Grand Rapids Green Revolving Fund

ENGINEERING 333

2025

Final Technical Report

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Background

As rising carbon dioxide emissions continue to elevate the Earth's temperatures, it faces increased threats to global health. The dangers associated with rising temperatures will cause irreversible damage to ecosystems, habitats, and civilizations. While there are several existing strategies for limiting and preventing climate change, the most direct method is to reduce carbon dioxide emissions.

Recently, the City of Grand Rapids has commissioned and accepted the Climate Action and Adaptation Plan (CAAP) into policy this year. The CAAP outlines 16 goals to be implemented by 2030 to get our city on the pathway to carbon neutrality by 2050. Among the strategies and actions listed in the document is the mention of exploring the feasibility of innovative financing solutions like creating a green revolving fund, or GRF [CAAP, p.60].

Introduction

In order to assist in reaching the CAAP goals, the 2025 Thermal Systems Design and Optimization Class (ENGR 333) partnered with the City of Grand Rapids to answer the following question: "What would it take for the City of Grand Rapids to establish and operate a GRF?" The class's client for this project is Grand Rapids Mayor LaGrand who, alongside several municipal dignitaries, generously provided their time and effort in guiding the class throughout the semester long project.

Description

A green revolving fund, as seen in Figure 1, is a self-sustaining fund used to fund energy efficiency projects. The savings from each project, such as lower utility bills, are paid back into the fund to replenish, sustain, and gradually grow the fund's balance. The cycle created between funding projects and receiving returns from the projects gives the fund its revolving nature. As time goes on, this fund will grow to take on more projects, bigger projects, and use part of its savings to support projects for community and environmental health that may not have the ability to pay back the fund.

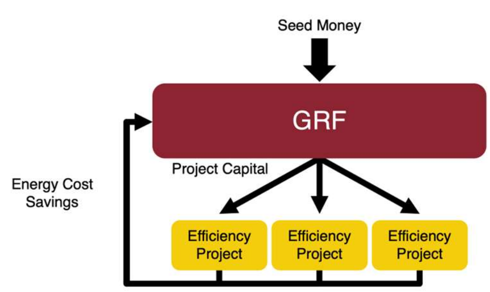

Figure 1: Simplified Cashflow Diagram for a Green Revolving Fund

Therefore, to be successful, the Grand Rapids Green Revolving fund (GRGRF) needs a governing body and regulatory policy, a thorough financial analysis tool, and potential projects that provide financial and environmental benefits. To establish feasibility of the GRGRF, the ENGR 333 class organized into three teams to determine what successful implementation and operation would look like from the policy, financial, and project perspectives. Conclusively, the policy team has developed a GRGRF management team structure and a governing policy. The project team has generated project examples that specifically apply to the City of Grand Rapids that could be implemented to establish and perpetuate the fund. The financial team has provided thorough project analysis of the GRGRF, including cashflow projections and suggestions for project construction ordering.

To move the GRGRF forward, the ENGR 333's recommended order of operations is as follows: perform energy audits on the buildings within reach of the fund's capabilities, evaluate inefficiencies and shortcomings at these locations, follow GRGRF policy to rank project opportunities in order of environmental impact and investment requirement, and implement projects. Because this order of operations was outside of the scope of the semester study and is not a necessary step to determining the feasibility of the GRGRF, the ENGR 333 class has provided specific example projects, financial evaluations and projections, and a general policy framework and management structure for implementation.

Results

Overall, the results of the project and financial analyses can be seen in Figures 2-5, knowing that they would be implemented according to the policy described in Appendix A. For the full financial analysis, see Appendix B. For the full project results, see Appendix C. To compare projects, the results are reported per dollar invested. Figure 2 illustrates the annual energy savings per dollar invested.

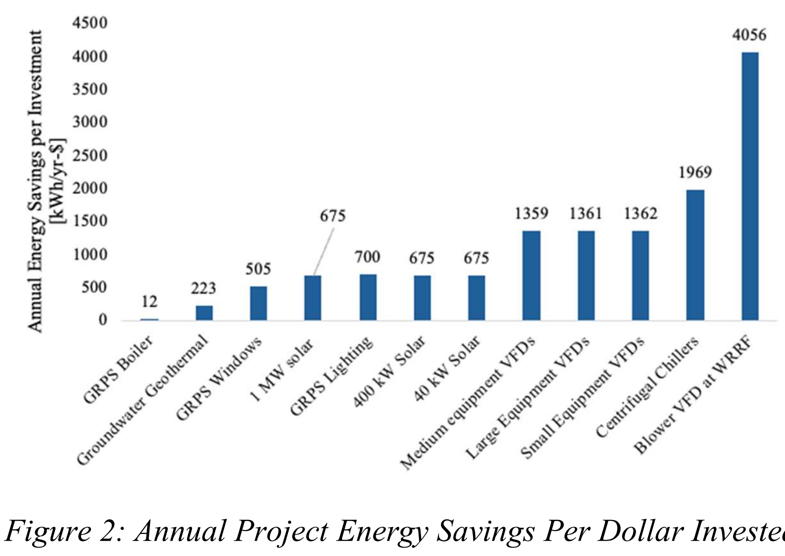

Figure 2: Annual Project Energy Savings Per Dollar Invested

Note that many of these projects are scalable, such as the solar projects and VFDs, allowing for their energy and environmental benefit to be repeated throughout the city. Next, Figure 3 displays the annual carbon dioxide savings per dollar invested and color codes the projects. Blue indicates a strong financial return while green denotes a project with a focus on sustainability and may not have payback into the fund. Read more about this distinction in Appendix A. Within this plot, it can be seen that blue projects can have strong environmental impact like green projects. Furthermore, note that carbon dioxide is only one metric that plays into the value of a green project and other factors like public health, property value, and citizen enjoyment are not accounted for in these metrics.

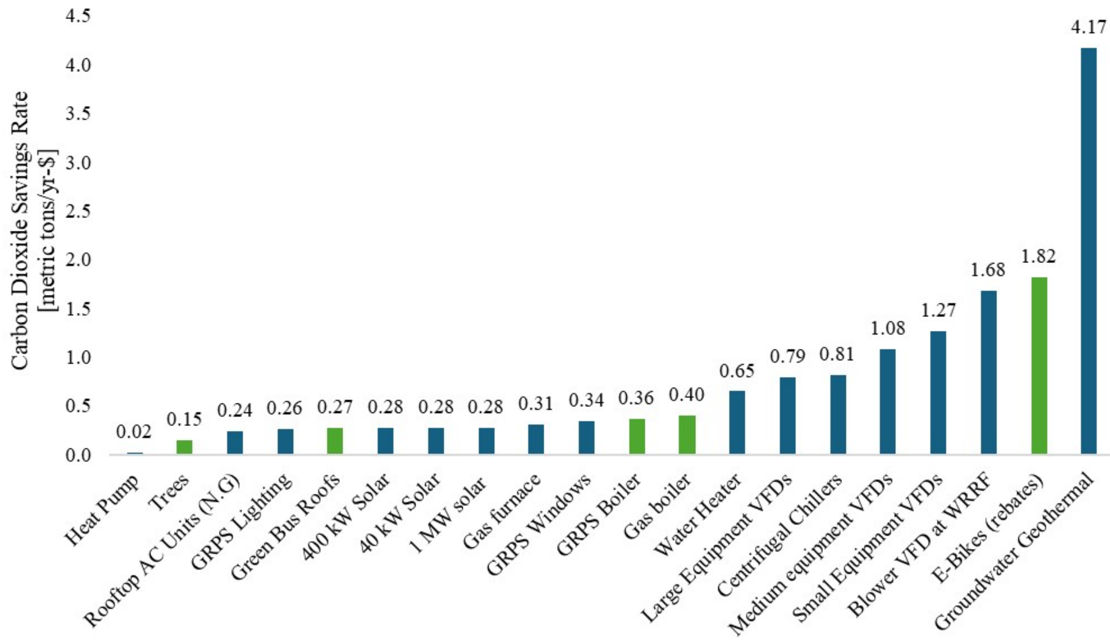

Figure 3: Annual Carbon Dioxide Savings Per Dollar Invested

As for the financial analysis, the goal of producing thorough project analyses and cashflow projections can be summarized by the following two figures. The first figure, Figure 4, depicts how the gradual implementation of projects would sustain and grow the fund through the returns. Additional benefits can also be seen such as the social cost of carbon and viewership (similar to advertising benefits). Although these benefits do not directly impact the status of the fund, they have a strong benefit for the communities they are implemented in.

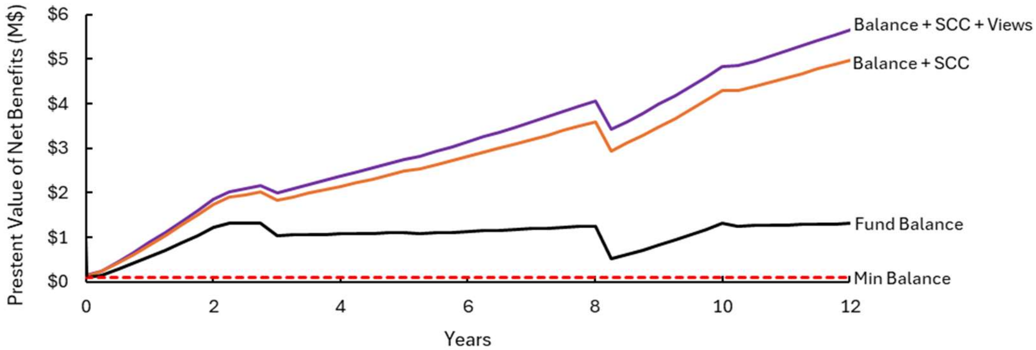

Figure 4: Present Value of Net Benefits Per Year

Additionally, Figure 5 summarizes completed project analyses, illustrating the relative investment size, lifespan, payback, and profits of the projects. This figure, when considered in conjunction with city needs, could be used in the decision-making process to schedule projects and depict their behavior over time. This figure can also serve as a project implementation visual in conjunction with the fund balance if ordered in the same manner.

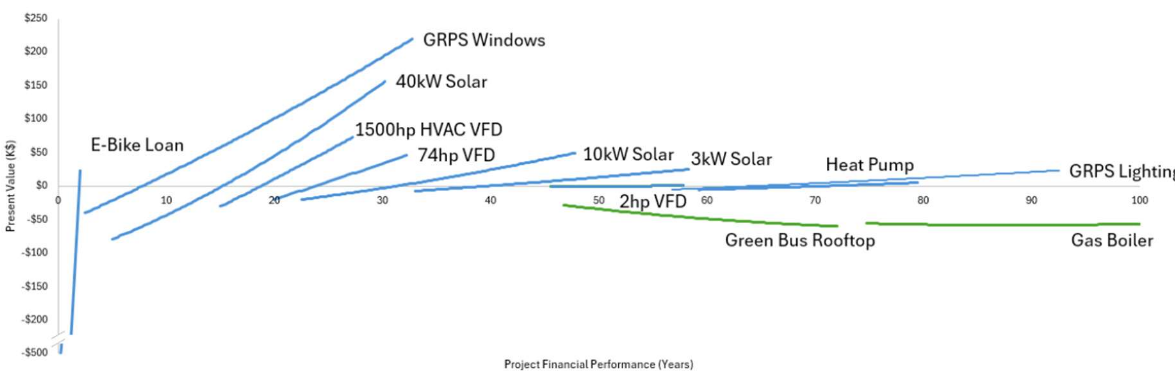

Figure 5: Present Value of Project Financial Performance

Conclusion

Conclusively, the Calvin University senior thermodynamics students have demonstrated that to establish and operate a green revolving fund, the City of Grand Rapids would need policies and an oversight board as written in the policy document, an initial allotment of seed money, reporting by the board, a cost delivery mechanism, and energy efficiency projects including proposals, feasibility analysis by the board, implementation contracts, and project monitoring. Together, these traits indicate that a green revolving fund is feasible for the City of Grand Rapids to assist meeting CAAP goals.

Appendix A

GRGRF Policy

Introduction

The Grand Rapids Green Revolving Fund (GRGRF or "Fund") is a financial mechanism designed for the City of Grand Rapids municipal departments to implement high impact sustainability and energy efficiency projects. By reinvesting savings generated from approved projects, the Fund creates a continual cycle of improvement that reduces greenhouse gas emissions, lowers operational costs, improves community wellbeing, and supports the City's Climate Action Adaptation Plan (CAAP) and Sustainability Framework. This final report summarizes the development of the GRGRF, including financial structure, governance policies, and project feasibility work completed.

Description

The GRGRF Policy Document establishes how the Fund operates, who is responsible for decision making, and how projects are selected and evaluated. The major components include:

- **Fund Management & Governance**
  Defines the structure of the Board and Fund Director, ensuring accountability and transparency. Clear roles and term lengths help provide continuity despite staff turnover.
- **Financial Structure**
  Establishes a reinvestment model where savings from blue category projects replenish the Fund. A minimum reserve guarantees fund stability and enables continuous project support.
- **Process & Operations**
  Outlines Board meeting frequency of decision-making ethics, transparency and requirements, and reporting expectations. These processes ensure responsible stewardship of public resources.
- **Project Categories**
  Creates a balanced framework where the majority of funds support measurable energy savings projects (blue), while still reserving capacity for sustainability, education, and community benefit projects (green).
- **Selection and Evaluation Procedures**
  Standardizes how proposals are submitted, reviewed, and ranked using quantifiable metrics. Post implementation measurement and verification ensure projected savings are achieved.

Each of these policy sections is important because they collectively ensure the Fund remains financially healthy, strategically aligned with sustainability goals, and accountable to the public.

Results

The final GRGRF Policy includes:

- Established governance structured defining roles for the Fund Director and Board.
- Reinvestment strategy requiring a portion of verified savings to be returned to the Fund.
- Minimum reserve policy to maintain financial sustainability.
- Project classification system (90% blue/ up to 10% green annually).
- Quarterly monitoring, reporting, and public transparency requirements.
- Standardized proposal process including payback analysis, CAAP alignment, and community impact assessment.
- Measurement and verification protocol based on industry standards.
- Updated project change management process to ensure continued performance.

These policies form a foundation that enables the Fund to grow over time while maintaining accountability and measurable progress toward climate goals.

Conclusion

As the City of Grand Rapids continues to pursue decarbonization and resilience, the GRGRF must remain flexible and responsive to emerging technologies, community priorities, and cultural shifts. Future policy updates may include more advanced lifecycle carbon accounting, expanded funding for nature-based solutions, partnerships with local institutions, and community facing grant programs. Regular reviews every three years will ensure the Fund evolves as costs, technologies, and sustainability need to change. Ultimately, by reinvesting savings and maintaining transparent governance, the GRGRF positions the City to meet long term climate goals while delivering ongoing financial and social benefits.

While the GRGRF will initially focus on municipal operations to build a strong financial foundation, future phases of the program may expand to include partnerships with external organizations. As the Fund grows and community awareness increases, collaboration with local businesses, institutions, and nonprofits could amplify both financial returns and community wide environmental benefits.

Board membership will primarily consist of representatives from key municipal departments such as Public Works, Finance, and the Sustainability Office. Over time, expanding participation to include community or institutional representatives may strengthen transparency, public engagement, and diverse expertise in project selection.

The current emphasis on blue projects ensures continued fund growth; however, this balance may shift over time as technology costs evolve or as state and federal policies create new incentives to prioritize social or environmental outcomes. The Board will retain the flexibility to adjust funding allocations to ensure alignment with future sustainability and equity goals. Together, these adaptive strategies ensure the GRGRF remains a durable and forward-looking tool in advancing Grand Rapid's climate leadership.

Appendix A1: Policy Document

Grand Rapids Green Revolving Fund Policies

Executive Summary

The Grand Rapids Green Revolving Fund is financial mechanism available to Grand Rapids Municipal Departments to implement energy efficient and sustainable projects aimed to align with goals presented within the City's Climate Action and Adaptation Plan (CAAP) and Sustainability Framework.

