Determining an Earlier Date for Carbon Net Neutrality for Calvin University

ENGR-333 Section B

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Abstract

Calvin University is currently committed to being carbon neutral by 2057. However, by 2057 the earth will see irreversible damage due to global warming. Because of the constant rise in global carbon emissions, President Boer tasked the students of ENGR-333 to find an earlier date for Calvin to become carbon neutral. Carbon net neutrality involves eliminating the emissions associated with heating and electricity. To have the most immediate impact, it was desired to reduce the most carbon as fast as was cost effective. Starting immediately, Calvin would start buying carbon free electricity from Consumer’s Energy, continuing until 2040 when Consumer’s Energy claims to be carbon neutral. This eliminates all emissions associated with electricity consumption. The emission from heating would be eliminated by replacing the natural gas boilers with electric heat pumps starting in 2026. Efficiency projects would be implemented throughout campus to lower energy consumption. Funding for these projects will come from donner campaigns, IRA tax credits, and from various forms of Federal and State funding programs. These initiatives were determined to be the most cost effective and will achieve carbon net neutrality for Calvin University by 2029, 28 years sooner than the previous commitment.

Introduction

Calvin University is currently committed to being carbon neutral by 2057. However, by 2057 the average global temperature will have risen by well over 1.5°C, a temperature change experts say will cause irreparable damage to the global climate. Thus, President Boer has tasked the mechanical engineering students of the Engineering 333 class to determine the best earlier date for Calvin University to set to become carbon neutral. Calvin will be considered carbon neutral if all emissions produced on site and from its energy consumption are mitigated. To achieve this, Calvin must address emissions linked to campus heating and electricity consumption. Energy efficiency initiatives offer a viable approach to curbing campus energy consumption. The class was broken down into four teams – electricity, heating, efficiency, and finance – with each contributing to the goal.

Methods

Heating

Calvin University is currently heating using natural gas boilers. To reach carbon net neutrality, Calvin must mitigate the emission associated with burning natural gas. To do this, several options were investigated. These options included buying carbon-offset natural gas, electric boilers, and heat pumps. If the electric boilers and heat pumps are used, the emissions from the added electricity must be mitigated to become carbon neutral from a heating standpoint. A more in-depth analysis of mitigating Calvin's emissions from heating can be found in Appendix A.

Electricity

Emissions from production of consumed electricity must be mitigated before Calvin University can be considered carbon neutral. Several methods were investigated. Carbon free electricity can be bought from Consumer's Energy for an additional cost, eliminating the emissions from electric consumption. Another approach was generating renewable electricity on campus or in other parts of the United States. A more in-depth analysis of mitigating the emissions from Calvin's electricity consumption can be found in Appendix B.

Efficiency

Calvin University can lower its carbon emissions by lowering the amount of energy consumed. Many different efficiency projects were investigated with the goal of reducing electricity consumption as much as possible. These projects included double-paned windows in dorms, academic buildings and the KE Apartments, thermostatic valves and more efficient radiators in the dorms, and smart thermometers in the KE Apartments. A more in-depth analysis of Calvin's efficiency projects can be found in Appendix C.

Finance

The initiatives and projects to reach carbon net neutrality will cost a substantial amount of money. To raise the capital needed to cover the costs of the proposed projects, Calvin University's fundraising strategy would comprise of federal and state grants along with private funding from donors. The federal funding would come through the Inflation Reduction Act. Several state level grants that Calvin could apply were found with the help from District Director Kooyman. A more in-depth analysis of carbon net neutrality financing can be found in Appendix E.

Results

Using the information gathered from each team, several comprehensive models were developed. These models combine all the data from each team – the project, the amount of carbon the project will save, the cost of the project, and the year the project will be implemented. Three distinct models were created: Grid Decarbonization, Texas Wind Farm, and the Carbon Offsets Model. Grid Decarbonization was determined to be the most feasible option, as it is the most time and cost effective and contains the least uncertainty. See Appendix D for more detail on all models.

In the Grid Decarbonization Model, Calvin reaches carbon net neutrality by 2029. Calvin University will buy renewable electricity from consumers energy at a 12% price increase starting immediately, eliminating all emissions linked to electricity. Carbon-free electricity will be purchased until 2040, when Consumer's Energy will become carbon neutral. The natural gas boilers will be replaced with electric ground-source and air-source heat pumps, mitigating the emissions of burning natural gas, beginning in 2026 and would be completed by 2029. Energy efficiency projects will be implemented throughout the campus to reduce energy consumption. Carbon net neutrality is reached in 2029, when heating is electrified, and carbon-free electricity is purchased until 2040. Figure 1 shows the emissions and spending for this model. More details of the Grid Decarbonization model can be found in Appendix D.

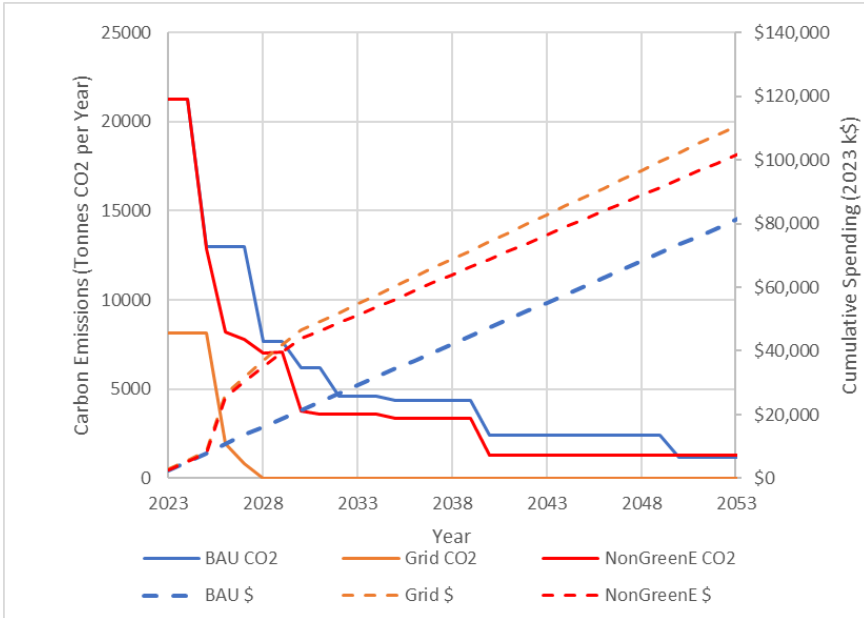

Figure 1. Emissions and Spending for the Grid Decarbonization Model

Conclusion

The Grid Decarbonization Model was chosen as it is the most cost-effective and reaches neutrality within 7 years, 28 years sooner than the previous carbon neutrality date. Commencing in 2025, ground and air source heat pumps will be eligible for a 30% tax credit on their highest-cost acquisitions. This initiative aims to render Calvin's heating load entirely carbon neutral once the process of decarbonizing electricity is completed. Accomplishing this involves the purchase of carbon-free electricity from Consumers Energy, albeit at a higher cost, with immediate implementation to swiftly mitigate emissions. Carbon-free electricity must be purchased until 2040, when Consumer’s Energy claims to become carbon neutral. Efficiency projects such as double-paned windows, upgraded control systems, and efficient radiators will be implemented throughout campus.

As a Christian academic institution, Calvin University aspires to serve as a model for addressing global warming caused by carbon emissions. Although Calvin University's own carbon emissions are not substantial compared to manufacturing industries or larger universities, it seeks to set an example for entities with larger environmental footprints. Given the escalating global emissions and the corresponding rise in temperatures, the commitment of Calvin to achieve carbon net neutrality reflects a sense of responsibility for its own emissions, contributing to the broader effort to combat climate change.

Appendices:

Appendix A – Heating Analysis of Calvin University

Contributors: Ally Gauss, Stuart Johnston, Zach Rosendall, and Nora TerBeek

Introduction

In order complete the President's request for a carbon neutral campus, the mechanical engineering class split into categories deemed the more urgent due of their impact in relation to the rest of campus. The main contributor of CO2 on campus are the current natural gas boilers. With Calvin's goal of being carbon neutral in mind, the following analysis outlines the suggestions made by the heating and cooling team.

Methods

With the guidance of the reports from the previous years, the heating and cooling team researched ways to implement new sustainable options. Initial research was conducted by reviewing previous sections' work on Calvin's heating and cooling systems. From there, the team researched similar schools that have been successful in their carbon neutrality transition and unified these ideas to propose the following: a combination of ground source and air source heat pumps, switching the current system to electric boilers, or the option of purchasing carbon neutral natural gas. The cost values and time estimates were calculated for each scenario and were subsequently compared to determine the best course of action.

Status Quo

Currently, Calvin releases approximately 148,000 mcf (thousand cubic feet) of CO2 in volume a year through the current natural gas boilers. The option of continuing business as usual is the idea that Calvin would stay on its current system and achieve carbon neutrality through buying offsets or switching to carbon neutral natural gas. Currently, the University supports seven natural gas boilers located across campus. After consulting engineering building faculty member Paul Pennock, the approximate total costs spent to replace the current system with new natural gas boilers was estimated to be $1,114,125 ($2023). However, this cost does not consider the current lifespan of the boilers on campus; rather, this estimate is how much it would be to replace all the boilers at the same time. This method would mean that the earliest Calvin's heating system can be carbon neutral is when offsets are purchased to include the amount of carbon emission related to the natural gas, or through the purchase of carbon neutral natural gas.

Ground Source and Air Source Heat Pumps

Utilizing research from the past reports, the option of converting Calvin campus to geothermal heating was further explored. A visual diagram of how ground source heat pumps (GSHP) and air source heat pumps (ASHP) work can be found in Appendix A2. Ground source heat pumps and air source heat pumps run completely on electricity and have efficiencies of 400% and 300% respectively (Clay). If that said electricity was carbon neutral, then the GSHPs would be a carbon neutral system. It is expected that electricity will be carbon neutral in 2040, as promised by Consumers Energy. Installing GSHP could theoretically make Calvin's heating and cooling carbon neutral in 2040, this is relying on Consumers Energy to stay true to their proposed carbon neutrality timeline. Another potential issue with GSHPs is the high upfront costs as well as the intensive construction process. The proposed GSHP system would require a total of 1,473 boreholes with an estimated installation time of one year. The purchase cost and maintenance costs are shown in Table 1A. The GSHP would run on loops in tangent with an air source heat pump loop to heat the KE Apartments, since the loop is too small to warrant its own GSHP system. The proposed loops are shown in Figure A2.3, With high efficiency and low maintenance costs, GSHPs working with ASHPs could be a viable option for Calvin University.

Electric Boilers

Another feasible option is to convert the current natural gas boilers to an electric alternative. Again, Calvin would be relying on Consumer's promise and reach carbon net neutrality by 2040. One of the main issues with this conversion is that many companies don't produce industrial sized electric boilers. Because of this, the campus would need a total of 113 3000 kW boilers (Behler-Young). The purchasing cost of the boilers is just below 12 million dollars and adds a yearly electricity cost of $3,537,717 per year. Due to the vast amount of electricity needed to heat the campus, additional efforts to research this option were not pursued.

Carbon Neutral Natural Gas

The option of purchasing carbon neutral natural gas has the ability to push Calvin into an accelerated timeline. With this commitment, Calvin would rely on DTE to provide carbon neutral natural gas. Thus, having the possibility of making Calvin's cooling and heating systems carbon neutral as soon as possible. The price of these offsets would exceed just over 1 million dollars a year. However, this option is not feasible in the long run. DTE is also only guaranteeing a lock on the price until the year 2026, and researchers expect the price of offsets to increase up to 3000% in the next five years (Carbon Offset Price).

Results

When comparing ground/air source heat pumps, electric boilers, and carbon offsets, both cost and time come into play. The table below summarizes the findings from the options suggested above. The heating and cooling team ultimately decided to recommend that Calvin switches to ground source and air source heat pumps because it would switch our campus to geothermal heating. With this option, it is feasible to have construction done as early as 2029, a thorough timeline can be found in Appendix A.

Table 1A. Outline of the feasible heating and cooling options

	PEC- includes installation ($2023)	OM ($2023/yr)	Electricity (kWhr/yr)	Electricity ($2023/yr)	Natural Gas Cost ($2023/yr)	"Life" (yrs)
GSHP + ASHP	$29,400,000	$422,833	10,345,693	$879,383.91	0	20 yrs (GSHP) 15 yrs (ASHP)
Electric Boilers	$11,954,044	$50,000	41,620,200	$3,537,717	0	25 yrs
Status Quo	$1,114,125.1	$50,000	0	0	$205,637	30 yrs
Carbon Neutral Natural Gas	$1,114,125.1	$50,000	0	0	$1,205,637	50 yrs

Conclusion

After consulting the other teams, the heating and cooling team has decided to recommend that Calvin switches to ground source and air source heat pumps. Although the proposal will not be cheap, there would be no future carbon emissions related to heating while on a geothermal loop. Upgrading the boilers advances the campus to the goal of carbon zero emissions. Alongside the heating and cooling project proposal, the proceeding report sections outline how the rest of campus is expected to achieve carbon net neutrality.

