support Energy Navigator energy tracking activity.

Financial Assessment of Energy Efficiency Projects

One of the advantages of actively monitoring granulized energy data is the added ability to track the performance of buildings before and after implementing energy efficiency projects. In order to properly assess the economic performance of a project, the following data is necessary:

(a) Project First Cost ($)
(b) Annual energy savings (kWh/yr, therm/yr, or kBtu/yr)
(c) Annual energy cost savings ($/yr)

An electrical monitoring system can provide accurate data for items (b) and (c), but also offer modules within the software for facilities personnel to input the first cost of a project and associate that cost with an energy data point in the system (e.g. lighting energy, chiller energy, etc.). This way the system can automatically track and record the financial performance of efficiency projects as they are implemented, providing valuable data on what aspects worked and what did not. This data will lead to the most cost effective measures to be implemented and implemented at a much larger scale with tangible data to back performance.

2. Building Envelope (Enclosure) Commissioning and Improvements

Infiltration, as it relates to building design, is the unintended leakage of outside air into a conditioned space. In cold climates like Colorado, infiltration is a major factor in a building's heating energy consumption and has been shown to account for a third of the total heating energy over the course of a year[6].

It is estimated that close to 20% of Colorado Mountain College's heating energy consumption is due to building infiltration[7]. Besides energy implications, leaky buildings can cause occupant discomfort. In order to quantify an existing building's envelope performance and to identify ways to improve it, a building can undergo "Building Enclosure Commissioning".

Investing in improving a building's envelope is investing in a solution that will last 30+ years and that will operate reliably over the course of its lifetime; as compared to mechanical and equipment which typically have shorter lifespans.

Building Enclosure Commissioning Process (Air Barrier Testing)

The goal of building enclosure commissioning is to:

(a) Quantify building's infiltration rate (cfm/sf)
(b) Identify leakage areas through thermography photography

First the building is sealed at known exit points, than pressurized to create a pressure difference between the outside and building inside. The infiltration rate, described as the flow rate over the surface area of the building envelope (exterior walls, roof, floor), is the rate at which outside air leaks out of a building while the building is positively pressurized during the test.

Once the building is pressurized and leakage occurs, a thermal image is taken to identify where leaks are occurring.

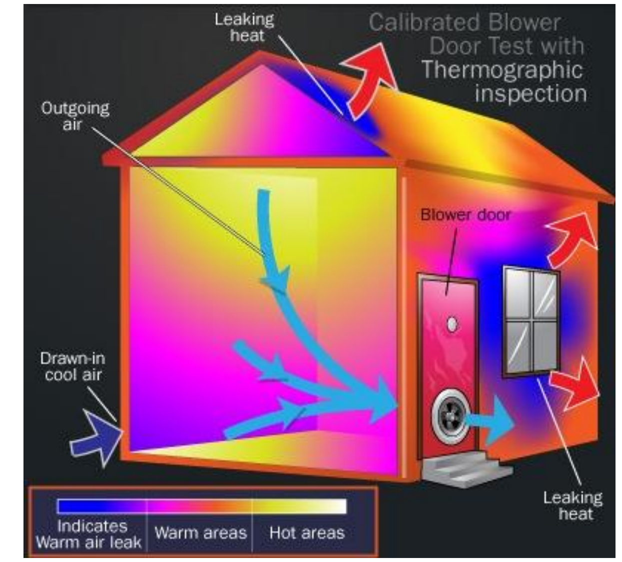

Figure 4 – Building Enclosure Commissioning Pressurization Test Schematic

Utilizing the Results

The results of a building enclosure commissioning process will include a report, which summarizes the building's effective infiltration rate (cfm/sf) and an identification of where problem areas exist. Old buildings generally have a leakage rate between 0.3 – 1.0 cfm/sf where a high efficiency envelope will have a leakage rate of 0.10 cfm/sf.

There are two levels of improvements that can be implemented on a building envelope, as informed by enclosure commissioning. The first level is repairing the "low-hanging fruit" opportunities, which are usually one or all of the following:

(1) Penetrations resultant from poor sealing of windows
(2) Penetrations in hidden areas, for example between floors
(3) Penetrations in poorly sealed doors
(4) Leaky outside air intake or relief dampers in mechanical systems allowing outside air through ducts.