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1. **Introduction**

The City of Grand Rapids Green Revolving Fund (GRGRF or "Fund") is a financial mechanism supporting sustainability, resilience, and energy efficiency initiatives across municipal operations. The Fund finances projects that reduce resource consumption, lower greenhouse gas emissions, and generate measurable cost savings that are reinvested into future projects. The GRGRF directly advances the goals of the City's Climate Action and Adaptation Plan (CAAP) and Sustainability Framework, specifically responding to the CAAP's *Key Sectors of Focus,* Strategy 3, Action 3, which calls for the establishment of a Green Revolving Fund to accelerate climate forward facility upgrades.

2. **Mission Statement**

The mission of the GRGRF is to assist the City of Grand Rapids to achieve greenhouse gas emissions reduction goals in a cost-effective and transparent manner via improving the energy efficiency and sustainability of municipal facilities.

3. **Purpose of Policy Document**

This document guides all city departments and stakeholders involved in the GRGRF. It defines fund governance, project eligibility, decision-making, and accountability mechanisms to ensure long-term transparency and sustainability.

4. Fund Management

4.1 GRF Roles:

- Fund Director – Oversees the projects in their day-to-day functions, ensuring that the projects are functioning up to project standards. The fund director cannot be a board member and can serve a maximum of 2 terms that are 5 years each.
- Board Director – Oversees meetings, represents the GRGRF publicly, and ensures adherence to policies.
- Members of the Board - A member of the board has the following responsibilities: present during meetings, voting on projects, monitoring project outcomes, financial returns, approves policy updates, reviewing the fund, and enforcing compliance and reporting standards. Members are appointed from their respective departments at the discretion of the department director.

4.2 Responsibilities:

4.2.1 Fund Director:

- Oversees annual independent audits for project performance verification.
- Oversees quarterly, internal audits for performance verification
- Oversees financial flows of the GRF and submits quarterly reports to the GRF board.
- Presents viable project proposals, status, and updates to the GRF Board at quarterly meetings.
- Manages active projects and oversees changes as requested by the mayor.
- Works with the municipal departments to generate project ideas.
- Attends the GRGRF Board quarterly meetings

4.2.2 The Board:

The GRGRF Board holds fiduciary responsibility for the Fund and reports to the City Sustainability Office, coordinating with the Finance Department for auditing and financial tracking. 5-8 members are a part of the board. Internal members may include elected people from government offices like finance, maintenance, and sustainability. External members could be from GR school systems, major companies, etc.

The Board will:

- Conduct quarterly meetings for project review and policy updates
- Approve or decline projects. See section 9, project evaluation.

4.3 GRGRF Board Composition:

The GRGRF Board (the Board) will consist of voting members representing key city departments including Sustainability, Finance, Public Works, and Facilities. The number of members will be approximately 5-8 depending on the number of participating departments. Non-voting members may include technical advisors, external experts, or student interns. Members are appointed by virtue of their departmental role to ensure continuity regardless of staffing changes.

4.4 Appointment and Terms:

4.4.1 Fund Director:

The Fund Director is elected by a popular vote by the Fund Board. They will serve a term length of five years and can be renewed for a total of two terms. The Fund Director cannot be an active member of the board during their term.

The Fund Director will have about 0.15 FTE. Compensation for work performed will come from the fund reserve, outlined in section 5.2.

4.4.2 Board:

Appointed members will serve term lengths of three years, or until the conclusion of the individual's employment in their department and may be renewed once. Members should expect to dedicate 4-10 hours per month, equivalent to about 0.05 — 0.08 FTE in compensation for board members.

5. Fund Financial Structure

5.1 Reinvestment Policy:

Verified cost savings generated by approved GRGRF projects shall be reinvested back into the Fund to support future projects. Reinvestment will follow the City's established accounting procedures, ensuring that savings are documented, tracked over the life of each project, and attributed back to the Fund in a transparent and auditable manner.

The reinvestment procedure will return cost savings to the Fund after reaching payback, for a period equal to 40% of the project's payback period. Additional cost savings beyond that period will be given to the municipality/owner. Green projects are very weak or have no payback period and may not be able to fit this strategy; these projects will be discussed in section 7.1. It is up to the GRGRF board's discretion on how to handle the reinvestment procedure for green projects.

5.2 Minimum Reserve:

To maintain fund stability and ensure continuity of project financing, the GRGRF will maintain a minimum reserve balance equal to $100,000 in Fund value or an amount defined by the Board based on annual project needs.

The reserve serves as a financial buffer to manage cash flow, cover year-to-year variability, project performance, and protect the Fund against unanticipated expenses. If the Fund balance falls below the minimum reserve threshold, new project approvals may be paused or limited until the reserve level is restored.

The fund will also supply compensation for the fund director's work completed through money that is re-routed back into the fund through cost savings.

6. **Processes and Operations**

Actions	Project Proposal	Board Voting		Proposal Approval/Rejection	Project Launch	Payback & Auditing	Project Implementation	
Project Types	Proposed Projects	Pending Proposal		Pending Proposal (Inactive Proposal)	Active Project		Working Project	
Activity Participants	Project Proposer	GRGRF Interns	GRGRF Board	GRGRF Board	Project Implementer	GRGRF Board	GRGRF Board	
Cash Flow		(-) Wages			(-) O&M	(+) Audited Savings		
Budget							(-) Maintenance	(+) Savings

Figure 1. Process Flow Diagram

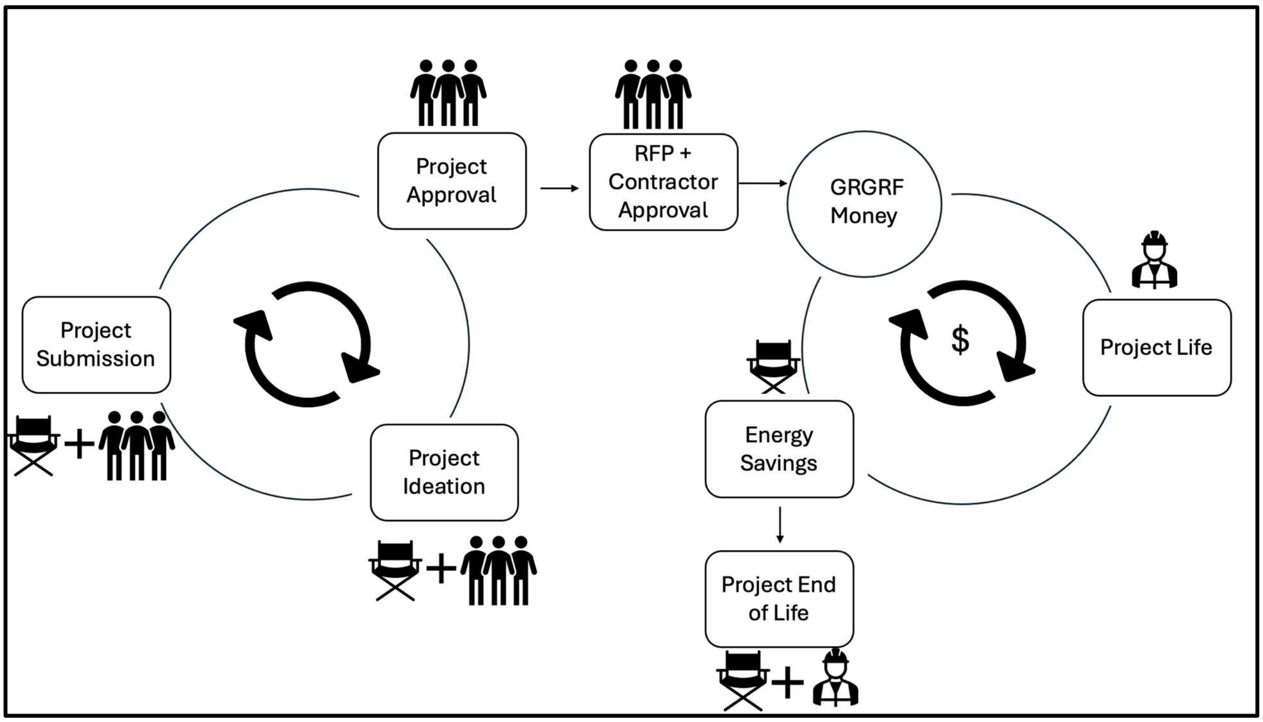

Figure 2. Project life cycle

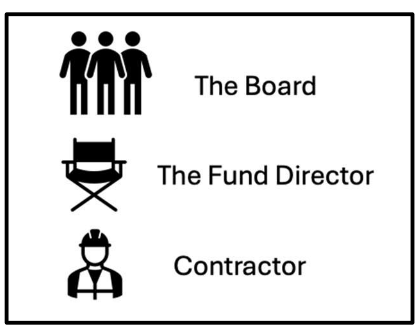

Figure 2a. Key for Figure 2.

6.1 Board Meeting Frequency:

- The board will meet quarterly.
- Additional meetings can be called by the chair or fund director as needed for project review cycles and decisions.

6.2 Decision Making and Voting Ethics:

- For project approval and decision-making, a majority vote will determine the result, where the majority is defined as most voting members present.
- Tie votes will be resolved by the Board manager.
- Conflicts of interest must be disclosed prior to voting. The voting eligibility of conflicted members is decided by the rest of the board.
- Members must annually sign the City Commission Policy 100-06, Conflicts of Interest & Ethical Standards of Conduct: https://www.grandrapidsmi.gov/files/assets/public/v/1/documents/policies/city-commission-policies/ccp-100-06-conflicts-of-interest-and-ethical-standards-of-conduct-policy-for-elected-and-appointed-officials.pdf
- Meetings must follow the standard procedures for Grand Rapids city commission meetings.

6.3 Transparency:

- Annual project and overall Fund information will be provided in the City's annual report.
- Details will include fund energy performance, status of current projects, changes to existing projects, and financial savings.

6.4 Accountability:

- The board shall provide the following:
    - Quarterly reports for the city council.
    - Annual financial and performance reports to the public that include project savings, emission reduction, and other impacts.
    - Compliance with all municipal transparency and ethics policies.
    - This policy document shall be reviewed at least every three years by the GRGRF board in consultation with the Sustainability Office and Finance Department.
    - Policy changes and revisions will be implemented upon a majority vote of the board members.

6.5 Website Requirements:

- Upon the initial start of GRGRF, a public website shall be constructed or added to the Office of Sustainability website.
- The website will be maintained according to the City's standard process requirements.
    - This website shall provide transparency and quarterly updates for past, present, and future projects.

7. Projects

Projects will be implemented through a two-step process:

1. An initial decision on eligibility of a project
2. Once a project is approved for implementation, it will be implemented to the standard City RFP process.

7.1 Project Types:

- **Blue Projects:**
    - Must demonstrate a short payback period of less than 20 years.
    - Savings generated by reducing energy expenses are repaid to the fund, thus providing capital for future projects.

- **Green Projects:**
    - Demonstrates a long payback period of 20 years or longer or no payback period at all
    - Minimal focus on financial savings but leads to progress on sustainability goals.
    - Must demonstrate positive economic or environmental impacts on the ecosystem or human well-being.
    - May support education, outreach, recycling, or the operation of sustainable programs.
    - Projects of this type do not always replenish the GRGRF.

Projects will be divided into blue and green projects. GRGRF funding shall be no less than 90% for blue projects and no more than 10% for green projects per year.

8. **Project Proposal and Selection Process**

8.1 Proposal Requirements:

All project proposals must include:

- Estimation of payback and payoff time, based on projected energy savings.
- Must demonstrate alignment with Grand Rapids climate goals and CAAP priorities.
- Must demonstrate energy, water, or emissions reductions based on the project.
- Must demonstrate community or social benefits.

8.2 Guidelines:

Proposers, defined as city departments, facilities, or divisions within the organization, are responsible for submitting a project proposal to the board via website submission. (See Appendix A.A)

The application process will follow the stages:

1) Initial project ideas submitted to GRF Board via Form 1
2) Board evaluates project submissions
3) Selected projects become a request for proposal (RFP) within the Purchasing Department
4) Responses to RFP are reviewed and scored with a weighted decision matrix
5) Board approval
6) Implementation and Monitoring

Each proposal must include:

1) A project Proposal Form, shown in Appendix A.

9. **Project Evaluation**

9.1 Performance Verification:

Following project implementation, performance verification shall occur by the Board frequently to ensure the continued viability and effectiveness of the project. Each project will undergo monitoring at least once ***per quarter*** to verify that operational, environmental, and financial outcomes remain consistent with the approved proposal and projected performance metrics. Projects will be monitored quarterly by the Fund Director to monitor and report the progress to the Board for performance verification.

9.2 Financial Tracking:

All projects supported by the GRGRF are subject to ongoing financial tracking. Cost savings will be reported, including financial and energy saving performance, on a quarterly basis. Reports shall be submitted by the proposer to the Fund Director for review and inclusion in the annual summary.

The Fund Director will submit quarterly reports to the GRGRF Board. The Board compiles results into an annual report reviewed by the City Sustainability Office and made publicly available on the Fund website, see section 6.5.

9.3 Project Revisions & Change Management:

Any modification to an approved project must be reviewed through the GRF change proposal process prior to the end of the fiscal year.

- Proposal of change: Project managers shall submit a written request outlining the proposed revision, justification, and anticipated impacts on performance and financial returns.
- Review process: The GRGRF board will assess the proposed change for continued alignment with fund objectives, cost-effectiveness, and sustainability outcomes.
- Documentation: All approved revisions must be formally documented and appended to a running project filing system determined by Board members. Transparency of decision-making shall be recorded and maintained.
- Shift in cost, scope or outcome: Any shift in project cost exceeding 10%, material change in project scope, or alteration to expected outcomes requires explicit written approval from the GRF Board prior to implementation.

9.4 Measurement & Verification Protocols:

- Energy performance shall be verified using pre- and post-project implementation information data.
- Baseline utility data must include at least 12 months of history.
- For energy projects, M&V shall follow an IPMVP option B or similar standard.

Appendix A.A:

Initial Proposal Structure and Required Elements Form

Date:		**Project location:**	
Project title:		**Amount requested:**	

Contact information:

Email:	**Phone number:**	**Department Affiliation (if applicable):**

NOTE*: All projects must relate to a Grand Rapids municipal party, https://www.grandrapidsmi.gov/Government/Departments

Sustainability theme: (One or more may be selected from this list)

- **Energy Systems**: Addressing the generation, distribution and consumption of fossil fuel-based energy.
- **Residential Homes**: Increasing the affordability, energy efficiency, health, climate resilience and access to renewable energy of housing
- **Buildings & Industry**: Reducing GHG emissions from buildings & industrial processes
- **Transportation**: Reducing reliance on fossil fuel powered single-occupancy vehicle usage, increasing active and shared modes of transportation, and increasing access to electric vehicles.
- **Nature Based Solutions**: Increasing sequestration and increasing nature's resilience to climate change.
- **Food Systems**: Reducing waste and increasing access to local food and growing opportunities

Processes and Project categories: All projects must fall into an identified category.

- **Blue Projects (Yes or No) -** Blue projects must demonstrate quantifiable savings for the GRF and must have a 10-year payback period. Funds revolve so that savings generated by reducing operating expenses are repaid to the fund, thus providing capital for future projects.
- **Green Projects (Yes or No) -** Green projects have a payback period of over 10 years and represent some degree of unquantifiable savings but lead to progress on sustainability goals. Projects must demonstrate positive economic or environmental impacts on future resources, ecosystem health, and human wellbeing. Projects in this category may support education, outreach, recycling, or
the operation of sustainable programs. Projects of this type do not always replenish the GRF.

Proposed Project Details

Summarize your project in 3-5 sentences:

Estimated Project Costs and Lifespan

Project Lifespan:	
Total Initial Investment Required:	

Estimated Project Savings (if quantifiable):

Amount saved per quantifiable resource reduction (payback period):	
Maintenance and Verification Plan: (including energy monitoring and financial accounting plan):	
Anticipated payoff period:	

Additional comments:

Appendix B

GRGRF Finance

Introduction

The financial team evaluated the monetary and non-monetary benefits of projects proposed by the project teams. Models were developed for each project with factors including the cash flow into the GRF, the Social Cost of Carbon (SCC), visibility, and avoided maintenance costs. Each project was projected using the Net Present Value (NPV) and includes a 4% inflation rate per year. A potential cash flow model was constructed given the projections of each project, adhering to the policy written by the Policy Team.

