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RECAPITALIZING AGING INFRASTRUCTURE FOR A NET-ZERO FUTURE

by

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in partial fulfillment of requirements for the degree of

Master of Engineering Technical Management

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

EXECUTIVE SUMMARY

The Chemistry and Metallurgy Research Facility (CMR) was built in 1952. The original structure consisted of five laboratory wings and office and administration wings. Wing 9 was added in 1959 to house unique equipment and capabilities for the national security mission of the United States. At the time, a centralized heat and power (CHP) plant was the best and most efficient option for serving large campuses, as was the use of fossil fuels, so CMR was put on LANL's utility steam loop. Given the magnitude of heating energy requirements for the facility, it is a substantial greenhouse gas (GHG) contributor at Los Alamos National Laboratory (LANL) and has been for over 70 years.

Climate change and transitioning from fossil fuels to renewable energy is not new. However, the Biden administration recently signed an executive order to decarbonize all federal institutions by 2050. LANL currently uses a system of gas-fired boilers to heat almost 40 buildings on campus. The CMR represents one-quarter of the total load during winter months. Overuse and poor maintenance practices have rendered the steam system more inefficient than otherwise and have made it increasingly dangerous over time.

In the 1980s, Laboratory and Department of Energy (DOE) leadership began to have concerns about CMR's useful life, and in the mid-90s, they decided to formulate a plan for exiting the facility. A replacement project began developing in the early 2000s but has yet to fully meet the expectations of the original plan (and likely never will). Since 2007, CMR wings 2, 3, and 4 have been deactivated, but significant hazards remain, necessitating wet fire suppression and, therefore, freeze protection.

A clear and complete exit plan for program activities has yet to be determined and has once again been prolonged to 2028. Wings 5, 7, and 9 support the weapons mission and possess unique capabilities for many DOE endeavors. Future projects that will require the facility's endurance far beyond the most recently targeted exit date are planned. Champions of other DOE missions and others connected to National Nuclear Security Administration (NNSA) endeavors are seeing value in a continued contribution from the CMR facility. Whether the vision is continued use or immediate abandonment, the facility will require significant upgrades to weather the term between now and its deconstruction safely.

The CMR is still a hazard category two nuclear facility and is a risk to national security and the public, who must remain protected. The current state of utilities poses a significant safety risk to those within the building and the public should those systems fail when they are needed most. In addition to their disrepair, these systems drain resources elsewhere required for mission success, and their upkeep is an inefficient and ineffective use of taxpayer dollars. However, over the remaining life of the building, there is a way that an annual average return equal to the project's cost can be realized. By upgrading the CMR to an electrified, automated heating, ventilation, and air conditioning (HVAC) system, the facility's safety, security, and financial envelopes will all see long overdue improvements for the betterment of the institution, DOE, and the Nation.

ACKNOWLEDGMENTS

Gratitude

I would like to thank my faculty advisor, Dr. Gao, and my management chain—Aaron Perry, Steve Karpi, and Stu McKernan—for their guidance and support throughout this research. I also want to thank my friends, colleagues, and the department faculty and staff for making my time at Texas A&M University a great experience.

Thanks to my mother, Lenda, for her constant encouragement toward higher education and the assurance that I could succeed at anything.

Finally, to my wonderful, beautiful wife, Katia. You are due an abundance of gratitude for your patience, love, and tolerance of all the time and attention diverted from our lives to this graduate program; this was no small sacrifice, and I owe you a ton of overtime now that it's over.

Contributors

The Utilities and Infrastructure group at LANL provided the data analyzed/used to calculate energy consumption and costs.

The Plutonium Facilities Engineering team supporting the Chemistry and Metallurgy Research Facility at LANL provided facility system specifications and data for the HVAC analyses.

Funding Sources

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This work was also made possible with resources for infrastructure projects funded by the National Nuclear Security Administration's Office of Infrastructure (NA-90) as part of the annual institutional budget for real property operation and maintenance.

RECAPITALIZING AGING INFRASTRUCTURE FOR A NET-ZERO FUTURE

1. INTRODUCTION

1.1 Project Proposal

A. Objective

The project was intended to identify the most cost-effective and feasible means to establish an alternative to steam heating in the Chemistry and Metallurgy Research Facility (CMR) at Los Alamos National Laboratory (LANL). A pilot project would then be established to convert an isolated portion of the facility and provide a "proof-of-concept."

B. Problem Background

In 2022, the U.S. Department of Energy (DOE) established the Net Zero Labs (NZL) Pilot Initiative and allocated funding to 4 of the 17 laboratories in the DOE complex. The initiative aims to support the Biden administration's vision of net-zero greenhouse gas (GHG) emissions by 2050. DOE felt there was no better way to lead by example than to start working on the administration's vision within their department. Independent of the NZL plan, the DOE also mandated a net-zero fleet across all federal laboratories to achieve the vision by 2030. The original four laboratories identified for the NZL did not include LANL; however, the Lab will soon be added, and with an institution that employs over 15,000 people and has hundreds of buildings and vehicles, enacting these initiatives will be no small feat. To achieve deadlines, efforts need to begin sooner rather than later.

C. Project Overview

a. History

The CMR building was commissioned for use in 1952 and consisted of five similarly designed laboratory wings, an administration wing, and an office wing. In 1959, a uniquely constructed wing was added to accommodate advanced activities relevant to the national security mission. The CMR consists of approximately 560,000 square feet across three levels: two above ground and one below. Each wing has an independent HVAC system, executing an estimated 15 to 20 air changes per hour for the entire facility for an airflow of approximately 520,000 cfm. The heating capacity necessary to maintain the CMR at a suitable temperature for personnel and scientific equipment is the most significant contributor to fossil fuel consumption at the institutional steam plant.

b. Justification of Need and Impact

Nuclear research facilities need robust and reliable heating, with the average overnight low temperatures for a Los Alamos winter being well below freezing. The centralized steam plant currently provides this quality of heating; typically, there are no more than one or two short-term outages per season. Fuel prices have risen recently, though, and the cost of this reliability has become too high, both financially and environmentally. The steam system has no insulation on much of the piping, further contributing to cost through inefficiency. Repetitive high-hazard maintenance must be performed year after year and consumes a significant portion of a maintenance budget that has, at best, remained static for the last five years or more. The inability to forecast corrective maintenance on a 70-year-old system makes budgeting tricky, and overruns are a perpetual risk.

The steam plant's cost is also considerably high, as 35 facilities are still serviced. The CMR building is the largest and constitutes 25% of the steam plant capacity during winter. A utility study in 2021 estimated that the steam plant output is approximately 400,000 MMBtu per year, with ~75% of that being provided during the winter months. Of that ~75%, based on square footage and volumetric flow rate, the estimated heating energy for the CMR during an average winter is around 62,000 MMBtu. Reducing the reliance on steam would realize significant savings in fuel and preventive and corrective maintenance costs.

D. Measures of Success

Several methods were identified to define project success. The first is schedule adherence via meeting milestones. Delayed projects are often costly, and Laboratory budgets are planned and approved each fiscal year, so staying on schedule is imperative. Historical data on fuel expenditure and maintenance costs were collected and used to determine a return on investment (ROI) over the proposed life of the building (current Lab experience with building turnover to DOE-Environmental Management (DOE-EM) is on the order of 20 years).

Other criteria are more qualitative. Successful implementation and proof of concept give tangible evidence to LANL leadership and lend credibility to large-scale implementation. Proof that the CMR can be transitioned provides confidence that the other steam-reliant buildings can do likewise.

1.2 Literature Review

A. Precedence and Feasibility

To comply with the directive to completely decarbonize federal buildings by 2050, with a 50% reduction by 2032 [1], the CMR must break away from its dependence on the natural gas-fired boiler at the centralized heat and power (CHP) plant. Centralized heat and power have been the status quo in many places across the globe for more than a century. Historically, this has been the most effective way to provide these precious commodities where space and resources are limited. Since climate change is a significant concern, governments and large institutions seek opportunities to reduce their carbon footprint.

Electrification of facilities is the current directive, with the DOE recommending that buildings heated by steam convert to lower-temperature water or decentralized, smaller providers of heating and cooling [2]. The conversion to electric-powered equipment will be costly at the CMR, but some savings may be found using existing infrastructure. A study in the Baltic region suggested that reusing existing infrastructure with large-scale heat pumps could serve about two-thirds of district heating needs by 2050 [3]. In Scandinavian countries, large-scale centralized heat pumps have been used since the 1980s; Siemens Energy recently provided one for MVV in Mannheim, Germany [4].

The facilities serviced by the LANL CHP could easily be compared to those of a college campus in terms of configuration, purpose, and varying sizes. A 2022 study at Western Washington University found that a decentralized, nodal approach to heating and cooling was the most attractive option concerning the cost of ownership over the study period. Although upfront capital costs were significant, the decentralized approach resulted in a 98% reduction in GHG emissions over 50 years [5]. Similarly, the University of Oregon commissioned a study on its thermal systems and found that an 84% reduction in GHG emissions was achievable with a decentralized approach [6].

B. Operations and Maintenance Costs

The steam heating system at CMR was part of the original construction in 1952 and, without significant upgrades, is on the precipice of failure. Craft personnel work countless hours each summer to repair deficiencies discovered in winter. Inconsistency of flow from the CHP has caused steam to condense and freeze, resulting in pipe bursts. The lack of a formal small valve maintenance program and the resources to execute it has led to steam-cut valve seats, and severe corrosion has caused significant issues like stem-to-disc separation in isolation valves. Under high-temperature operations and poor maintenance, heating equipment significantly declines performance, resulting in lowered efficiency and increased fuel consumption [7].

The system has become a safety hazard with no hope of catching up on decades of lost maintenance opportunities. Since the 1950s, there have been significant advances in the design and construction of piping systems. The CMR system has many locations of potential increased wear and tear and many areas where thermal and cyclic stress can concentrate. Areas where heating media experience sudden changes in direction are particularly susceptible to corrosion, erosion, and failure, especially tee connections [8]. This has recently occurred at CMR; fortunately, it was in an uninhabited space, and there was no opportunity for injury to personnel.

System-wide overhaul and replacement is not ideal due to the complexity, scope, and high cost of materials and labor. The producer price index of steel pipe is still significantly above pre-pandemic levels, and the rising costs of labor severely compound capital costs and lower ROI [9] [10]. It is also more feasible and cost-effective to automate and control newer technology. The CMR heating system is currently controlled by mechanical instrumentation that routinely fails or needs to be recalibrated. Coupling a modern control system with a more efficient heat source can significantly reduce energy consumption and emissions while prolonging system life [11], [12].

C. Social and Environmental Concerns

Human contributions to climate change are centered around GHG emissions, with CO_2 equivalency being the unit of measure. In 2020, the energy consumption of buildings in the US constituted almost one-third of all GHG emissions, with an even higher percentage attributed to powering buildings on a global scale [13]. With the estimated 62,000 MMBtu that the CMR uses for heating, the building is contributing approximately 7.25 million lbs. of CO_2, per the natural gas emissions factor established by the EIA [6].

Legislation involving a "cost of carbon" is becoming increasingly popular, requiring businesses to purchase carbon offsets if specific criteria are unmet. In 2020, California Air Resources Board data suggested an offset of $16.93 per metric ton of CO_2 equivalents (MTCDe) [6]. These regulatory costs could be used to meet GHG reduction criteria and then be reinvested in the company after the payback period. There is also a concern about the "social cost" of carbon—the monetary cost of the damage done by each additional ton of carbon emissions. Following the Biden administration's executive order on public health and climate change, the Interagency Working Group studied that cost. Their estimate was $51 per MTCDe [6].

1.3 Business Case

A. Introduction

Concerns for the viability of the CMR building were raised in the 1980s, and the vision of decommissioning and demolishing it has existed since the 1990s. Presently, there is still no replacement for it and its unique capabilities. The CMR laboratories still heavily support the plutonium mission, and LANL struggles to implement its successor. New projects outside the weapons program are finding that the CMR still holds value and stands alone in providing the resources to execute these projects, some of which are critical to the nuclear fuel and healthcare sectors, providing resources for the good of humanity.

Replacing the CMR with a comparable facility would cost American taxpayers billions of dollars and take years to complete. Likewise, reducing the facility's hazards to a level that no longer requires vital safety systems would be costly and time-consuming. In addition to time and money, risk reduction exercises would unnecessarily expose workers to hazards that need not be addressed until final demolition. This project provides a means to maintain a valuable, habitable workspace while increasing worker safety and saving taxpayer dollars.

B. Scope

This project's initial efforts included a case study to determine which alternate heating method is most achievable. Once a method was determined and an area for the pilot project was confirmed, the remainder would be executed either by internal LANL resources or externally via an EPC (engineering, procurement, and construction) contract. Due to limited Laboratory resources, using a subcontractor is strongly encouraged. As the pilot ends and proves successful during trial runs, plans will be developed for the remainder of the building. From the alternative study to the completion of the pilot, the project timeline will span 2–3 years. If the pilot is successful, additional facility wings are expected to be converted every 6–12 months, and the process could be shared with other steam-heated facilities at LANL.