Other improvements require more intrusive work by contractors to peel back layers of the envelope to identify and fix a problem. This is more expensive work, and should be considered in very poor performing buildings or in buildings where major renovations are already being planned.

[6] "Impact of Infiltration on Heating and Cooling Loads in U.S. Office Buildings" by Steven J. Emmerich. http://www.infiltec.com/PAPER2005042_Emmerich_AIVC_energy.pdf

[7] The is calculated using "Impact of Infiltration on Heating and Cooling Loads in U.S. Office Buildings", which estimates 33% of a buildings cooling and heating load is due to poor infiltration. These results are calculated using whole building energy simulations. The 20% of CMC energy consumption value was calculated by multiplying the total gas load of CMC's site by 33%.

Cost of Enclosure Commissioning

The cost of enclosure commissioning is commonly overestimated. In an effort to quantify the cost effectiveness of enclosure commissioning, a study was done where the cost of a number of different enclosure commissioning projects where quantified. The results are shown in the figure below.

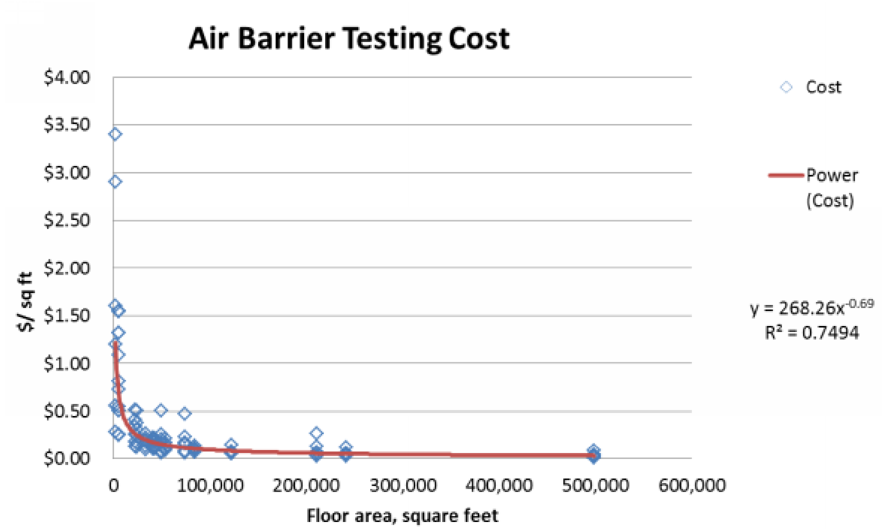

Figure 5 – Cost of Enclosure Commissioning[8]

The figure above demonstrates that, for most projects, the cost of performing enclosure commissioning falls somewhere in the $0.10 - $0.50 per sf range. Note that this cost only includes the cost to perform enclosure commissioning. Costs of envelope upgrades are estimated to be $1.7 million for the whole college and will vary depending on the findings of envelope commissioning.

Below is contact information for a firm which provided information included in this report, and who can provide the necessary envelope enclosure testing.

Dale Stevens, Project Manager at Intertek, dstevens@archtest.com, (303) 408 7685
970 Mercury Drive Lafayette, CO 80026

[8] *"Cost-effectiveness Analysis of Building Air Leakage Testing" R. Hart, 2015*

3. Mechanical and Lighting System Improvements

After installing the proper energy monitoring infrastructure necessary to track energy use characteristics and after improving envelopes to decrease infiltration, Colorado Mountain College should invest in equipment upgrades. The reasoning behind the chronological position of this measure is that:

(A) Energy monitoring system identifies the best opportunities to invest in improvements, therefore money can be spent with more effectiveness.

(B) Improving envelope can lower to total building heating/cooling loads, leading to smaller mechanical equipment sizing when equipment is replaced.

With that being said, there are low-cost measures that can be implemented simultaneously with the implementation of an energy monitoring system and envelope improvements. Table lists the recommended equipment improvement energy efficiency measures.

Cost of Mechanical and Lighting System Improvements

Table shows typical estimated implementation costs, energy cost savings, return on investment, 10-year net present value, and simple payback for each measure. The All Measures row shows these values if all measures are implemented at all potential buildings.