Appendix A1: Status Quo

Table A1.1. 2022 Heating Consumption

Month	MCF Volume	DTH	BTU factor	Cost
Aug	6,584	6,954	1.0563	$13,996.90
Sep	7,241	7,651	1.0567	$14,646.51
Oct	10,281	10,839	1.0543	$17,650.03
Nov	15,745	16,519	1.0491	$23,048.56
Dec	19,328	20,347	1.0527	$26,588.56
Jan	20,119	21,230	1.0552	$29,124.30
Feb	22,080	23,256	1.0532	$31,099.20
Mar	16,602	17,460	1.0517	$26,299.2
Apr	10,970	11,570	1.0547	$20,103.63
May	8,105	8,578	1.0584	$17,268.14
Jun	6,040	6,349	1.0513	$15,224.01
Jul	5,581	5,874	1.0524	$14,770.43
Total Consumption:	148,675	156,628		$249,819.48

Table A1.2. Cost Overview of the current heating system in $2023

Location	Engr Building	Knoll Crest	Commons	Library	Total
Power (hp)	400	225	300	1300	4150
Cost (in 2023 $)	$134,003.05	$94,883.00	$112,759.00	$271,797.00	$613,442.05
number of boilers	2	2	1	2	7
Total Cost (in 2023 $)					$1,114,125.10

Appendix A2: GSHP + ASHP

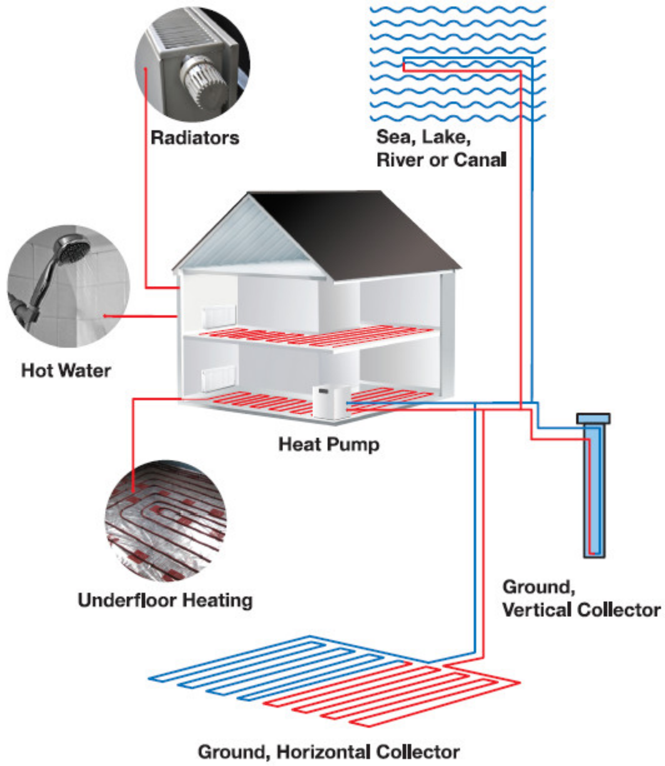

Figure A2.1. Visualization of Ground Source Heat Pumps

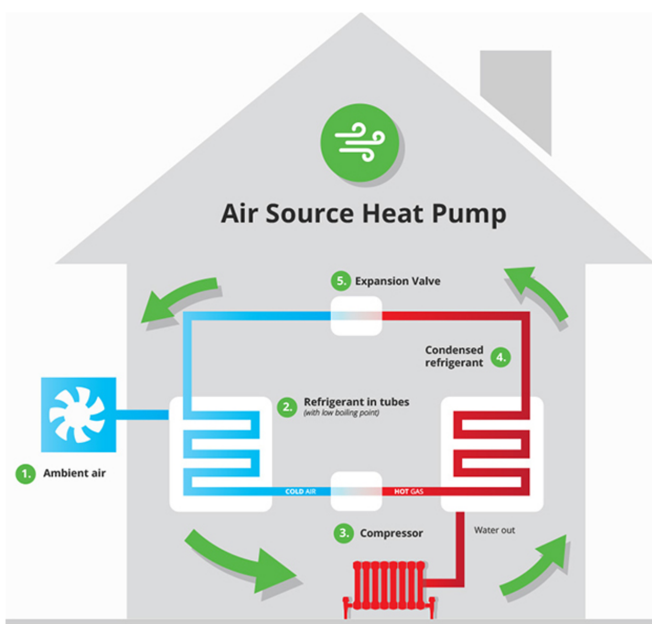

Figure A2.2. Visualization of Air Source Heat Pumps

Figure A2.3. Map Outlining the Locations of the GSHP and ASHP systems.

Figure A2.3. above outlines the placement for the GSHP and ASHP. Loop 1 is in red, and loop 2 in blue, with the facilities loop in purple. The ASHP are located in the KE apartments, which is outlined yellow. The boreholes are located under the parking lots (1-10 and 17) in orange.

Table A2.1. Comprehensive timeline of proposed GSHP and ASHP installation

2025	2026	2027	2028	2029
Borehole Construction	Loop 1 installation	Loop 2 installation	KE ASHP installation	Facilities Loop installation

Table A2.2 ASHP Cost Breakdown

ASHP break down	Unit	Installation	Total Cost
New Construction	$175,000.00	$375,000.00	$550,000.00
Alpha-Beta-Delta	$150,000.00	$450,000.00	$600,000.00
Phi-Chi	$150,000.00	$375,000.00	$525,000.00
Rho-Tau	$150,000.00	$375,000.00	$525,000.00
Theta-epsilon	$150,000.00	$375,000.00	$525,000.00
Zeta-Lambda	$150,000.00	$375,000.00	$525,000.00
Total	$925,000.00	$2,325,000.00	$3,250,000.00

Table A2.2. Cost Overview of proposed GSHP and ASHP systems.

System	PEC (in 2023$)	Number of Boreholes	Borehole Area (ft^2)
Heating Loop 1	$21,956,250.00	1,335	534,000
Heating Loop 2	$2,353,750.00	110	44,000
Facilities Loop	$1,840,000.00	28	11,200
KE ASHP	$3,250,000.00	-	-
Total Cost (in 2023 $)	$29,400,000.00	1,473	589,200