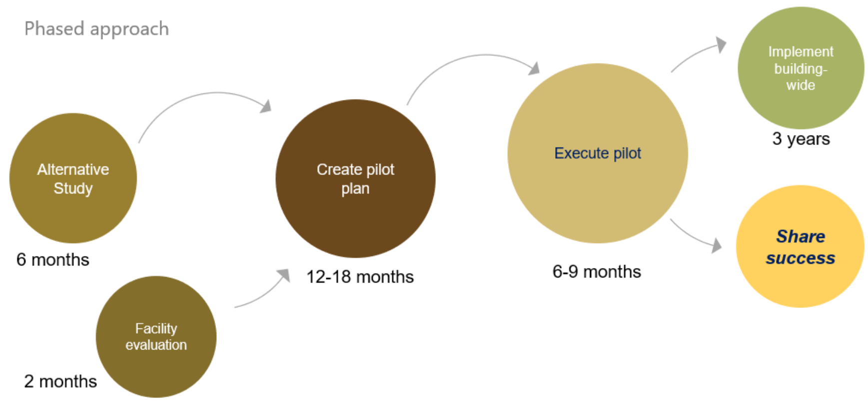

Figure 1: Phased scope flow diagram

C. Benefits

Long-term benefits that will offset immediate capital costs include reductions in maintenance labor, material costs, and energy consumption. During preliminary investigations, the project found that corrective steam-system maintenance at the CMR averaged nearly $500K annually.

There is precedent that hazardous facility turnovers to DOE's Environmental Management Division (DOE-EM) are taking an extended period of time. There are DOE-EM turnover projects forecasted out to 2037—at least one known facility is on LANL property and will be in the queue ahead of the CMR. This project will help ensure the facility's safety at a reduced cost until the radiological risks can be fully mitigated.

Electricity consumption can be sourced from renewable providers, further lowering our contribution to climate change and increasing public trust. Reduced carbon footprint lowers GHGs and the Lab's contribution to the social cost of carbon (increased health risks, groundwater pollution, etc.). Preparing the facility for continued occupancy and using existing resources lowers the environmental effects of producing and transporting new materials, avoiding the indeterminate amount of waste generated by its demolition.

Cap-and-trade type carbon offset costs are increasingly popular in some states to incentivize eco-friendly operations. It is reasonable to expect local and federal governments to move toward those policies. This effort would protect the Lab from those future costs as well. All the realized savings mentioned can either be reallocated to programs in need or not included in future budgets, saving taxpayer dollars.

D. Projected Return on Investment

Considering that steam-system maintenance has run almost $500K per year over the last few years, plus the cost of natural gas consumption, the estimated net present value (NPV)—the present value of cash inflows and outflows over a certain period—sums up to an approximate savings of $182M over the evaluation period. The consequence of maintaining business-as-usual over that same period is a cost of around $214M. Future legislation and the need to buy carbon credits could be as high as $15M. The return on investment (ROI) estimate uses the current 20–30-year discount rate for internal government projects of 2%, per Office of Management and Budget (OMB) Circular A-94, dated February 2023.

Using a graduated approach, the first few years will still incur maintenance and energy consumption costs for the portions of the facility awaiting conversion. However, all steam-system maintenance and heating-related natural gas consumption will be eliminated by the end of year five. Risk reduction efforts were assumed to still be executed during project implementation. If the plan aligns with assumptions, then by the end of the project, the inactive wings will no longer need fire and freeze protection, further reducing their operating costs.

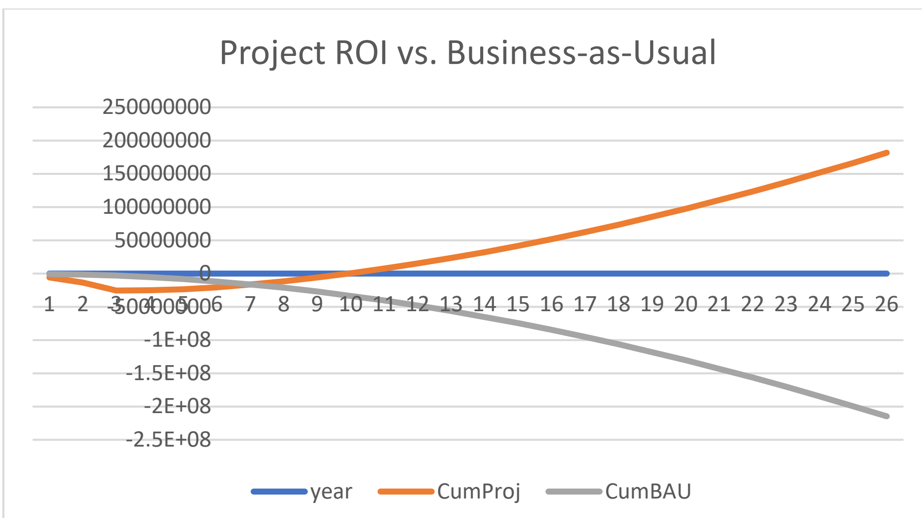

Figure 2: Original estimate of return

2. METHODS

2.1 Methodology

A. Research Design

a. Exploratory Measures

The initial project stages were exploratory and served to identify the best possible solution for converting the facility's steam heating system to an alternative method. Additional exploratory measures included research and calculations to select an alternative way to adequately heat and cool the active wings of the building. Facility management collaborated with the resident research groups and engineers to explore pilot project locations and minimize adverse impacts on mission-critical activities.

b. Confirmatory Measures

Although the project targeted a solution using heat pump technology, the intended exploratory measures were expected to confirm the target while mitigating research bias. A data set of expected ROI, reduction in at-risk maintenance and operations, and reduction in facility contribution to GHGs were collected and compared to the assumption made for the business case. When the pilot portion is implemented, the feasibility and effectiveness of continuing implementation throughout the facility and other areas serviced by the CHP will be apparent.

c. Qualitative Data

Qualitative data is derived from the facility's operational history. The risk of maintenance activities and forecasted system failure will be analyzed from a safety perspective and prioritized/ranked utilizing a risk matrix. Additional data is extracted concerning the social and moral impacts of maintaining the status quo versus implementing the project.

The perceived risks and associated consequences can be identified, and potential impacts regarding mission delays, injury time off, worker morale, and company image can be measured. Of course, no price can be levied on any employee's life or significant injury, and organizational goals are set at zero occurrences.

d. Quantitative Data

Quantitative data is processed to understand the capabilities needed to achieve adequate heating and cooling in the facility, historical cost, resource data for maintenance of the current HVAC system, and long-term ROI after project implementation. A heat-load study is underway and will provide the details necessary to size the system upgrades. Significant data from the utility group shows energy consumption for areas serviced by the CHP; this can be used to deliver savings (ROI) once reliance on the CHP is eliminated. Continued monitoring of the upgraded system will also provide long-term efficiency data to compare to historical energy consumption.

A thorough literature review will provide precedence on implementing the targeted solution, with detailed examples used as background for large institution implementation. Credible examples involve institutions of higher learning, with extensive case studies providing quantitative data on energy savings and GHG reduction from the University of Oregon and Western Washington University.

Two costs provided quantitative data in terms of ROI. The first is real (actual) cost, including capital expenditures for the project and savings realized from eliminating steam-system maintenance and fuel usage. The second data set comes from potential costs and monetized social impacts. Potential costs could be actual but have not yet been incurred due to current policy (i.e., carbon credits).

B. Participants

The investigation, planning, and execution of the project require participation across many departments within LANL and the issuance of an engineer-procure-construct subcontract. Ideally, the Laboratory would provide input to the subcontractor concerning nuclear facility safety requirements and establish the support network for activities beyond the EPC scope or disallowed per contract terms.

C. Procedure

a. Quantitative data collection

The quantifiable aspects of initial project research were gathered via

- an alternative heating study,
- energy consumption data from CHP personnel,
- the steam and HVAC system engineering design descriptions,
- an analysis of historical maintenance costs of the CMR steam system,
- a case study comparison of similar institutions,
- carbon emissions data, and
- industry data on the cost of employee injury/death.

b. Qualitative data collection

Additional data of a more intangible nature was gathered by evaluating

- potential risk reduction of facility maintenance,
- mission impact/delay reports from the research group,
- alignment with federal mandates and organizational vision, and
- safety culture impacts and employee morale.

D. Data Analysis Plan

a. Quantitative Analysis

The quantitative data collected was evaluated to compile an overall ROI for the project and provide tangible data that lends credibility to decarbonization. Maintenance cost evaluations spanned the past two years, as the craft collective bargaining agreement has recently been amended, and older data would skew the cost history. Once the heating study is complete and equipment sizing can be determined, future energy consumption can be estimated and incorporated into the long-term return calculation.

b. Qualitative Analysis

Qualitative data will be evaluated from a meets/does-not-meet perspective. Milestone satisfaction does not typically have a dollar impact on the missions supported by the CMR; however, it is still necessary to gauge mission success and must be reported. Interviews of affected workers and logs of resident complaints illustrate whether conditions have improved. Employee comfort and happiness and the delayed activity reports will be evaluated during the first winter season after implementation.

2.2 Project Plan

A. Scope

a. Early Stages

The project started with an alternative heating engineering study and heat-load calculation for the facility. These began in April 2023 and provide the foundation for determining the project's execution path. Facility evaluations were also conducted to determine the least impactful area in which to implement the pilot project. Preliminary investigations of available equipment and technology suggested that heat pump technology is preferred. Since wings 5 and 7 have existing chiller systems for cooling purposes, infrastructure and building penetrations are already in place to accommodate a heat pump system. These two wings are identical in construction and configuration, so either would be suitable and less costly than other wings for a pilot project.

b. Design and Planning

The facility design change and modification process should be conducted before implementation to ensure that the safety and integrity of the building will be maintained. Due to internal resource constraints, the project recommends petitioning for subcontract bids to ensure performance without delay and to minimize the impact on budget and schedule. Successful implementation will prove the project's efficacy, and then building-wide planning and implementation will commence.

This stage will require collaboration between the selected EPC subcontractor and LANL resources. Data provided by the Modification Engineering Department's alternative study will be used to source appropriately sized equipment, determine utility upgrade requirements, and develop a design for LANL approval. The CMR-assigned cognizant system engineer (CSE) and facility design authority representative (FDAR) will review designs at the 30, 60, 90, and 100% stages. These design approval stages will represent sub-milestones within the overall milestone of developing the execution plan.

LANL work execution management (WEM) will identify and align internal support resources as required by the subcontract and the Prime Contract with DOE. Using the resource list generated, the LANL work controls department will create the work control documents and hazard analysis required for support work packages and submit them for approval by site management.

c. Pilot Execution and Building-Wide Implementation

The Utilities and Infrastructure Division is required to implement the new heating system. The 13.2 kVA feed to the CMR site is adequate, but there are insufficient step-down transformers to support the new electrical load. Ground preparation, foundations, and support structure installation must occur before setting up the new equipment.

Once site preparation is complete, the installation of the new equipment will commence for either wing 5 or 7, and it will be retrofitted to the existing chilled water piping and supply plenum air handlers. Ideally, this execution phase will be conducted during the winter, allowing the project to install the new system while cooling is not required. Additionally, the steam system feeds into the supply air at an independent location, allowing for continuous facility heating during this phase.

The steam can be isolated from this area after commissioning the new system and verifying operability. Data collection on efficiency, fuel consumption, and maintenance costs will commence and be used to validate the pilot and determine efficacy and success. Favorable outcomes and satisfaction of success criteria will allow the project to move into Phase IV (building-wide implementation).

The building-wide implementation phase will follow the pilot project's schedule for the remaining areas of the building. Since wings 5 and 7 have almost identical compositions and the existing chiller systems are mirror images of each other, the project's next area of execution will be whichever one of them is not used for the pilot. Design, safety analysis, and preparation should move quickly, as the pilot project will provide a template for execution with very little need for modifications. Wings 1 and administration will follow, with the final implementation area, wing 9, being the most complex and costly.

B. Schedule

a. Overview

Following the sequence briefly explained in the project scope, the project schedule will progress through phases of analysis, planning, and pilot-project execution, culminating in replicating the pilot in each building area.

The data collection and analysis phases began in April 2023, using reallocated funding from a failed project in preparation for this endeavor. The alternative method and heat load/building efficiency studies were due at the end of the calendar year 2023 (CY23). They should have provided the necessary data to build a design and implementation plan. Unfortunately, circumstances involving employee turnover prevented this deliverable from being completed on time, and funding was subsequently pulled. The return of funding to a level that will allow this plan to execute is indeterminate.

Absent resource issues, the ideal schedule would have included a phase-gate interval to assess milestones and authorize continuance. For example, at 60% design completion, the required utility and infrastructure upgrades would have been known and could commence on either wing 5 or 7 during the winter of 2024–25. The pilot project would continue through 2025, and the decision to move to building-wide implementation would be made based on its performance.

The remaining wing (either 5 or 7) would commence planning, along with wings one and administration, at the beginning of CY26 and should finish mid-year 2027. Wing 9 will follow, and completion is estimated for Q2 of 2029 (Appendix B, *Project Schedule).*

b. Milestones

The project milestones have been categorized as major and intermediate, as identified in the following milestone outline:

1. Engineering Studies
    a. In-House Alternative Study
    b. Building Efficiency Report

2. Planning and Procurement
    a. 30% design
    b. 60% design
    c. 90% design
    d. 100% design
    e. Capital equipment delivery

3. Pilot Project Execution (wing 5 or 7)

4. Building-Wide Implementation
    a. Plan/procure wing 5/7
    b. Execute wing 5/7
    c. Plan/procure wing 1/administration
    d. Execute wing 1/administration
    e. Plan/procure wing 9
    f. Execute wing 9

C. Project Budget

Preliminary capital equipment estimates gave the project a rough order of magnitude of about $3M each for wings 5, 7, and 9. Wings 1 and administration are considerably smaller, costing less for equipment, material, and labor. The original total project cost (TPC) was just over $18M. Since the planning and execution phases will span approximately five years, the present value of the project's original funding request would have been roughly $25MM, including 10–15% held in management reserves. Subsequent data collection proved otherwise, and a reduced TPC is discussed in the data analysis.