On-Site Renewables with Solar Photovoltaics

Figure 6 – Rooftop PV (left) and Carport PV (right)

Placing 5.94 MW of new PV on available building rooftops and parking lots is enough for Colorado Mountain College to reach carbon neutrality, after implementing the recommended energy reduction strategies. This capacity includes a 20% safety factor of the anticipated 4.95 kW that is estimated to be needed after energy efficiency measures are implemented. The recommended strategy is to maximize rooftop solar PV capacity at around 2.56 MW because this is the most cost-effective form of PV. The available rooftop area is not enough to reach carbon neutrality, so an additional 3.38 MW of carport PV over parking lots would be needed. Carport PV is more expensive than rooftop PV and will require additional expense to remove snow to prevent snow sliding off the shallow angled panels and becoming a danger. An alternative to rooftop-mounted PV and carport PV is a ground-mounted PV system. This is the type of system CMC currently has installed at the Rifle and Leadville campuses.

The priority of PV installation should be:

- New buildings rooftop PV (most cost-effective and easiest to design)
- Carports or ground mount systems are potentially easier to scale up because of fewer obstructions to design around compared to more obstructions with existing roofs.
- Before installing rooftop PV, the existing roof age, roof replacement schedule, and roof structural capacity should be considered.
- However, carport PV is more expensive than rooftop PV and will require additional maintenance to remove snow to prevent snow sliding off the shallow angled panels and becoming a danger.
- Whenever PV is installed, the amount of PV production should be maximized at that location to reduce the amount of overhead and take advantage of all available space and provide planning flexibility.

Error! Reference source not found. shows a possible installation schedule. CMC is familiar with installing 200 kW of PV. The first year starts with installations of 300 kW of PV followed by a 1/3 growth in additional new installations each year, which will also allow CMC to take advantage of the falling prices of PV which is expected to continue. Of note, only 3.6 MW is needed to offset existing and future building electricity use, with EEMs implemented.

Table 5 – PV Sizes for Offsetting Electricity vs Carbon Emissions

PV Size Needed to **Offset Building Electricity Use** (Existing and Future Buildings w/EEMs)	PV Size Needed to **Offset Carbon Emissions** (Existing and Future Building Energy w/EEMS and Vehicles)
3.6	5.9

A survey of available rooftop space and parking lot space was conducted using Google Earth satellite images. The age and structural capacity of existing roofs were not evaluated. To estimate the solar production potential of each campus, the following standard panel efficiencies and production numbers were used:

- Rooftop and Carport PV panel density is standard efficiency 14.8 W/sf with 50% roof coverage and carport coverage over parking spaces while leaving fire truck access lanes.
- Production is estimated at 1,364 kWh/kW for rooftop and 1,452 kWh/kW for carport[9].

The current PV production from Timberland and Rifle PV arrays (~200 kW) was accounted for when calculating the additional on-site renewable capacity needed to reach carbon neutrality. These two arrays generated an annual average of 298,000 kWh/yr over 2013-2015.

Vehicle emissions are estimated as 470 metric tons of CO2 per year.

[9] National Renewable Energy Laboratory (NREL) PVWatts Calculator

Table 6 – Future Building Energy Use ("Business as Usual" EUI Emissions Estimate)

Campus	Space Type(s)	Additional Floor Area (sf)	Electricity Use (kBtu/sf/yr)	Natural Gas Use (kBtu/sf/yr)	Total EUI (kBtu/sf/yr)
Summit	Academic, Student Services	20,000	34	70	104
Central Services	Community Center, Offices	12,000	55	18	72
Aspen	Academic	25,000	23	36	59
Aspen	Residence hall	20,000	27	49	76
Alpine (Steamboat)	Residence hall	65,000	27	49	76
Roaring Fork / Spring Valley	Residence hall	40,000	27	49	76