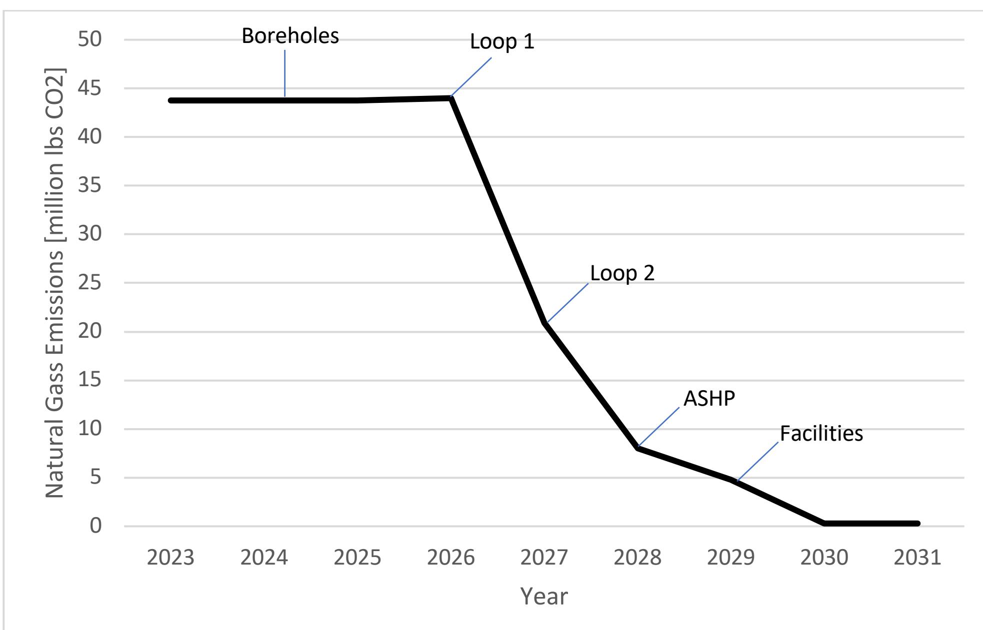

Figure A2.1. Carbon Emission Reduction Due to Plan Implementation

Appendix A3: Overview

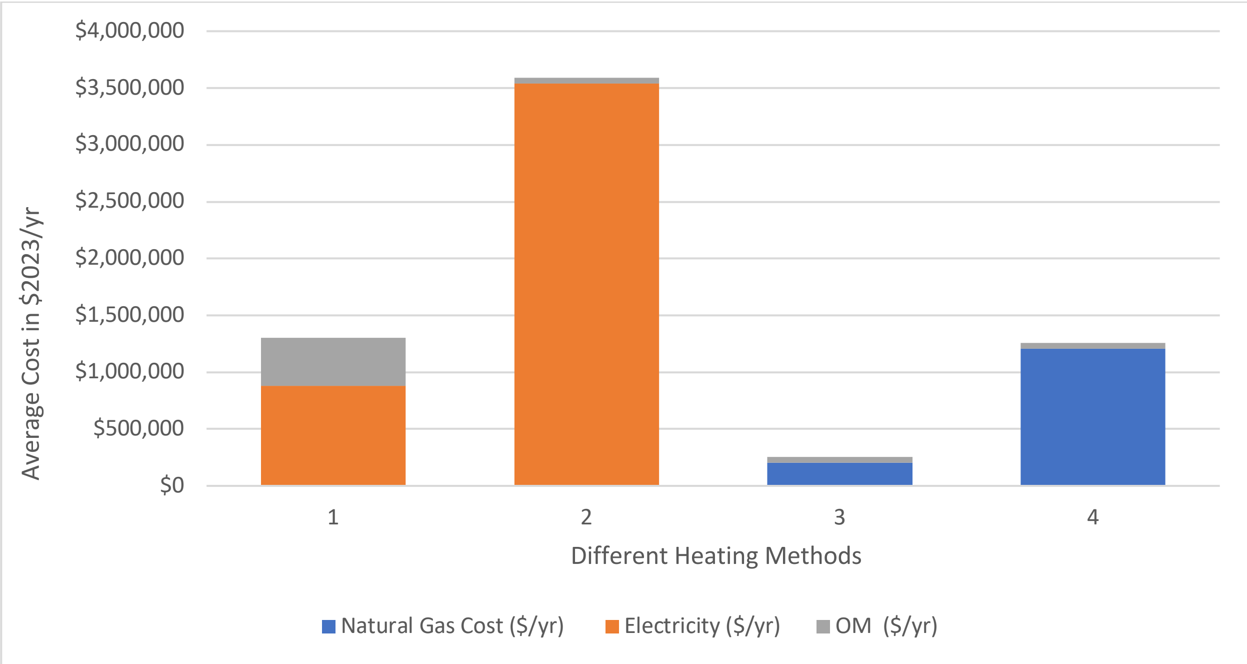

Figure A3.1. Average Annual Costs of the Proposed Heating Systems

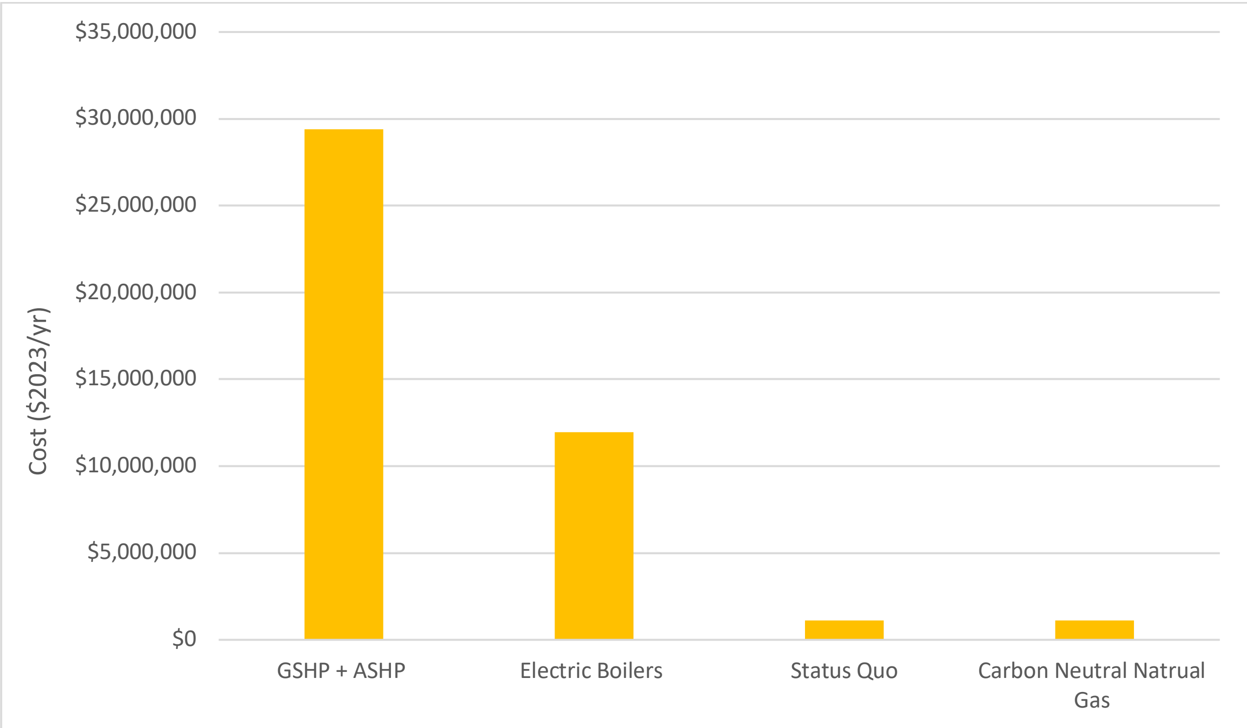

Figure A3.2. Purchasing and Installation Cost of the Proposed Systems

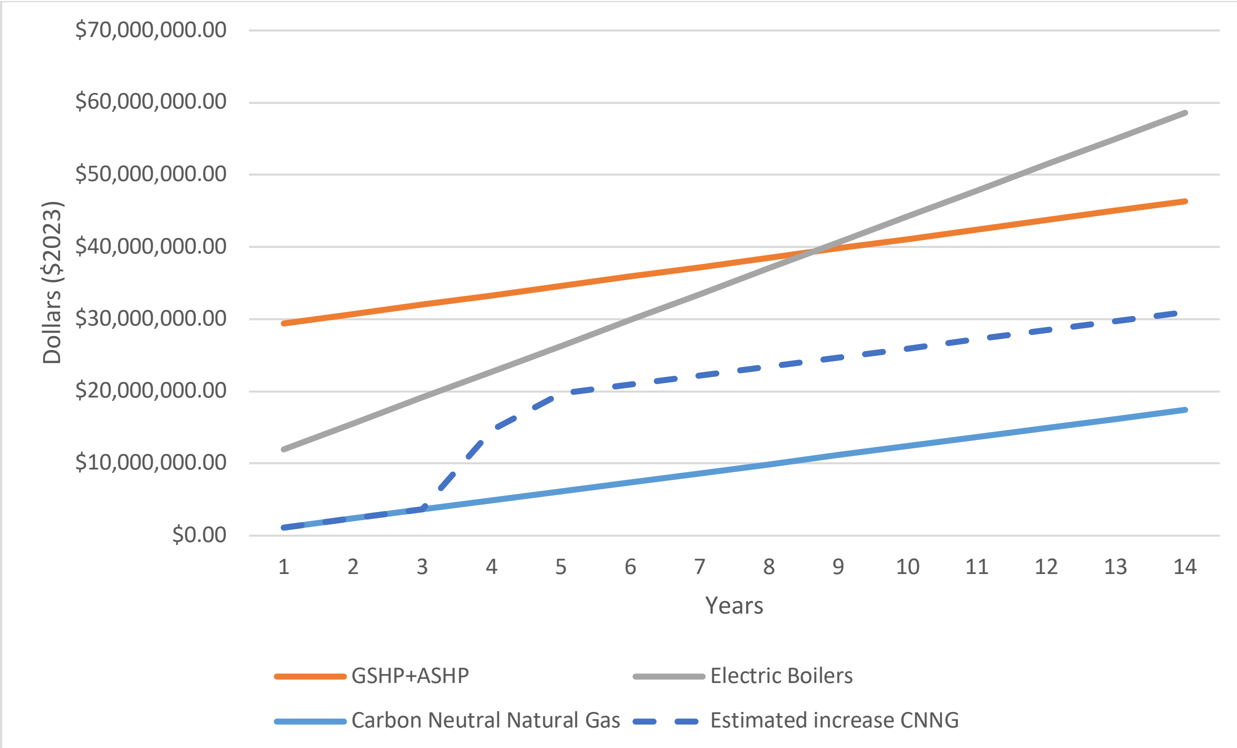

Figure A3.3. Cumulative Comparison of the Proposed Options Overtime

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Appendix B – Electrical Analysis of Calvin University

Contributors: Samantha Bush, Daniel Cordeiro, David Harris, Nathan Zylstra

Introduction

The overall goal of the Calvin Carbon Neutrality project is to determine a new date before 2057 for Calvin to be carbon neutral. The goal of the electricity team was to determine if Calvin University should pursue the production of carbon-free energy prior to the electricity grid decarbonizing and if so, what measures to take.

Methods

Current energy consumption at Calvin University is almost 20 million kWh per year. If heating at Calvin University goes electric using ground and air source heat pumps, it will add about 10 million kWh per year (according to the Heating Team's data and calculations) which would make the total energy consumption to be about 30 million kWh per year. Furthermore, the Efficiency Team proposed several projects to reduce carbon emissions, which would reduce Calvin's energy consumption by 0.8 million kWh. With the electricity grid decarbonizing by 2040, Calvin will have to act fast if it wishes to implement carbon-free electricity solutions before the electrical grid decarbonizes itself.

Solar Panels on Campus

Installing solar panels on campus to decarbonize Calvin's electricity was the initial idea the electricity team looked into. This would convert the source of Calvin's energy from a non-renewable to a renewable one. In order to determine the feasibility of solar energy on campus, the energy consumption rate was needed. Currently, Calvin does not have the equipment to meter individual buildings to see how much electricity each building consumes. However, having a yearly consumption rate for the entire campus was enough to start making calculations regarding converting to renewable energy sources.

The electricity team reached out to local connections to gather relevant data to help foster understanding about the requirements for implementing solar power on campus. These connections include South Christian High School, Calvin Professor Eric Walstra, Calvin Alumni and GIS grad student Isaiah Hageman, and Michigan's department of transportation (MDOT). Summaries of the research from South Christian, Professor Eric Walstra, and MDOT can be found in Appendix B1.

GIS Data

To identify how big a solar field would be needed to power Calvin's campus, and the best viable locations for the solar field, a GIS grad student at Calvin University was consulted. The GIS grad student, Isaiah Hageman, was given the number of solar panels needed to power Calvin's campus as well as the size of the solar panels. He then calculated how big the solar field would have to be and pieced together all the best sites on campus where solar panels could be installed so that there would be enough to power all of Calvin. The map he created is shown in Figure B1. The green areas are rooftops, the yellow areas are parking lots and sport fields, and the red areas are the nature preserve and Gainey Athletic Complex.

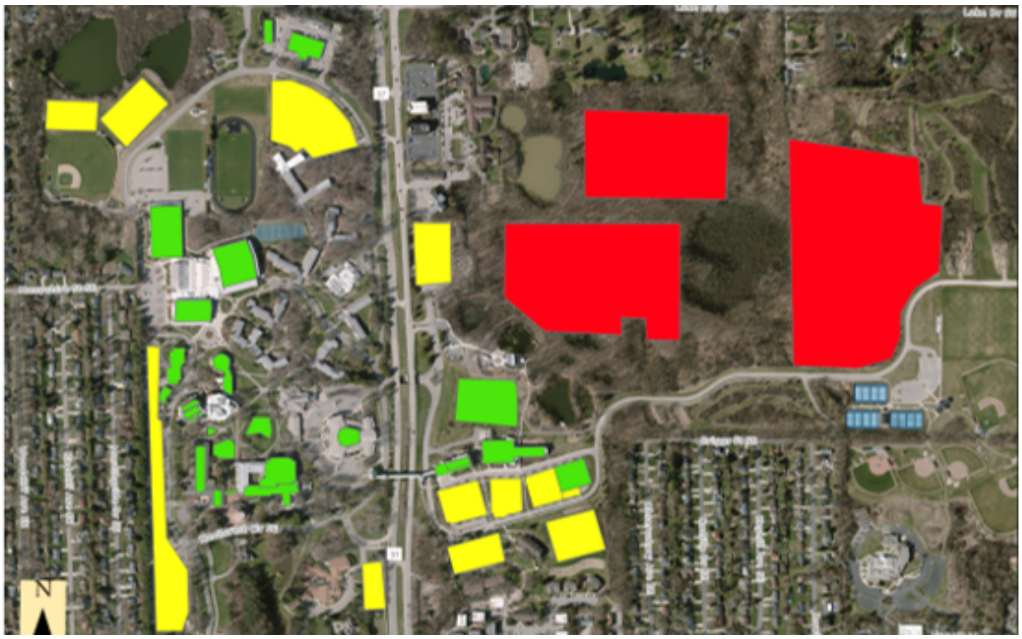

Figure B1. On Campus Solar Panel Locations. Source: GIS Grad Student, Isaiah Hageman

Floating Solar Panels

A secondary solution involving solar power was floating solar panels. This possible solution would decrease the land area on campus needed to produce enough electricity. Floating solar panels are conceptually straight forward, they are solar panels that float on top of a body of water as to not take up land area that could be used for other purposes. Floating solar panels have been found to be up to 15% more efficient than land panels due to the cooling effect for the panels from the water (Sullivan). It also has been concluded that floating solar panels don't harm the ecosystem of the body of water they cover, instead they help reduce evaporation.

Buying land outside of Michigan

As previously mentioned, Calvin University is located where sunlight is only strong during the summer and where winds are too weak for wind turbines. An option to work around this is to find a piece of land outside of the state where sunlight and wind speeds are much stronger. The location that was decided on was West Texas because its sunlight is the strongest year-round, as shown in Figure B.1 in Appendix B2. Also, wind speeds are adequate for wind turbines ("U.S. Average Annual Wind Speed at 80 Meters"). Furthermore, west Texas has some of the cheapest land in the country, with the average cost per acre being $1000 to $2000 (Nolte), as shown in Figure B2.2 in appendix B2.

Wind Farms

An out-of-the-box solution proposed was to build a wind farm in West Texas. The previous section explained how land in West Texas is inexpensive with an average of $1000 per acre. Also, this location has good wind speeds so that wind turbines could operate with an average of 20% to 40% capacity ("U.S. Average Annual Wind Speed at 80 Meters").

Wind turbines have several needs to be met before they are installed. Turbines need to be about seven rotor diameters away from each other, which is about three-fourths of an acre per MW of electricity. The turbines need to be placed on land that has no obstructions with flat land being the most ideal (Gaughan).

Purchasing Green Energy

A more passive solution is to purchase green energy directly from the grid. Consumer's Energy (CE) has a green energy credit program where Calvin would just have to pay an additional $0.014 per kWh and Consumer's Energy will release the amount of energy paid for with energy from renewable production sources. This means that all of Calvin's energy usage would be deemed carbon free. This is because Consumer's Energy is already producing carbon free energy with their renewable energy sources and can control where that energy goes. By paying extra for the green energy credits, Consumer's would release more green energy into the grid. That extra money would then be used for installing and maintaining more renewable energy sources.

Wait for Grid Decarbonization

Another solution method for Calvin University is to continue like normal in pertains to electricity usage and wait for the entire grid to decarbonize. With this passive approach Calvin will wait for the energy grid to decarbonize on its own. Calvin's current energy provider, Consumers Energy is currently acting on their own plan to achieve clean energy by 2040. CE's goal is to produce clean carbon free energy while meeting energy demands (especially at night). Their plan includes 10% of their production being sourced from natural gas, but CE is adjusting for the emissions with carbon offsets. CE has already been making improvements including closing their coal plants and some of their natural gas plants. CE has published their goals of electric capacity for their transition to clean energy. This data is shown in Figure B2.

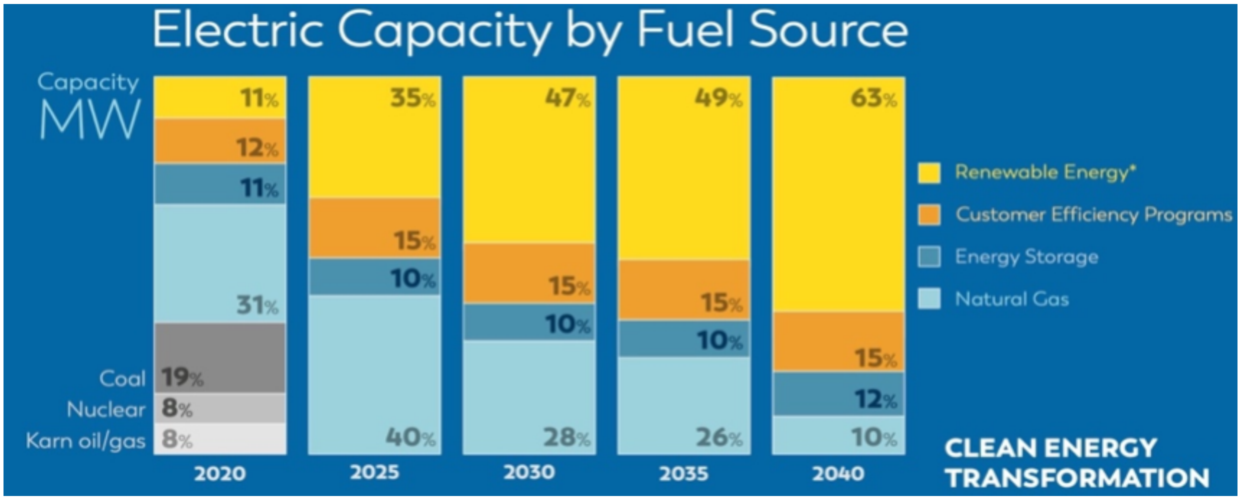

Figure B2. Consumers Energy Plan for Electric Capacity by Fuel ("Leading Michigan's Clean Energy Transformation").

This is an appealing possible solution since Calvin would not have to take any further actions, implement any multi-step procedures, or invest a large sum of money to convert all electricity to carbon free electricity. However, this approach does not highlight Calvin's desire to actively pursue sustainability and carbon neutrality. It also causes Calvin University's carbon neutrality plan to be solely dependent on CE so if CE doesn't meet their goals, Calvin does not meet theirs.

Results

Issues with Solar on Campus Solution

Analyzing the available data of similar solar projects that have been implemented in the Grand Rapids area and enlisting the help of a GIS student to model Calvin's campus provided a solid understanding of how extensive of a project installing solar panels to cover Calvin's energy usage would be. This understanding brought many issues to light. These issues include required land area, placement, costs, and maintenance.

Estimating Calvin's energy consumption and calculating the amount of energy per solar panel using South Christian data, resulted in around 63,196 panels being required to meet Calvin's demand with projected increases from other projects being implemented. This was then converted into a total surface area of 764,640.5 sq ft, or 17.55 acres, based on panel dimensions and mandatory spacing between panels defined by Isaiah Hageman, the GIS student. So much space is required because of how cloudy Michigan is.