PROJECT COST BREAKDOWN			
Area (by Wing)	Capital Equipment Cost	Labor & Materials	Total
Wing 5	$3,000,000	$1,320,000	$4,320,000
Wing 7	$3,000,000	$1,320,000	$4,320,000
Wing 9	$3,250,000	$3,300,000	$6,550,000
Wing 1/Admin	$1,500,000	$1,650,000	$3,150,000
		TPC	$18,340,000

Figure 3: Estimated budget

D. Resources

Because of LANL's ultimate responsibility to uphold state and federal requirements per Triad's Prime Contract with DOE, the execution of this plan will rely on the combined efforts of the EPC subcontractor and internal Laboratory resources. Once the project is greenlit, the individual staffing necessary to execute will be finalized during the planning phase.

E. Risk Management Plan

a. Identification

During the planning phase, the project team will collaborate to establish a comprehensive risk register. The primary objective is to identify potential pitfalls, devise mitigating strategies, and proactively implement preventive measures. The process requires qualitative and quantitative methodologies and a mixed-mode approach. The risk assessment spans various categories.

- safety,
- compliance/regulatory adherence,
- financial considerations,
- operational impacts,

- schedule and budgetary constraints,
- quality benchmarks, and
- political and social factors.

A 5×5 risk matrix will be used to assess the probability and likelihood of identified risks, with an assigned severity score being the product of those two values (Fig. 4). The project identified risks that will exist regardless of discoveries during the planning phase (Appendix C, *Risk Register*). Should the project receive a green light in the future, these risks will be communicated to the sponsor for disposition.

PROBABILITY | 1 – 5	IMPACT | 1 – 16	PI SCORES | 1 – 80
1 - RARE	1 - INSIGNIFICANT	1 – 2 • NEGLIGIBLE
2 - UNLIKELY	2 - MINOR	3 – 8 • LOW
3 - POSSIBLE	4 - MODERATE	10 – 16 • MEDIUM
4 - LIKELY	8 - MAJOR	20 – 32 • HIGH
5 - ALMOST CERTAIN	16 - SEVERE	40 – 80 • EXTREME

IMPACT	PROBABILITY 1	2	3	4	5
1	1	2	3	4	5
2	2	4	6	8	10
4	4	8	12	16	20
8	8	16	24	32	40
16	16	32	48	64	80

Figure 4: Risk scoring and matrix

b. Mitigation/Response

The project will be accountable to the sponsor for reporting on identified risks and efforts to mitigate and/or respond. Acceptable risk and adequacy of countermeasures are determined under the authority and approval of the sponsor. As the project progresses, the risk register will be periodically evaluated/updated and submitted to the sponsor for re-approval under the following circumstances:

- During regularly scheduled progress meetings
- When risks materialize, whether previously identified or unexpected
- Upon closeout of mitigation/prevention measures
- Before advancing through each phase gate

Under the project charter, all risks with safety implications (personnel or facility) shall constitute a pause work, with a countermeasure presented to the sponsor for approval within ten days of occurrence. Any work paused and having no plan for resolution in place by the tenth day shall constitute a formal stoppage of work. The project will identify leadership from each resource department to assemble as an emergency response team (ERT) dedicated to hastening issue resolution.

F. Research Plan Methodology

c. Method

The quantitative and qualitative techniques used to gather data supporting the project plan. Categories of collected data included:

- Alternative heating study
- Energy consumption data from CHP
- System engineering design descriptions
- Program impacts/facility availability
- Analysis and projections of maintenance costs [9] [10]
- Case study comparisons of similar institutions [5] [6]
- Carbon emissions data [13] [14]
- Industry data on cost of employee injury/death [15] [16]
- DOE guideline for the use of the Earned Value Management System (EVMS) [17]

Qualitative data supporting incalculable justifications of need, feasibility, and project benefits were evaluated via the following:

- Hazard level reduction in maintenance activities
- Engineering system health reports
- Alignment with federal mandates and organizational vision [1]
- Safety culture impacts and employee morale

d. Use of Research to Define Success

Quantitative data was used to compile an overall ROI for the project and lend credibility to its efficacy. Maintenance cost evaluations from the past two years provided a baseline for the savings generated and reduced hazardous work performed. Although not yet complete, the engineering heating studies will give numerical data to support planning and provide a reference to measure efficiency after the plan is implemented. This data will further support the projected ROI over the facility's life. The EVMS tracks expenditures against the project's planned value and timeline while providing early detection of budget and schedule impacts.

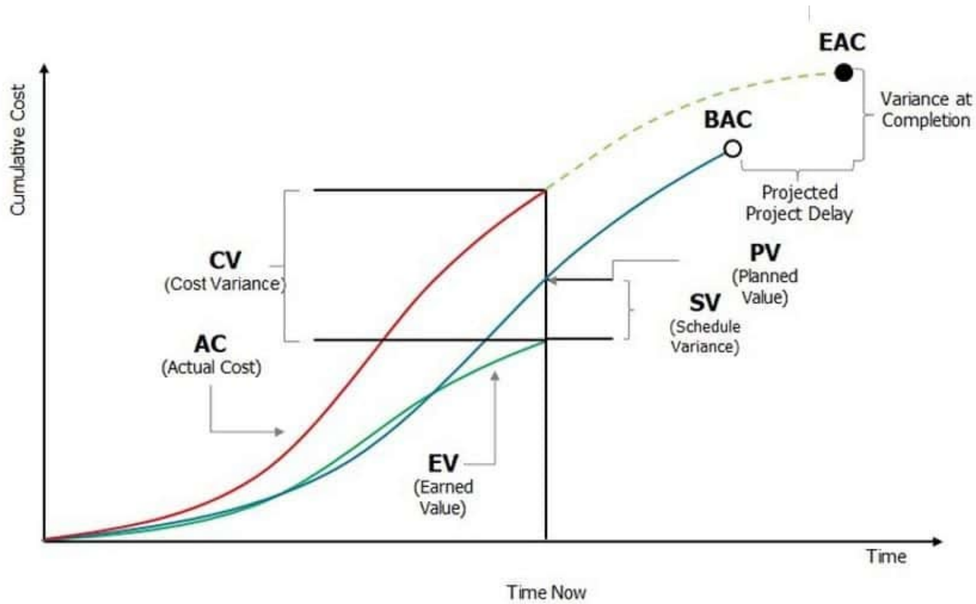

Figure 5: Example of EVMS variance tracking

Qualitative data tracks improvement within the defined category or can be used to assess go/no-go for meeting directives. Timeliness is also captured via EVMS. Between phases, interviews of affected workers will be conducted, and facility management will review logs of resident complaints about facility conditions. Employee comfort and happiness will be evaluated after implementation during the first winter season of the new system. Success metrics have been compiled to define the categories to be evaluated and the mechanisms by which they will be measured.

Table 1: Success criteria

SUCCESS MATRIX	
Increase in safety	Elimination of steam-reliant heating
	Reduction in moderate-to-high-hazard steam system work packages
Prolonged facility endurance	Reduction in corrective maintenance and equipment failures
Satisfaction of federal decarbonization requirements	Reduction in CHP natural gas consumption
Operations and cost savings	Energy cost evaluation
	PV of maintenance budget savings over facility life
	Reduction in T&E for operations surveillance
Project budget and schedule	Earned value management: cost/schedule performance indices
	Setting project milestones
	Consumption of management reserves
Mission impacts	Frequency of program interruptions/delays

3. RESULTS

3.1 Data Analysis Report

In the methodology framework, a mixed-mode approach to data collection was used to assess the project's effectiveness and impact. Qualitative and quantitative data have been collected to evaluate benefits from fiscal, safety, and production perspectives. Thus far, only exploratory measures have been executed due to budget constraints, lack of direction, and substandard/late deliverables from the engineering studies. For those reasons, this project was transitioned to an impact study and the creation of a plan under better circumstances.

A. Executed Process

The engineering department tasked with conducting the alternative heating solution study for the CMR made two attempts, and neither was an acceptable body of work. Resources and cost codes carried over into this engineering study are no longer available in FY24, and project management puts the burden of funding and delivery on the engineering department. The project remains hopeful that the ask will be met this year.

The third-party contracted to develop a plan for the CHP retirement has delayed their assessment due to difficulty in collecting data and establishing a baseline for many of the facilities. In short, the Laboratory has not kept adequate records of energy consumption and facility assessments. The full report is still pending and is expected to be ready by the end of April. The project did receive a preliminary data set of facility heat loads. The report will show less than 9% difference between updated calculations and the archived data used for the project baseline.

B. Collected Data

a. Developing Key Performance Indicators from Available Data

According to the data management and analysis firm Sydle, there are six major categories from which all key performance indicators (KPIs) are derived [18]. The collected data can be used to evaluate the project's direct impact on the major categories of financial, customer service, and human resources. By directly addressing needs in these areas, data collection and analysis will show how efforts indirectly impact the other three: quality, productivity, and strategy.

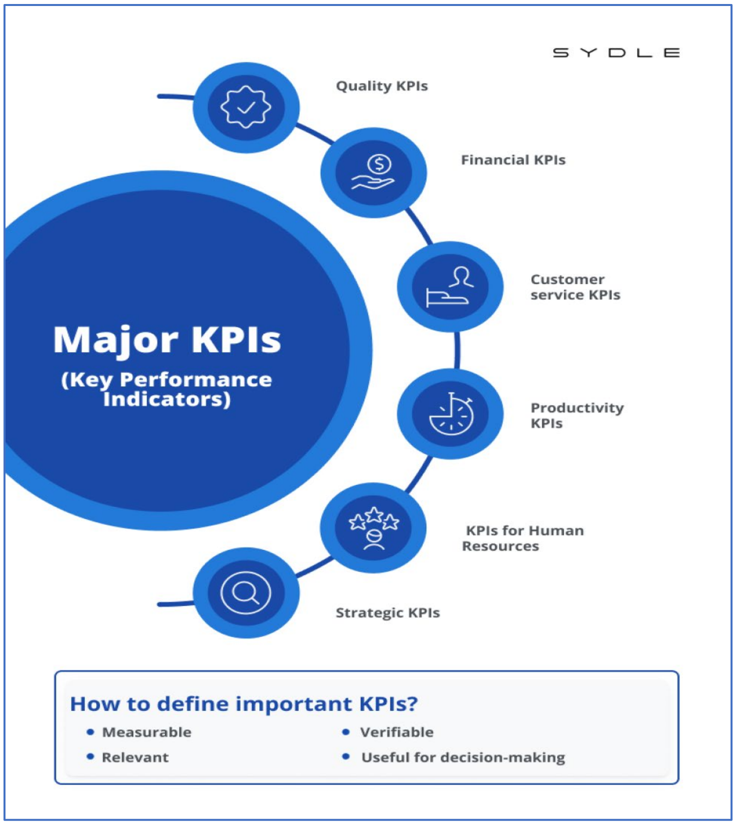

Figure 6: Major KPIs according to Sydle

b. New Discoveries and Financial Impact

Despite the lack of deliverables expected before the end of FY23, the project has continued investigating solutions and petitioning facility stakeholders for data. Extensive electrical upgrades will be necessary to power the heat pump units. New stepdown transformers must be installed, and new supply lines must be used to feed them. Wings 7 and 9 can share one transformer; likewise, wings 1, 5, and administration.

Although electrical upgrades will add cost, additional discoveries suggested a more favorable projection. While the existing chilled water systems in wings 5 and 7 are rated at 200 tons, only 100 tons of capacity are necessary to cool each wing. The two systems are designed to be cross-connected should one ever fail. The preliminary ROMs used to establish the business case and project plan were based on the HVAC industry's rule of thumb for this region. That rule quadruples the required cooling capacity to overcome the ΔT needed for heating. This discovery suggested the initial figures used to estimate TPC improve the outcome by reducing capital equipment and labor costs.

Table 2:Updated cost estimate

PROJECT COST BREAKDOWN				
Area	Equipment Cost	Labor & Materials	Infrastructure mods	Area Total
Wing 5	$1,500,000.00	$1,650,000.00	$150,000.00	$3,300,000.00
Wing 7	$1,500,000.00	$1,650,000.00	$150,000.00	$3,300,000.00
Wing 9	$1,750,000.00	$2,475,000.00	$150,000.00	$4,375,000.00
Wing 1/Admin	$1,000,000.00	$1,237,500.00	$150,000.00	$2,387,500.00
			TPC	$13,362,500.00

c. Customer Service Level

The programmatic resident group of the CMR kept a record of mission-related task delays and interruptions. Of those recorded, climate control issues were segregated and determined to account for the bulk of work area upsets (see Appendix D: Laboratory Upset Log). During FY22 and FY23, there were a total of 58 working days that experienced a temperature-related process upset. The CMR operations team makes the facility open and available on a basis that supports the program group's 9/80 schedule. The logged upsets represent mission impacts on roughly 15% of all days considered a working day during the observed period.