Description

To further the development of the projects presented by the project teams, the financial team analyzed and projected each project over its lifespan given initial cost, initial rebate, maintenance costs, and end of life costs. Also included in the financial analysis were escalation rates for various monetary and non-monetary factors, as well as net present value given a 4% inflation rate. The non-monetary factors analyzed were SCC, valued at $290 per metric ton of carbon dioxide; views, valued at $0.00961 per view; and road maintenance costs avoided, which applied specifically to the E-bike projections.

In addition to net present value, the financial team also supplied values for the additional SCC of each project and visibility values of each project. These were found given projected saved emissions for the SCC value and an assumed value for $/view calculated from data based on billboard analytics.

Results

The results of the financial team were summarized into two graphs. The first graph, shown in Figure B1, explores a modelled green revolving fund over time with projects from the project team. This model used a one-million-dollar seed fund to start and implement various scalable projects over time. It also shows how the SCC and views impact the fund.

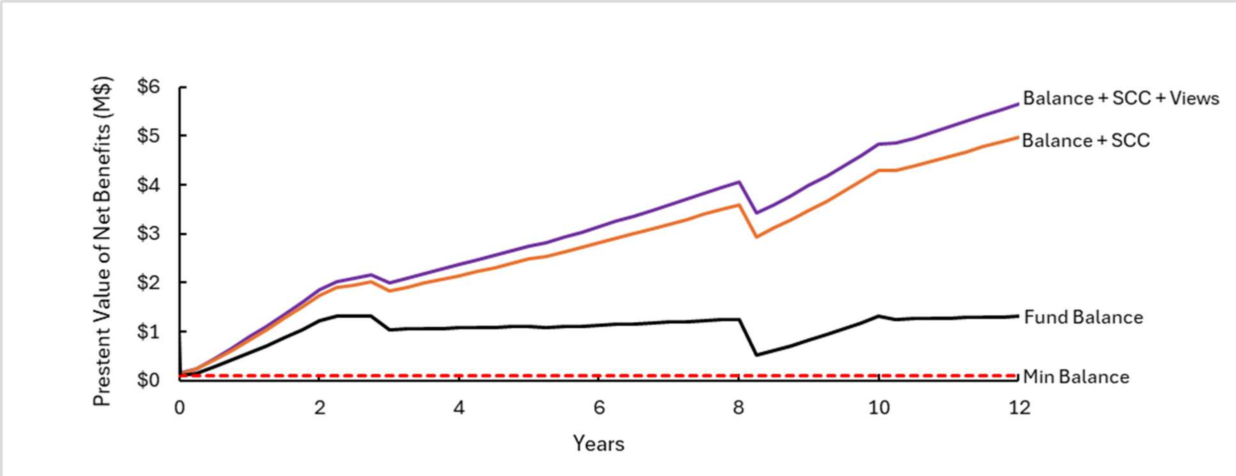

Figure B1: Hero graph depicting potential overall fund reserves given implemented projects over time, including projections for NPV, minimum balance, Social Cost of Carbon, and Views

Figure B2 shows each individual project sorted by financial performance over time, with green lines designating green projects, and blue lines designating blue projects.

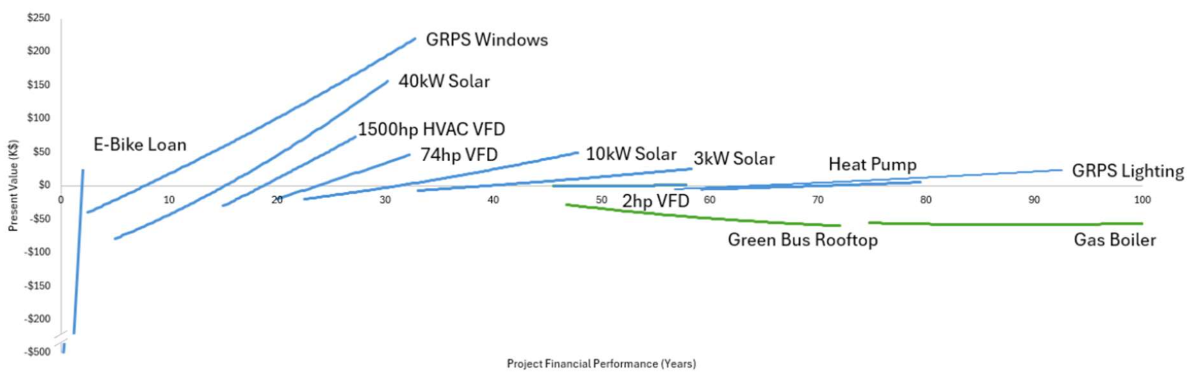

Figure B2: Hero graph depicting all projects with projected Net Present Value over the lifetime of the projects, skewed over time and ordered by financial performance

In addition to graphical analysis, a summary table, shown through Table B1, Table B2, and Table B3, and which was based on Calvin University's Green Revolving Fund was used to lay out the important aspects of the projects, including but not limited to payback time, lifespan, fund profit, and various energy savings.

Project Name	Project Status	Project Team	Project Number	Project Cost ($)	Years Monitor	Estimated Payback Date (Yrs)	Fund Profit ($)
Solar 3KW		1		7,000	25	6.5	3,161
Solar 10KW		1		19,774	25	8.5	9,570
Solar 40KW		1		79,063	25	10	38,029
VFD 55 kW		1		19,423	12	3.5	8,127
VFD 373 kW		1		30,201	12	3.5	12,686
VFD 1.5 kW		1		395	12	3.5	166
Gas Boiler		2		55,230	25	Never	-56,451
Green Bus Roof		2		28,000	25	Never	-59,895
Heat Pump		2		5,077	20	10.75	2,432
E-Bike Loan		3		500,000	8	2	24,201
E-Bike Rebate		3		500,000	8	Never	-178,760
GRPS Window (Electric		3		44,000	30	5.25	19,595
GRPS Lighting		3		4,800	35.5	6.75	1,992
GRPS Gas Boiler		3		75,000	35	Never	-36,821
GRPS Window (Gas)		3		44,000	30	18	11,617

Table B1: CERF style table depicting savings and details of all proposed projects

Project Name	Profit ($)	% of Payback	Maintnence Costs ($)	Total Cost Savings ($)	Total Energy Savings (kWh)	Natural Gas Savings (MCF)
Solar 3KW	25,122	358.8857143	5,000	62,319	159,075	0
Solar 10KW	48,743	246.5004551	22,500	146,420	373,751	0
Solar 40KW	154,056	194.8522065	97,500	522,292	1,333,200	0
VFD 55 kW	47,082	242.4033363	0	86200	316883	0
VFD 373 kW	73,326	242.793285	0	134185	493283	0
VFD 1.5 kW	959	242.7848101	0	1755	6451	0
Gas Boiler	-56,451	-102.210755	53,500	54,279	0	8,159
Green Bus Roof	-59,895	-213.9107143	50,000	0	0	0
Heat Pump	5,388	106.1256648	3,000	19,504	57,501	0
E-Bike Loan	74,201	14.8402	0	607,165	0	0
E-Bike Rebate	-178,760	-35.752	33,016	376,240	0	0
GRPS Window (Electric	219,898	499.7681818	0	370,451	945,613	0
GRPS Lighting	14,184	295.5	0	33,237	84,840	0
GRPS Gas Boiler	-36,821	-49.09466667	35,000	72,972	22,220	12,503
GRPS Window (Gas)	19,622	44.59545455	0	85,801	0	15,452

Table B2: CERF style table depicting savings and details of all proposed projects, continued

Project Name	Gasoline Savings (Gallons)	Total CO2 Savings (metric tons)	Total Views	Notes
Solar 3KW	0	65	pending	
Solar 10KW	0	153	pending	
Solar 40KW	0	544	pending	
VFD 55 kW	0	254	0	
VFD 373 kW	0	395	0	
VFD 1.5 kW	0	5	0	
Gas Boiler	0	2,511	0	
Green Bus Roof	0	189	9,499,125	
Heat Pump	0	24.4	0	
E-Bike Loan	259,951	1,848	19,125,124	Consumer saves $5,443 on Gas
E-Bike Rebate	259,951	1,848	19,125,124	Consumer saves $5,443 on Gas
GRPS Window (Electric	0	416	3,668,250	Electric Boiler assumed
GRPS Lighting	0	125	4,340,763	Maintence is ignored from imporvement
GRPS Gas Boiler	0	693	0	
GRPS Window (Gas)	0	177	3,668,250	Gas Boiler assumed

Table B3: CERF style table depicting savings and details of all proposed projects, continued

A sample projection model, shown in Table B4, was created to assist the customer or any other interested parties in projecting more projects with various interest rates and user inputs, shown in yellow. Boxes shown in green demonstrate the net present value of the project over its entire lifetime and the amount of money returned to the fund during the profit period.

Example Project		Savings Metrics	Total	Quarterly
Project Implementation		Cost Savings ($)	$1,197,129	$6,894
Installation Cost ($)	-$200,000	Energy Savings (kWh)	1,696,800	16,800
Maintenance Cost ($ / quarter)	-$1,000	CO2 Savings (Metric tons)	693	6.86
End of Life Cost ($)	-$3,000	Natural Gas Savings (MCF)	10100	100
Project Length (years)	25	Gasoline Savings (Gallons)	101000	1000
Inflation (Elec) (%)	0.05	Water Savings (Gallons)	101000	1000
Inflation (Natural Gas) (%)	0.02	Views	5000000	50000
Inflation (Water) (%)	0.02	CO2 Cost Savings ($)	$200,880	$1,989
Inflation (Gasoline) (%)	0.0346			
Cost of money (1/yr)	0.04			
Quartly Interest Rate (%)	0.0099			
Rebate ($)	$1,000			
Net Present Value ($)	$428,558			
NPV Fund ($)	$84,441			

Table B4: Sample project using the Financial Team's Excel calculator and projection model

Conclusion

The evaluated projects were implemented in the model as follows with this theoretical scenario. Year 1: 80 kW solar project, 3 efficient window projects, 1 high efficiency gas boiler project, 3 GRPG lighting projects, and 1 E-Bike project. Year 2.75: 120 kW solar project. Year 5: 1 air handler VFD project and 1 E-Bike project. Year 8: 1 E-Bike project. Year 10: 1 Green bus stop roof project.

The projects are staggered to allow money to be returned to the fund before investing in new projects, to allow for a positive balance in the fund at all times. High return projects are implemented first, to get the fund running and making money, where lower return projects can be implemented later when the fund is stable and fully self-sustaining. There are a few exceptions to this to allow for projects with high public visibility, such as the Year 1 E-Bike project. Visibility to the public allows people to see projects in action, where they can see an impact and be introduced to the GRGRF and its goal of sustainability.

The allocations of money to different projects follow the 90-10 split rule and a minimum fund balance of $100,000. 90% of all invested funds are allocated to "Blue" projects, and the remaining 10% are allocated to "Green" projects. "Blue" projects are defined as having a strong payback period relative to other projects where monetary savings are a result of energy savings due to the project implementation, which are repaid to the fund as returned capital. "Green" projects are defined as projects with a weak, or no payback period, where the project has minimal focus on cost savings, and a higher focus on environmental and sustainability goals.

Appendix C

GRGRF Project Team

Introduction

The City of Grand Rapids needs a set of energy, emissions, and cost-saving project ideas to support the initial establishment and growth of the GRGRF. Of the ENGR 333, example project research and development for the GRF was conducted by Hunter Knudson, Henry Phippen, Noah Postema, Devon Heckathorn, Marcus Breuker, Ezekial Hardy, Caleb Schillinger, Brady Vroom, Tristan Carne, Samuel VanOrman, Braden Gilmore, and Marc Rozendal. This team was led by Brayden Meyer, Ethan Bosscher, and Dafna Heule. Together, this team evaluated the feasibility of potential project implementations into the Grand Rapids Green Revolving Fund considering energy, emissions, and cost savings. Not only do these projects lay the ground work for analysis if the fund is implemented, they also provide a framework for developing policies and the financial structure. The scope of the research included primarily municipal buildings, with a few projects external to the city.

Description

The project team researched multiple different project ideas to find the most environmentally friendly and cost-saving projects for the GRGRF. These projects were intended for application internal to the City of Grand Rapids, however many of these could have commercial or residential applications as well. Internal refers to specific projects being done to benefit the city of Grand Rapids and the areas in which the city controls. External refers to anything outside of the city's control.

The project team was tasked with finding projects in the categories of internal solar and VFDs, internal non-solar, and external respectively. Each team calculated the net present value (NPV), CO_2 savings, payback period, and total installation and maintenance costs for their project ideas. In addition to the calculated variables, other benefits like visibility, safety, and the social cost of carbon were considered. These factors aided the policy and financial teams in deciding which if and when projects should be implemented. Many projects were implemented; however, this memo will detail which ones were initially deemed feasible by the financial and policy teams.

Results

The table below summarizes each project analyzed, presenting their required investment and their savings in either natural gas or electric, and carbon dioxide. The methods through which these numbers were calculated can be found in Appendices C1-11,

Table C 1: Sample Project Types Information Summary where tons are listed in metric tons.

Project Name	Required Investment [$]	Annual CCF Savings [CCF/yr]	Annual Electric Savings [kWh/yr]	Annual CO_2 Savings [tons CO_2/yr]
40 kW Solar	79,063	0	53,328	22
400 kW Solar	790,630	0	533,328	218
1 MW Solar	1,976,575	0	1,333,200	545
2 HP VFD	395	0	538	0.5
74 HP VFD	19,423	0	26,400	21
500 HP VFD	30,201	0	41,100	24
Green Bus Stop Roofs	28,000	0	0	7.5
Trees	65,000	0	0	9.6
Groundwater Geothermal Heating	350,000	266,000	78,000	1,458
Blue Energy Star Heat Pump	14,350	4.559	0	0.25
Blue Energy Star Gas Furnace	14,350	81.299	0	4.46
Blue Energy Star Gas Boiler	42,490	311	0	17.07
Blue Energy Star Water Heater	4,290	51	0	2.77
Blue Energy Star Rooftop AC	12,210	53.132	0	2.91
Blue Energy Star Chillers	272,000	0	535,680	221.56
WRRF Large VFD	180,000	0	182,500	75,482
E-Bikes	123,000	0	0	224
GRPS Energy Efficient Windows	430,000	0	217,000	145
GRPS Lighting Controls	4,800	0	3,360	1.23
GRPS Boiler Replacement	75,000	5,335	880	27.24

Figure C 1 displays the carbon dioxide savings from Table C 1 as a function of initial investment (per $1000 invested). This figure shows which projects are most high impact relative to their cost and thereby their effect on the fund's monetary balance. Each project has also been color coded as a blue or green project. It is important to note that green projects may not be financially advantageous for the fund despite CO_2 savings.