The second main problem is placement of the soler panels. As mentioned, the square footage required to produce enough energy for Calvin's consumptions is very large. To achieve this much coverage, many areas would need to be covered in solar panels. These areas include most of the academic building roofs, all the parking lots, a few practice fields, the nature preserve and part of Gainey. A visual of the locations used for the required square footage is shown in Figure B1. This poses many issues and push back because this solution would be taking away a lot of space that is used for other purposes and would require the clearing of many trees which are nature's best way to remove CO_2 from the air which would be counterintuitive to Calvin's values. This also poses the issue of aesthetics and how students and faculty would feel if the entire campus was covered in solar panels.

Installing solar panels also has a large $52 million up front cost and a $303,000 yearly maintenance cost. Although the system would eventually pay itself off because Calvin would no longer have to buy energy from the grid, $52 million is an intimidating number and raising those funds will not be easy. These situations show that there are many issues with the on campus solar energy solution proposal that would have to be considered and discussed before there could be any movement toward progress.

Issues with Floating Solar Panels

Although there are many stated benefits to floating solar panels there are also many negatives. A diagram of floating solar panels with indicated pros and cons from ESMAP is shown in Figure B2.3 in appendix B2. These include maintenance cost for both above and below water components. The panels would need basic maintenance and cleaning and the underwater components such as anchoring would require monitoring and maintenance vis scuba diving. Electrical safety and equipment wearing is also an issue. Whenever electricity, wires, and water mix there is a potential hazard and outdoor weather conditions can cause expedited wear of equipment which can lead to issues and safety risks. Lastly, location is still an issue. Calvin would have to find a body of water that they could cover with solar panels. Freezing winters and lakes icing over, floating solar panels are not fit for year-round use in Michigan, and they are not meant to be set up and taken down on a yearly basis.

Wind Farm in Texas

The costs for a wind turbine average about $1.3 million per MW of electricity-producing capacity. Its maintenance cost is about $40 to $50 thousand per MW of electricity-producing capacity per year. Installation costs can vary depending on location, construction contracts, cost financing, the number of turbines placed, and more (Blewett). A single 2 MW turbine can produce about 6,000 MWh per year at 35% capacity. With four 2 MW turbines, it would produce 24,500 MWh per year at 35%, which would exceed the needs of Calvin University currently. However, the wind turbines would come with a $13 million price tag.

Consumers Energy

Both buying green energy from Consumers Energy and waiting for them to decarbonize their grid have downsides. Although buying green energy from CE is one of the easiest methods of obtaining carbon net neutrality, it is a solution that will never pay itself off and is only a passive approach to carbon neutrality that has a questionable global impact. In other words, buying green energy from consumers leads to no proactive action on Calvin's part to reducing the amount of carbon released, it is merely a change in accounting. Furthermore, waiting for CE to decarbonize their grid forces Calvin University to rely solely on CE for their Carbon Neutrality. If CE fails, Calvin fails.

Conclusion

Before 2040 - The Earlier the Better

The sooner Calvin can be carbon neutral, the more payoffs Calvin can take advantage of. The plan is to buy green electricity from Consumer's Energy to quickly become carbon neutral. This is a passive strategy since Calvin will not need to update its infrastructure or build a solar farm on campus to become carbon neutral. The graph below shows how buying green energy compares to waiting for grid decarbonization.

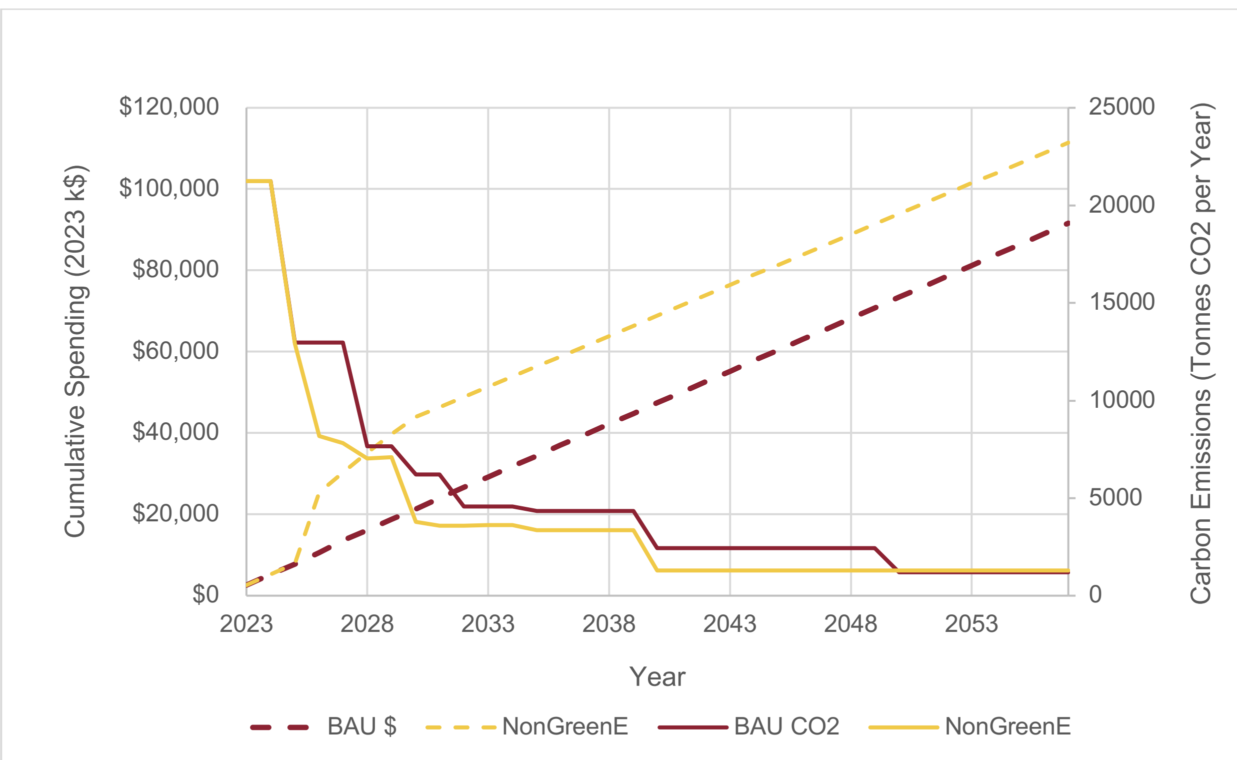

Figure B3. Hero Graph Comparing Business as Usual (BAU) Cost and CO2 Emissions versus Buying Green Energy Cost and CO2 Emissions

Calvin can also build a wind farm in West Texas to go carbon neutral. With the wind farm, it would be an active strategy since Calvin will not just be buying green energy but would be producing green energy. This is what Calvin needs to do to be carbon neutral before 2040.

2040 – Grid Decarbonization

2040 is the moderate date for Calvin University to be carbon net neutral. If Calvin waits until 2040 when Consumers Energy electrical grid plans to achieve clean energy there is no need to implement any carbon free electricity solutions on or off campus. By changing all the natural gas burning heaters to electric, all of Calvin's energy consumption will be green through CE's clean energy plan by 2040. This solution date is passive in approach and does not reap many substantial benefits, but it bumps Calvin's original carbon neutrality date forward by 17 years.

After 2040

Waiting until after 2040 is a solution. By then, the electricity grid should be carbon neutral, as Consumers Energy plans to achieve. Furthermore, DTE should also be carbon neutral by 2050. They plan to achieve that by using a lot of carbon offsets. That would mean that there would be no reason to switch heating from natural gas to electricity. Waiting till 2040 is not a promising idea because it relies on Consumer's Energy and DTE to go carbon neutral. For these reasons, it is not better to wait till after 2040 for Calvin University to be carbon neutral ("Michigan's Clean Energy Future").

Final Remarks

The electricity team explored many possible solutions, each with its unique advantages and challenges. The utilization of real-world data from South Christian High School's solar field, insights from Professor Walstra, MDOT's covered parking project, and GIS data provided a solid foundation for the decision-making process in pertains to solar energy. However, the extensive land requirements, potential disruptions to campus spaces, and substantial upfront costs associated with on-campus solar installations pose significant challenges that necessitate careful deliberation.

The other proposed solutions, including wind farms in West Texas and floating solar panels, have their own challenges such as land acquisition, maintenance, and environmental impact. The option to purchase green energy credits emerges as a more straightforward and immediate alternative, although it has an ongoing cost. Buying green energy from Consumer's also means Calvin is dependent on Consumer's Energy for carbon neutrality and questions Calvin's active steps towards sustainability.

Appendix B1: Research

South Christian High School Data

While solar energy is becoming increasingly popular around the world, it is still difficult to find consistent, reliable information about installation costs and energy production without getting a customized quote from a contractor. This is mostly because the effectiveness and cost of solar panels is largely dependent on the location and positioning of the solar panels. This made it very important to find a system similar to what Calvin would need in order to calculate model the required amount of panels, space, and the cost for Calvin to install its own solar field. This is why the electricity team reached out to South Christian High School.

South Christian High School is a local Christian high school with strong ties to Calvin University. In 2021, South Christian installed a donor sponsored 660 kW solar field on their campus. Data from this solar field was used to model the requirements for a solar field at Calvin since the fields and schools are very similar. Since the schools are close geographically, the solar radiation will be the same, meaning that the output per panel would be the same. Figure B2.4 in Appendix B2 was provided by South Christian High School and shows the amount of energy produced by their solar field over one year.

This was valuable information because it was scaled up to calculate how many panels and how much space will be needed for a solar field on Calvin's campus. Also, another benefit of these schools being so geographically close is that the same contractors and installation crews are available, so cost rates should be similar. Knowing the cost of South's solar field also helps estimate a cost for a field at Calvin. Additionally, since both schools are private Christian schools, they both deal with fundraising and donors in a similar manner. Because of this, valuable information about fundraising and paying for such expensive systems was gained by working with South Christian.

Professor Walstra

Professor Eric Walstra is an adjunct engineering professor at Calvin University. He was consulted because he has years of experience dealing with solar panels on both a residential and commercial scale. Several years ago, he installed several solar panels on his property which provide enough energy to power his entire house. He also has ties with South Christian and helped them when they were installing their solar field by consulting them through the process. Professor Walstra was able to provide great information on the basics of solar panels and how they work. He also informed the team about solar panel payback time, transferring energy credits, as well as different ways of paying for solar field.

MDOT Covered Parking Data

Calvin University has a lot of parking lots that could be used as spaces to place solar panels across campus. Placing solar panels on covered parking lots seems like a promising solution and one that the Michigan Department of Transportation (MDOT) implemented.

MDOT built a covered car parking lot in Grand Rapids at the I-96/M-44 (East Beltline Avenue) Interchange. The system was operational in 2011 and designed to produce about 100,000 kWh per year. They also have a website showing how much electricity the system is producing in real time, as shown in Figure B2.5 in Appendix B2. It also has data on how much electricity it has produced since 2012. With this data, estimations can be made on how many solar panels Calvin will need to produce the needed amount of electricity on a yearly basis. The estimations can be more accurate since the Covered Parking Lot is near Calvin, so they experience the same weather as Calvin University.

From Figure B2.5 in Appendix B1, the solar panel system produces the most electricity during the summer. During the winter it produces barely any electricity. If Calvin were to adopt solar panels, it would need to implement other solutions to produce or buy power during those colder and cloudier months.