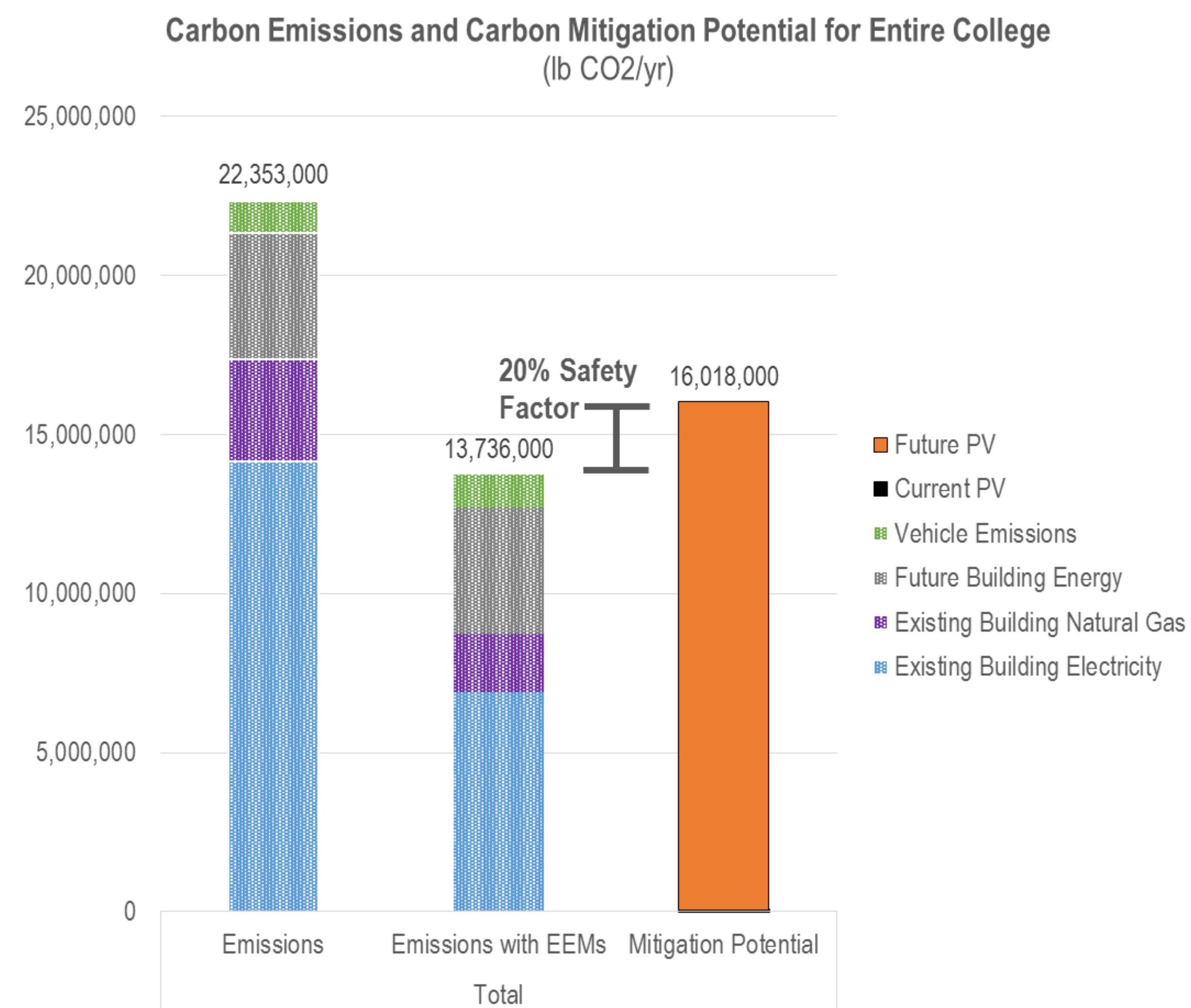

Figure 7 – CMC Carbon Emissions and Mitigation Potential

Financial Assessment of On-Site Renewables with Solar PV

The proposed combination of building rooftops and carports is estimated to cost $19.6 million to install enough solar PV onsite to offset building and vehicle emissions. This does not include any battery storage for on-site energy storage of PV power production. Cost-effective financing strategies, such as a Power Purchase Agreement (for which CMC has used for previous solar PV installations) should be explored because the 30% federal tax incentive for solar PV is not available to nonprofits like Colorado Mountain College. The financial analysis for PV shows a simple payback period above 20 years. This could be improved to below 20 years if federal and utility incentives can be captured. The 30% federal tax incentive could be captured through a lease like structure with a third party owning the panels. Depending on how the college sources its electricity, solar performance incentives provided by the two utilities, Xcel Energy and Black Hills Energy, could also be captured.