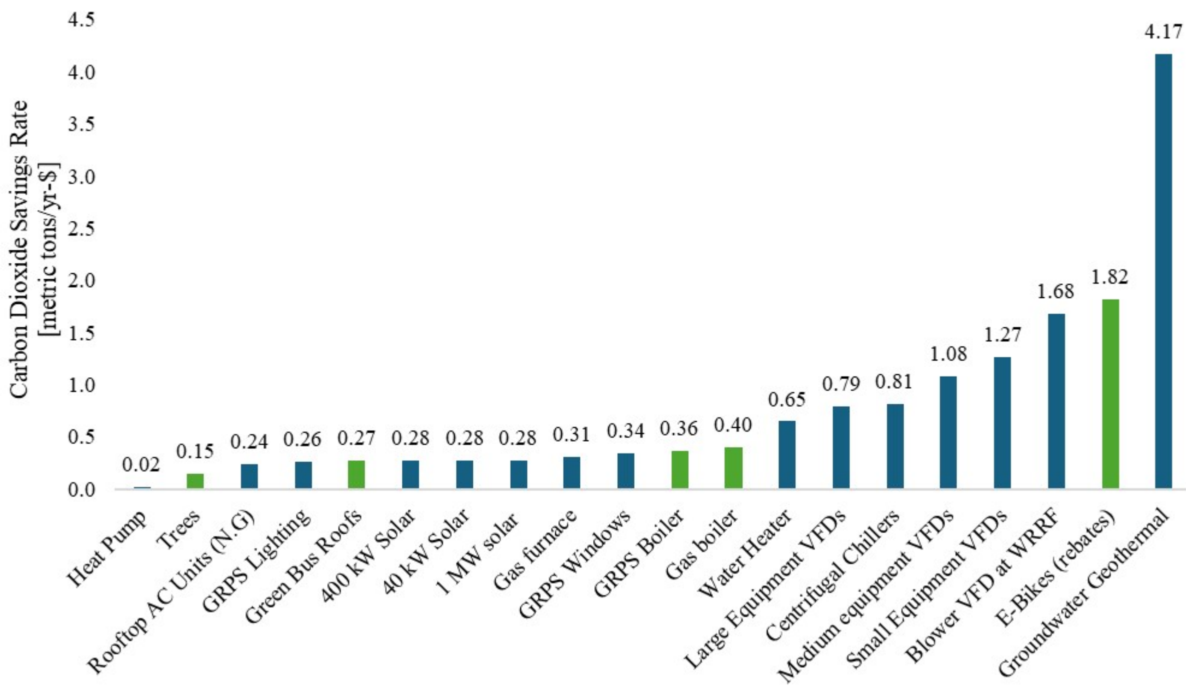

Figure C 1: Summary of all green and blue projects based on annual metric tons of carbon dioxide saved per 1000 dollars invested.

Conclusion

The eleven proposed project types for the GRGRF each show increased energy efficiency and reduction in carbon emissions, including several projects provide large returns in NPV over time and others that do not can do good for the Earth and Citizens of Grand Rapids through benefits like reducing carbon dioxide emissions, green transportation accessibility, and lower electricity bills.

Appendix C1: Scalable Solar Panel Systems

Introduction:

The first project that the project team worked on was solar panels. Solar panels are a good way of reducing energy consumption by producing some energy used by the building, by capturing the energy of the sun to create electrical energy which can be used for a multitude of purposes. For the purposes of this project the solar panels are utilizing unused space on the ground or roofs and initial funds to create energy that can be used instead of energy from the grid which both provides savings to the building in the form of a lower energy bill as well as avoiding energy produced by burning fossil fuels in the grid.

Description

Every building or open land that is owned by the city of Grand Rapids has the ability to contribute to green energy using solar panels. By implementing solar panels on solar ready roofs or using unoccupied land energy can be created for the buildings' use. This solar application would be more beneficial for new buildings with flat roofs, so that the life span of the solar systems can be maximized with the lifespan of the roof. When determining what size system can be installed the area available, budget, and desired energy output are needed beforehand. Once these factors are determined then a system can be purchased from a distributor. Our team collected data for sizes of solar panel systems ranging from 3 kilowatts to 40 kilowatts from a retail website, GoGreenSolar. The website gave values for total cost of the system, the estimated energy saving, the power in kilowatts, and area in square feet for each size. These data points were sent to the financial team to determine the annual CO_2 savings, net present value of the system after 25 years of operation and the payback period of the system.

After receiving these values, the 40kW system was the most accurate in all of these categories with values of the total energy savings, total CO_2 saving's and the net present value after 25 years. Because a 40kW system is rather small (2300 ft^2), our team scaled up to a large 1 MW system using 40kW as a base. This demonstrates a linear relationship between increasing the size of the solar system and the total energy savings, total CO_2 saving's and the net present value.

Results

The table below shows the total cost of different sizes of systems and how they scale linearly as they increase in size. The total energy savings, total CO_2 saving's and the net present value after 25 years are also demonstrated in this table. Figure C -Figure C 4 show the payback period of each size solar system. Solar systems 40kW to 1MW, scaled from the largest size from GoGreenSolar website because it had the most reasonable results after calculations.

Table C 2: Financial and energy results of the solar panel projects

Project Financial Results						
Project	Project Cost	Estimated Payback Period	Total Energy Savings	Total CO_2 Savings	Project Lifespan	Average NPV
40 kW (2300 sq. ft)	$79,063	10 yr	1,333,200 kWh	544 metric tons	25 yr	$119,781
100 kW (5,750 sq. ft)	$197,658	10 yr	3,333,000 kWh	1,360 metric tons	25 yr	$299,452
200 kW (11,500 sq. ft)	$395,315	10 yr	6,666,000 kWh	2,720 metric tons	25 yr	$598,905
400 kW (23,000 sq. ft)	$790,630	10 yr	13,332,000 kWh	5,440 metric tons	25 yr	$1,197,810
600 kW (34,500 sq. ft)	$1,185,945	10 yr	19,998,000 kWh	8,160 metric tons	25 yr	$1,796,715
800 kW (46,000 sq. ft)	$1,581,260	10 yr	266,64,000 kWh	10,880 metric tons	25 yr	$2,395,620
1 MW (57,500 sq. ft)	$1,976,575	10 yr	33,330,000 kWh	13,600 metric tons	25 yr	$3,850,000

The figure below displays the financial analysis for a 40kW solar system with a 10-year payback period. The 40kW project gives a fund profit of $38,029 which calls for the 40% profit period defined by policy.

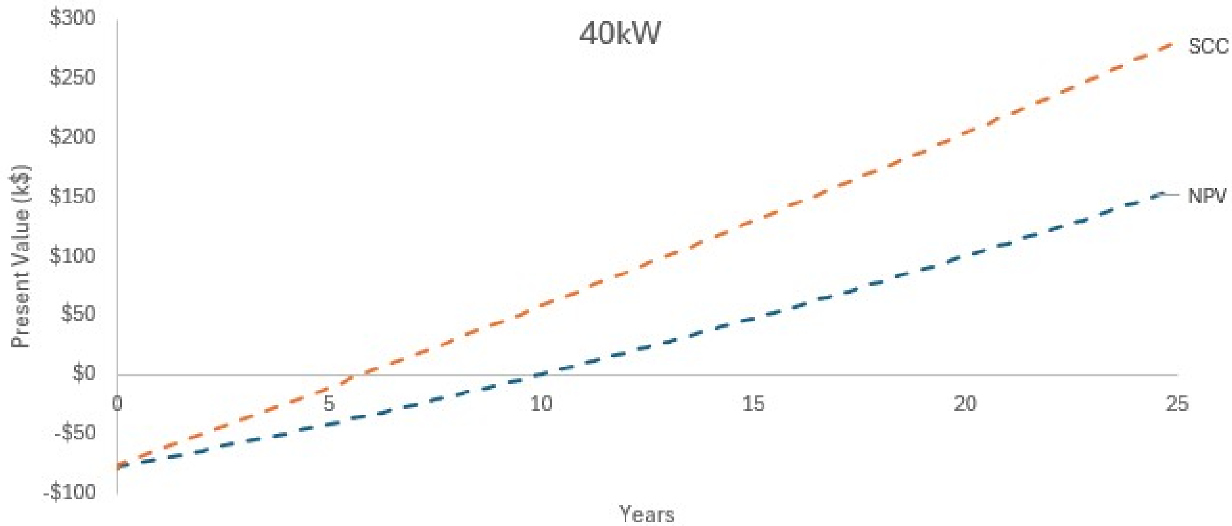

Figure C 2: Payback period (0-10 yr) and financial profits (10-25 yrs) of the 40kW solar panel system

The 400kW financial analysis below is the same as the 40kW system but multiplied by 10. The payback period is still 10 years, but the fund profit is $331,791.

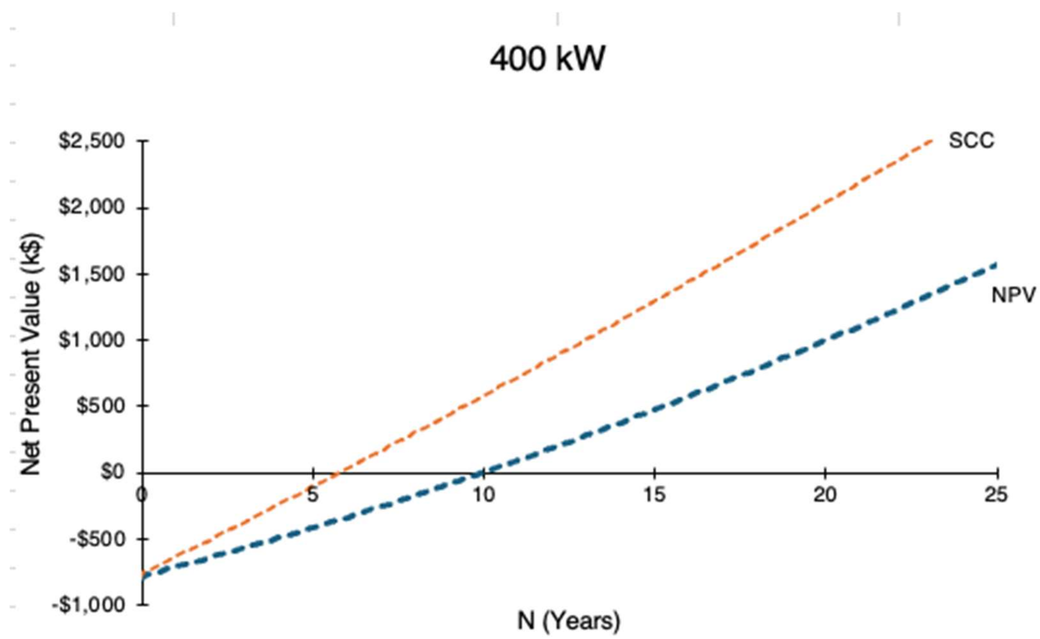

Figure C 3: Payback period (0-10 yr) and financial profits (10-25 yrs) of the 400kW solar panel system

The 1 MW system has a 10-year payback period with a fund profit of $829,478. These solar projects show great promise in terms of renewable projects that pay great money back to keep the fund going.

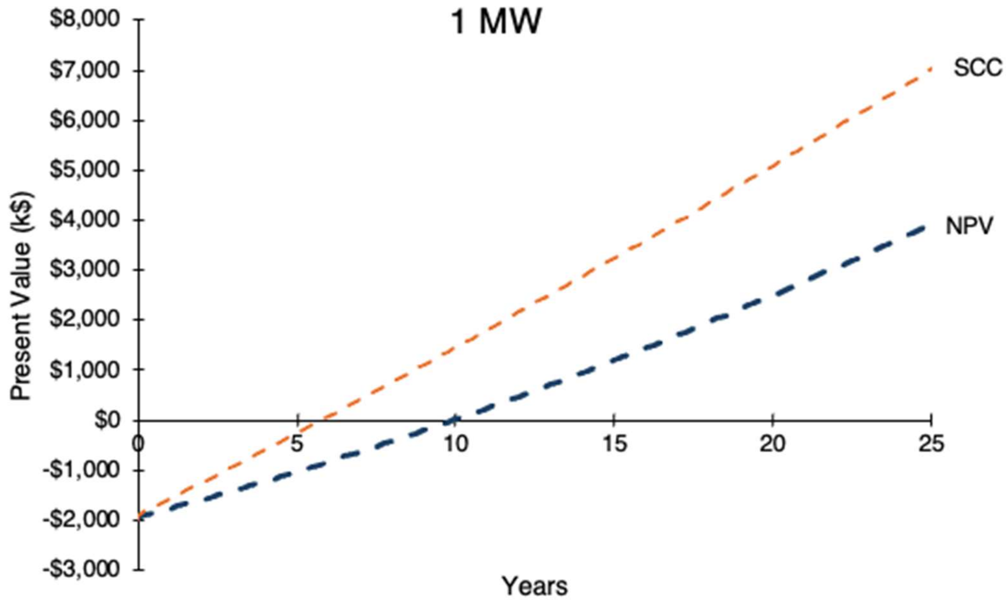

Figure C 4: Payback period (0-10 yr) and financial profits (10-25 yrs) of the 1MW solar panel system

Conclusions

Solar panels are a great way to advance the green revolving fund with consistent savings. With an average payback period of 10 years, the remaining 15 years of the solar panels' life can be used to add funds in the GRF for more projects. With large scale solar projects being just as efficient as smaller ones, the only requirement from these projects is available space. Because the city of Grand Rapids has plenty of open roofs and open land the large 1MW systems should be implemented wherever possible to make efficient use of the space available. In return millions of dollars can be accumulated in the lifetime of the solar systems.

Appendix C2: Single Equipment Variable Frequency Drives (Small VFDs)

Introduction

The second project that the project team worked on was variable frequency drives, or VFDs. A variable frequency drive is an electronic device that controls the speed and torque of an AC motor by varying the voltage coming into the motor. These devices not only provide great energy savings but also increase the longevity of the motor it is attached to, such as a water pump or HVAC system.

Description

To gain a better understanding of how VFDs work and the process behind how a system is chosen, several members of the project team met with Brett Hoogewind, who is a facilities director at Calvin University and one of the leaders in Calvin's CERF program.

To spec a VFD system properly, the input voltage and amperage are used. The payback period of VFDs was found to be around 3 years, with a range of 40-50% energy savings. On larger scale systems, this savings number can be upwards of 55%+. VFDs come with financial incentives of up to $1/6^{th}$ of the purchased equipment cost from Consumers Energy. The installation process of these devices is straightforward and simple, and there is no maintenance required.

An important downside to note about these devices is that it is important to keep them cool, bringing in an added cost. Compared to the be total energy savings over its lifetime, this cost is minimal.

Results

Table 1 presents prices for VFDs systems for a wide range of voltages and amperages, including installation costs. Prices in this table are from VFD.com, a large online retailer.

Table C 3: Financial costs for VFD projects

Each Cell lists the unit cost and corresponding hp below		Amperage Rating [A]																					
		1.2	1.4	2.4	4.2	7.5	10	20	25	55	80	90	110	150	180	202	248	370	480	650	720	860	877
Voltage [V]	120	$298	$312	$344	$385	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	HP	.25HP	.33HP	.5HP	1 HP	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	240	$312	$320	$246	$365	$376	$661	$1,157	$727	$2,405	$3,396	$9,400	$11,277	$15,165	$17,230	$19,423	$22,555	--	--	--	--	--	--
	HP	.25HP	.33HP	.5HP	1HP	2HP	3HP	7.5HP	7.5HP	20Hp	30HP	30HP	40HP	50HP	60HP	74HP	100 HP	--	--	--	--	--	--
	480	$547	$378	$395	$1,982	Not Sold	$954	$3,364	$1,288	Not Sold	$3,755	$6,236	$8,455	$6,517	$9,848	$15,455	$22,555	$45,910	$24,316	$30,201	$39,467	$53,961	$60,836
	HP	.5HP	.5HP	2HP	2HP	2HP	10HP	10HP	15HP	40HP	40HP	60HP	75HP	100Hp	150HP	175HP	200HP	299 HP	400HP	500 HP	600 HP	700 HP	700 HP

Using these prices, the financial team calculated the NPV, total energy savings, and the total CO_2 savings for 3 different VFD systems using a project lifespan of 12 years. This is shown in Table C 4.

Table C 4: Financial and energy results of increasing sizes of VFD projects

Project Financial Results						
Project	Project Cost	Estimated Payback Period	Total Energy Savings	Total CO2 Savings	Project Lifespan	Average NPV
VFD 2 HP	$395	3.5 yr	6,451 kWh	5 metric tons	12 yr	$959
VFD 73.7 HP	$19,423	3.5 yr	316,883 kWh	254 metric tons	12 yr	$47,082
VFD 1500 HP	$30,201	3.5 yr	493,283 kWh	395 metric tons	12 yr	$73,326

The 2hp VFD project has a financial analysis that displays a 3.5-year payback period with a fund profit of $166. This type of VFD would be implemented mostly for environmental reasons, but does not negatively impact the funds health financially.