Appendix B2: Figures and Tables

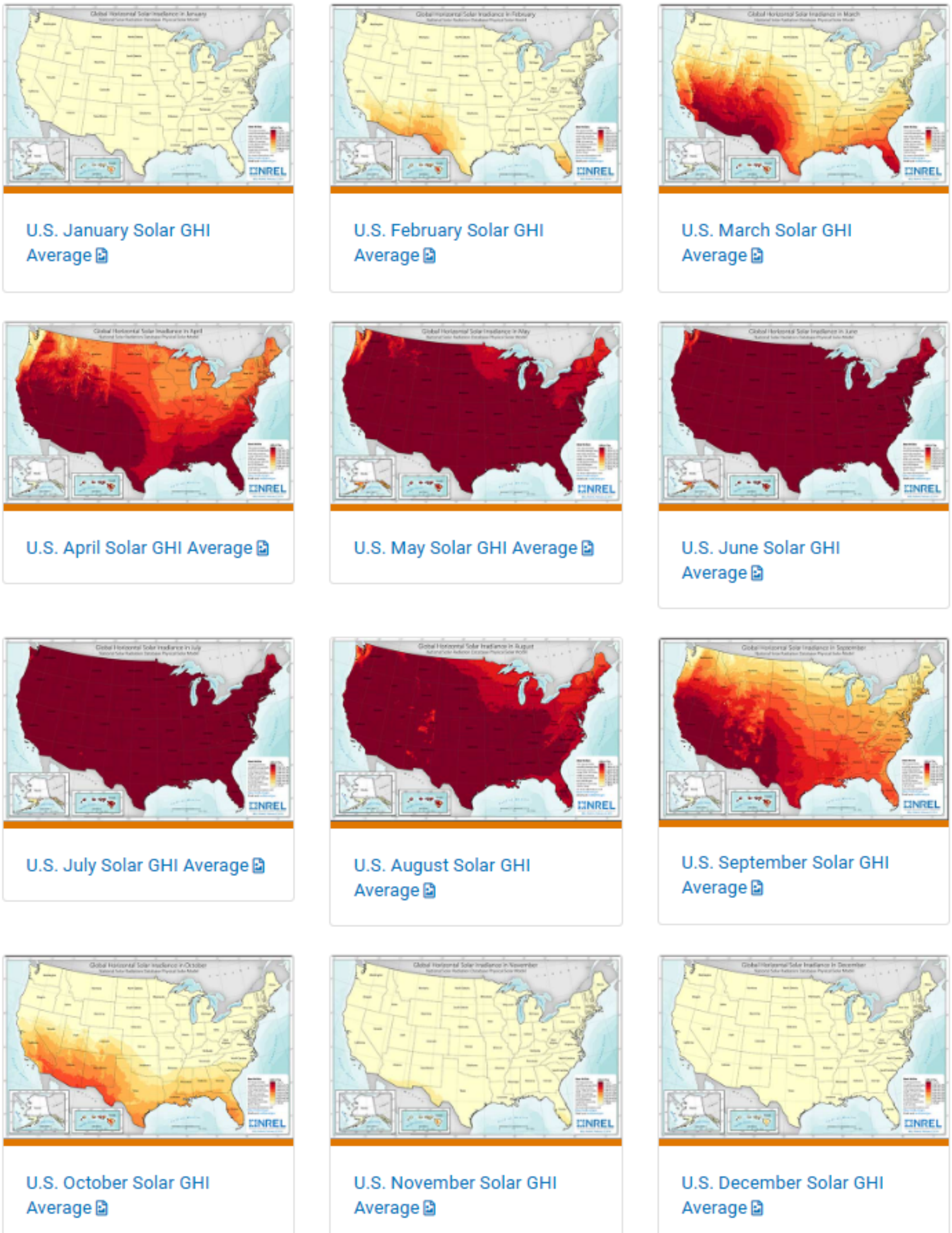

Figure B2.1. Monthly Solar GHI Averages Map for the United States ("Solar Resource Maps and Data")

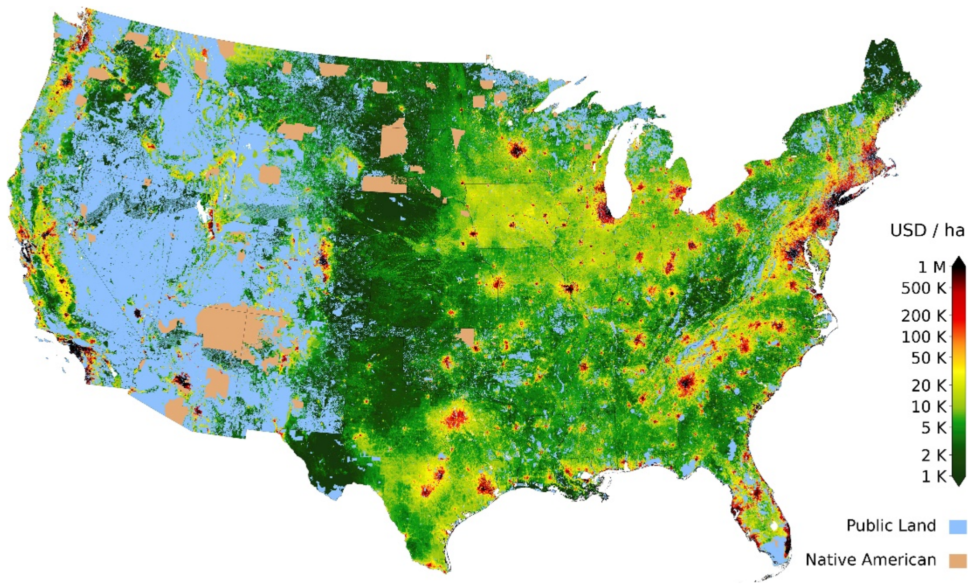

Figure B2.2. Map of Land Prices for the United States (Nolte)

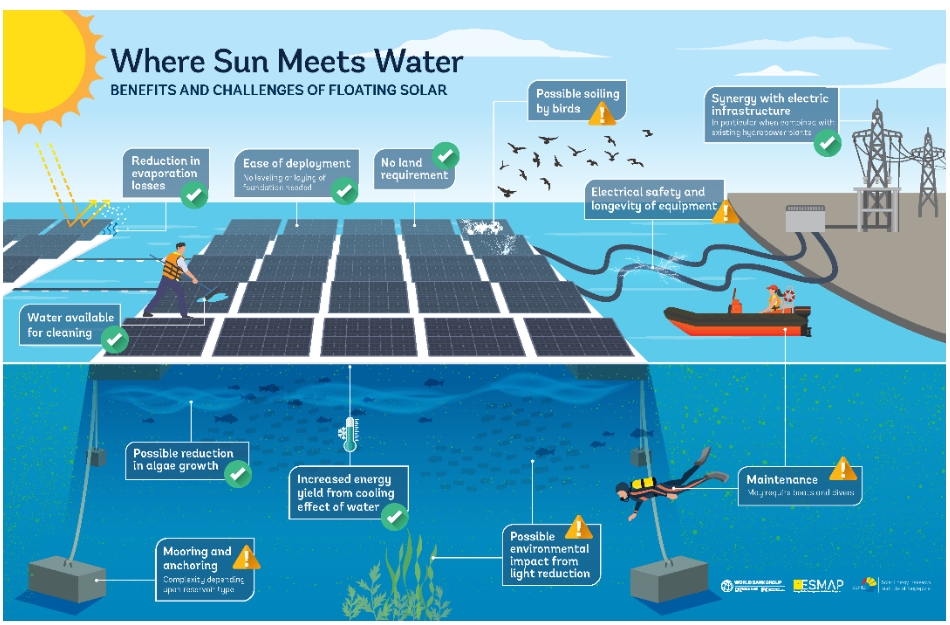

Figure B2.3. Diagram of floating solar panels ("Where Sun Meets Water: Floating Solar Market Report")

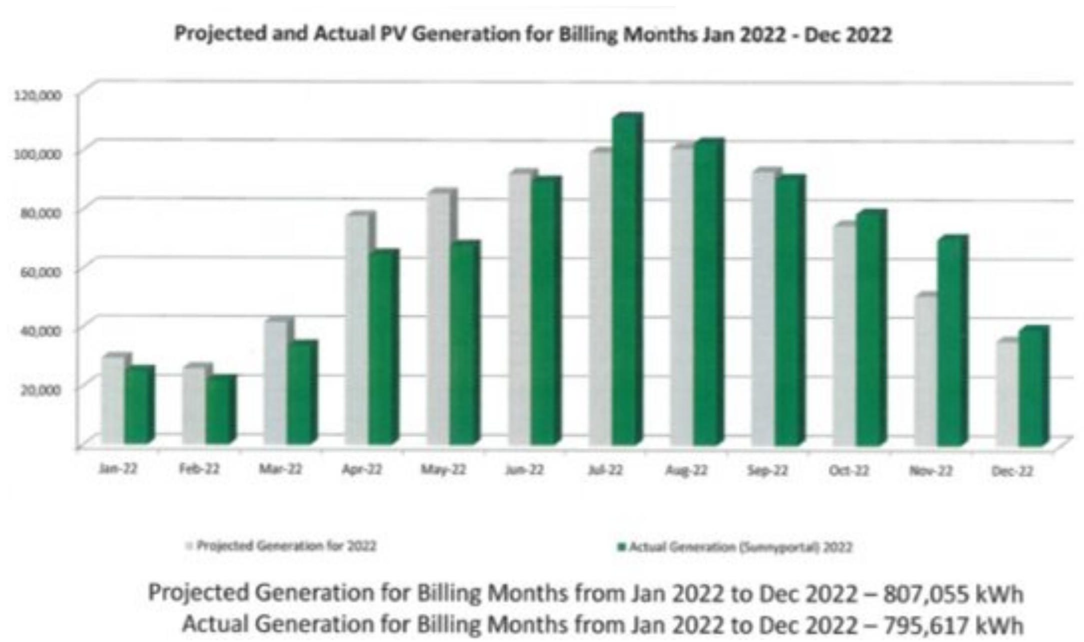

Figure B2.4. South Christian High School's Solar Field Monthly Production for 2022

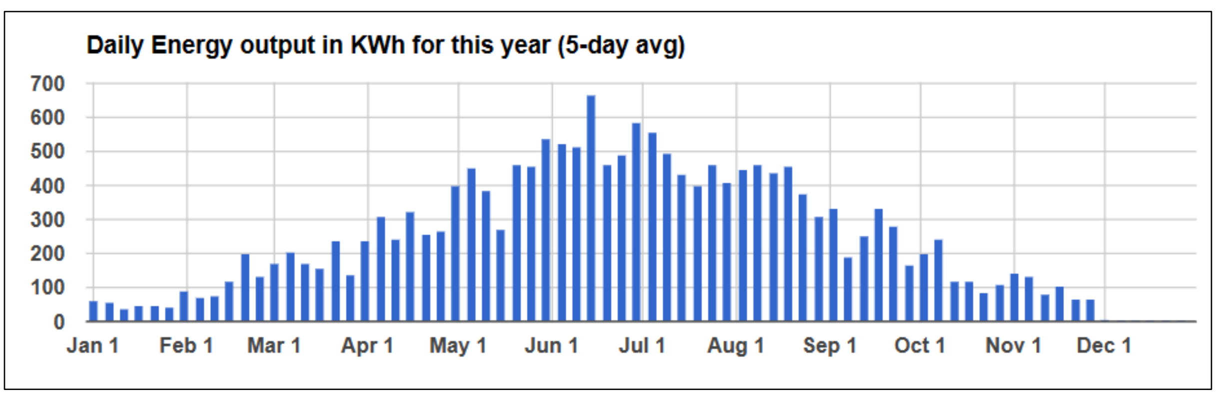

Figure B2.5. Graph Showing How Much kWh the Covered Parking Lot Produced During 2020 with a Five-Day Average ("Grand Region Solar Canopy").

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Appendix C – Energy Efficiency Analysis of Calvin University

Contributors: Mikayla Bindon, David Schmurr, Zachary Swart, Micah VanDeBurg

Introduction

The goal of the efficiency group was to explore ways to minimize carbon emissions by enhancing systems and processes at Calvin University, aiming to significantly decrease energy consumption. Different areas were investigated. Figure C1 shows how the areas were identified for investigation.

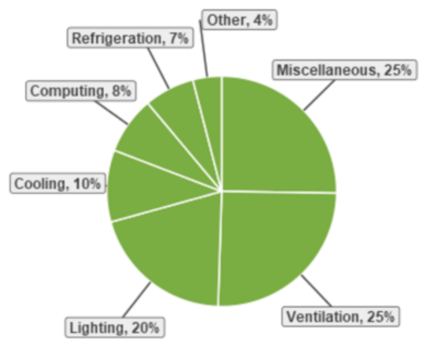

Figure C1. Average Breakdown of Electricity Uses by Midwest Universities

Calvin's CERF (Calvin Energy Recovery Fund) program has spent a lot of time and resources working on lighting and computing on Calvin's campus. Therefore, the efficiency team decided to focus mostly on HVAC projects.

The projects that were investigated as part of the efficiency team are as follows: Installing double pane windows to every window on campus, replacing radiators with more efficient ones in the dorms, adding thermostatic valves on those radiators that could help regulate temperature, adding smart thermostats to the KE apartments, adding insulation to the dorms and/or KE apartments, and finally replacing gas mowers with electric mowers.

Methods

With the goal of minimizing carbon emissions by enhancing systems and processes at Calvin University the best way to do that is turn everything into running off electricity, and then making that electricity carbon neutral. With our projects, the team was able to make models of the amount of energy leaving/entering our system that was not being wasted. Once that energy was found the team could relate it back to the amount of electricity or natural gas needed to create the needed quantity of energy.

For the double pane windows, the team investigated how much energy could be saved by adding one or two more panes to each window. Information was found from 2022 Engineering 333 class.

They were able to find heat loss through the windows. The price of triple pane windows made it not worth the benefit of energy saved. We were able to take the heat loss calculations and find how much carbon could be saved from it. With the project, the team also looked into the windows and glass doors in the KE apartments to find the heat and therefore emissions from those windows/glass doors.

The team investigated how to heat the dorms more efficiently. This included better radiators, thermostatic valves, and smart thermostats (for KE apartments only). This would help decrease the amount of heat loss because there could be better control of the individual environments. With the implementation of all these products the team was able to find how much carbon Calvin currently emits from heating the dorms and KE apartments. Then the amount of heat actually needed was calculated and from there the amount of carbon could be found with the implementation of the radiators, thermostatic valves and smart thermostats.

The team investigated how the improvement of insulation could help to reduce emissions for Calvin. This project also looked into how much heat was lost with current insulation and how much less heat would be lost with different insulation. This was very similar to the calculations done for the single pane windows but with a different resistance value.

The last thing the team investigated was electric mowers. With this the mowers would become carbon neutral by not running on fossil fuels and then having the electricity decarbonize. The team found the amount of emissions from the mowers right now which would be the amount that would be saved. This project was also considered as something that could be good PR for Calvin.

Results

The results of our calculations and analysis are broken down into carbon emissions impacts and financial repercussions. The Heating Team determined the best option to mitigate carbon emissions from the natural gas heating system is by completely electrifying the system using heat pumps. If the natural gas boiler were replaced with heat pumps, the amount of CO_2 the efficiency projects would mitigate correlates to the amount of CO_2 produced by generating the electricity. Because CO_2 emissions are produced for the consumption of electricity, the less electricity consumed due to the efficiency projects, the less emissions Calvin University is responsible for.

