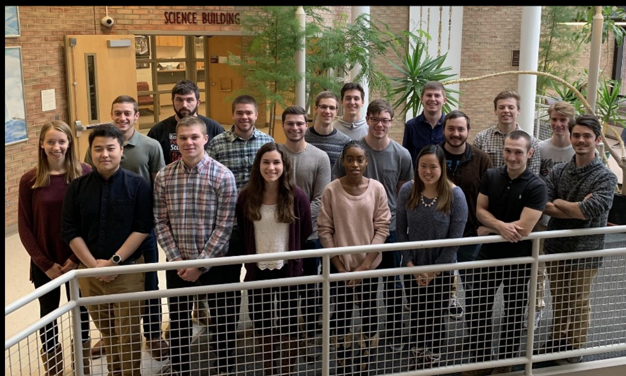

Renewables at Calvin

ENGR 333: Thermal Design and Optimization

Rachel Evans, Alex Gross, Daniella Sugijanto, Jake Shaarda

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Problem Statement

What is the largest possible reduction in Calvin's annual energy expenses from a $5 M investment in renewable energy?

Calvin's current energy expenses: $3 M/year

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Outline

- Renewable Energy Technologies
- Main Recommendation
- Analyses
- Options & Alternatives
- Conclusion

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Renewable Energy Technologies

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Solar

- Energy from sunlight
- Focus on photovoltaic (PV) panels

https://www.sciencenews.org/blog/science-ticker/solar-panels-are-poised-be-truly-green

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Wind

- Electricity from wind
- Height restrictions around airport

https://www.politico.eu/article/small-old-wind-towers-make-for-big-new-problems/

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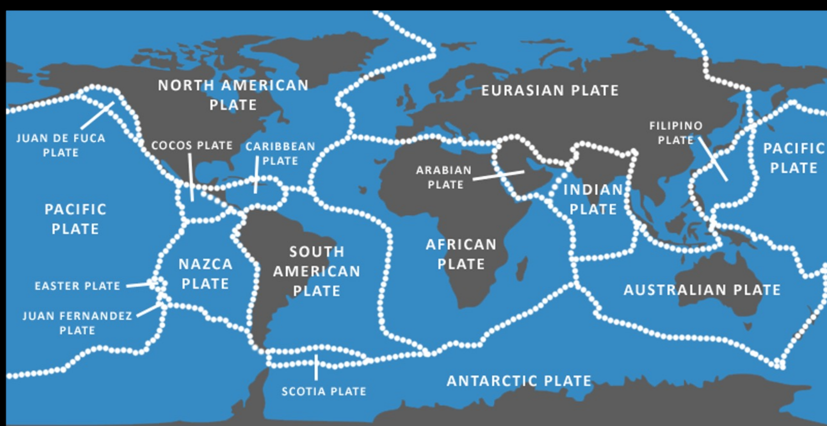
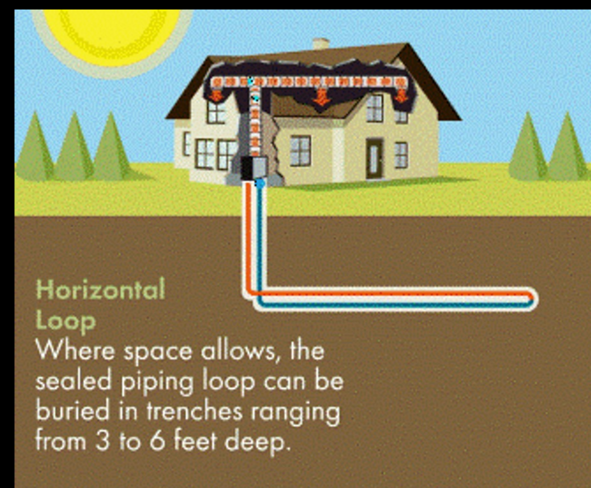
Geothermal