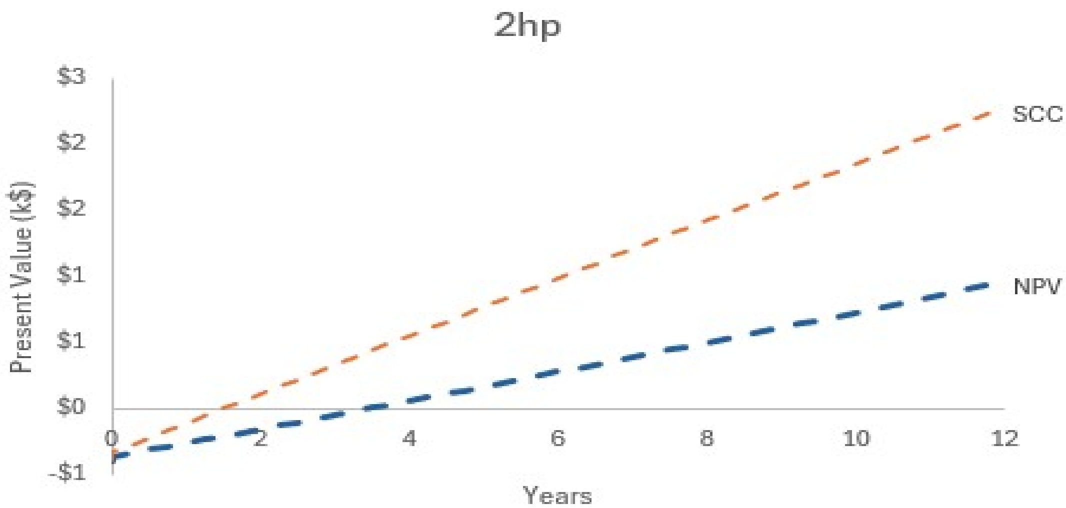

Figure C 5: NPV and SCC payback period with 2 HP VFD

The 74hp VFD financial analysis displays a 3.5-year payback period with a fund profit of $8,127. This project displays great financial gain based on a $19,423 investment.

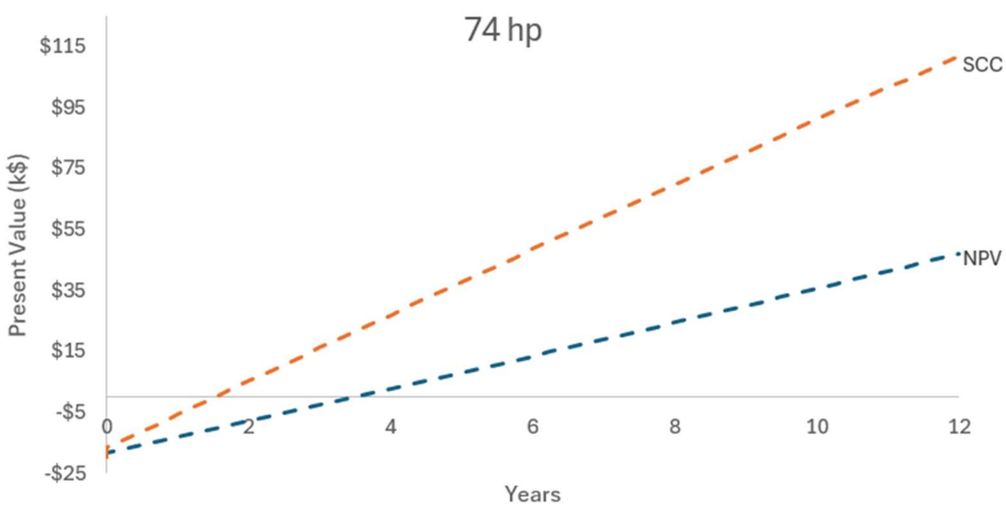

Figure C 6: NPV and SCC payback period with 74 HP VFD

The 500hp VFD project again displays a 3.5-year payback period with a fund profit of $12,686 which again shows it's a group project for the GRF because of the carbon savings and profit.

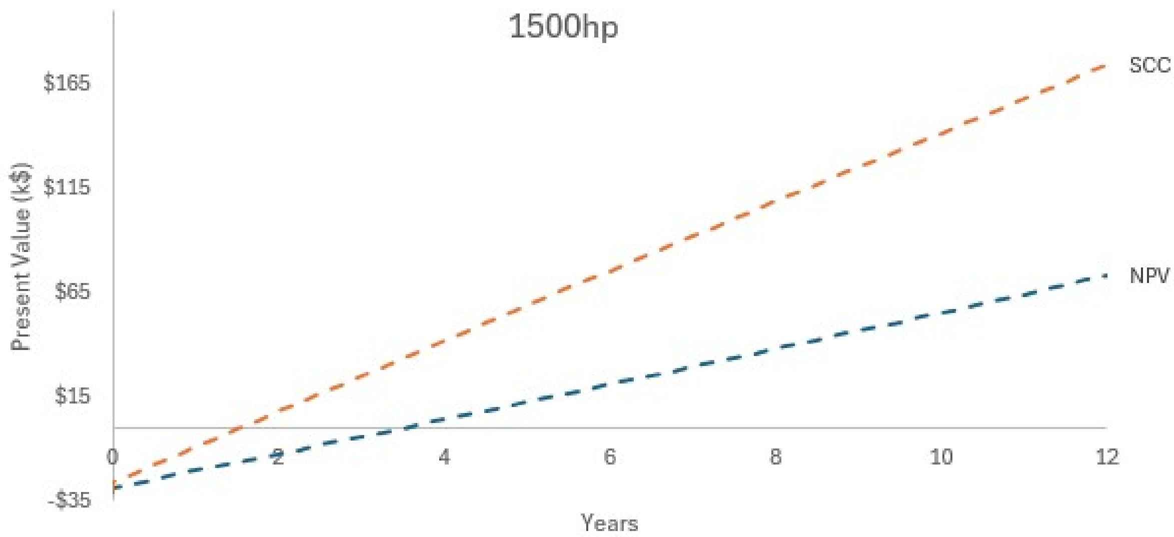

Figure C 7: NPV and SCC payback period with 1500 HP VFD

Conclusions

Variable Frequency Drives are a great way to provide energy savings with a very short payback period. They are easy to install and maintain and can increase the longevity of different systems. These benefits are notable and have been seen on Calvin University's campus. VFDs should be implemented in more buildings and systems throughout Grand Rapids.

Appendix C3: Green Bus Stop Roofs

Introduction:

Green roofs on bus stops is one of the five green projects analyzed for the green revolving fund. A green project is one that doesn't have direct, monetary payback. However, its value lays in its contribution to creation care. These types of projects reduce atmospheric pollution through carbon sequestration. Many additional, nature-based benefits vary from green project to green project. Green roofs model this project type well. They would support aspirations for a green revolving fund in Grand Rapids, as well as contribute progress towards the nature-based solutions in the Climate Action Adaptation Plan (CAAP).

Description

The team analyzed the implementation of this project on 25 bus stops in Grand Rapids. As a result of varying bus stop roof surface areas, we estimated an average of $75ft^2$ per bus stop. Planting a green roof on each of these would equate to a total of $1{,}875\ ft^2$. Further analysis allowed our team to determine investment and maintenance costs, as well as atmospheric CO_2 sequestration and storm water collection rates (all of these per ft^2 and easily scalable).

The investment cost of buying and installing a green roof depends on whether it is intensive or extensive. Intensive green roofs use deeper soil, oftentimes non-native plants, and can hold a lot more stormwater at a given time. Extensive green roofs have slightly more shallow soils, native plants that are lower maintenance, and tend to be a lot cheaper to buy and install. Choosing an extensive green roof would be more suitable for the project. Furthermore, local, low maintenance plants would be very fitting such as Blue Sledge grass and Aster flowers (both perennials). The price to purchase and install this project would be $15 per square foot and $10 per square foot respectively. This would be a total purchase and installation cost of $46,875. Furthermore, maintenance costs are estimated to be between $2,500 and $3,000 per year.

Results

This project would result in great progress toward strategy 3, action 4 of the CAAP's nature based solutions. It would reduce atmospheric CO_2 by up to $0.375\frac{kg}{ft^2}$of green roof, totaling 703

kg (or 0.703 metric tons) per year for this project. Furthermore, the average amount of stormwater collected per square foot of an extensive green roof is about 15 gallons per year. This would total 25,000 gallons per year for this project, reducing flooding and damage done by such. Varying value analyses of this project can be assessed below, such as net present value, social cost of carbon, and views.

The financial analysis below is for the green bus roof top green project. There is no payback period, and the fund loses $59,895 from the project. Based on the views analysis the payback period is 7.5 years.

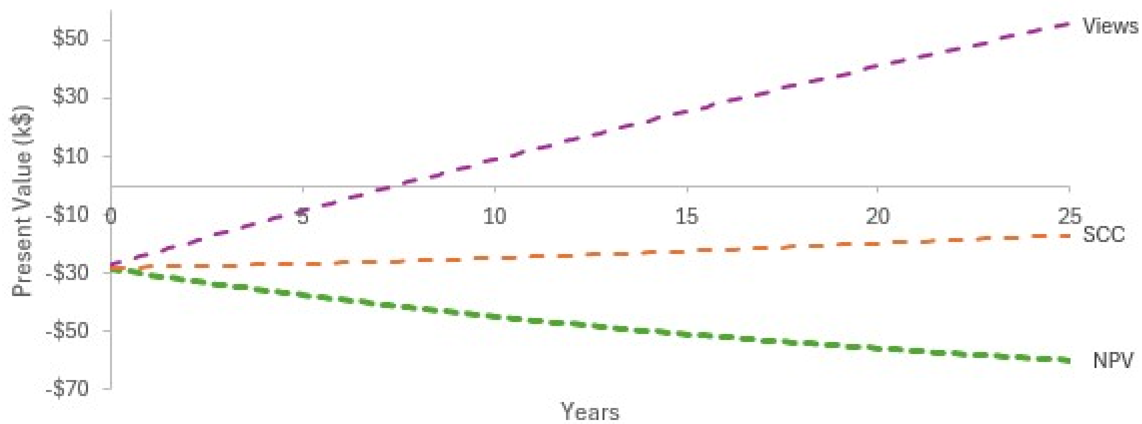

Figure C 8: Bus Stop Green Roofs Payback Period

Conclusions

Although there isn't a traditional return on this investment in the form of money, it doesn't make this project any less significant. Its focus is mostly on carbon reduction in Grand Rapids, which is a big component of the CAAP. Both the social cost of carbon and value assigned by the number of views from bystanders demonstrate continued and promising growth in figure 1 above.

Appendix C4: Trees

Introduction:

Planting trees was our second green project idea. The heart behind this project was to have the same potential effects as the bust stop green roofs project. However, two additional benefits to this project include the potential for reduced air conditioning energy bills through shading (great for an internal project focus), and increased property values. Although this project will overall be more expensive than the green roofs, it offers more value in a few ways.

Description

Our recommendation for the implementation of this project is 100 trees. The focus would be to plant them in low tree equity/canopy neighborhoods to increase neighborhood value. Another great location would be near internal (city) buildings to reap the benefits of increased property value and air conditioning energy savings through shading. The cost of this project would be $300 to $350 per tree to purchase, and $300 to $350 per tree to plant. The total investment cost here would be around $65,000 with a yearly maintenance cost of $5,000. However, these depend on the type and size of tree.

Our recommendation would be to select trees that are younger in order to minimize initial costs. CO_2 sequestration rates wouldn't suffer either because small trees that are growing fast tend to utilize a lot of CO_2 from the atmosphere as well. Three of our specific recommendations are the American Basswood, Paperback Maple, and/or Blue Beech. Each of these are native to Michigan and are high in hardiness ratings (up to 8 or 9) reflecting an ability to endure harsh climates.

Results

The resulting CAAP nature-based solution focus of this project is strategy 1 action 1. CO_2 sequestration for this project would be upwards of 100 kg per tree per year. This would equate to 7,500kg per year or 7.5 metric tons. Stormwater collected would be between 1,000 and 3,000 gallons per tree per year, depending on the size and type of tree. Property value affected by these trees have a potential increase of 15%, making this project great for neighborhoods with low tree equity. Finally, buildings in direct contact of these trees can have significant reductions in air conditioning energy bills. Shade from trees can act as natural air conditioning through reducing building temperature by up to 8 degrees Fahrenheit.

Conclusions

Once again, the value of this project doesn't necessarily result in a direct, monetary payback. However, its value lays in its contribution to nature-based solutions from the CAAP. It would have a significant, positive impact on carbon reduction and storm water collection. Furthermore, it has the potential to increase property value either internally or externally. Increasing property value of low tree canopy neighborhoods can have a really positive impact on the quality of life for citizens living in those areas.

Appendix C5: Groundwater Geothermal Heating

Introduction:

Groundwater Geothermal Heating is one of the blue projects analyzed for the green revolving fund. Being a blue project, it is focused on generating savings that will be directed back into the fund. Unlike conventional geothermal systems, groundwater based geothermal is a new technology that leverages naturally occurring aquifers within the earth. Wells are drilled into these aquifers and a heat exchanger is placed at the bottom. A submersible pump enables thermal exchange and is connected to surface level mechanical equipment. The high heat capacity of water, combined with stable aquifer temperatures, enable the system to reliably deliver high heating/cooling loads with a 70-80% reduction in energy usage.

Description

Darcy Solutions was contacted to determine the feasibility of groundwater geothermal at two municipal locations. These two locations were the LMFP (Lake Michigan Filtration Plant) and the WRRF (Water Resource Recovery Facility). Feasibility is determined via a geological study that identifies whether the location has a suitable aquifer. Feasibility results showed that the WRRF location was expected to be conducive to a Darcy well. To find additional information, a test well would be required to confirm the stratigraphy and lithologic properties of the target aquifer.

With feasibility verified, historical data of natural gas usage and related utility costs at the WRRF were used to find the trailing 3-year average of operational costs per megajoule of heating. It was assumed that the entirety of natural gas usage was for heating at the site. In comparison, the operational cost of a heat pump (representing the Darcy Dipole System), also in $/MJ Heat, was found with an assumed COP of 3 and the Finance Team's current cost of electricity. Using both of these values, a difference in operating costs per MJ of heating was determined, giving the operational cost difference of the system. This value could then be scaled by any desired amount of megajoule heating to find the cost savings of the groundwater geothermal system. A table with each of those values is included below in Table C 5.

Table C 5: Operational cost of natural gas heating systems, estimated cost of geothermal heat pumps, and their resulting difference in $/MJ Heat.

Energy Cost of Natural Gas Heating	$0.146/MJ Heat
Energy Cost of Heat Pump	$0.0185/MJ Heat
Difference in Operational Cost	$0.127/MJ Heat

Research on previously installed groundwater geothermal systems showed that these projects consistently had a payback time of right around a decade. These values came from 5 different local news articles covering the installation of these systems, which quoted representatives on the anticipated payback period. Each of the 5 mentioned payback times were within the 9-11 year range, with articles ranging from 2018 to 2025.

Using the estimated savings per year, and an assumed payback period of 10 years, the estimated initial cost of installation could be found. A payback period of 10 years was assumed since it was consistent with real life values. This was also assumed after a 30% rebate. Otherwise, the effective payback of the system would be ~14 years. With all that being said, the actual payback period could vary, and is dependent on many factors. These include properties of the target aquifer, well depth, future utility costs, existing mechanical equipment, available rebates, and applicable tax credits.

Results

Two versions of results are included below. The first is for a groundwater geothermal system that would replace every joule of heating at the WRRF. The second is a proposed version with an initial cost of $350,000. This acts as a representation of what it might practically look like to install the system in stages, which could be achieved by shifting heating loads over to geothermal one building at a time, for example.

Table C 6: Key Results for Proposed Projects

Entire WRRF Facility		Proposed Project	
Initial Cost (Before Rebate)	$4.15 Million	Initial Cost (Before Rebate)	$500,000
Initial Cost (After Rebate)	$2.90 Million	Initial Cost (After Rebate)	$350,000
Yearly Energy Production	2.32 Million MJ	Energy Production	280,740 MJ
Yearly Savings - $	$296,200	Yearly Savings - $	$35,700
Total Payback (50-year Lifespan)	$11.9 Million	Total Payback (50-year Lifespan)	$1.43 Million

The table above shows the initial cost, expected heating generation, yearly savings, and total payback of the system over its 50-year lifespan, all in late 2025 dollars. Figure 1 shows the anticipated NPV of the $350,000 proposal. This system shows to have an almost immediate payback but is likely in error. A more accurate analysis could be found by evaluating the escalation rates of natural gas and electricity over the next 50 years to find the expected cost savings by year.