Figure C2 shows the amount of carbon generated before and after all efficiency projects have been implemented, assuming Calvin's heating system is completely electrified. The projects combined reduce Calvin's carbon emissions by roughly 26%. When the is completely electrified, the carbon emissions of electricity will decrease as the carbon content of the electricity decreases. Consumer's Energy claims to be carbon neutral by 2040. The emission savings if the natural gas boilers are left in place can be found in Appendix C1.

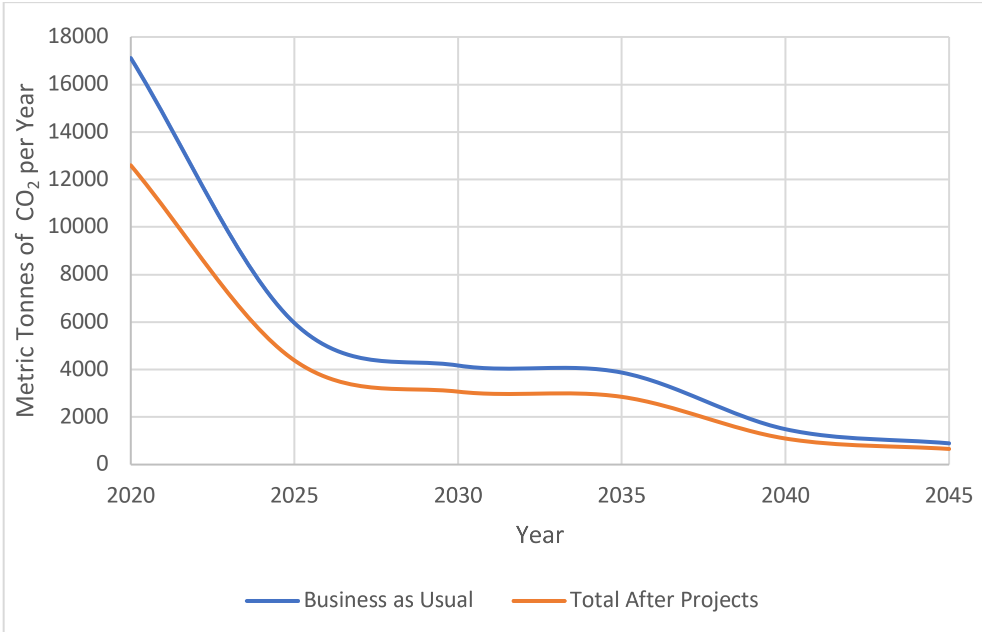

Figure C2. Total Emissions After Project Implementation

Figure C3 shows the carbon savings per project. Additional insulation has the greatest impact on carbon emission savings, followed by more efficient radiators and double pane windows and glass doors throughout campus. The emission savings associated with smart thermometers in the KE apartments were considered negligible compared with other projects. Electric mowers are not shown on this chart as their contribution to savings is a mere 0.3 tons of CO_2 savings. Appendix C2 shows the electric mower analysis.

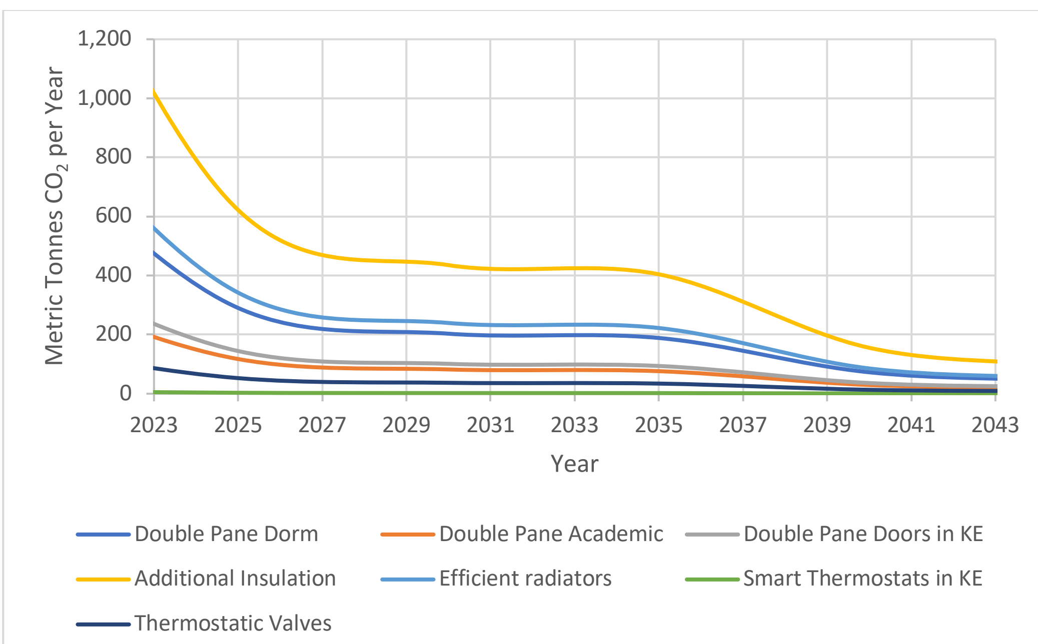

Figure C3. Carbon Savings Per Project

Taking into consideration the financial costs of each solution is also incredibly important and is a large factor in determining the feasibility of each project. Table C1 shows the internal rate of return (IRR) for each of the individual projects.

Table C1. IRR for each Efficiency Project using Electric Heating

Electric IRR			
Project	**Cost**	**Yearly Savings**	**IRR**
Double Pane Dorm	$1,533,439.40	$159,638.05	10%
Double Pane Academic	$645,883.00	$64,544.56	10%
Double Pane Doors in KE	$812,721.00	$79,452.01	10%
Additional Insulation	$623,611.00	$342,010.57	55%
Efficient radiators	$554,000.00	$188,142.35	34%
Smart Thermostats in KE	$48,090.00	$1,730.52	4%
Thermostatic Valves	$163,600.00	$29,014.04	18%

From this information, it is suggested that Calvin University implements all efficiency projects except smart thermostats in KE. A hurdle rate of 5% was used to determine if a project should be implemented. These IRRs assume that heating is completely electrified. If the transition to electric heat pumps is not made, none of the efficiency projects meet the desired IRR and implementation is not suggested. The discrepancy is due to natural gas being much cheaper than electricity on a kWh basis. The IRRs for each project using natural gas boilers can be found in Appendix C1.

Conclusion

The efficiency group looked at many projects that Calvin could implement to increase energy efficiency and decrease carbon emissions. The projects that were focused on were double-paned windows, additional insulation in the dorms, more efficient radiators, smart thermostats, and thermostatic valves. If the campus switches to full electric heating, it is recommended that all projects except smart thermostats in KE be implemented as the they an IRR above 5%. If the campus continues to heat through natural gas, none of the projects have an IRR above 5% and would be implemented purely to reduce carbon emissions. The implementation of electric mowers is also not recommended as Calvin would lose money on this endeavor. The emissions produced by landscaping equipment should be covered by carbon offsets. With electric heating, as proposed in the chosen Grid Decarbonization Model, the proposed efficiency projects reduce carbon emissions by a substantial 26%.

Appendix C1: Carbon Emission Saving using Natural Gas Boilers

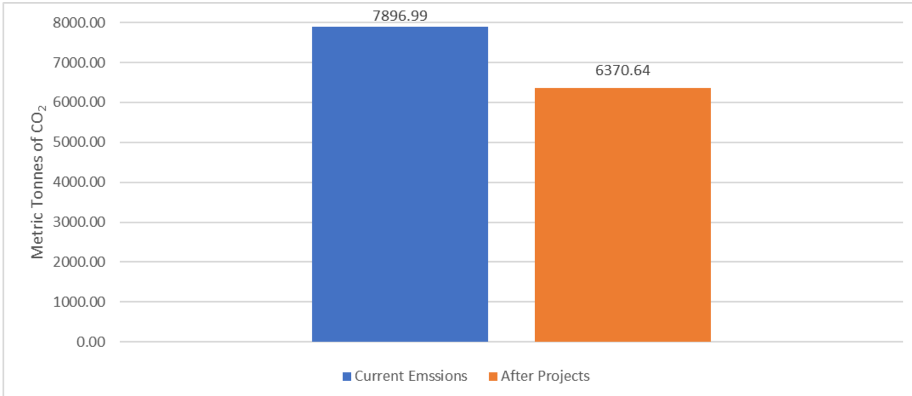

Figure C1.1. Total Emissions After Project Implementation

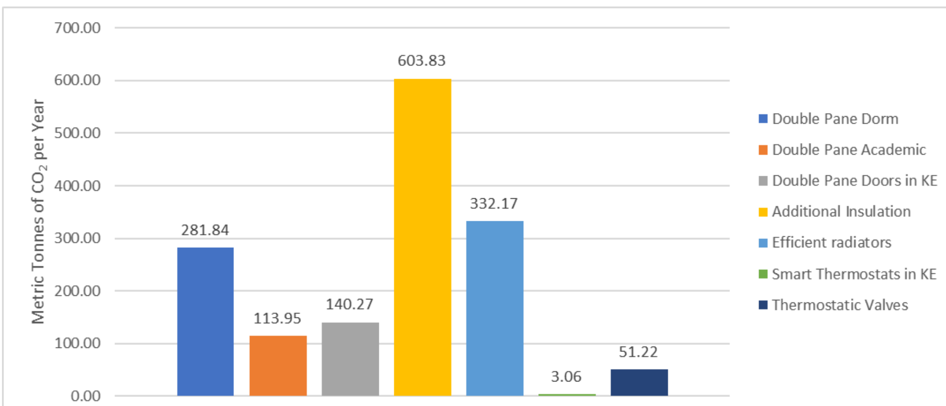

Figure C1 .2. Breakdown of carbon savings based on project.

Table C1.1. IRR for each Efficiency Project using Natural Gas Boilers

Natural Gas IRR			
Project	**Cost**	**Yearly Savings**	**IRR**
Double Pane Dorm	$1,533,439.40	$ 8,125.35	0.53%
Double Pane Academic	$645,883.00	$ 3,285.23	0.51%
Double Pane Doors in KE	$812,721.00	$ 4,043.99	0.50%
Additional Insulation	$423,611.00	$ 17,407.85	4.11%
Efficient radiators	$554,000.00	$ 9,576.17	1.73%
Smart Thermostats in KE	$48,090.00	$ 88.08	0.18%
Thermostatic Valves	$163,600.00	$ 1,476.77	0.90%

Appendix C2: Carbon Emission Saving using Natural Gas Boilers

Table C2.1. Automated Mowing Information

Mammotion LUBA AWD 5000		
Summary	**Value**	**Units**
# Mowers Reccomended	25	#
Principle Purchasing Cost	77500	$
Approx. Current Mowing Cost	126406	$/yr
Alternate Electric Mowing Cost	21.22	$/yr
Approx. Maintenance Cost	10896	$/yr
Cost Savings	115510	$/yr
CO2 Savings	360.9	kg CO2/yr

Table C2.2. Riding Electric Mower Information

Summary	Value	Units
Gas Mowing CO2	422.77	kg CO2/yr
Electric Mowing CO2	218.55	kg CO2/yr
CO2 Savings	204.22	kg CO2/yr

Appendix D – Comprehensive Model

Contributor: Ben Nymeyer

Introduction

To best-analyze the effects of each team's proposals, a model is needed to synthesize and express the institutional behaviors from all proposals. Creating a model allows the team to visualize and understand how individual projects might impact overarching financial and carbonic behavior. More importantly, a comprehensive understanding of the effects and timeline of project proposals allows the team to make informed design decisions to determine the new Carbon Neutrality date for Calvin University.

Methods

Rather than blindly beginning to compile data into models, it made more sense to work backwards to proceed forwards faster. The initial phases of the model involved workshopping to determine what data was necessary and what data was extraneous. Once all baseline data was compiled, models began to be formulated based on target year. The Executive Team initially landed on aiming for three dates: 2032, 2040, and 2048. These dates served as a jumping-off point for all future calculations, allowing for the University to become carbon-neutral as quickly as feasible.

2032 was chosen because it is the final year of the IRA. This is a theoretical, extremely aggressive proposal meant to maximize the financial savings incurred during the operating period of the Inflation Reduction Act (IRA) that allows green projects to be partly compensated in the form of direct financial credits. Previously, private institutions like Calvin University were not eligible for this benefit, but the onset of the IRA changed the surrounding regulations.

2040 was selected based on grid de-carbonization. According to Consumers Energy, their electricity grid is going to be carbon-neutral at their end in 2040, with a quoted carbon content of electricity of only $6x10^{-4}$ tonnes of carbon per kWh of electricity. The rest of their carbon content is offset in the manner that they have employed. 2040 was seen as an in-between number: reasonable – particularly, given the decarbonization of electricity – and attainable.

2048 was a pseudo-emergency number. If funds could not be raised in time, the logistics of the projects do not work, or some other complication arose, 2048 would still accomplish the goal of becoming a carbon-neutral entity before 2057. There are two reasons why the team left 2048: (1) the optics of becoming carbon neutral after entities like our power providers and (2) the earlier dates proved to be quite feasible.

Within the confines of a goal-date, several permutations of projects from each of the Electricity, Heating and Cooling, and Efficiency team were combined to fit each goal. The total list of projects for each of these plans was optimized to favor key capital projects within the confines of the IRA. Frequently, this meant implementation of Ground Source Heat Pumps (GSHPs) by the end of 2032.