Electricity



https://getech.com/plate-tectonics-50/

Heating and Cooling



https://cairhvac.com/geothermal-heat/

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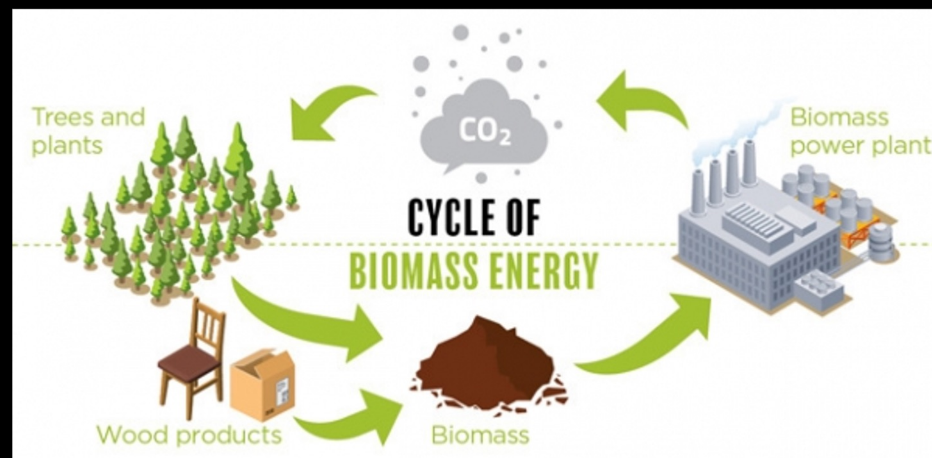
Biomass

- Energy from waste/OM
- Large implementation costs
- Not viable at Calvin



https://www.canadianbiomassmagazine.ca/biofuel/any-renewable-energy-solution-requires-extracting-the-full-value-of-biomass-6499

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Main Recommendation

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Main Recommendation

- Invest into solar technology (~$3.5 M)
  - Covers 10% of Calvin's electricity needs
  - Reduces CO_2 emissions by 6.7%
  - Options available for remaining funds

https://earth911.com/eco-watch/energy/community-solar-farms/

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Analyses

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Section B Analysis

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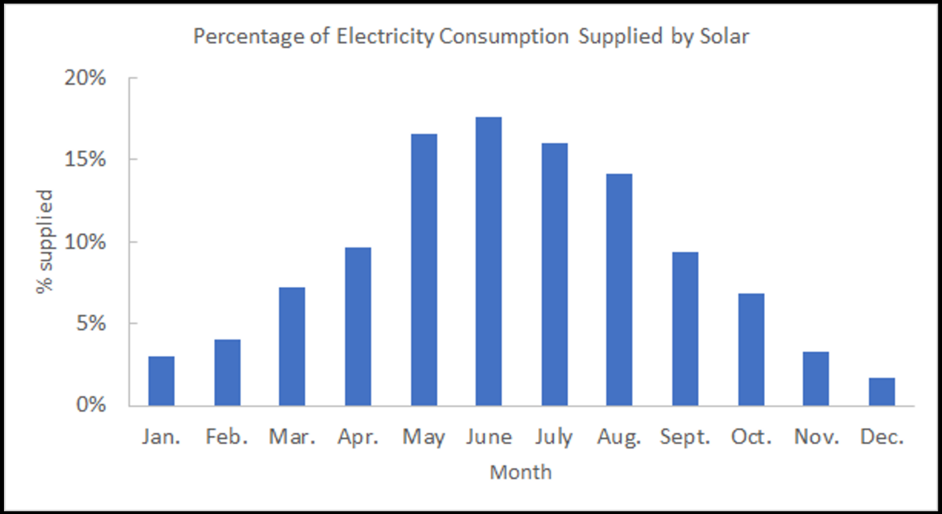
Main Recommendation

Max out rooftops with solar

- $3.7 M
- 5889 solar panels (~5 acres)
- 2.115 GW-hr/yr
- $184 k/year
- 20-year payback



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Rooftop Locations

- Using all possible available roof space
  - Weight/loadings
  - Tree cover
  - Calvin architecture group

https://calvin.edu/map/campusmap.pdf

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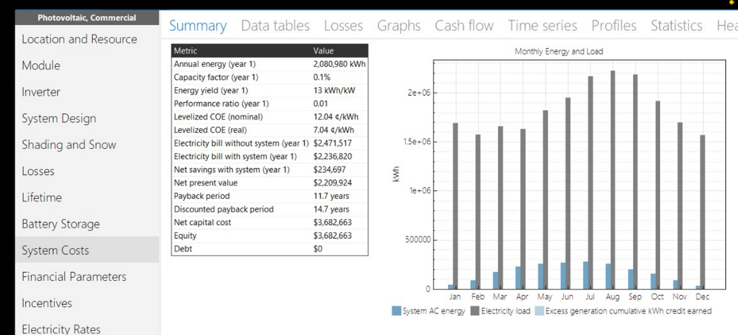
Calculations - SAM vs. Our Model