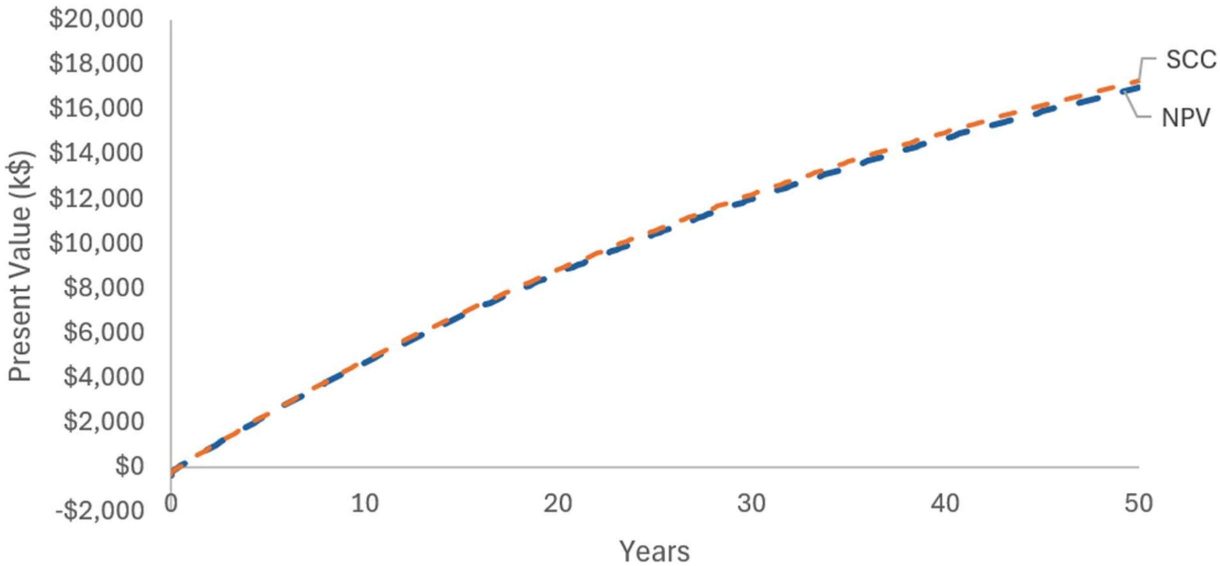

Figure C 9: NPV and SCC of the proposed $350,000 system over the next 50 years

Conclusions

To conclude, installation of a Darcy Dipole groundwater geothermal system could be a very promising investment for the GRGRF and can be appropriately scaled to replace heating systems at the WRRF. Additional engineering consulting is encouraged to determine which building, or series of buildings, would work best with the system described above. With the goals of the GRF in mind, it is recommended that a system that closely matches a city-determined initial cost, and which has the shortest payback period, is prioritized in any future evaluation at the WRRF.

Appendix C6: Blue Energy Star Improvements

Introduction:

The Blue Energy Star Certification is a status given to any appliance, heating and cooling system, lighting, computers, and even laptops that runs at a specific efficiency to reduce energy consumption. This project aimed to target old and inefficient heat and cooling equipment in Grand Rapids municipal buildings and replace them with Energy Star certified equipment. This would result in electrical and natural gas savings along with carbon dioxide emissions.

Description

Much of the data utilized for calculations were found in the Energy Information Administration (EIA) Residential and Commercial Building Technologies study along with another research provided by EIA.

To begin, the calculation of the natural gas usage was converted from the BTU capacity in units of $\frac{BTU}{hr}$ was then multiplied by the average time of usage to obtain the energy used per year. This annual usage calculation was estimated based on their cycle time, daily usage, and estimated seasonal use. The year heating capacity was then converted to cubic feet of natural gas or kWh per year. These values were then multiplied by the efficiencies of the new and older models to o savings were then assessed based on the difference between older and newer model efficiencies. Then to find CO_2 savings, a factor given by the EIA was converted to desirable which was then used to convert the fuel source to kg CO_2 for each model. The savings were then found by finding the difference between the newer and older model.

Results

Figure C 10- Figure C 15 illustrates the payback period for net present value (NPV) and social cost of carbon (SCC) for each project based on the data from the EIA. Table C 7 shows natural gas and CO_2 savings per year, and the initial cost for implementation. Determining a good project that could be implemented is based on the payback period and overall energy saved and carbon emissions prevented. The payback time occurs when the NPV line intersects with the x-axis (unit lifespan in years). A project who's NPV line doesn't cross the x-axis is not viable for the fund.

Table C 7: Energy Star Efficiency Improvement Results

Equipment Type	Initial Cost ($)	Natural Gas Savings (Ft^3/yr)	kg CO_2 Savings/yr
Gas Boilers	$42,490	311399	17067
Gas Furnaces	$1,260	81299	4456
Heat Pumps	$14,350	17728	249
Water Heaters	$4,290	50591	2773
Centrifugal Chiller	$272,000	0	2912
Rooftop AC	$12,210	53132	221557