Generally, processes conducted in the CMR laboratory spaces require either a whole day to complete or need to run during off hours at night or on weekends. Significant productivity is lost when morning temperatures and overnight forecasts suggest prerequisites will not be met. Approximately 30 programmatic employees across four analytical chemistry teams are impacted by extreme temperature upsets. Data analysis results will discuss how these impacts permeate institutional objectives and the various KPIs that can be generated/evaluated based on this data.

d. Human Factors

Making improvements to safety is a force multiplier and is linked to improvements in every other KPI category. We are reducing the likelihood of serious injury by eliminating the steam system, a source of hazardous work in the building. During FY22 and FY23, 55 major maintenance activities were performed on this high-energy steam system at an estimated cost of over $872K (see Appendix E, Steam Maintenance Register). As of mid-February, FY24 has seen 12 major repair activities for $180K.

Repairs to this system constitute approximately 90% of the corrective maintenance requiring hazardous energy control. This is a considerable amount of risk that can be eliminated, along with the costs incurred for executing high-hazard work. If the risk results in injury, the cost is further increased. According to OSHA's $afety Pays Program, the average direct cost for a burn injury is over $47K, with an indirect cost ratio exceeding 100% [15]. Employee morale and faith in leadership should improve by eliminating these safety concerns.

Unexpected interruptions can harm morale and drive down performance indicators like productivity and quality. Sometimes, these occurrences have a lasting effect. An investigation involving random equipment failure effects showed a 3.3% decline in productivity the following day [19]. Explanations for this effect ranged from declining morale to apprehension about equipment and the workplace.

C. Data Analysis Results

a. Financial Comparison

Evaluating ROI based on the new cost estimate shows that the payback period is reduced by approximately one year, and long-term benefit is significantly increased over the remaining life of the facility. Compare the original business case ROI to the update below.

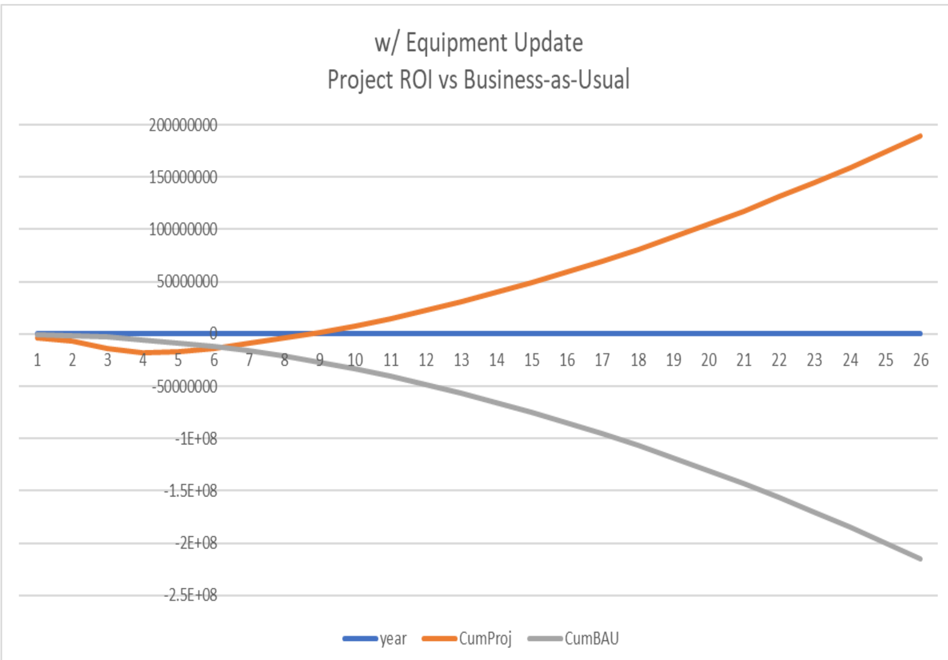

Figure 7: ROI with equipment update

b. Customer Service Level

When equipment failures cause interruptions, the mission faces lost time that can jeopardize productivity and put it behind schedule. While this project did not evaluate the cascading effects of CMR downtime on the greater weapons modernization effort, a reasonable assumption can be made that it is quite costly. Facility availability improvements measure success in the customer service KPI category.

In addition to some of the incalculable and intangible benefits of maximizing customer service level, delays can also be translated into a financial impact. Laboratory equipment is running, and analyses are underway for approximately 50% of working time at the CMR. As mentioned, up to 30 personnel are assigned to teams where climate control issues will cancel their work. Accounting for the 15% cancellation rate, this is approximately 2.25 full-time equivalents (FTE) of lost time per year.

Granted, the time is not entirely lost; employees can do other things, but the value of alternate tasks pales compared to the execution of the day's planned activities. The project aims to eliminate these upsets, and if the savings in lost FTEs are considered in overall ROI, the assumed benefit vs. business-as-usual will look like Fig. 4 below. The payback period is further reduced by another year.

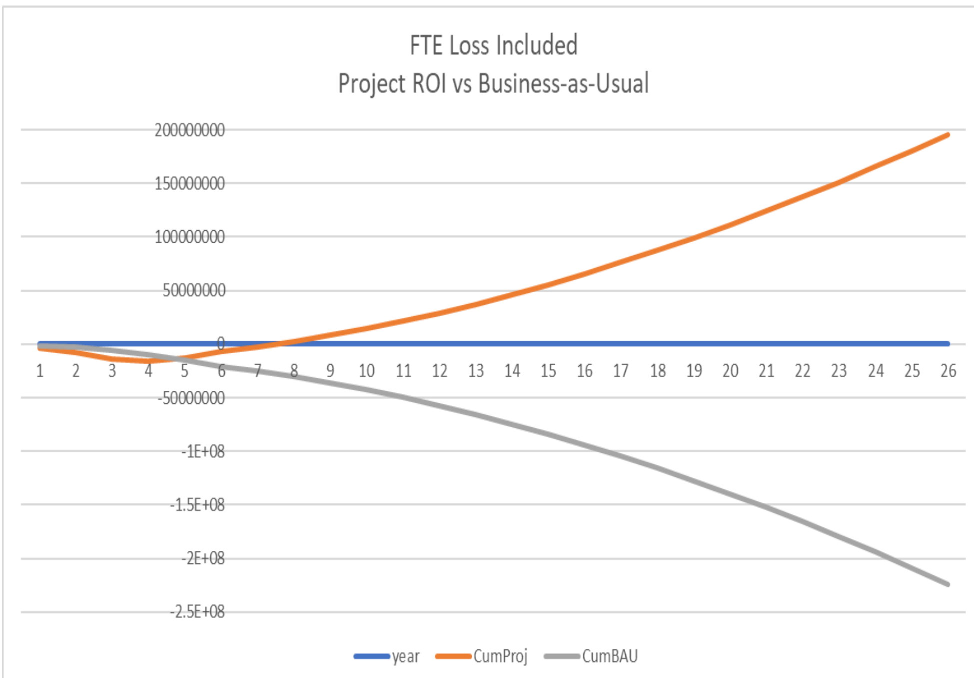

Figure 8: ROI with the recovery of non-productive time

c. Productivity and Quality

The Facilities & Operations (FO) directorate's customer provides a quality check on the chemistry process for pit production; without their results, the process cannot move to the next step. The FO's obligation to maintain systems such that mission delays are avoided is not minimized or given relief due to the age and deterioration of the facility. Eliminating a source of failure that significantly impacts mission milestones can only improve productivity, efficiency, and worker morale. The potential for interruptions mid-process will also be substantially reduced, increasing the quality of analysis results. An upset occurring while an evolution is underway can skew results and may lead to quality issues in subsequent stages.

While this project does not collect or analyze specific data concerning the customer's analytical processes, the upset log can give some indication. Mission milestones are often shared across the Weapons Production directorate, and positive status reports will indicate that deliverables required from CMR laboratories are on schedule.

d. Strategy

The following graphic displays what the Laboratory strives for, how leadership intends to achieve it, and how its employees should behave to meet collective goals. National security and stockpile stewardship are two main focal points for the LANL mission. The most important task at hand for the institution is meeting a production output of 30 plutonium pits per year. Constant unplanned downtime due to equipment failure is misaligned with the overall strategy that senior leadership has implemented to meet that directive. Establishing specific strategy KPIs for this project isn't necessary because they already exist as a byproduct of all the others. Realizing performance improvements in all the other categories will lead the project and the Laboratory to strategic success by default.

Figure 9: LANL Mission Statement

3.2 Decision-Making Report

The culmination of the data analysis exercise and the budgetary constraints resulted in an official recommendation to terminate any attempt at executing this project until conditions allow. The remaining activities focused on mission impacts, feasibility, and suggestions for future activities. Many factors remain undetermined at institutional and federal levels, and the repeated continuing resolutions in Congress have eliminated any hope that over-target budget requests will be granted. The decision-making process focused on selecting a tool that would appropriately address the key factors influencing this project in the future. Data analysis results were considered where applicable and available.

A. Choosing a Tool

There are many decision-making tools to choose from, depending on the type of project being evaluated and the KPIs used to determine success. Given that this is a government infrastructure recapitalization project with several drivers beyond those financial, a PEST/PESTEL or VMOST technique would be most appropriate. The ability to evaluate forces internal and external to the institution is also necessary. PESTEL is a single tool capable of accounting for both sets of factors that influence the decision, and it was chosen for its versatility and efficiency.

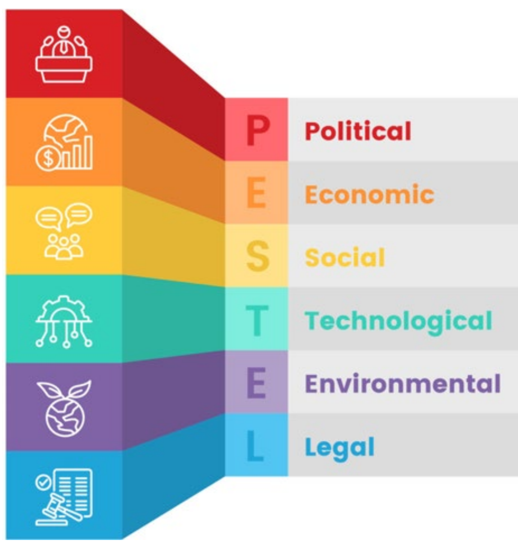

Figure 10: PESTEL analysis categories

B. Applying the Data

a. Politics

Political factors influencing project outcomes have already started to take effect and contribute highly to the decision to terminate implementation. The constant bouts of continuing resolutions in Congress have prompted the NNSA to freeze budgets and withhold funding for any over-target requests.

Although these negative impacts helped drive the decision to halt the project, there will be future opportunities, and the recommendations herein will prove useful when the political climate is more favorable. Internal politics are also a factor, as there is a stigma associated with the CMR that is 30 years old and difficult to overcome. There is a general reluctance to invest money in the facility since it was designated for closure in the late 1990s. However, the project will provide value in one political aspect as it moves the Laboratory and the DOE toward meeting legislation requirements on emissions: action that will assist LANL in gaining favor with local media and critics.

b. Economics

Since the CMR building is a government asset and public funds will be allocated for upgrades, the political climate heavily influences economic factors such as funding. Data supporting favorable economic factors such as ROI, local stimulus, and jobs also exist. Recall from the data analysis that an estimated $13.4MM will be injected into the local economy via equipment purchases and wages (recall Table 2). There is also an opportunity to save the taxpayer roughly $125MM over 20 years, with a payback period of around seven years (Table 3).

c. Social

People are LANL's greatest asset, and the collected data paints this project in a favorable light on the social front. Injecting the local economy with project cash and creating jobs is good for the community. Making our existing employees feel safe is also a force multiplier. Reducing high-energy, high-hazard maintenance activities will boost morale and allow resources to focus on more meaningful work. Since the beginning of FY22, over one million dollars have been spent maintaining the CMR steam heating system. Such an expense could go toward funding new jobs, further increasing the Laboratory's positive effect on surrounding communities. Also worth mentioning is the reduction in fossil fuel consumption that contributes to the social costs of carbon, such as healthcare expenses and quality of life.

Table 3: NPV of project vs. business-as-usual

year	Project	Project Cumulative	BAU	BAU Cumulative
0	($4,026,720.00)	($4,026,720.00)	($1,375,152.33)	($1,375,152.33)
1	($3,729,443.03)	($7,756,163.03)	($1,348,188.55)	($2,723,340.88)
2	($6,571,189.49)	($14,327,352.52)	($2,669,942.04)	($5,393,282.92)
3	($2,073,417.33)	($16,400,769.84)	($3,965,778.79)	($9,359,061.71)
4	$3,311,750.02	($13,089,019.83)	($5,236,206.98)	($14,595,268.69)
5	$5,964,030.36	($7,124,989.47)	($6,481,724.81)	($21,076,993.49)
6	$4,375,570.77	($2,749,418.70)	($4,375,570.77)	($25,452,564.26)
7	$5,055,610.88	$2,306,192.17	($5,055,610.88)	($30,508,175.13)
8	$5,722,316.86	$8,028,509.04	($5,722,316.86)	($36,230,492.00)
9	$6,375,950.19	$14,404,459.22	($6,375,950.19)	($42,606,442.18)
10	$7,016,767.17	$21,421,226.39	($7,016,767.17)	($49,623,209.35)
11	$7,645,019.11	$29,066,245.50	($7,645,019.11)	($57,268,228.46)
12	$8,260,952.39	$37,327,197.89	($8,260,952.39)	($65,529,180.85)
13	$8,864,808.54	$46,192,006.44	($8,864,808.54)	($74,393,989.40)
14	$9,456,824.38	$55,648,830.82	($9,456,824.38)	($83,850,813.78)
15	$10,037,232.07	$65,686,062.89	($10,037,232.07)	($93,888,045.85)
16	$10,606,259.21	$76,292,322.10	($10,606,259.21)	($104,494,305.06)
17	$11,164,128.96	$87,456,451.05	($11,164,128.96)	($115,658,434.01)
18	$11,711,060.08	$99,167,511.13	($11,711,060.08)	($127,369,494.09)
19	$12,247,267.06	$111,414,778.20	($12,247,267.06)	($139,616,761.16)
20	$12,772,960.19	$124,187,738.38	($12,772,960.19)	($152,389,721.34)

d. Technology

The technology exists to make this project a success and exponentially increase the efficiency of our energy consumption. The Trane modular heat pump allows equipment selection to meet needs more closely without oversizing. Heat pumps have improved so much that they are no longer contraindicated for high-elevation cold climates. There will be less opportunity for energy losses by eliminating escape from miles of steam piping and associated leaks from the corrosion and erosion of an antiquated system. The specifications and performance data for the Trane AXM030 are found in Appendix F.