For the financial analysis, rooftop PV installation cost is estimated at $3/W and carport PV at $3.5/W. At around $3.25/W installed cost, ground-mounted PV systems are comparable in cost to rooftop and carport PV systems and may also be reduced at scale.

Operation and maintenance (O&M) costs are estimated at $19/kW/yr. In addition, electricity costs for the college as a whole are just $0.10/kWh which makes PV less attractive economically than in areas where retail electricity rates are as high as $0.20/kWh. Depending on the utility rate schedule each of the campuses pay, solar PV could reduce demand charges which would further improve the financial metrics.

The levelized cost of electricity is a useful metric for evaluating the cost-competitiveness of solar PV. In other words, this is the $/kWh cost of building and operating PV over its estimated 25 year financial life. At the full build-out of solar PV, the levelized cost of electricity from solar PV is $0.15/kWh. This number is higher than the current utility cost of electricity which has been purchased at an average price of $0.10/kWh. This is because at the full build-out of solar PV, there is more electricity production than electricity consumption. The extra electricity production is to offset carbon emissions of natural gas use and college-owned vehicles. This extra electricity production cannot be credited at retail electricity rates. Instead it is bought back by the utility at lower wholesale rates (estimated at $0.04/kWh).

The levelized cost of electricity is also reflective of current net metering rules allowed by utilities in Colorado which allows excess electricity generation during the day to be credited back at retail rates for consumption from the grid at night. It is uncertain if net metering rules as they are defined now will exist in the future because many utilities across the country have been advocating for removing net metering rules.

Table 7 – Energy Efficiency Measure Details and Timeline

Timeline	Measure	Description	Example Building(s) For Measure Calculation	Annual Electricity Savings (kBtu/yr)	Annual Natural Gas Savings (kBtu/yr)	Annual Cost Savings ($/yr)	Estimated Implementation Cost ($)	Return on Investment (%)	10-Yr NPV [1] ($)	Simple Payback (yr)
Year 1	Implement Energy Monitoring System	Implement "universal" system capable of displaying and tracking all building system performance.	Leadville (whole campus) Spring Valley (whole campus) Steamboat (whole campus) Edwards Breckenridge	1,553,500	1,762,700	$ 59,400	$135,000 implementation cost + $30,000 per year	22%	$ 179,800	2.3
Year 2-4	Conduct Building Enveloope Commisioning and Implement Improvements	Commission existing envelopes to identify areas of opportunity, invest in improvements where appropriate.	Leadville (whole campus) Spring Valley (whole campus) Steamboat (whole campus) Edwards Breckenridge	-	6,980,500	$ 55,200	$ 1,161,400	5%	$ (626,100)	21.1
Year 2-5	Reduce Total Lighting Fixtures and Replace with LEDs	The improved lighting quality of LEDs will allow for less fixtures necessary to light an area, as compared to the existing fluorescent fixtures. Therefore, when installing LEDs, use less fixtures than the number of fixtures existing before.	Hill Hall (Steamboat) Lighting	202,300	-	$ 6,200	$ 21,400	29%	$ 39,300	3.4
	Controls to Mitigate Non-Occupied Energy Usage for HVAC equipment	Implement automated controls to ensure HVAC equipment stays OFF when it is not needed. This can be accomplished through aggressive space temperature set-point resets.	Library (Leadville) HVAC	68,000	341,700	$ 5,500	$ -	n/a	$ 53,400	n/a
	VFDs on Chilled Water and Hot Water Pumps	In any situation where 2-way valves exist , install a Variable Frequency Drive (VFD) to modulate pump power according to demand.	New Discovery (Leadville) HW Pumps	34,400	-	$ 900	$ 3,100	30%	$ 5,700	3.4
Year 4+	LED Fixtures with Automated / Digital Control	Automated lighting control systems can be expensive for retrofits, but when paired with a fixture replacement that would happen anyway, the incremental cost of adding automated control becomes feasible.	Bristol (Steamboat) Lighting	389,000	-	$ 12,000	$ 64,500	19%	$ 52,000	5.4
	Implement Ground Source Heatpumps as Replacements [2]	The heating efficiency associated with electrically driven ground source heat pumps can be triple that of a typical boiler. In addition, utilizing electricity instead of gas can allow for solar power to offset heating demand.	Callaway Academic (Spring Valley) HVAC	170,100	1,581,100	$ 3,300	$ 99,000	3%	$ (66,800)	29.8
	Choose Condensing Boilers as Replacements [2]	In situations where ground source heat pumps are not feasible for replacing an old boiler, use condensing boiler, which have efficiencies >95%.	Morgrdige Center (Aspen) HVAC	-	124,400	$ 1,300	$ 2,600	50%	$ 10,100	2.0
Year 1+	All Measures	All Measures	All Campuses	13,060,300	11,604,300	$ 840,300	$ 5,216,200	16%	$ 2,676,300	6.2
Year 1-10	On-Site Solar PV	Maximize rooftop solar PV and install carport PV to the extent that the whole college reaches carbon neutrality.	All Campuses	-	-	$ 847,400	$ 19,556,000	4%	$ (12,317,400)	23.1