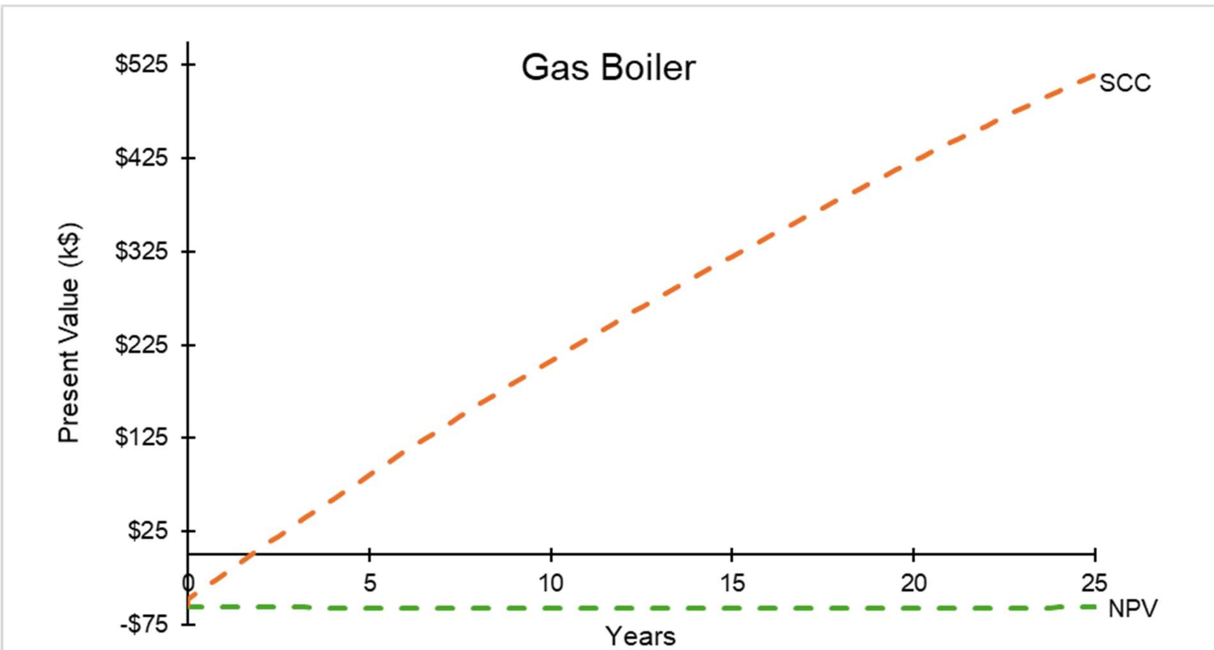

Figure C 10: Payback Period of Implementation of a New Gas Boiler

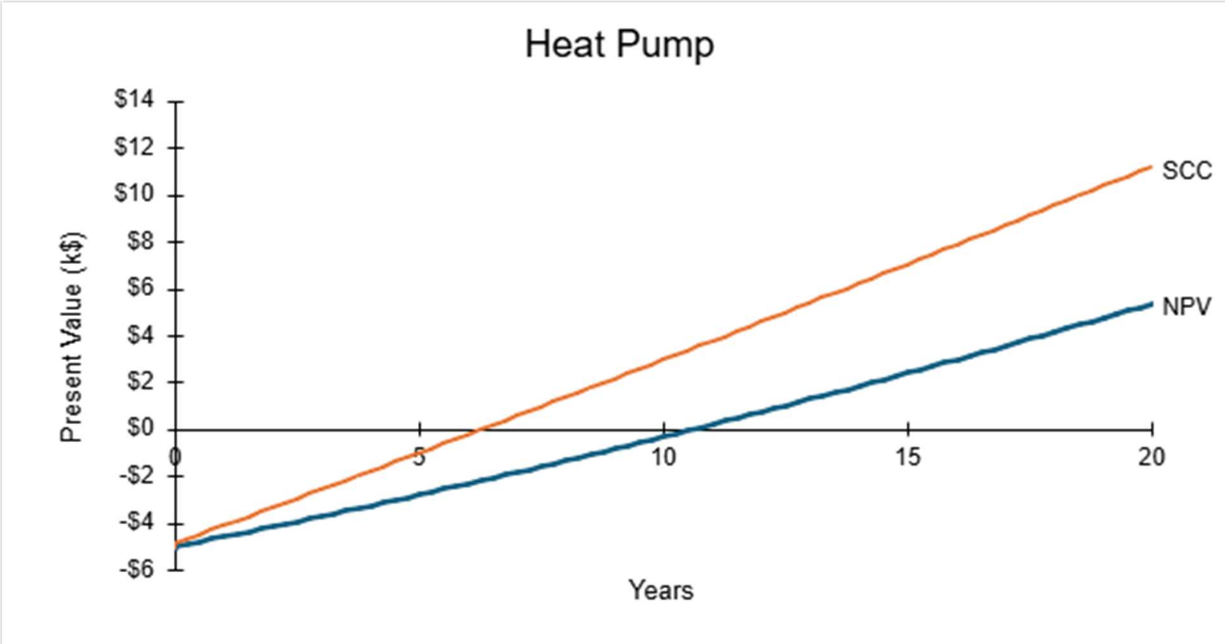

Figure C 11: Payback Period of Implementation of a New Heat Pump

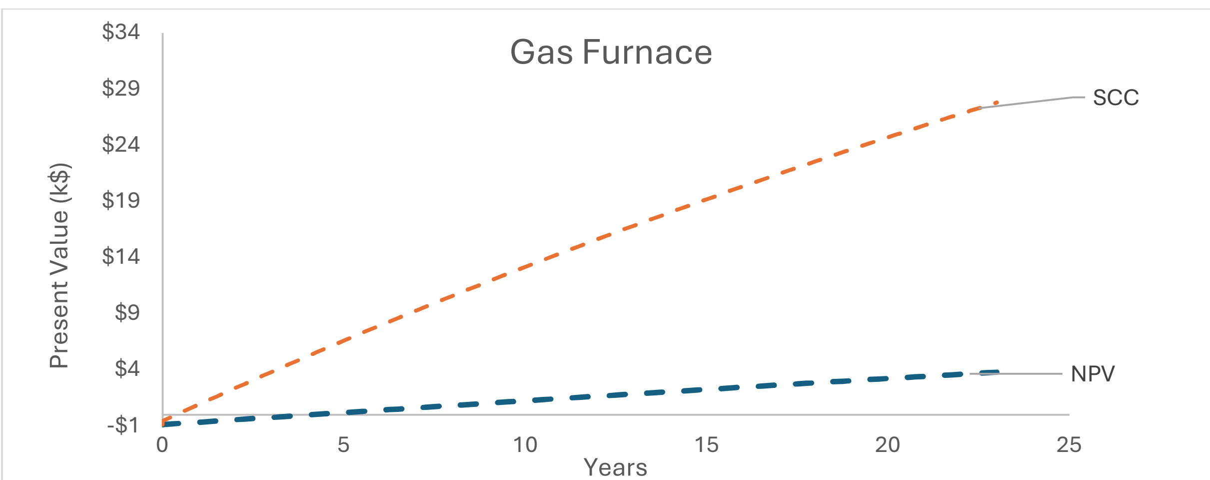

Figure C 12: Payback Period of Implementation of a New Gas Furnace

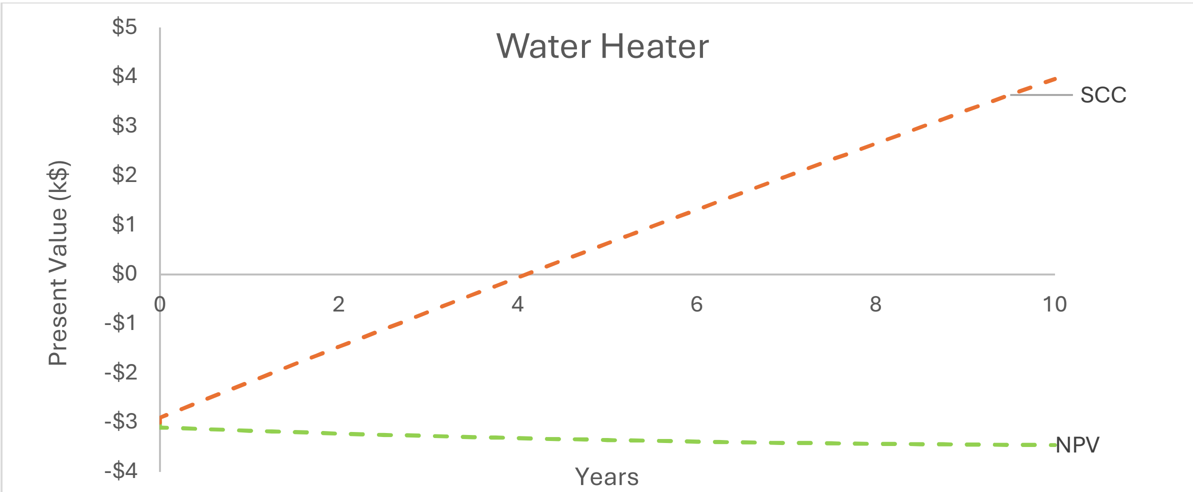

Figure C 13: Payback Period of Implementation of a New Water Heater

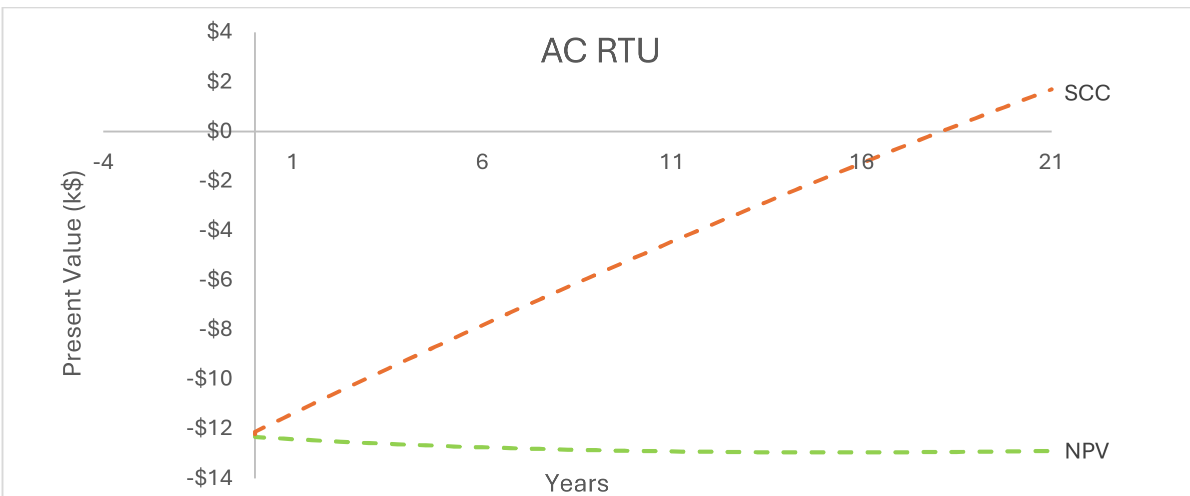

Figure C 14: Payback Period of Implementation of a New Rooftop AC Unit

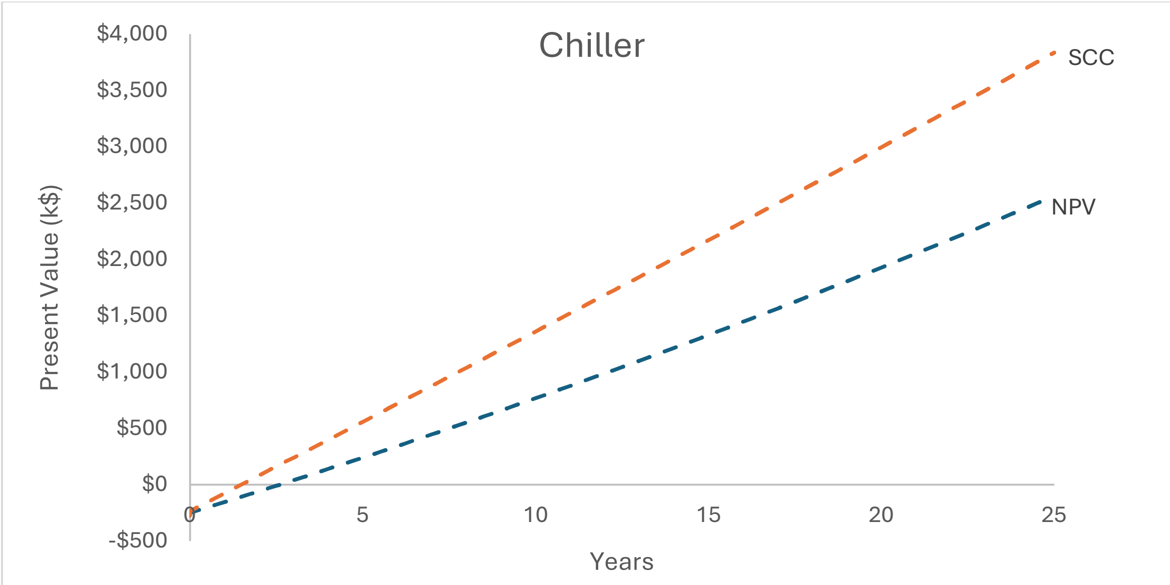

Figure C 15: Payback Period of Implementation of a New Chiller

Conclusions

To conclude, from the figures shown above, implementation of a gas boiler, water heater, and rooftop AC unit would provide no benefit towards the GRF. However, the heat pump, furnace, and chiller would be projects worth implementing. Implementing these projects would save 17,728 and 81,299 cubic feet of natural gas per year. Along with natural gas savings, these good projets would save 249, 4,456, and 221,557 kilograms of CO_2 saved per year respectfully. Lastly, these project all present good payback period of 5-10 years with most units having 20-year lifespans, which results in more money being saved and sent back to the fund.

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Appendix C7: WRRF Variable Frequency Drives (Large VFDs)

Introduction

This project involves the installation of variable frequency drives (VFDs) at the Grand Rapids Water Resource Recovery Facility (WRRF). This facility uses up to six large centrifugal blowers, shown below, to aerate their water basins. These blowers use 1000-hp motors that are constantly being run at full speed, regardless of the amount of aeration that is needed in the basins. Because of this, these blowers are a great use case for installing VFDs, which allow motors to run at a slower speed by varying the supplied frequency and voltage. This project evaluates the impact of installing one VFD on one of these blowers, however this number could be scaled up to be used on all operating blowers.

Figure C 16: Centrifugal Blower for VFD Installation

Description

Based on the size of the motors used in these centrifugal blowers, an AC variable frequency drive system was found from a vendor being sold for $144k and assumed installation costs were $36k. From information obtained during a tour of the WRRF, the two buildings housing these blowers, the North and South Aeration buildings, were using $1900/day in electricity. We assumed that the majority of this cost was being used to operate the four blowers that were currently running that day. Because VFDs work by reducing the motor's speed, and the nature of these motors currently running at full speed, an energy savings number of 20% was decided as a baseline, conservative case.

Results

The graph below shows the net present value (NPV) and net present value including the social cost of carbon (SCC) over the 10-year lifespan of a VFD. This graph includes the initial investment of the project, which includes the purchase cost and installation cost. The lifespan of 10 years was found to be a conservative average of most VFD systems. As seen in the graph, this project has a payback period of just under 5 years. The reduced electricity usage is also expected to reduce over 75000 kilograms of carbon dioxide per year.

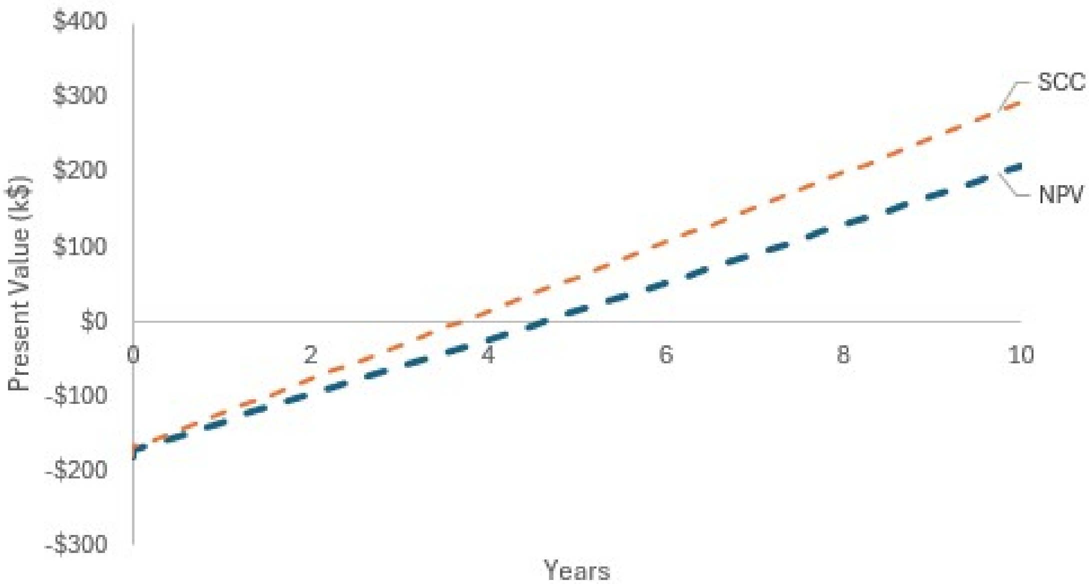

Figure C 17: Net Present Value of VFD Installation

Conclusions

Based on the financial analysis of this project, the installation of a VFD system for the centrifugal blower motors at the WRRF is a good project to pursue with a GRF. The initial investment of $180k is significant, but well within the total budget of the GRF. Additionally, the short payback period of five years makes it attractive as positive net present value will be seen in the following five years of the project's expected lifespan. This project, if successful, could also be scaled up to be used on any number of the six blowers used at the facility.

Appendix C8: E-bikes

Introduction:

Several members of the Project team dedicated themselves to exploring "external projects." where one concept brought to attention was implementation of an e-bike program. Preliminary research showed that e-bike programs have been successful in many cities such as Columbus, Ohio, and Denver Colorado, due to their ability to reduce CO_2 emissions, promote physical activity, improve transportation accessibility, and offer a cost-effective alternative to short-distance car travel. These findings highlighted the potential benefits an e-bike initiative could bring to the City of Grand Rapids and guided the direction of our project.

The "E-Bikes" project evaluated two possible implementation models: a loan program and a rebate program. The loan model proposed that the City of Grand Rapids purchase a fleet of approximately 165 e-bikes and make them available for public use through a lending system. In contrast, the rebate model did not require the city to purchase bikes directly; instead, it offered residents an incentive of an average of $750 toward the purchase of an e-bike from approved vendors. The $750 would be scaled based on the purchaser's income. Both models were analyzed to determine how each could encourage residents to shift away from car-based transportation and support the city's broader sustainability goals in the CAAP.

Description

The e-bike project is a green project. This means e-bikes are a project with little to no financial gain, but a project for environmental considerations and public visibility. Working with our customer, our team learned that about ~6% of Grand Rapids residents commute to work via bike. Our customer wanted to test the idea of whether integrating an e-bike program into the city would promote friendlier infrastructure and influence future city decisions and development.

First, the loan method has the City of Grand Rapids purchasing a fleet worth $500,000. Then the city loans the bikes out to residents at a ~4.3% interest rate over the course of two years. This method gives a small financial benefit back to the Green Revolving Fund just from residents' payments. The rebate method is an alternative approach to implementation. Using rebates, the City of Grand Rapids can incentivize qualifying residents (qualifying based on financial need and willingness to offset their personal vehicle) by giving rebate handouts. To simplify the analysis, a flat cost of $750 was used for each of the 165 bikes. Using this, residents would use it as a discount at designated e-bike shops around the city, promoting small businesses and personalized options.

After looking at studies done in Brighton England, and British Columbia with their own respective e-bike programs it was determined that people who bought e-bikes would replace approximately 30% of their driving. After obtaining this number the total amount of CO_2 reduced was able to be found by taking the average CO_2 emissions caused by 165 cars in Grand Rapids and reducing that number by 30%. This gave a total CO_2 emission reduction of 224 metric tons per year.

Another factor that was analyzed was potential road cost savings due to reduced car traffic. However, after doing calculations it was found that the cost savings for roads would be negligible, in fact, Professor Christopher Douglas, from the University of Michigan, says this in a study he did "In fact, the cost per mile of pavement damage for passenger vehicles is only a fraction of one cent and rounds down to zero." (Douglas, 2018)

On top of that, the e-bike team worked directly with the financial team to discuss other aspects that should be considered during an analysis. These relate to the Social Cost of Carbon (SCC), Net Present Value (NPV) and lastly, Views. The social cost of carbon represents a dollar value on emitted CO_2. With our analysis, our team took the difference between CO_2 emission of the average Grand Rapids work commute driving a car vs riding an e-bike. That difference was then implemented into the cost of carbon, and the difference is what is saved. Net Present Value represents project feasibility, knowing that e-bikes do NOT give large financial gain back into the GRF, the NPV tells how much e-bikes is worth by comparing the expected initial cost with the money the project is expected to earn/save. Lastly, working with the financial team, we found a way to put a dollar value on daily views of someone riding an e-bike, like how billboard companies appraise the value on their billboards. If the e-bikes have a Grand Rapids logo and are viewed by the public, this would hopefully encourage more biking infrastructure and culture.

Results

After our research into E-bikes and implementation in a city, our team worked with the financial team to calculate the overtime value of the project. Below you can see figures for both the loan and rebate method of e-bikes.

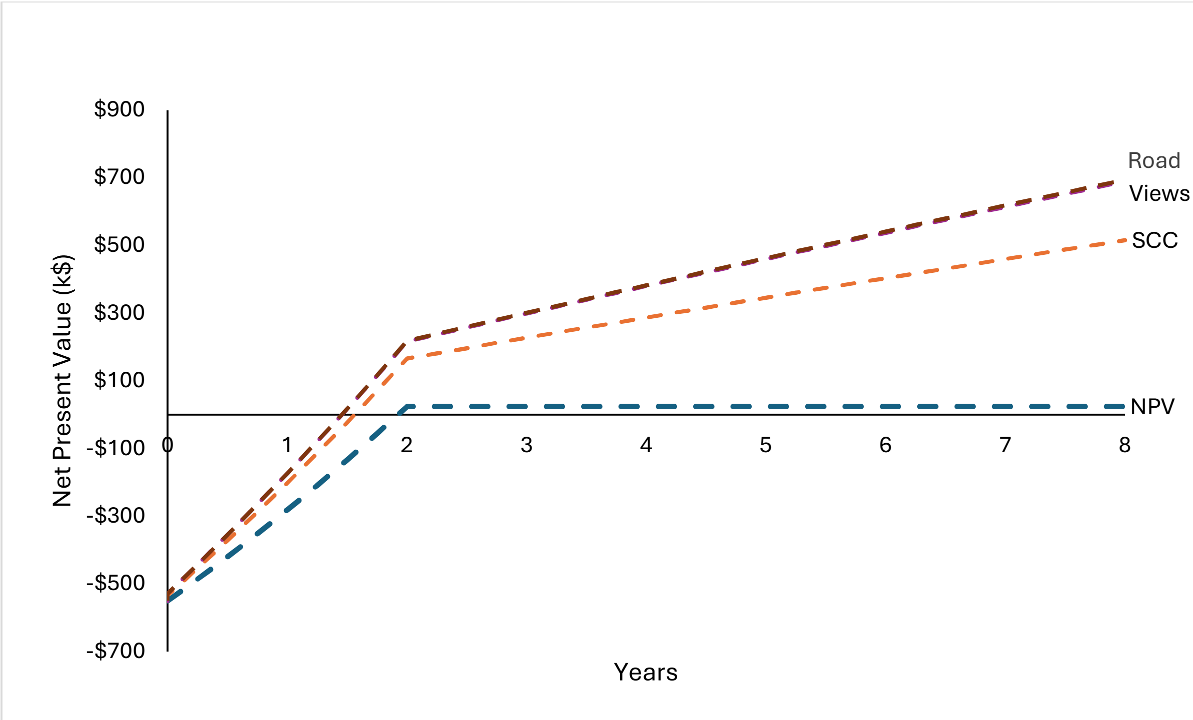

Figure C 18: E-Bikes Financial Chart (Loan Method)

Looking above, one may see the results from the loan e-bike project. As discussed above in the description section, one may see results for the Net Present Value, Social Cost of Carbon, and Views. The NPV represents the initial investment cost and the payoff overtime. One can see the \$500,000 investment being paid off overtime with the ~4.3% interest rate over two years. On the contrary, the dollar amount for CO_2 saved (less emitted) and views are the impact factor for the e-bike project.

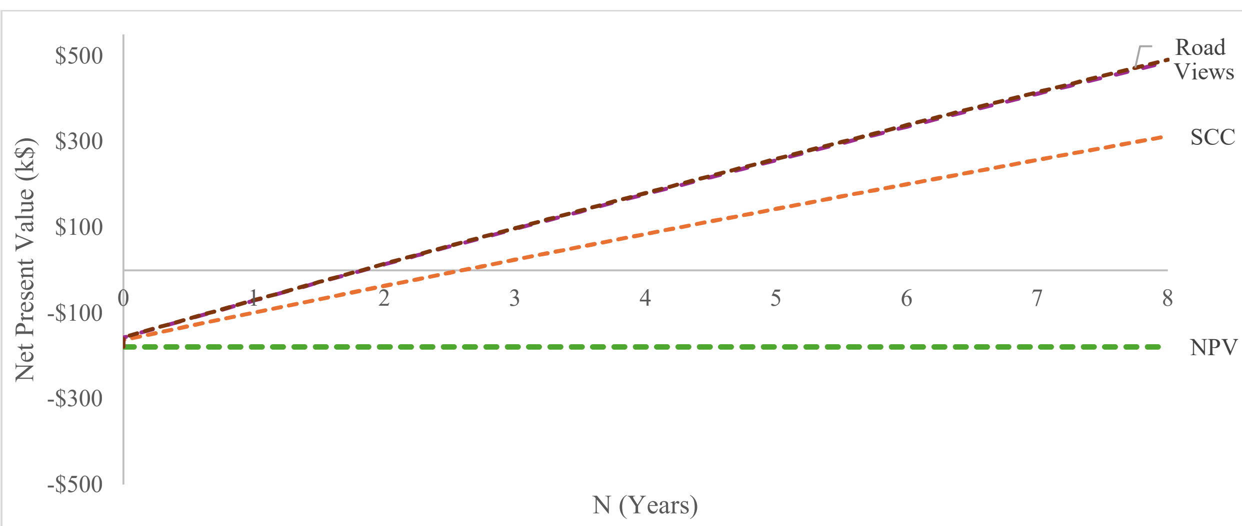

Figure C 19: E-Bikes Financial Chart (Rebate Method)

Looking above, one may see the results from the rebate e-bike project. As discussed above in the description section, one may see results for the Net Present Value, Social Cost of Carbon, and Views. The NPV represents the initial investment cost and the payoff overtime. One can see the initial investment of $123,750 staying linear, that is due to the nature of this method of e-bike implementation. Giving out rebates to qualifying residents does NOT give any financial return, yet this method was discussed due to its large impact on aspects relating to the social cost of carbon and the value of views.