Up-to-date instrumentation and controls will provide a way to monitor and manipulate the HVAC systems to increase efficiency, a capability the CMR cannot achieve with the current steam system. Increased control of conditions indoors and reduced failures will lead to less downtime and more consistent mission support. With a lost-time ratio of 15%, poor equipment performance also has implications in the social realm: job frustration and dissatisfaction.

e. Environmental

An average winter at the CMR commands the consumption of 62K MMBtu of energy to maintain suitable working conditions in the active wings and freeze protection for the inactive wings. All heating energy is provided via centralized natural gas boilers with bunker fuel as a backup. The combustion of natural gas to achieve a 62K MMBtu output results in approximately

7.25MM pounds of CO_2 emissions. This number increases heavily when outages occur, and backup fuel is used. Achieving this size reduction and providing a template for other facilities to follow gives indisputable evidence of an environmental win for LANL.

f. Legal

Data supporting the project from a legal standpoint can only be speculative but should not be discounted by any measure. Liability falls within the realms of compliance violations and litigation for workplace injuries. A failing heating system can lead to other problems, such as freeze protection failures. The inability to maintain life safety systems per codes and standards may result in fines from regulatory authorities. Workplace injuries related to high-hazard maintenance and operations can also be costly and are difficult to predict. The CMR is a nuclear facility; acceptable risk regarding the safety of localized workers and the public is very low. The regulatory risks and potential liability for accidents of any magnitude substantially support the project from a legal perspective.

C. Final Decision

This project report should be archived and ready for reference when political and financial climates improve. Although it is ill-advised to move forward now, the project has concluded that an ROI can be realized over the long term aside from moral, ethical, and regulatory obligations. Implementation is viable, would lead to improved productivity, and is a financially sound decision that should be strongly considered for the institution's good, regardless of the CMR facility's continued use or mothballing for future destruction.

3.3 Financial Analysis Report

A. Intangible Benefits

Productivity is linked to employee happiness, and establishing a more comfortable and reliable work environment will undoubtedly raise the efficiency of workers. As detailed in the data analysis, an approximate loss of 2.25 FTEs per year is associated with current system failure rates and corrective maintenance scheduling. A rudimentary estimate of this impact on overall ROI is shown in Figure 13. Factoring in the morale impacts and time lost from repeated and unexpected start/stop cycles, the financial impacts of employee inefficiency due to facility maintenance issues go beyond what can be captured in this project's scope [19]. In addition to those losses, it can be reasonably assumed that cascading effects of interruption are realized downstream in the pit production process.

B. Tangible Benefits

a. Break-Even

The payback period for the project varies depending on assumptions and criteria. The collection of data and careful analysis during the project revealed equipment cost savings that could be realized. In addition, the assumption that productivity losses could be recouped after project implementation further improves the break-even point. Any cost improvement beyond the status quo is considered breaking even despite not yet seeing a return above zero dollars. The following figures represent A progression of payback by the intersection of the cumulative project ROI (orange) and business-as-usual (gray) lines.

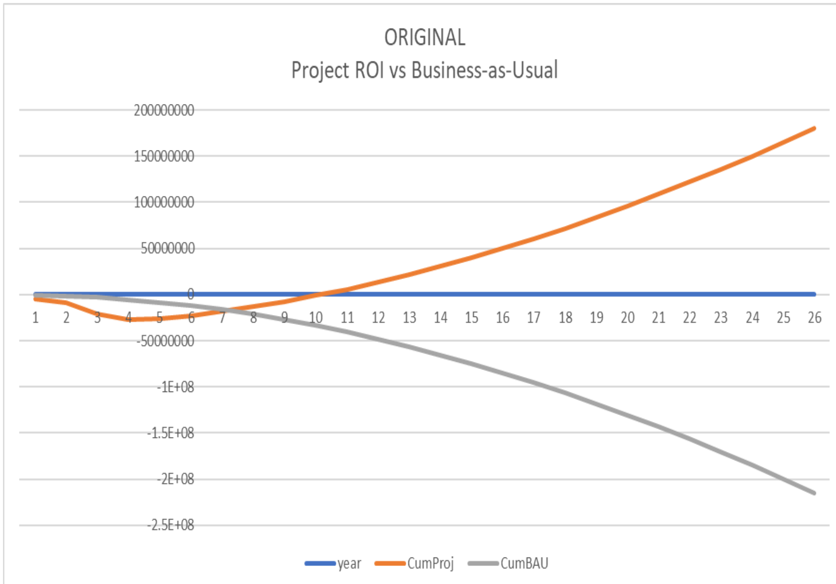

Figure 11: Original ROI comparison

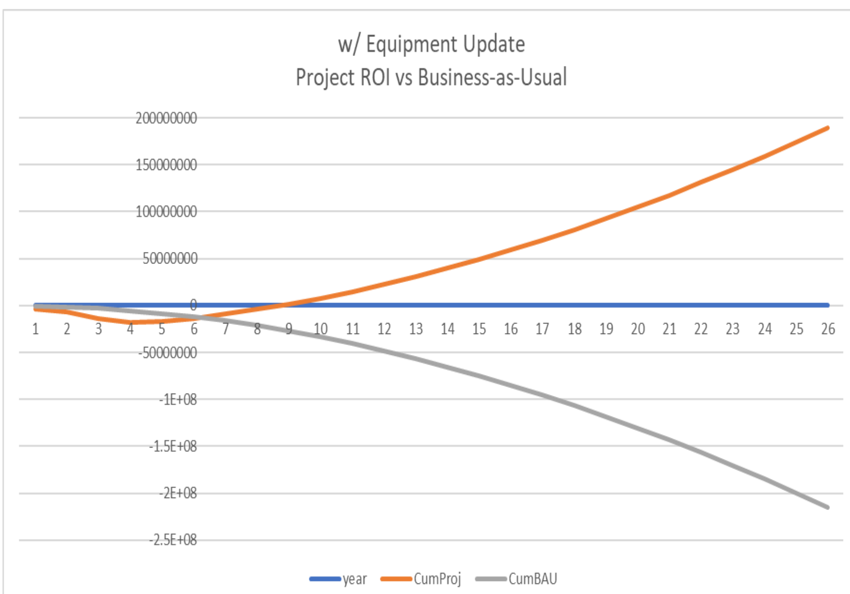

Figure 12: Updated ROI comparison

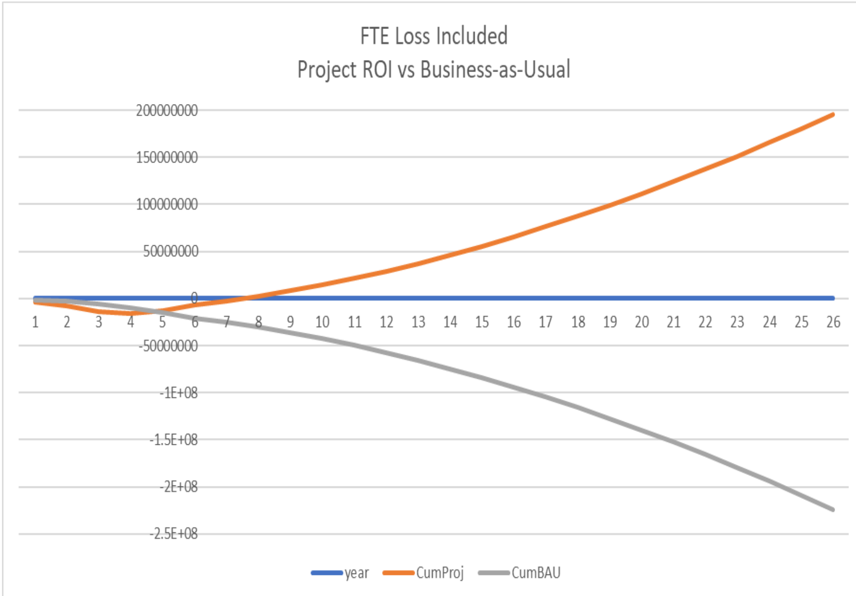

Figure 13: ROI, including wages paid for unproductive time

b. Return on Investment

Much like the payback period, the ROI can be viewed from many perspectives, depending on the criteria. If one is interested in a holistic approach that includes socio-environmental impacts and potential penalties for GHG emissions, the ROI would look like Table 4. This calculation includes the current presumed cost of carbon at $51 per MTCDe and carbon credit purchase of $17 per MTCDe [6] [20].

Although the discovery was long after calculations were finalized for this project, recent California Air Resources Board website data show the most recent auction price for carbon offsets eclipsed $40/MTCDe in Q1 of this year [21]. If adopted in New Mexico, a carbon credit policy could be even more costly than this study suggests.

Costs such as this are difficult to visualize. To provide a more tangible data set, the real dollar costs associated with capital expense, reduction in facility maintenance, and fossil fuel consumption can be separated. Accounting for the recently determined capital equipment cost and additional time/materials necessary for infrastructure upgrades, a more tangible ROI is calculated in Table 5.

Table 4: ROI, including social costs and offsets

year	PV	Cumulative	BAU	CumBAU
0	($4,248,525.00)	($4,248,525.00)	($1,596,957.33)	($1,596,957.33)
1	($3,903,407.74)	($8,151,932.74)	($1,565,644.44)	($3,162,601.76)
2	($6,829,578.24)	($14,981,510.98)	($3,100,589.96)	($6,263,191.73)
3	($2,329,281.22)	($17,310,792.20)	($4,605,438.52)	($10,868,630.24)
4	$3,142,835.36	($14,167,956.83)	($6,080,780.24)	($16,949,410.48)
5	$7,009,499.24	($7,158,457.59)	($7,527,193.69)	($24,476,604.18)
6	$5,617,996.15	($1,540,461.44)	($5,617,996.15)	($30,094,600.32)
7	$6,491,130.85	$4,950,669.41	($6,491,130.85)	($36,585,731.18)
8	$7,347,145.28	$12,297,814.69	($7,347,145.28)	($43,932,876.45)
9	$8,186,375.10	$20,484,189.79	($8,186,375.10)	($52,119,251.55)
10	$9,009,149.44	$29,493,339.22	($9,009,149.44)	($61,128,400.99)
11	$9,815,790.94	$39,309,130.17	($9,815,790.94)	($70,944,191.93)
12	$10,606,615.95	$49,915,746.11	($10,606,615.95)	($81,550,807.88)
13	$11,381,934.58	$61,297,680.70	($11,381,934.58)	($92,932,742.46)
14	$12,142,050.89	$73,439,731.59	($12,142,050.89)	($105,074,793.35)
15	$12,887,262.96	$86,326,994.55	($12,887,262.96)	($117,962,056.31)
16	$13,617,863.02	$99,944,857.57	($13,617,863.02)	($131,579,919.34)
17	$14,334,137.60	$114,278,995.17	($14,334,137.60)	($145,914,056.93)
18	$15,036,367.57	$129,315,362.74	($15,036,367.57)	($160,950,424.50)
19	$15,724,828.33	$145,040,191.07	($15,724,828.33)	($176,675,252.83)
20	$16,399,789.86	$161,439,980.93	($16,399,789.86)	($193,075,042.69)

Table 5: ROI for real dollar costs (maintenance, project, and fuel costs)

year	PV	CumProj	BAU	CumBAU
0	($4,026,720.00)	($4,026,720.00)	($1,375,152.33)	($1,375,152.33)
1	($3,729,443.03)	($7,756,163.03)	($1,348,188.55)	($2,723,340.88)
2	($6,571,189.49)	($14,327,352.52)	($2,669,942.04)	($5,393,282.92)
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15	$10,037,232.07	$65,686,062.89	($10,037,232.07)	($93,888,045.85)
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19	$12,247,267.06	$111,414,778.20	($12,247,267.06)	($139,616,761.16)
20	$12,772,960.19	$124,187,738.38	($12,772,960.19)	($152,389,721.34)

Given that turning over the building for demolition will likely take the full 20 years, the return of over $152MM for a worst-case scenario investment of $15MM makes the decision to move ahead with this project a clear one. Even more appealing is that the project return is out of the red during year seven.