[1] For measures with a negative 10-Yr NPV, the 30-Yr NPV is positive because cost savings continue to accrue through those longer time periods.
[2] Includes incremental cost of ground source heat pump system over standard efficiency hydronic boiler.
[3] Includes incremental cost of condensing boiler over standard efficiency hydronic boiler.

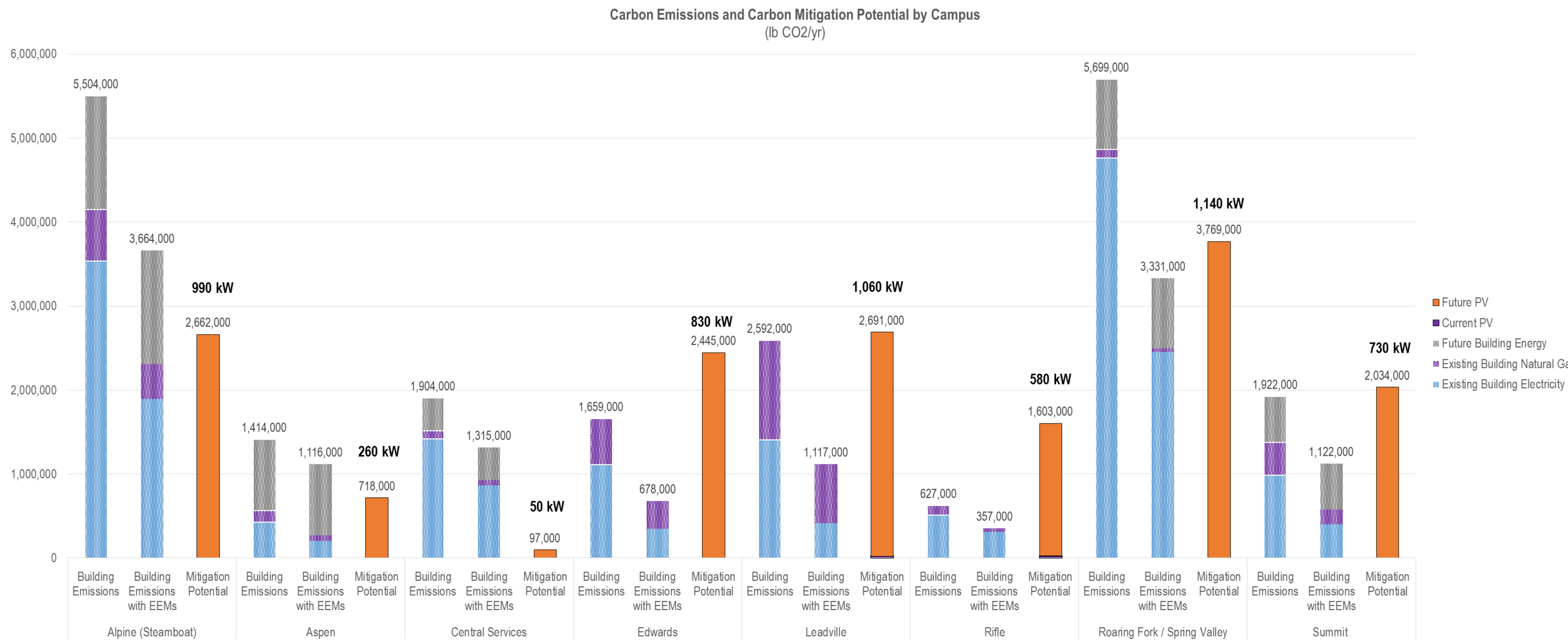

Figure 8 – Carbon Emissions and Mitigation Potential by Campus

Table 8 – Rooftop and Carport PV Available Capacity and Capacity Needed

Campus	Rooftop (Future PV)			Parking (Future PV)			Total (Future PV)		
	Available Capacity (kW)	Capacity Needed (kW)	% of Available Capacity	Future PV Available (kW)	Future PV Needed (kW)	% of Available Capacity	Future PV Available (kW)	Future PV Needed (kW)	% of Available Capacity
Alpine (Steamboat)	440	440	100%	870	550	63%	1,310	990	76%
Aspen	90	90	100%	270	170	63%	360	260	72%
Central Services	50	50	100%	0	0	N/A	50	50	100%
Edwards	190	190	100%	1,000	640	64%	1,190	830	70%
Leadville	600	600	100%	720	460	64%	1,320	1,060	80%
Rifle	250	250	100%	520	330	63%	770	580	75%
Roaring Fork / Spring Valley	690	690	100%	1,180	750	64%	1,870	1,440	77%
Summit	250	250	100%	750	480	64%	1,000	730	73%
Total	2,560	2,560	100%	5,310	3,380	64%	7,870	5,940	75%

Table 9 – Building Energy and Carbon Emissions and Mitigation Potential

Campus	Building Energy Use			Building Carbon Emissions				Building Energy Generation		EEM Potential Energy Savings		Carbon Emissions Mitigated				