Conclusions

In conclusion, two different methods of distributing e-bikes were analyzed and both had different results. Both projects would be considered green projects due to their low or non-existent cash flow back into the fund. Both projects were projected to have an annual CO_2 reduction of 224,000 kilograms which equates to 0.448 kilograms of CO_2 reduced per dollar invested for the loan method and 1.81 kilograms of CO_2 reduced per dollar invested for the rebate method.

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Appendix C9: GRPS Energy Efficient Windows

Introduction:

In the interest of external projects, our team identified Grand Rapids Public Schools (GRPS) as a strategic partner for the Green Revolving Fund. Many of the school buildings, spread throughout the Greater Grand Rapids, are built in the mid-20th century, highlighting them as highly inefficient regarding energy usage. Only 3-5 buildings in the school system have energy efficient windows. The school system operates primarily during Grand Rapids' coldest months, during which poor insulation and outdated boiler systems contribute to the need for excessive energy to keep the buildings at a comfortable temperature for students. A single section of one of these public schools was analyzed for a window retrofit, allowing for energy, emissions, and cost saving calculations to be made. Replacement of boilers was also considered and is detailed in Appendix E4.

Description

After discussing feasibility with the GRPS Director of Projects and Maintenance, it was determined that the original structure of Frost Middle/High School could be targeted, including 13 windows of various sizes. A spreadsheet was created to calculate the heat transfer through the number and size of windows specified. The method for calculating the savings at Frost can be scaled to any building, with the key factors being number and size of the windows to be replaced and the U-value of the new and old windows. This U-value value measures the rate of energy transfer through a window. The equation below was used for calculating the savings of this project, it relates heat transfer to the U-value of a window, the area of window, and heating degree days. Heating degree days were used as they accurately record the difference between the temperature of a comfortable work environment and outdoor temperatures over a length of time. This temperature difference is what drives heat transfer through a window. The 9-month GRPS high school schedule was used for the time range and the inputs related to an upgrade from single pane windows with a high U-value to double glazed windows, with a significantly lower U-value.

$$Q = \Delta U \times A \times HDD \qquad (1)$$

Where Q is heat transfer in $\left[\frac{W \times day}{year}\right]$, U is in $\left[\frac{W}{m^2 \times K}\right]$, A is area in $[m^2]$, and HDD is heating degree days in $\left[C \times \frac{days}{year}\right]$

The purchase and installment cost for this project is \$44,000 at Frost (\$660 per window including labor), with a lifetime of 30 years.

Results

Cost savings as well as CO_2 production associated with the decrease in energy consumption with these new windows is graphically presented below in financial terms. Net present value (NVP) was calculated based on the energy rates. The social cost of carbon (SCC) added to this value is also depicted, it is calculated with a dollar value assigned to a unit of CO_2 emissions avoided. Both SCC and NVP depend on whether the boiler used is electric or natural gas run, as electric cost rates are significantly higher and electric boilers produce more CO_2 emissions. This project will save 15,000 MCF with 180 metric tons CO_2 saved over its lifetime given a gas boiler system. It would be 946,000 kWh and 420 metric tons CO_2 saved given an electric boiler. Frost Middle/High utilizes a gas boiler, but many new systems include an electric boiler instead. Lastly, a dollar value was attributed to the publicity (Views) of the Green Revolving Fund and is added to the total profitability as a separate curve.

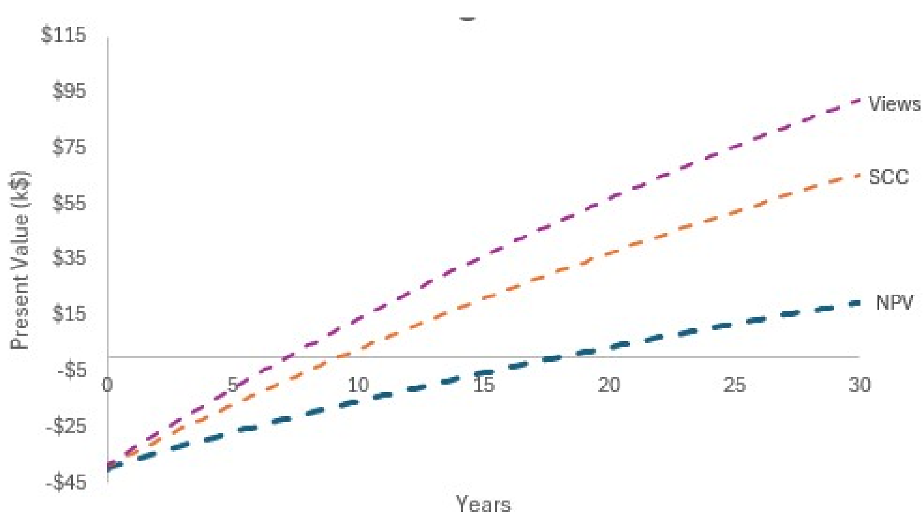

Figure C 20: GRPS Windows Financial Chart – Gas Boiler

Profit for gas boiler systems such as Frost is $20,000 with payback at 18 years.

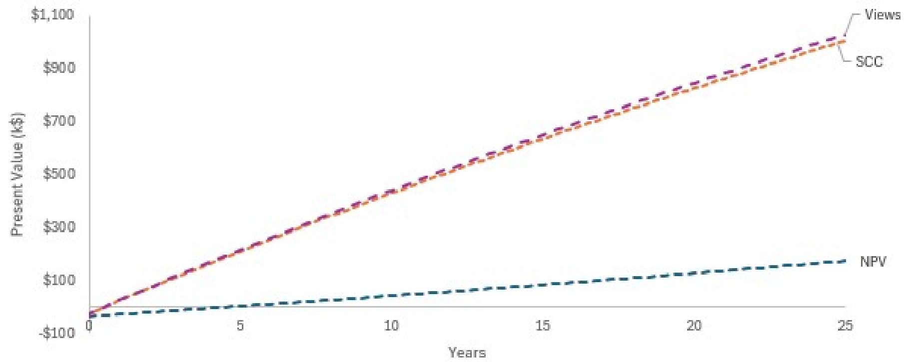

Figure C 21: GRPS Windows Financial Chart – Electric Boiler

Profit for an electric boiler project of the same scale is $220,000 with a payback of 5.25 years.

Conclusions

If given the opportunity to upgrade 13 windows of Frost Middle/High, GRPS could avoid unneeded costs and emissions while support the Green Revolving Fund. Targeting electric boiler systems creates more profitability and faster payback. Window replacement projects are especially profitable if recognizing social cost of carbon and views.

Appendix C10: GRPS Lighting Controls

Introduction:

Grand Rapids Public Schools have switched all old lighting to LED lighting; however, no controls have been implemented with any of the lighting. The project team reached out to GRPS about the potential of implementing motion sensor lights in GRPS buildings. Motion sensor lights offer an easy way to reduce energy waste. According to the department of energy, motion sensor lights in bathrooms can cut down energy use anywhere between 30 and 90%.

Description

For this project, a model scenario of a building with 10 bathrooms where each bathroom had 4 LED panel lights was used. The purchase and installment cost for this project is $4,800. The lifespan of the bulbs are 35 years. The analysis was done using an estimate of 50% which is on the lower end of the Department of Energy's energy savings range. The project is analyzed on net present value (NPV), social cost of carbon (SSC), and views. Those will be calculated by the financial team. The NPV analysis is looking at strictly the monetary value of the project with the time value of money (TVM) considered. The SSC method assigns a monetary value to every metric ton of carbon dioxide saved. The key equations for this analysis are listed below:

$$\text{Energy Usage} = \text{Bulb Wattage Rating} \times \text{Operating Hours} * \text{Total Bulbs} \quad (2)$$

$$Energy\ Usage = Bulb\ Wattage\ Rating \times Operating\ Hours \times Total\ Bulbs \quad (3)$$

$$Lifetime = \frac{50000\ [hrs]}{operating\ hours} \quad (4)$$

Results

In the model scenario without any motion sensors, the building used 6720 kWh/yr. With the motion sensor lights, the building would save 3360 kWh/yr. Due to the energy savings, the project would also save 1234.5 kgCO_2/yr. After the financial team's analysis, it was determined the projected saves a total of 84,840 kWh and has a profit of $14,184. Payback was achieved after 6.75 years.

As shown in Figure 19, the NPV, SCC and Views are shown for the first 25 years of the project. The pure monetary savings are shown in the NPV curve. Both the SCC and Views add to the value of the project in some aspect. Both of these don't have a real world monetary value that is saved through the project but they have a beneficial impact on society.

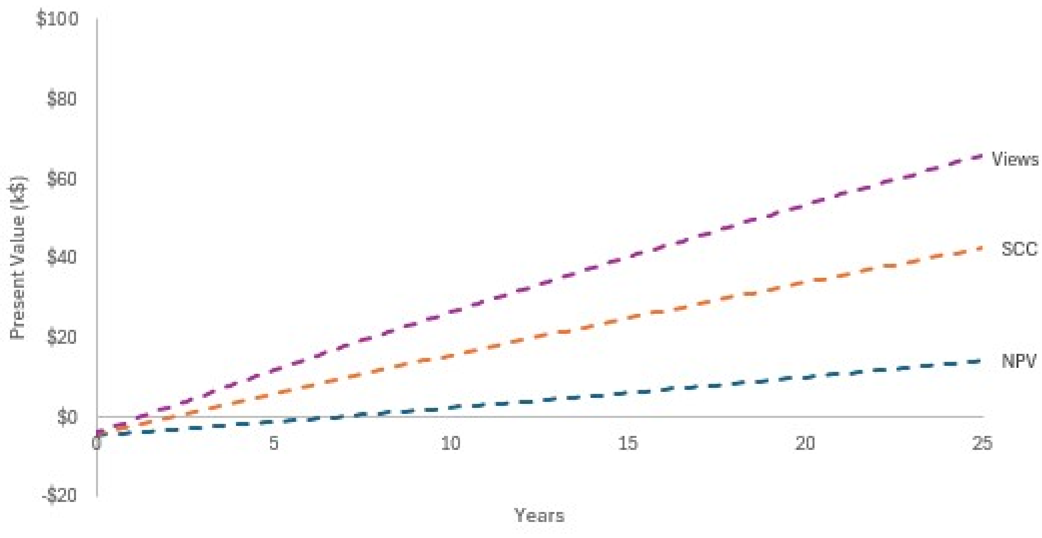

Figure C 22: GRPS Lighting Financial Chart

Conclusions

In conclusion, with an energy saving rate of 50%, motion sensor lights provide a payback of just under 7 years. The Department of Energy states that energy savings could range from 30% to 90%. Depending on the actual energy savings, this project could reach payback much sooner. Either way, replacing current lighting options with motion sensor lights is a feasible project.

Appendix C11: GRPS Boiler Replacement

Introduction:

After talking with GRPS, the project team was encouraged to investigate the feasibility of replacing an old boiler with a newer, more efficient boiler. Initially both electrical and gas boilers were considered. However, due to higher electricity prices and the larger carbon emissions in the electric grid, electric boilers were removed from consideration because of the large financial losses with them. The project team performed an analysis on replacing an old gas boiler at Frost Middle/High School with a higher efficiency boiler.

Description

The current gas boiler at Frost Middle/High School had an efficiency of 69%. The new gas boiler has a purchase cost of around \$25,000 with an efficiency of 94%. This was based on specifications given for their desired boiler, which is a Viessman CI2-2000. The analysis will be based on a conservative estimate of \$75,000 for the total purchase and installment cost. Based on gas usage and bills gathered from GRPS, a yearly gas usage of 19,530 therms at a rate of .505 \$/therm was used for the analysis. The useful heat provided by the old boiler is 1.42E6 MJ/yr. This value was kept constant for the new boiler, but due to its higher efficiency it meant that the new gas consumption was only 14,390 therms/yr. The yearly maintenance on the new boiler is \$1000/yr compared to the maintenance cost of \$1500/yr for the original boiler. The old boiler runs on 1.342 kW while the new boiler runs on 0.911 kW. Gas and electricity savings were summed. The financial team analyzed both the Net Present Value (NPV) and Social Cost of Carbon (SCC) for this project. Some of the key equations for this project are listed below where η denotes efficiency:

$$Useful\ Heat = (Gas\ Input\ )(\ \eta_{boiler}) \tag{5}$$

$$\eta_{boiler} = (\eta_{combustion})(\eta_{thermal}) \tag{6}$$

$$Operation\ Hours = \left(17\ \frac{hours}{day}\right)\left(6\ \frac{months}{year}\right)\left(20\ \frac{days}{month}\right) = 2040\ \frac{hr}{yr} \tag{7}$$

Results

After performing energy analysis, it was determined that implementing a new boiler would save 5140 therm/yr, 880 kWh/yr, and 27,240 kgCO_2/yr. The project would save a total of 12,503 MCF of natural gas, 22,220 kWh, 693 metric tons of CO_2 and would have a deficit of $36,821 However, when including the SCC, the equivalent value of the project is around $150,000.

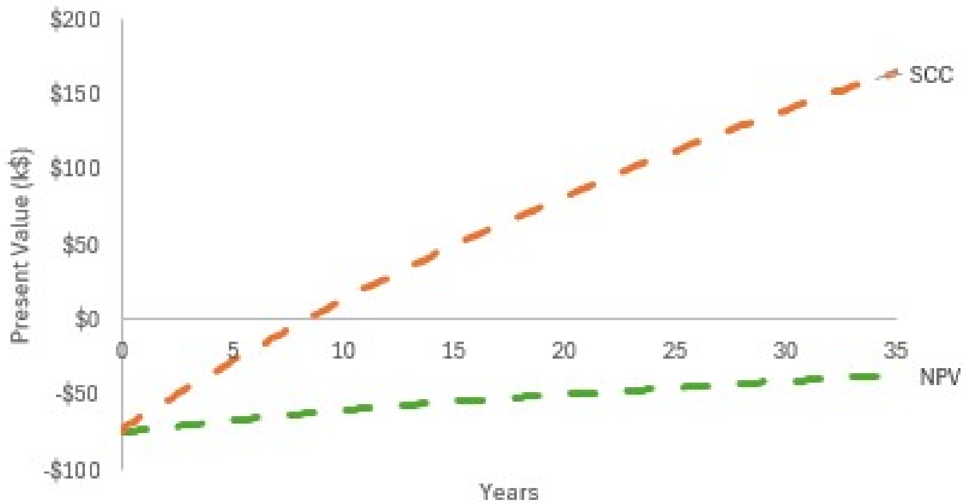

Figure C 23: GRPS Boiler Financial Chart

Looking at the chart above, the NPV for the GRPS boiler project has a deficit of around $36,000. When the social cost of carbon is taken into consideration, the final value gets up over $150,000 in profit because of the significant reductions in carbon emission due to the reduced fuel consumption. While the SCC isn't direct monetary savings, it is still important to take into consideration when determining feasibility of this project.

Conclusions

In conclusion, if a boiler is going to be replaced by a brand-new boiler, a gas boiler is the superior option to an electric boiler. Due to the high cost of electricity compared to natural gas and the impurities in the electric grid, an electric boiler is both more expensive and a bigger carbon emitter than a gas boiler. The gas boiler doesn't fully reach payback either, it has a deficit of about $36,000. However, if a boiler needs to be replaced, the gas boiler presents the best option. When looking at the SOC, the boiler does have a positive value; however, this isn't monetary value back into the fund. Because the gas boilers need to be replaced either way, retrofit options should be explored. One option is replacing the burners and electronic controls. The team did not have time to analyze this option within the semester but were told by the head of facilities at Calvin University that this can extend boiler lifetime up to 50 years and is the cheapest method.