C. Risk

Financial risk has already been realized during this project, with the failure of on-time completion of the alternative heating studies commissioned by this project and the site-wide effort by LANL’s Utilities and Infrastructure Sustainability group. At the CMR, approximately $80K was spent on engineering resources to provide alternative approaches to the steam heating in the facility. Although this expenditure did not achieve the intent before budgets were constrained, the process yielded some redeeming data. The reduced chiller capacity was determined during this activity, and the need for infrastructure modifications was identified. Without this new information, the project cost estimates would have been inaccurate and less attractive.

In the future, a financial risk will always exist in the form of funding cancellation. The Laboratory has recently experienced budgetary issues, and reductions have been requested despite this FY's allocations already being made. One suggestion to eliminate this risk is to contract the work to a third-party EPC contractor. If funds are earmarked and contractual obligations exist, the project will be less prone to cancellation or failure for funding reasons.

4. DISCUSSION AND CONCLUSION

4.1 Discussion

The CMR building is aging, and the utility systems are following suit. During winter, the CMR facility represents approximately one-quarter of the steam plant's capacity. Given the contribution of building energy consumption to overall GHG emissions and the negative impacts on the future of our planet, there is an opportunity to make improvements that mitigate the human effect.

Historically, the steam system experiences multiple failures yearly, and extensive maintenance is necessary every summer. Since January 2022, maintenance costs associated with this aging system have cost almost $500K annually. In addition to repair and preventive maintenance costs, the estimated winter heating costs approach a contribution of $300K to the total seasonal fuel consumption of the CHP. The steam system's consistent failures and poor condition also present a safety concern that far exceeds the budgetary impacts of maintenance and fuel consumption. The absence of a small valve maintenance program and periodic evaluation of piping integrity make the timing and failure mode of the system unknown, presenting risks that can neither be mitigated nor forecast.

When considering the results of the data analysis in conjunction with the PESTEL decision tool, this recapitalization project is overwhelmingly supported as a worthwhile investment for LANL and the DOE. As a government project, it not only passes the ROI litmus test but also provides a payback period that satisfies most private industry capital project requirements. Data exists that proves feasibility, and although it may be a financial burden now, the future cost of failing to invest is too great.

For perspective, an alternative to this method would involve completely removing all nuclear/hazardous materials, such that a wet fire suppression system would not need freeze protection. An operation of this magnitude would cost hundreds of millions of dollars and would be unnecessary since DOE-EM does not require risk reduction of that magnitude before turnover. In comparison, providing energy-efficient electrification for the CMR's climate control is the most financially responsible solution.

4.2 Opinion

Throughout the exploration into solving the climate control and freeze protection issue at the CMR, the project has discovered how damaging the perpetuation of an uninformed narrative can be to an organization. The viability of this facility has been questioned since the 1980s, and the plan to replace, abandon, and demolish it has existed since the late 1990s. The CMR has been "going away" since most current Laboratory employees were hired. Over several decades, a combination of neglect, escalating commitment to failures, and competing priorities in pit production have created an impenetrable wall of opinion biased by anchoring, framing, and bandwagon effects.

The pit-production mission has been the focus of attention for many years, remains so today, and will continue to be for years. It is easy to see how a 70+-year-old eyesore is not a priority. However, the CMR facility's contributions are not currently replicated elsewhere, and its value is routinely overlooked. Not only has it been ignored from a maintenance standpoint, but this year's funding level suggests the comptrollers are also ready to overlook it financially.

Informed decision-making by senior leadership at the Laboratory and federal levels is paramount to success, no matter the fate of the CMR. However, there seems to be great reluctance to delve into the specifics and dedicate resources to figuring out what is best for the institution, the mission, and the Nation.

4.3 Conclusion

Although this project and the current fiscal climate were untimely, the data collected and estimates supported this endeavor as a worthwhile project. A relatively quick payback period and the opportunity to save ten times the cost of the project between now and the time DOE-EM takes custody of the building make this an attractive financial decision. Considering that the need for this capability may extend well into DOE-EM's conservatorship of the CMR, the cost to the taxpayer will be reduced during the decommission and demolition period as well.

If implemented, this project will improve safety, provide data to institutional and federal authorities, reduce negative socio-environmental impacts, and show good stewardship of taxpayer dollars. These goals will be achieved by implementing the targeted industrial-scale heat pump technology solution based on existing resources, infrastructure, and efficiency studies. Careful planning, strict adherence to operational risk and project management principles, and putting safety first ensure project success. A combination of the requirements enacted by the project charter and the plan guidelines will deliver the project on time and within budget.

When current events and the political climate (i.e., funding) are more favorable, this project should be revisited for implementation, and a formal directive should be given to execute it. Regardless of the fate of the CMR facility, the integrity of its vital support systems is essential for the safety of collocated workers and the public until all hazards are clear and destruction commences. The day will certainly be decades in the future; the logical solution is an effort to preserve it, which will save taxpayer dollars in the meantime.

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APPENDIX A: PROJECT CHARTER

A. Project Description

The project will identify the most cost-effective and feasible means to establish an alternative to steam heating in the Chemistry and Metallurgy Research Facility (CMR) at Los Alamos National Laboratory (LANL). Once identified, a pilot project will be established to convert an isolated portion of the facility as a proof of concept.

Initial efforts will be conducting a case study (or studies) to determine which alternate heating method is most achievable. Feasibility, efficiency, and meeting project objectives will guide this determination. Once a path is chosen for the method and the isolated area for the pilot project is confirmed, the remainder of the project will be executed either by internal LANL resources or externally via an EPC (engineering, procurement, and construction) contract. Due to limited Laboratory resources, a subcontractor will likely need to be sourced. As the pilot ends and has proved successful during trial runs, plans will go into development for the remainder of the building.

Several drivers are behind this project, which will dictate the success criteria as discussed later in this charter. Credible gains can be realized through savings in eliminating repetitive maintenance costs for the existing steam system. Efforts to de-carbonize government institutions per federal mandates will be initiated within a suitable timeframe to achieve President Biden's goal. Public and environmental health and safety concerns will be addressed and can be monetized to show return. Facility resident safety will also be improved by eliminating a hazardous energy source that could present failure of an indeterminate mode or severity at an unknown time.

B. Sponsor Information

The sponsor identified for this project is Stuart McKernan, the facility operations director (FOD) for Technical Area 55 (TA-55) at LANL. Although allocation for funding and prioritization of the project lies with the director of the Infrastructure Program and Planning Office, Mr. McKernan is the final approving authority for all facility modifications and safety basis impacts within the directorate. The FOD will be consulted and reported through all phases of the project and will be the deciding authority for transition through each phase gate.

C. Scope

The project will take a phased approach and progress to subsequent stages depending on success in each preceding step. The intention is to complete the project during the next five years while current NNSA mission resources are scheduled to occupy the building. The return would be realized toward the end of the project and during the years that the facility is either repurposed for other DOE missions or awaits DOE-EM turnover.

The early stages consist of data collection and an engineering study conducted by the Shared Services Office to ascertain the facility heating requirements and identify solutions that could meet said requirements. Those solutions will be evaluated on cost, feasibility, and long-term benefits. The targeted answer is a system that implements industrial-sized heat pump technology due to the attractiveness of efficiency rating and the overall goal of electrification for decarbonization efforts.

Additionally, facility management will collaborate with in-house engineering support to conduct their study and identify an area of the facility most suitable for executing a pilot project. National security mission milestones dependent upon facility availability and operability will be considered, as well as resource constraints and safety implications. The targeted location would be an operating wing of the facility with a refrigerated chilled water system for cooling. The existing infrastructure can be repurposed to retrofit a heat pump in place of the current chiller unit.

Upon selection of solution and location, the facility design change and modification process will be conducted to ensure that the safety and integrity of the building will be maintained upon implementation. Due to internal resource constraints, project management will advise the PMO that subcontract bids should be petitioned to ensure performance without delay and to minimize impact on budget and schedule milestones. Successful implementation will prove the project's efficacy and building-wide planning and implementation will commence.

This project does not include any activities assumed to be planned for inactive wings of the CMR. The assumption is that independent projects already in planning will resolve the risk reduction issues necessary to render these areas inoperative and beyond the scope of needing a heating system conversion.

D. Schedule

The project will be executed under a phased approach, with success at each phase gate determining advancement. The phases are described below, with a subsequent diagram to visualize the project timeline.

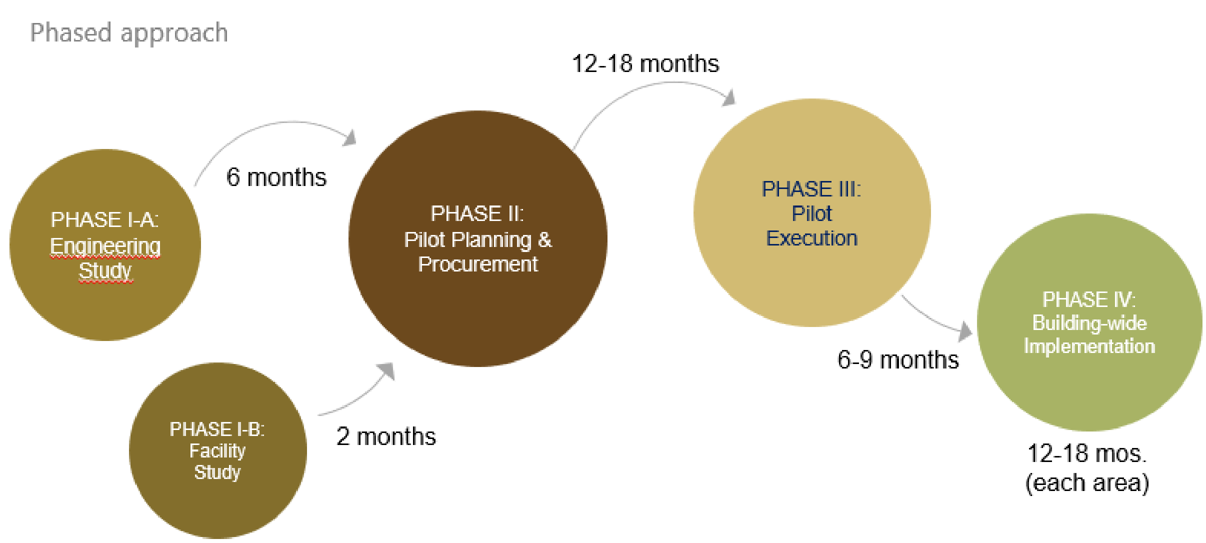
- PHASE I-A: Data collection and alternative study; 6 months
  Determine heat load calculations for the facility and identify solutions. This study was funded in fiscal year 2023 by reallocating resources from a discontinued recapitalization project.

- PHASE I-B: Facility management assessment of pilot project location; 2 months
  Consult with programmatic, engineering, and safety-basis leadership to evaluate project impacts on national security mission milestones, facility integrity, and authorization basis (nuclear facility safety). This evaluation can be executed in tandem with Phase I-A and would take approximately two months to complete.

- <u>PHASE II: Pilot project planning; 12 to 18 months</u>
  This phase consists of multiple sub-parts, including the following:
  1. Equipment sizing
  2. Procurement channels/lead time established
  3. Facility design modifications
  4. Utility upgrade (new line-side feed and transformers)
  5. Subcontractor bidding
  6. Ground penetrating radar and permitting
  7. Work package development
  8. Resource scheduling

- <u>PHASE III: Pilot project execution; 6 to 9 months</u>
  This phase consists of multiple sub-parts, including the following:
  1. Site preparation (foundations/concrete pads/mounting hardware)
  2. Equipment installation
  3. Facility modifications execution
  4. Existing system components retrofitting
  5. Hook-up and commissioning
  6. Performance evaluation

- <u>PHASE IV: Building-wide implementation; 12 to 18 months in each area</u>
  A combination of Phases III and IV for other facility areas needing conversion. Ideally, the timelines for completing subsequent wings would be accelerated due to similar scope and the ability to replicate the pilot project's plan.



E. Cost

Preliminary cost estimates are based on the following:

- Equipment sizing using rules of thumb based on current 200-ton chiller capacities

- 50% estimation rule for construction project labor costs
- LANL standard multiplier for burdened labor (2.2)
- Repurpose the current cooling system components in wings 5 and 7
- Increased engineering and safety basis efforts for Wing 9

No consideration is made for abandoned wings (wings 2, 3, and 4) that are not actively serving a DOE mission and have no expectation for future use (these wings will undergo risk reduction efforts and do not need fire/freeze protection).

PROJECT COST BREAKDOWN			
Area (by Wing)	Capital Equipment Cost	Labor & Materials	Total
Wing 5	$3,000,000	$1,320,000	$4,320,000
Wing 7	$3,000,000	$1,320,000	$4,320,000
Wing 9	$3,250,000	$3,300,000	$6,550,000
Wing 1/Admin	$1,500,000	$1,650,000	$3,150,000
		TPC	$18,340,000

Applying present value principles for the project duration and using the Office of Management and Budget's standard discount rate for internal government projects, the total cost in today's dollars would be approximately $25MM.