	Electricity (kBtu/yr)	Natural Gas (kBtu/yr)	Total (kBtu/yr)	Electricity (lb CO2/yr)	Natural Gas (lb CO2/yr)	Future Buildings (lb CO2/yr)	Total (lb CO2/yr)	Future PV (kBtu/yr)	Current PV (kBtu/yr)	EEM Savings Electricity (kBtu/yr)	EEM Savings Natural Gas (kBtu/yr)	Future PV (lb CO2/yr)	Current PV (lb CO2/yr)	EEM Savings Electricity (lb CO2/yr)	EEM Savings Natural Gas (lb CO2/yr)	Total (lb CO2/yr)
Alpine (Steamboat)	6,357,349	5,255,075	11,612,424	3,534,105	614,724	1,355,060	5,503,889	4,788,458	0	2,944,750	1,730,288	2,661,945	0	1,637,011	202,404	4,501,360
Aspen	771,443	1,181,939	1,953,382	428,852	138,260	846,572	1,413,683	1,290,686	0	402,429	635,552	717,503	0	223,714	74,345	1,015,562
Central Services	2,549,066	825,007	3,374,073	1,417,048	96,507	389,857	1,903,411	175,285	0	989,484	327,570	97,442	0	550,063	38,318	685,823
Edwards	2,001,509	4,671,106	6,672,615	1,112,656	546,413	0	1,659,069	4,397,938	0	1,374,670	1,847,040	2,444,851	0	764,191	216,061	3,425,103
Leadville	2,532,350	10,123,992	12,656,342	1,407,755	1,184,276	0	2,592,031	4,799,409	40,722	1,781,539	4,136,777	2,668,032	22,638	990,373	483,908	4,164,951
Rifle	921,936	972,394	1,894,330	512,512	113,748	0	626,260	2,836,243	46,598	363,370	577,180	1,576,692	25,904	202,001	67,517	1,872,113
Roaring Fork / Spring Valley	8,569,233	865,907	9,435,140	4,763,710	101,291	833,883	5,698,884	6,780,135	0	4,150,756	519,187	3,769,135	0	2,307,441	60,733	6,137,309
Summit	1,778,222	3,334,409	5,112,631	988,529	390,050	543,437	1,922,016	3,658,114	0	1,053,287	1,830,747	2,033,577	0	585,531	214,156	2,833,264
Total	25,481,108	27,229,829	52,710,937	14,165,166	3,185,267	3,968,809	21,319,243	28,726,266	87,320	13,060,285	11,604,342	15,969,177	48,542	7,260,324	1,357,443	24,635,486