Results

After initial analysis, it became clear that Calvin University could become carbon-neutral well before 2040. There are three "best options" that the team settled on, albeit with a best option among these three.

The most aggressive model posed is referred to as "Texas Wind – 2040". This model began with a target goal of 2040 for carbon neutrality, using electricity produced at a theoretical wind energy farm in Texas. Produced electricity could be sold and offset the same carbon emissions from purchased electricity, so long as purchased electricity does not exceed the produced electricity. It was decided that required heating renovation would be accomplished by implementation of three GSHPs and one air source heat pump. These heat pumps increased the electricity demand by the University by 10,578 MWh of electricity annually. The peak electricity demand within the model was 30,578 MWh annually. Projects posed by the efficiency team reduced the overall electricity demand to 25,400 MWh per year. A timeline of projects proposed is available in Table D1 below.

Table D1. Proposed Project Implementation Timeline for 2040 Texas Wind Model

Project	Life	Units	Cost	Lead Time	Units	Year
Thermostatic Valves	35	years	$163,600.00			2025
Main Loop	50	years	$21,956,250.00	35	Weeks	2026
Heating Loop 2	50	years	$2,353,750.00	35	Weeks	2027
KE Heating	50	years	$1,920,000.00		Months	2028
Double Pane Academic	35	years	$645,883.00	12	Months	2028
Facilities	50	years	$1,840,000.00	35	Weeks	2029
Double Pane Dorm	35	years	$1,533,439.40	12	Months	2030
Double Pane Doors in KE	35	years	$812,721.00	1	Months	2030
Additional Insulation	80	years	$208,899.00	24	Months	2030
Efficient radiators	20	years	$154,000.00	12	Months	2030
Smart Thermostats in KE	10	Years	$48,090.00			2030
Wind Farm Texas	20	years	$13,152,367.00	36	Months	2033

Execution of the model revealed carbon net neutrality to be feasible by 2034 if this timeline was followed. Over the course of the proposal, Calvin University would spend approximately $105 million between 2023 and 2057. $105 million is nearly $15 million in excess of continuation of existing methods ($91.6 million). Key capital projects occur from 2026-2029 (heat pumps) and in 2032 (wind farm). Implementation of heat pumps occurs in a four-year block well before the end of the IRA period to provide a buffer for potential hang-ups. In a worst-case scenario where there were extreme delays, the school should still seek to install their main loop by the end of the IRA period.

This model never reaches a breakeven point. Electricity produced in Texas must be sold at wholesale-rate in Texas dollars, meaning that the school cannot sell at market rate, being relegated to selling to other producers who sell to the grid. The going rate for produced electricity in that capacity is $0.035 per kWh, providing nearly $1.01 million in annual revenue from electricity production. Although not enough to offset annual electricity spending ($2.9 million per year), the additional revenue makes the cumulative spending grow at a slower rate than under existing methods.

If this model had a longer projected life span, it may have been the most compelling proposition for the project. Unfortunately, the lifespan of wind turbines must be factored into the analysis. Because the turbines only have a 20-year designed life, they can be expected to come offline between 2052 and 2054, meaning that the perceived benefits of this process would be offset by (likely) renewing all of the installed turbines with new equipment. It is possible that this method would prove to be financially positive for Calvin University in the distant future, the high financial requirements and the extremely long timeframe to becoming positive dissuade it as the optimal solution.

Figure D1. Model Behavior for Texas Windfarm Model

Once it was determined that the hurdles and outside considerations for something like the Texas windfarm were too great, the most logical path remaining was grid reliance. Grid reliance is an unfortunate reality to grapple with – going carbon neutral cannot be wholly reliant on the University's behaviors. There are two ways to go about grid reliance: (1) purchasing offsets or (2) purchasing carbon-free electricity. To best evaluate the system at hand, both models were evaluated with a 2040 end goal initially in mind.

The first grid model evaluated maintains much of Calvin's existing infrastructure, opting to purchase carbon-free electricity from Consumer's energy at an increased rate ($0.1285 per kWh as opposed to $0.1145 per kWh) and spend additional funds on carbon offsets for natural gas. At current capacity, DTE (Calvin University's natural gas provider) estimated approximately $1 million annually will cover Calvin's current natural gas demand. Over the course of the model, that demand will decrease, particularly after the Efficiency team's proposals are implemented. Capital expenses are exceedingly limited in this model, limited to only overhauling existing infrastructure with new, replacement versions (e.g. boilers). This is an extremely attractive option because it requires very little from the University on the capital projects end, and implementation could be pushed off to develop some sort of savings fund or campaign for increased annual operating costs due to offsets. The problem with this model is the uncertainty with costs of carbon offsets. Due to increased demands and regulations around carbon neutrality, the offsets will likely be in much, much higher demand than they are now. Some project costs to rise over 3000% by 2029 (see Appendix A).

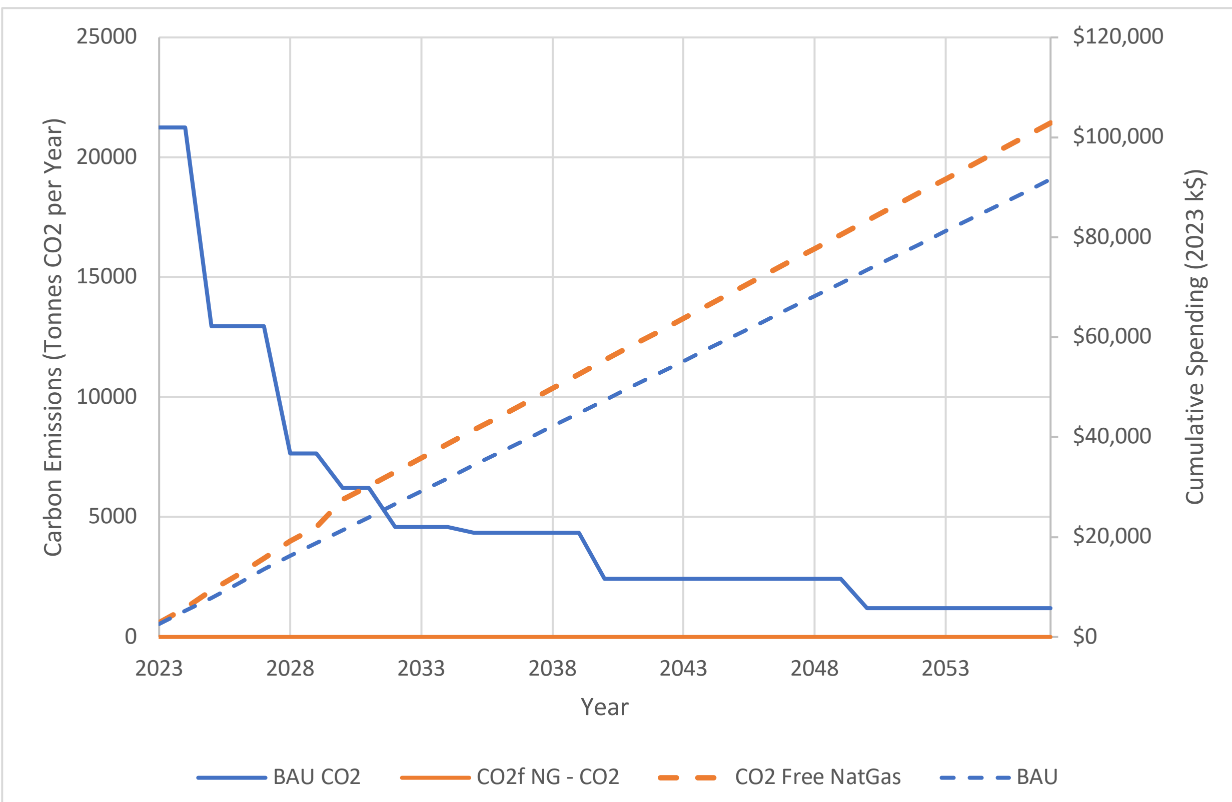

Figure D2. Grid Reliance while purchasing carbon offsets for natural gas

Another approach to this same process requires switching the heating and cooling infrastructure on campus over to electricity, eventually resulting in a wholly electrified campus. In this instance, ground source and air source heat pumps are used to heat campus, increasing the electricity demand on the campus by approximately 10,578 MWh annually. These would once again be installed over the course of four years from 2026-2029 for the same logistic and financial considerations listed earlier. Emissions behavior (seen in Figure D3 below) is very similar to the introduction of wind-power offsets in the Texas Windfarm Model, only seen sooner in this case. In this scenario, campus becomes carbon-neutral between 2028 and 2029. One additional consideration made was towards energy itself – would purchasing regular energy as opposed to green substantially alter model behavior? In this case, it did not, only reducing the spending rate for the University. At the end of the project, non-green energy with heat pumps spends approximately $111.4 million whereas green energy purchasing spends $121.8 million. This is analogous to purchasing $10 million of carbon offsets over the course of the project, but, because electricity is transitioning to renewables and this method relies on purchasing specifically that green energy, there is substantially less likelihood that the purchase rate of clean energy increases significantly.

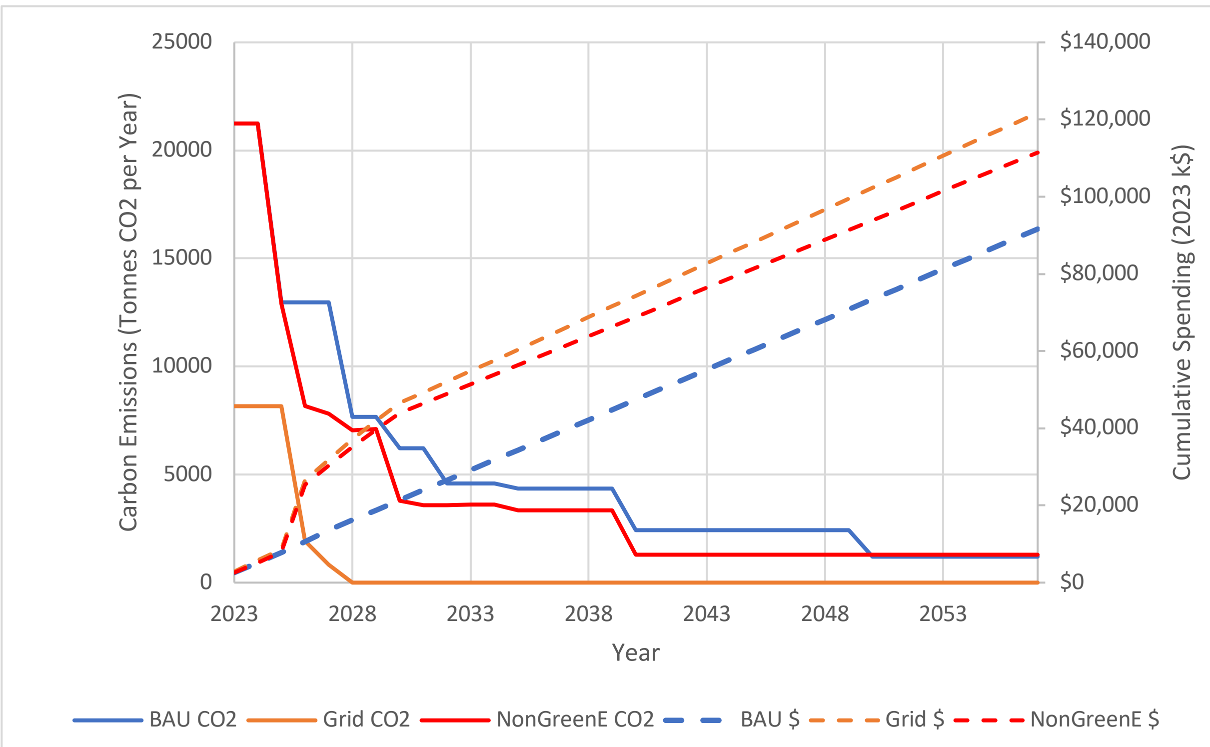

Figure D3. Grid Reliance with total electrification transition

Table D2. Project timeline for Grid Reliance with total electrification transition

Project	Life	Units	Cost	Lead Time	Units	Year
Thermostatic Valves	35	years	$163,600.00			2025
Main Loop	50	years	$21,956,250.00	35	Weeks	2026
Heating Loop 2	50	years	$2,353,750.00	35	Weeks	2027
KE Heating	50	years	$1,920,000.00		Months	2028
Double Pane Academic	35	years	$645,883.00	12	Months	2028
Facilities	50	years	$1,840,000.00	35	Weeks	2029
Double Pane Dorm	35	years	$1,533,439.40	12	Months	2030
Double Pane Doors in KE	35	years	$812,721.00	1	Months	2030
Additional Insulation	80	years	$208,899.00	24	Months	2030
Efficient radiators	20	years	$154,000.00	12	Months	2030
Smart Thermostats in KE	10	Years	$48,090.00			2030

Conclusion

After substantial modeling and consideration, it became clear that Calvin University should pursue a variation of the grid-reliant heat pump model. Several factors influenced the decision to suggest grid reliance with full electrification – namely the logistical concerns with remote electricity production and the uncertainty of the cost of carbon offsets for natural gas over time. It became clear that transitioning the school over to heat pumps and total green electrification is the best balancing point between preserving the existing infrastructure and way of living with a carbon-free future. Calvin University, in these conditions, would become a carbon-neutral entity at the completion of its heat pump infrastructure. If everything goes to plan, the University will be a carbon-neutral entity in the year 2029.