F. Risks

During the planning phase, the project team will collaborate on a risk register to identify potential problem areas, mitigating actions, and/or preventive measures. The evaluation will be both qualitative and quantitative (mixed mode), according to the following risk types:

- Safety
- Compliance/regulatory
- Financial
- Operational
- Schedule
- Budget
- Quality
- Political/Social

Once risks are identified and evaluated, they will be assigned a risk level based on a 5×5 risk matrix. Before including the official risk register in the final draft of the project plan, it will be presented to the sponsor for disposition and approval of acceptable risk. As the project progresses, the risk register will be periodically evaluated/updated and submitted to the sponsor for re-approval under the following circumstances:

- During weekly/monthly progress meetings
- When risks materialize, whether previously identified or unexpected
- Upon closeout of mitigation/prevention measures
- Before advancing through each phase gate

G. Success Criteria

The overall goals of this project are to

- improve safety,
- prolong facility endurance,
- Meet federal mandates on decarbonization,
- reduce operating and maintenance costs,
- maintain an established budget/schedule, and
- improve facility performance in meeting mission needs.

To evaluate success, the following metric/mechanism matrix will be used to assess project performance on an ongoing basis, at project close, periodically after closeout, or a combination of frequencies as necessary, to report successes and failures accurately.

SUCCESS MATRIX	
Metric	**Mechanism**
Increase in safety	Elimination of steam-reliant heating
	Reduction in moderate-to-high-hazard steam system work packages
Prolonged facility endurance	Reduction in corrective maintenance and equipment failures
Satisfaction of federal decarbonization requirements	Reduction in CHP natural gas consumption
Operations and maintenance cost savings	Energy cost evaluation
	PV of maintenance budget savings over facility life
	Reduction in T&E for operations surveillance
Project budget and schedule	Earned value management: cost/schedule performance indices
	Setting project milestones
	Consumption of management reserves
Mission impacts	Frequency of program interruptions/delays

H. Agreements and Acknowledgements

Project management shall uphold the parameters and expectations outlined in this charter until the project has been deemed a success or abandoned due to failure or development of unacceptable risk, as determined by the sponsor. Any revision to this charter will be conducted under the advisement of the project stakeholders and will be subject to final approval by the sponsor.

The project manager (PM) will conduct monthly status updates with the sponsor during the data collection and planning phases and bi-weekly during the execution phases. The PM shall manage all safety issues and project risks, with the deliverable of a path forward to the sponsor to minimize project delays to the maximum extent possible. Any unresolved safety concern beyond ten business days shall constitute a pause on work on the project until a sponsor-approved resolution is implemented.

The PM acknowledges that all activities from project approval through closeout shall conform to LANL institutional policies, the Triad National Security Prime Contract parameters, all local/federal regulations, and DOE orders applicable to nuclear facilities and capital projects. Furthermore, the PM acknowledges that no resources for this project have been approved beyond the initial engineering study (PHASE I-A), which is already in progress. No work beyond PHASE I-A and I-B shall be conducted until the sponsor is notified.

I. Authorization

As indicated by the signatures below, this charter is approved, and authorization to proceed is granted under the terms previously described:

Sponsor:

____

Stuart McKernan,
TA55 Facility Operations Director

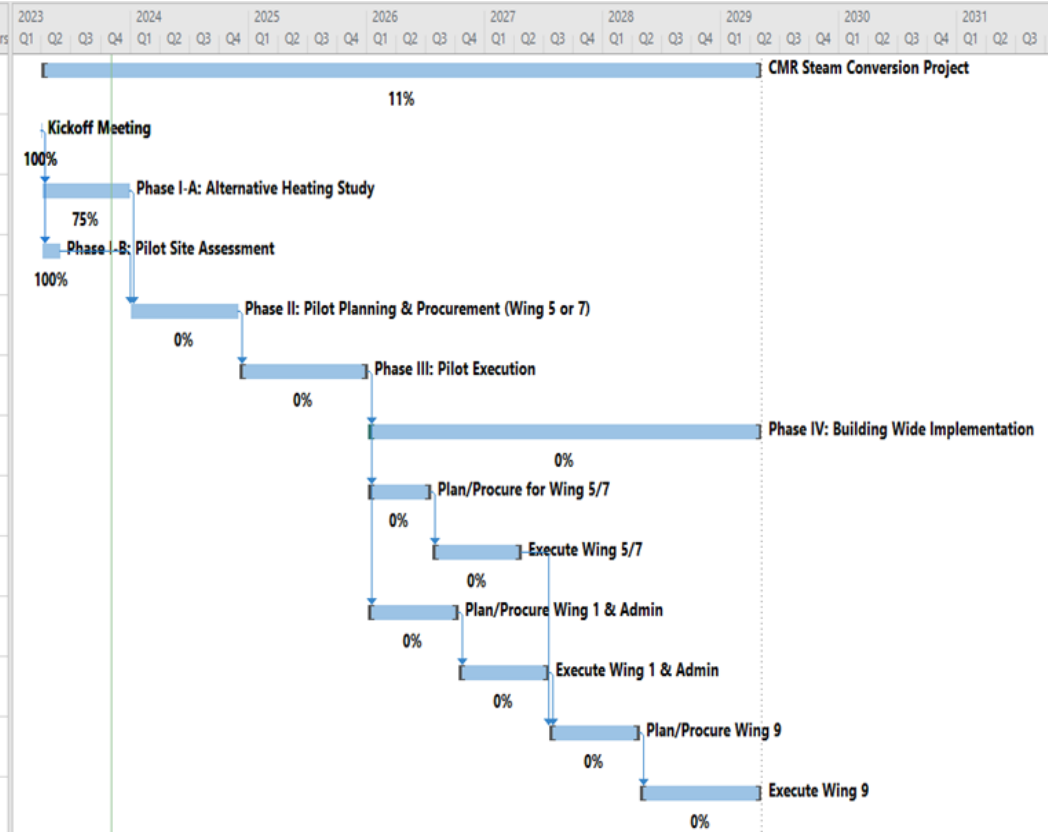
Project Manager:

____

Matthew Gray,
TA-55-CF Shift Operations Manager:

APPENDIX B: PROJECT SCHEDULE

	Task Mode	Task Name	Duration	Start	Finish	Predecessors
1		1 CMR Steam Conversion Project	1591 days	Fri 3/31/23	Sat 5/5/29	
2		1.1 Kickoff Meeting	1 day	Fri 3/31/23	Fri 3/31/23	
3		1.2 Phase I-A: Alternative Heating Study	195 days	Mon 4/3/23	Fri 12/29/23	2
11		1.3 Phase I-B: Pilot Site Assessment	40 days	Mon 4/3/23	Fri 5/26/23	2
14		1.4 Phase II: Pilot Planning & Procurement (Wing 5 or 7)	240 days	Mon 1/1/24	Fri 11/29/24	3,11
21		1.5 Phase III: Pilot Execution	285 days	Mon 12/2/24	Fri 1/2/26	14
25		1.6 Phase IV: Building Wide Implementation	870 days	Mon 1/5/26	Sat 5/5/29	21
26		1.6.1 Plan/Procure for Wing 5/7	140 days	Mon 1/5/26	Fri 7/17/26	21
31		1.6.2 Execute Wing 5/7	200 days	Mon 7/20/26	Fri 4/23/27	26
35		1.6.3 Plan/Procure Wing 1 & Admin	200 days	Mon 1/5/26	Fri 10/9/26	21
40		1.6.4 Execute Wing 1 & Admin	200 days	Mon 10/12/26	Fri 7/16/27	35
44		1.6.5 Plan/Procure Wing 9	200 days	Mon 7/19/27	Fri 4/21/28	40,31
49		1.6.6 Execute Wing 9	270 days	Mon 4/24/28	Sat 5/5/29	44



APPENDIX C: RISK REGISTER

REF ID	RISK DESCRIPTION	PROBABILITY 1 – 5	IMPACT 1 – 16	RISK SEVERITY SCORE Prob x Impact	MITIGATION / RESPONSE PLAN
1	Study reveals alternative method does not exist/not feasible	2	16	**32**	Response- Cancel Project
2	Positive USQD	3	4	**12**	Mitigation- Regular planning meetings and constant stakeholder engagement to reveal issues early
3	Unexpected radiological concern	2	8	**16**	Mitigation- Prejob surveys and rad protection planning involvement
4	Pulled or denied funding	3	16	**48**	Response- Cancel Project
5	Lack of resources	1	8	**8**	Mitigation- EPC subcontract issued to avoid reliance on internal resources
6	Shift in political climate and repeal of mandates	3	8	**24**	Mitigation- prior approval and funding to earmark future funds
7	Competing priorities and Pu mission impacts	3	2	**6**	Repsonse- Shift project areas to lessen impact (i.e. rearrange wing upgrade sequence)
8	Overbudget	2	1	**2**	Mitigation- inflation and problem areas accounted for in ROI assessment; 20% reserve included in budget request. EVMS tracking. Response- release management reserves as necessary
9	Behind Schedule	2	2	**4**	Mitigation- Slack built into the schedule to accommodate seasonal impacts should absorb moderate interruptions. Response- periodic stakeholder meetings to identify issues and tasks that can execute in tandem

APPENDIX D: LABORATORY UPSET LOG

Date	Notes
Tuesday, September 26, 2023	Wings 5 and 7: workspace temperatures starting in below 60s today, AAC ops focused on inventory preparation, steam introduced today (10:30 am)
Monday, September 25, 2023	Wings 5 and 7: workspace temperatures starting in below 60s today; AAC ops focused on inventory preparation
Thursday, September 21, 2023	Wings 5 and 7: workspace temperatures starting in below 60s today; AAC ops focused on inventory preparation
Wednesday, September 20, 2023	Wings 5 and 7: workspace temperatures starting in below 60s today; AAC ops focused on inventory preparation
Tuesday, September 19, 2023	Wings 5 and 7: workspace temperatures starting in below 60s today; AAC ops focused on inventory preparation
Monday, September 18, 2023	Wings 5 and 7: workspace temperatures starting in below 60s today; AAC ops focused on inventory preparation
Friday, September 15, 2023	Wings 5 and 7: workspace temperatures starting in below 60s today; AAC ops focused on inventory preparation
Thursday, September 14, 2023	Wings 5 and 7: workspace temperatures starting in below 60s today; AAC ops focused on inventory preparation
Wednesday, September 13, 2023	Wings 5 and 7: workspace temperatures starting in below 60s today; AAC ops focused on inventory preparation
Tuesday, September 12, 2023	Wings 5 and 7: workspace temperatures starting in below 60s today; AAC ops focused on inventory preparation
Monday, September 11, 2023	Wings 5 and 7: workspace temperatures starting in below 60s today; AAC ops focused on inventory preparation
Friday, April 28, 2023	Wings 5 and 7: workspace temperatures starting in the low 50s today, unsuitable for laboratory work (53 in 5111, 48 in office AM), no aliquots, 60 deg needed to weigh TIMS aliquots on balance
Thursday, April 27, 2023	Wings 5 and 7: workspace temperatures starting in the low 50s today, unsuitable for laboratory work (50 in 5111, 48 in office AM), no aliquots, 60 deg needed to weigh TIMS aliquots on balance

Wednesday, April 26, 2023	Wings 5 and 7: workspace temperatures starting in the low 50s today, unsuitable for laboratory work (53 in 5111, 52 in office AM), no aliquots, 60 deg needed to weigh TIMS aliquots on balance
Tuesday, April 25, 2023	Wings 5 and 7: workspace temperatures starting in the low 50s today, unsuitable for laboratory work (53 in 5111, 52 in office AM), no aliquots, 60 deg needed to weigh TIMS aliquots on balance
Monday, April 24, 2023	Wings 5 and 7: workspace temperatures starting in the low 50s today, unsuitable for laboratory work (52 in 5111, 52 in office AM)
Thursday, April 13, 2023	Wing 5 and 7 temperatures are too warm for the TIMS instrument and Davies & Gray/Coulometry electrochemistry operations. They are low in the 70s and increase to 80 F in the afternoon.
Wednesday, April 12, 2023	Wing 5 and 7 temperatures are too warm for the TIMS instrument and Davies & Gray/Coulometry electrochemistry operations. They are low in the 70s and increase to 80 F in the afternoon.
Friday, March 17, 2023	W5 & W7: Opening delayed due to weather, FOTEC involvement in 7016 observation and follow-up
Wednesday, February 15, 2023	LANL on-site operations were canceled due to the weather
Wednesday, January 18, 2023	Delayed start due to weather, then Lab closure
Tuesday, January 17, 2023	Delayed start due to weather and then Lab closure; those able to telework should work from home
Wednesday, November 30, 2022	Wings 5 and 7: morning temperatures in the 50s to 60s delayed and slowed analysts in completing sample prep and analysis activities
Monday, November 21, 2022	Wings 5 and 7: morning temperatures in the 50s to 60s delayed and slowed analysts in completing sample prep and analysis activities
Tuesday, November 8, 2022	CMR Facility: the steam plant is still not operational in the CMR steam introduction was announced at 1:30 pm
Monday, November 7, 2022	CMR Facility: The steam plant lost boiler 2 to fire; steam was not supplied to CMR
Sunday, November 6, 2022	CMR Facility: The steam plant lost boiler one over the weekend (heating coils), and steam was not supplied to CMR
Wednesday, October 19, 2022	Wings 5 and 7: temperatures in the 80s delayed and slowed analysts in completing sample prep and analysis activities

Tuesday, October 18, 2022	Wings 5 and 7: temperatures in the 80s delayed and slowed analysts in completing sample prep and analysis activities
Monday, October 17, 2022	Wings 5 and 7: temperatures in the 80s delayed and slowed analysts in completing sample prep and analysis activities
Tuesday, October 11, 2022	Wings 5 and 7: workspace temperatures starting in the upper 50s today, unsuitable for laboratory work (54.5 in office AM); steam introduced today
Monday, October 10, 2022	Wings 5 and 7: workspace temperatures starting in the upper 50s today, unsuitable for laboratory work (52.5 in office AM)
Thursday, October 6, 2022	Wings 5 and 7: workspace temperatures starting in the upper 50s today, unsuitable for laboratory work (59 in office AM)
Wednesday, October 5, 2022	Wings 5 and 7: workspace temperatures starting in the upper 50s today, unsuitable for laboratory work (59 in office AM)
Tuesday, October 4, 2022	Wings 5 and 7: workspace temperatures starting in the upper 50s today, unsuitable for laboratory work (59 in office AM)
Monday, September 6, 2022	Wings 5 and 7: workspace temperatures starting in the upper 50s today, unsuitable for laboratory work (57 in office AM)
Thursday, September 1, 2022	Wings 5 and 7: workspace temperatures starting in the upper 50s today, unsuitable for laboratory work (59 in office AM)
Wednesday, August 31, 2022	Wings 5 and 7: workspace temperatures starting in the upper 50s today, unsuitable for laboratory work (58 in office AM)
Monday, August 29, 2022	Wings 5 and 7: workspace temperatures starting in the upper 50s today, unsuitable for laboratory work (57 in office AM)
Thursday, August 25, 2022	Wings 5 and 7: workspace temperatures starting in the upper 50s today, unsuitable for laboratory work (56 in office AM)
Wednesday, August 24, 2022	Wings 5 and 7: workspace temperatures starting in the upper 50s today, unsuitable for laboratory work (58 in office AM)
Tuesday, August 23, 2022	Wings 5 and 7: workspace temperatures starting in the upper 50s today, unsuitable for laboratory work (56 in office AM)
Monday, August 22, 2022	Wings 5 and 7: workspace temperatures starting in the upper 50s today, unsuitable for laboratory work (56 in office AM)

Friday, August 19, 2022	Wings 5 and 7: workspace temperatures starting in the upper 50s today, unsuitable for laboratory work (57 in office AM)
Thursday, August 11, 2022	Wings 5 and 7: workspace temperatures starting in the upper 50s today, unsuitable for laboratory work (60 in office AM)
Wednesday, August 10, 2022	Wings 5 and 7: workspace temperatures starting in the upper 50s today, unsuitable for laboratory work (58 in office AM)
Tuesday, August 9, 2022	Wings 5 and 7: workspace temperatures starting in the upper 50s today, unsuitable for laboratory work (59 in office AM)
Monday, August 8, 2022	Wings 5 and 7: workspace temperatures starting in the upper 50s today, unsuitable for laboratory work (58 in office AM)
Tuesday, June 28, 2022	Wings 5 and 7: workspace temperatures in the mid-50s in the morning, unsuitable for laboratory work (56 in office AM)
Monday, June 27, 2022	Wings 5 and 7: workspace temperatures in the mid-50s today, unsuitable for laboratory work (54.5 in office AM)
Monday, June 20, 2022	Wings 5 and 7: workspace temperatures below 60 degrees today, unsuitable for laboratory work
Thursday, May 26, 2022	Wings 5 and 7: workspace temperatures are in the low to mid-50s today, unsuitable for laboratory work (54.5 in office AM)
Wednesday, May 25, 2022	Wings 5 and 7: workspace temperatures are in the low 50s today, unsuitable for laboratory work (48 in office AM)
Tuesday, May 24, 2022	Wings 5 and 7: workspace temperatures are in the low to mid-50s today, unsuitable for laboratory work (52 in office AM)
Monday, May 23, 2022	Wings 5 and 7: workspace temperatures in the low to mid-50s today, unsuitable for laboratory work (54 in office AM)
Friday, May 13, 2022	Wings 5 and 7: workspace temperatures in the low to mid-50s today, unsuitable for laboratory work (54 in office AM)
Thursday, May 5, 2022	Wings 5 and 7: workspace temperatures from the high 40s to mid-50s today, unsuitable for laboratory work (49 in office AM)
Tuesday, April 26, 2022	Wings 5 and 7: workspace temperatures from the high 40s to mid-50s today, unsuitable for laboratory work (48 in office AM)
Monday, April 25, 2022	Wings 5 and 7: workspace temperatures from the high 40s to mid-50s today, unsuitable for laboratory work (48 in office AM)
Thursday, February 3, 2022	Heavy snow day; no LANL on-site work
Wednesday, February 2, 2022	Snow day; no LANL on-site work

Wednesday, January 26, 2022	LANL delayed opening due to snow, CMR facility lost steam, steam restored at 11:30 am
Wednesday, October 27, 2021	No steam to heat CMR; reintroduce steam into CMR at 10:00 am
Tuesday, October 26, 2021	There is no steam to heat CMR; a Los Alamos County transformer failure took down the steam plant over the weekend
Monday, October 25, 2021	There is no steam to heat CMR; a Los Alamos County transformer failure took down the steam plant over the weekend

APPENDIX E: STEAM MAINTENANCE REGISTER

Task Description	Estimate	Status Date
030029 (6MO) WA STARTUP AND SHUTDOWN	$6,142.50	1/3/2022
030029 REPLACE WING 9 STM-9-8	$30,247.72	2/22/2022
030029 REPAIR STEAM TRAPS	$38,848.00	3/8/2022
030029 W5 REPAIR/REPLACE HVA-036 REHEAT TEMP CONTROL VALVE	$1,463.20	3/11/2022
030029 FY STEAM SHUTDOWN/START UP	$2,047.50	3/29/2022
030029 REPAIR PC-011/PC-012/PC-013 & PC-016	$32,360.00	4/5/2022
030029 REPAIR HV-003 FREEZE PROTECTION TEMP CONTROL	$1,114.24	4/6/2022
030029 THERMOSTATS ON HVA-52 AND HVA-51	$1,392.80	4/16/2022
030029 REPAIR STEAM LEAK TO HVA-22	$7,903.20	4/27/2022
030029 REPAIR CLAM SHELL OPENER ON HVA 30	$1,338.00	5/5/2022
030029 REPLACE TCV-9-135	$18,582.40	5/10/2022
030029 W2 REPAIR PREHEAT DAMPER ACTUATOR FSR#249142	$2,089.20	5/26/2022
030029 REPAIR LINKAGE TO CLAM SHELLS ON HVA-51	$1,121.60	5/27/2022
030029 HVA-51 AIR WASHER DAMAGED FLOAT WING 9	$1,593.60	7/28/2022
030029 W2 REPAIR/REPLACE TEMP CONTROLLERS ON HVA-006	$1,463.20	8/20/2022
030029 (6MO) WA STARTUP AND SHUTDOWN	$7,077.60	8/22/2022
030029 TS&R DEFICIENCIES RELATED TO HV-003 FSR#272028	$9,953.76	8/26/2022
030029 W9 REPAIR HVA-051 FSR#241921	$30,718.60	8/27/2022
030029 REPLACE COVERS ON PUMPS PWS-66 AND PWS-67	$1,593.60	9/26/2022
030029 REPAIR/ REPLACE MERCOID SWITCH	$1,392.80	10/20/2022
030029 REPLACE GUARD COVER ON PUMP PWS-68	$1,422.40	10/28/2022
030029 REPLACE STEAM TRAP BETWEEN VALVES C-0-72 & C-0-44	$9,859.20	11/10/2022
030029 (6MO) WA STARTUP AND SHUTDOWN	$7,171.20	11/28/2022
030029 REPLACE REGULATOR VALVE IN WINGS 1, 2, 3, 4, AND 7	$154,500.80	12/7/2022
030029 REPAIR FLOAT SYSTEM ON PC -008	$3,075.60	12/9/2022
030029 W7 REPAIR/REPLACE TEMP CONTROLLER ON HVA-044	$1,463.20	1/16/2023
030029 REPLACE WING-5 STEAM REGULATOR PILOT VALVE	$8,753.60	2/6/2023
030029 REPAIR W-7 HVA-003 PRE-HEAT STEAM COIL LEAK	$6,018.92	3/24/2023
030029 FY STEAM SYSTEM REPAIRS BUILDING-WIDE	$80,003.70	4/1/2023
030029 TS&R HVA-35 CLAMSHELL (DAMPERS) NOT ACTUATING	$2,897.55	4/6/2023
030029 REPAIR HUS-016/ HUS-032	$10,958.40	5/1/2023
030029 TS&R PC-7 MCC-AK 1-H	$3,450.10	5/1/2023
030029 REPAIR STEAM LEAK ON TEE CONNECTION	$13,191.70	5/9/2023
030029 PRV STEAM RELIEF VALVES TESTING	$3.70	5/13/2023
030029 REPAIR HVA-050 RE-HEAT COIL STEAM LEAKS	$6,565.20	5/13/2023
030029 REPAIR HUS-020/ HUS-007	$16,053.60	5/14/2023
030029 REPAIR REHEAT COIL ON HVA-50	$8,236.80	5/23/2023

030029 REPLACE PHW-21	$5,644.69	5/28/2023
030029 REPAIR HV-003 COIL STEAM LEAKS	$6,626.40	5/31/2023
030029 REPAIR VALVE CON-4-132 & 130 WING 4	$10,933.20	5/31/2023
030029 TS&R DEFICIENCIES RELATED TO HV-3 FSR#272028	$9,953.76	5/31/2023
030029 REPAIR STEAM LEAKS ON HVA'S	$33,649.64	6/14/2023
030029 (6MO) AIR WASHER STARTUP/SHUTDOWN	$7,566.30	7/1/2023
030029 REPAIR PC-007/ PC-010	$29,750.00	7/2/2023
030029 REPAIR PREHEAT COIL ON HVA-50	$6,611.00	7/5/2023
030029 REPAIR REHEAT/PREHEAT COILS ON HVA-51	$6,611.00	7/6/2023
030029 INSTALL NEW STEAM GAUGES FOR WINGS: 3, 7 AND 9	$7,285.20	8/3/2023
030029 REPLACE VACUUM BRAKER (CHECK VALVE) CON-9-58	$3,085.00	8/8/2023
030029 REPAIR STEAM SYSTEM BUILDING-WIDE	$137,261.60	8/17/2023
030029 WING 9 STEAM SYSTEM DRIP PAN REPLACEMENT	$6,081.60	8/20/2023
030029 INSPECT STEAM SYSTEM	$10,843.20	8/25/2023
030029 REPAIR STEAM LEAK TO HVA-21	$6,565.20	8/26/2023
030029 REPAIR STEAM TRAPS ON HUS-036	$1,692.00	8/26/2023
030029 REPAIR LEAKING STEAM VALVES W-4 FSR#250677	$7,030.10	8/30/2023
030029 REPAIR LEAKS ON STEAM VALVES	$20,279.20	9/7/2023
030029 ANNUAL STEAM TRAP PM CY 22-23	$22,718.29	9/30/2023
TOTAL	$872,256.57	

APPENDIX F: TRANE HEAT PUMP DATASHEET

TRANE

Version: Trane Select 1.4.6

CONFIGURED UNIT TECHNICAL DATA: AXM030

Unit		
Number of modules	7	
Model	AXM030	
Chiller power supply	460/3/60	V-ph-Hz
Refrigerant	R410A	
Compressors per module		
Type	SCROLL	
Number	2	
Refrigerant Circuits	2	
Total refrigerant charge	96	lbs
Fans per module		
Type	EC axial fan	
Number	2	
Evaporator per module		
Type	Brazed Plate	
Number	1	
Weight per Module		
Net weight per module	3000	lbs
Cooling conditions		
Fluid	Water	
Fouling factor	0.00010	h ft2- °F/Btu
Inlet fluid temperature	54.00	°F
Outlet fluid temperature	44.00	°F
Design ambient temperature	95.00	°F
Elevation	7498	ft
Cooling performance per bank		
Cooling capacity	205.71	Tons
Minimum unloading	14.7	Tons
Compressors input power	244.1	kW
Fans input power	21.00	kW
Total input power (A1)	265.1	kW
Flow rate	478.9	GPM
Pressure drop	10.1	ft H2O
EER (A1)	9.32	Btu/Wh
Efficiency - 100% Load	1.2885	kW/Ton
NPLV.IP	0.9125	kW/Ton
Total air flow	161001	SCFM

Page 1 of 4

Heating conditions

Inlet fluid temperature	109.99	°F
Outlet fluid temperature	129.99	°F
Design ambient temperature	0.00	°F
External Relative Humidity	75	%

Heating performance per bank

Heating capacity	1544.88	MBH
Compressors input power	258.0	kW
Fans input power	21.26	kW
Total input power (A1)	279.2	kW
Flow rate	158.4	GPM
Pressure drop	1.31	ft H2O
COP (A1)	1.62	
Total air flow	161001	SCFM

Electrical performance per Module (Chiller side)

Power supply	460/3/60	V-ph-Hz
Compressors	59.3	A
Fans	9.1	A
Chiller FLA	68.4	A
Chiller MCA	77.0	A
Chiller MOCP	110.0	A

Electrical performance per power supply (Chiller side)

Number of power supplies	1	
Modules per power supply	7	
Power supply	460/3/60	V-ph-Hz
Chiller FLA	478.7	A
Chiller MCA	487.0	A
Chiller MOCP	600.0	A

Sound levels per bank

Sound pressure (S2)	83.8	dB(A)

Notes

(A1) Compressor and fans power

(S1) The sound pressure levels are calculated per AHRI 370.

(S2) The equipment sound levels on the field can vary by proximity to reflective surfaces, other noise sources and site installation factors.