Appendix E – Financial Analysis

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Introduction

The Financial Team was responsible for finding funding avenues for Calvin's quickest path to carbon net neutrality. Understanding how the overall carbon-neutral project was to be funded was vital in determining the final proposed date since the quantity and timeline of funds needed would impact the project implementation schedule. The project implementation schedule would then determine the overall final proposal date for Calvin to become carbon neutral. Using the projects proposed by the Heating, Electricity, and Efficiency teams, the Finance Team created a fundraising strategy that would cover the costs of all projects by the proposed 2029 date. The funding avenues discovered by the Finance Team to accomplish this task involved public and private sources. Most of these funds came from, but were not limited to, the Inflation Reduction Act (IRA) from the federal government and the donor campaigns conducted by Calvin University. Additionally, collaboration with carbon neutral universities occurred.

Methods

The primary step in gathering information was identifying a clear understanding of the problem being asked. The next step used to gather information for this project was to conduct internet searches. The internet allowed for surface-level research for a variety of fundraising avenues. The research done in this phase of the project included finding information on the Inflation Reduction Act (IRA), grants, other colleges, and donor funding. Once the preliminary research was conducted, promising information avenues were pursued further. This was accomplished by reaching out to people who could answer the questions raised while doing internet research. Once the person had been found and contacted, a meeting was set up to gather all of the necessary information possible. After the information was properly gathered and recorded, the final step was to organize the information and present it as clearly as possible.

Results

Comprehensive Model

Using the research compiled from online sources, key personnel, and the carbon model seen in Appendix D, a financial model was created to represent how the funds would be raised to pay for the proposed carbon-neutrality date. Due to the uncertainty of acquiring the desired funds, the model was created using worst case scenarios and error bars to convey the base level case for fundraising. Figure E1.1 shows the finalized cumulative financing strategy for the proposed grid decarbonization model.

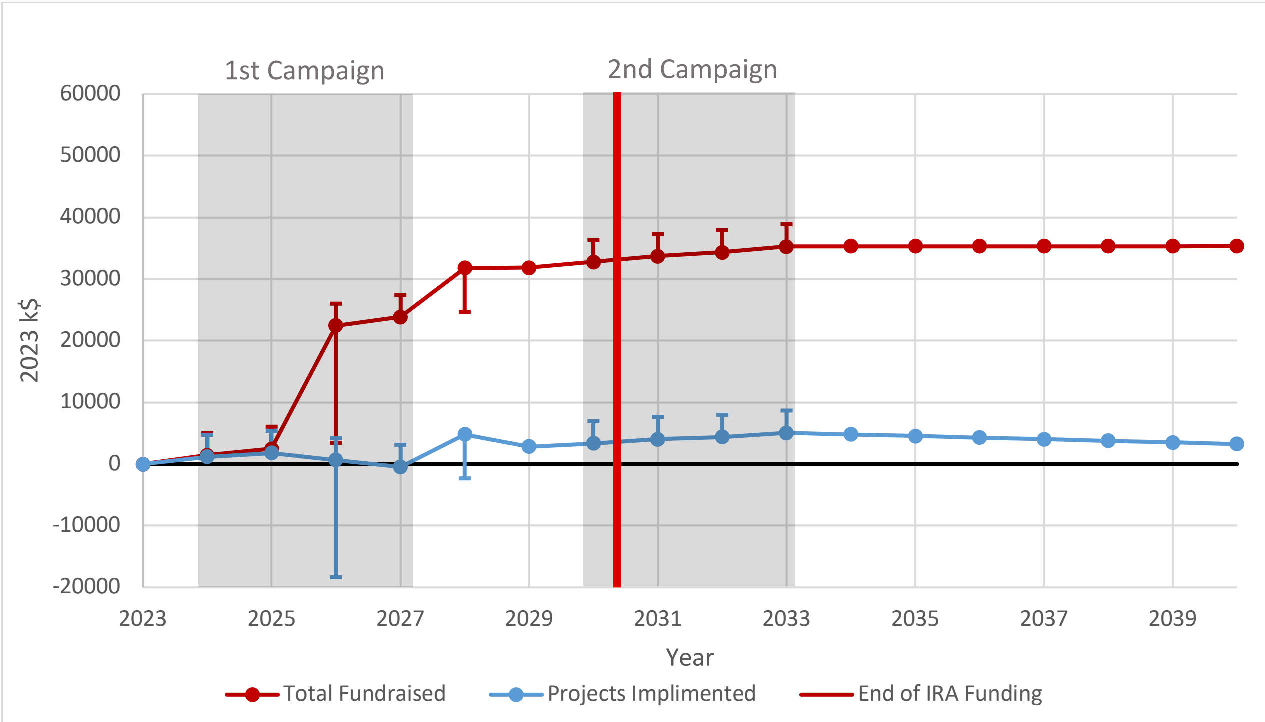

Figure E1. Cumulative Financing Strategy for the Proposed Carbon-Neutrality Date

Figure E1 shows the cumulative amount of money raised, in thousands of 2023 dollars, as a function of time, in years. The fundraised amounts are represented in two ways. The first way, seen by the maroon line, shows the total cumulative amount of capital raised over the lifetime of the proposed model. As can be seen by the figure, Calvin will need to raise about 35 million dollars to cover the costs needed to be carbon-neutral by and after the proposed 2028 date. The second way that the fundraised amounts are represented, seen by the blue line, shows the total cumulative amount of capital that Calvin has left after fundraising for and implementing the proposed projects. These projects include installing thermostatic valves, heat pumps, double pane windows, additional insultation, and more efficient radiators. Every time the blue line drops in value is an indication of one of these projects being implemented. The most notable project implementation can be seen in the year 2026 when the 22-million-dollar main loop heat pump is installed, as the blue line decreases and the maroon line jumps up by 20 million dollars, which comes from a grant the Finance Team is hoping Calvin acquires. The proposed plans also call for the purchasing of green electricity as soon as possible. The purchasing of green electricity costs Calvin around half a million dollars a year, which is most clearly seen after 2033 when Calvin no longer needs to raise funds (as shown by the maroon line), but still needs to pay for green electricity (as seen in the blue line). For the specific prices of each proposed project and year implemented, see Appendix D.

The gray bars in the graph represent the two donor campaigns that Calvin will conduct in the future. Based on donor research, the graph uses the conservative amount of one million dollars per year as the result of fundraising efforts during these campaigns. The larger spikes in the graph represent the grants or loans that Calvin would need to acquire to meet the carbon neutral timeline. The graph also considers the savings from implementing proposed projects, the increased overhead and maintenance costs of those projects, and the money raised from sustainable initiatives on campus. The error bars represent the increase or decrease in yearly funding that may take place whether donors give more money than expected, specific grants (mentioned below) are not acquired, the sustainable scholars program is or is not a success, and/or sustainability projects save more or less money.

The Finance Team is confident Calvin will be able to raise at least 4 million dollars per campaign. This puts Calvin at a net 8 million dollars fundraised by the end of 2033 if they start their four-year campaigns in 2024 and 2030. The Finance Team is also confident that Calvin will acquire nearly 9.5 million dollars from the IRA if all proposed projects are completed before 2032. This indicates that Calvin should be able to raise at least a net total of 17.5 million from proposed funding strategies. Depending on the reception of funding projects from other financial avenues, such as donors, Calvin students, and government entities, Calvin may be able to raise all 35 million of the funding it needs. The financial outcome will depend on the funding avenues Calvin chooses to pursue and the strategies they use when pursuing those funding avenues.

The following sections of this report summarize the financial avenues that the Finance Team recommends Calvin use to raise the total capital needed to reach the proposed carbon-neutral timelines. The sections also outline the recommended strategy for acquiring those funds. All suggested funding methods explained below were used to create the financial model seen in Figure E1.

Federal Funding

Our primary funding option for federal funding is the IRA that was signed by President Biden in 2022 to reduce inflation and help transition to clean energy. This Act applied to non-profit organizations in that way that non-profits were able to receive 30% reimbursement on any renewable energy expenditures. It should be noted that the IRA benefits end after 2032. This means that any purchases made after 2032 won't be able to receive 30% reimbursement from the federal government (Inflation Reduction Act). Additionally, secondary funding from the federal government came from the Office of Clean Energy Demonstrations, which has created the Energy Storage Demonstration and Pilot Grant Program. This grant has 355 million dollars to distribute to several entities, both federal and private, including universities (Office of Clean Energy Demonstrations). Tapping into this grant would be extremely beneficial for Calvin to complete its carbon-neutral projects.

Donor Funding

The majority of information concerning donor funding came from Greg Elzinga, the Vice President of Advancement at Calvin. According to information that he presented, Calvin University goes on a 4-year campaign every two to three years to raise funds to support/implement projects on campus. In the past, Calvin typically raised 200 million dollars from donors. Approximately 2% of these raised funds went to infrastructure projects, which was about four million dollars. Since infrastructure projects are not the most popular among donors, Greg Elzinga expects that future campaigns will likely continue to receive only four to five million dollars towards green initiatives; however, from an optimistic point of view he believes that Calvin may be able to raise up to 15 million dollars for this project as it is directly related to a growing global need to reduce carbon dioxide emissions. Furthermore, the finance team believes that the optimistic values could be more achievable if Calvin uses this student project in their pitch for infrastructure donations from donors. Using students' work will help demonstrate to donors that students care about infrastructure projects, indicating that these projects have a direct impact on students, a cause that donors love to donate to.

It should also be noted that if Calvin cannot raise all the required funds from donor donations, impact investing is a viable option. Impact investing is where a donor gives Calvin a loan with little to no interest rate. This type of loan would allow Calvin to build the proposed projects in line with the proposed carbon-neutral timeline, while not having an extensive payback period as would other loans.

State Funding

Most of the state-level funding came in the form of grants. District Director Kooyman was very helpful in directing the Finance Team towards grants that Calvin would be able to apply for. These grants included the Community Energy Innovation Prize, which totaled 7.5 million dollars (American-Made Challenges), and the Department of Energy Oversight, which had 20 million dollars to distribute to proposed projects (Department of Energy Oversight). Applying for these grants will be an important step for Calvin to take to be able to raise the capital needed to reach the proposed carbon-neutrality date. It should be noted that not all the grants Calvin applies for will be approved. Not acquiring these grants will leave a gap in the fundraising goal. To account for this potential gap, state-level loans could be applied for. The best state-level loan that was identified was the Department of Energy' Energy Infrastructure Reinvestment secured loan (DOE EIR) which typically covered 40 to 60 percent of the overall project cost (Loans Programs Office). Yet, if any loans were to be taken out, it is strongly recommended that impacting investing with donors be used over the DOE EIR due to interest rates and securities.

Sustainable Scholars and Donor Match

The idea of Sustainable Scholars arose in the later portion of the project through a recommendation from President Wiebe Boer. The idea behind Sustainable Scholars was to add an additional fee to the total cost of tuition intended to raise funds for Calvin carbon net neutrality. For example, tuition would increase by $1,000. This increase would result in an additional amount of approximately $3.5 million per year. Additionally, a proposition of donors matching Sustainable Scholars fund donor funds matching the Sustainable Scholars amount was proposed. Given both aspects, a total of $7 million per year would be raised. The concern with this proposal is that student frustration has the chance to increase as college tuition is already increasing.

Sustainability Project Savings

Over the course of this project, information was gathered from Allegheny College. The institution has been participating in energy reduction challenges for over 10 years. These are month long events where students and faculty are encouraged to use as little energy as possible. Residence halls compete during this month to use as little energy as possible, with rewards for the building that uses the least amount of energy. Allegheny has seen an increase in participation as they have introduced student-led events during peak energy usage times such as night hikes and other outdoor activities. Allegheny College estimates that they save between $5,000 to $15,000 a year from energy reduction challenges. Additionally, Allegheny College uses the money saved to purchase green initiatives that are able to be seen on campus. This allows students to see that they are making a difference and would likely increase participation. For example, Allegheny College was able to purchase two to three solar panels a year with money saved from energy reduction challenges.

Conclusion

Overall, as a financial team we were able to find ways to fund this project by utilizing the Inflation Reduction Act, federal and state level grants, donor funding, and sustainable projects on campus. All funding information was found by reaching out to the key financial individuals, such as the district director of Kent County, Calvin executives, and other carbon-neutral universities. Based on the fundraising strategies provided, and the uncertainty that comes with a project such as this one, Calvin should be able to raise at least 17.5 of the 35 million dollars it needs by 2033. If everything goes in Calvin's favor, it should be able to raise the needed 35 million dollars by 2033 or before. By combining the recommended fundraising avenues, this team shows that there are avenues that provide the possibility to raise the capital needed to fund the proposed 2028 carbon neutral date—making Calvin's quickest path to carbon net neutrality a feasible possibility.

Appendix E1: Financial Team Sources

American-Made Challenges. (n.d.). *Community Energy Innovation Prize*. HeroX. https://www.herox.com/CommunityEnergyInnovation

Department of Energy Oversight. Energy.gov. (n.d.-a). https://www.energy.gov/infrastructure/undersecretary-infrastructure/department-energy-oversight

Loans Programs Office. (n.d.-b). *Energy Infrastructure Reinvestment*. Energy.gov. https://www.energy.gov/lpo/energy-infrastructure-reinvestment

Office of Clean Energy Demonstrations. (n.d.). *Energy Storage Demonstration and Pilot grant program*. Energy.gov. https://www.energy.gov/oced/energy-storage-demonstration-and-pilot-grant-program

Inflation Reduction Act. IRS. gov

https://www.whitehouse.gov/cleanenergy/inflation-reduction-act-guidebook/