- System Advisor Model (SAM)
  - NREL
  - Uses GPS to draw up the entire system
  - Long processing time



- Our model
  - Built in Excel
  - Weather data, life cycle analysis, panel orientations
  - Within 10% of SAM

Solar Panels			
Number of Solar Panels		5889	Panels
Number of Strings		34	
Panels per string		173	
Price Per Solar Panel	$	170.00	2018$/Panel
Racking Price	$	-	2018$/Panel
Optimization Module Price	$	-	2018$/Module
Labor Cost	$	40.00	2018$/hr
Hours Labor/panel		2	hr/panel
Maximum Power		275	Wdc
Solar Panel X Dim		1.65	m
Solar Panel Y Dim		0.99	m
Space Between Panels X		0.05	m
Space Between Panels Y		1	m
Solar Panel Efficiency		17%	
Total Price Per solar Panel	$	250.00	$2018/Panel
Solar Panel Area		1.64	m^2/Panel
Effective Area of String		284.00	m^2/String
Effective Solar Panel Area		9656.04	m^2
Effective Solar Panel Area		2.39	acres
Total Required Panel Area		19975.05	m^2
Total Required Panel Area		4.94	acres
Power Output/string		80.65	kW
Volt DC/String		8471.98	V
Electricity Produced		2.12	GW-hr/yr
Yearly Sun Hours		1530.31	hours/year
Calvin Electricity Usage		22.08	GW-hr/yr
System Power		1621.12	kW
Racking Weight		42030.46	lbf

Given Range of Land Prices			
Avg Cost/acre	$	-	2018$/acre
Property tax		1.71%	
Avg Cost	$	-	2018$

Inverters - SE7600H			
Number of Inverters		21	
Inverter Power		7.60	kW
Inverter Max Voltag		400	V DC
Inverter Price	$	1,550.00	2018$/Inverter
Labor Cost	$	40.00	2018$/hr
Hours Labor/Inverter		2	hr/panel
Inverter Efficiency		0.99	
Cable Efficency		0.91	
Strings/inverter		2	
Panels/inverter		278	
Area per string		0.23	acres

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Solar - Equipment Choices

Solar Panel

https://www.civicsolar.com/product/canadian-solar-cs6k-300ms-300w-mono-quintech-blkwht-solar-panel-5bb

Inverter

https://www.sma-america.com/products/solarinverters/sunny-boy-30-us-38-us-50-us-60-us-70-us-77-us.html

Racking

http://files.ironridge.com/flat-roof-mounting/resources/brochures/Tilt_Mount_Data_Sheet.pdf

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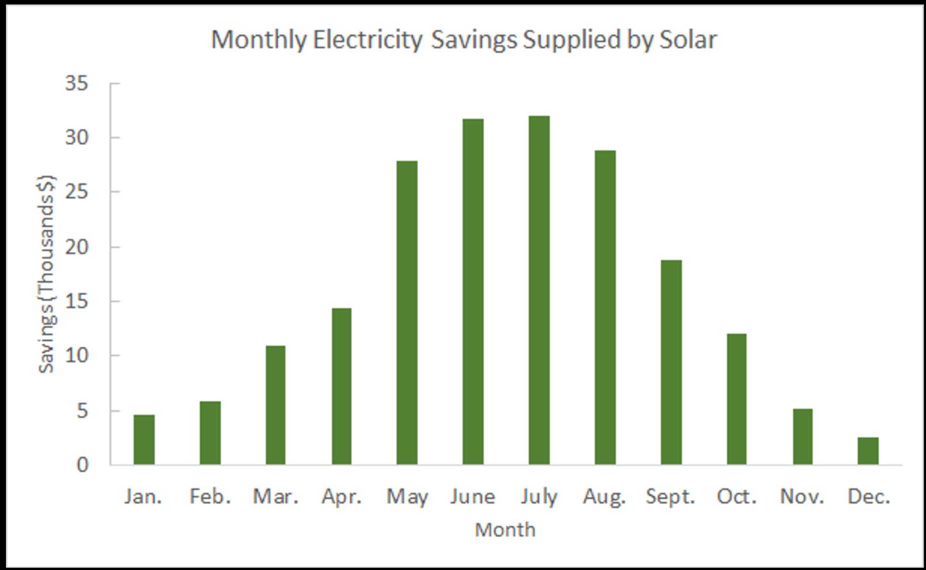
Why Solar?

- Financial benefits
  - $184 k/year
- Visual representation
  - Commitment
- Easily scalable



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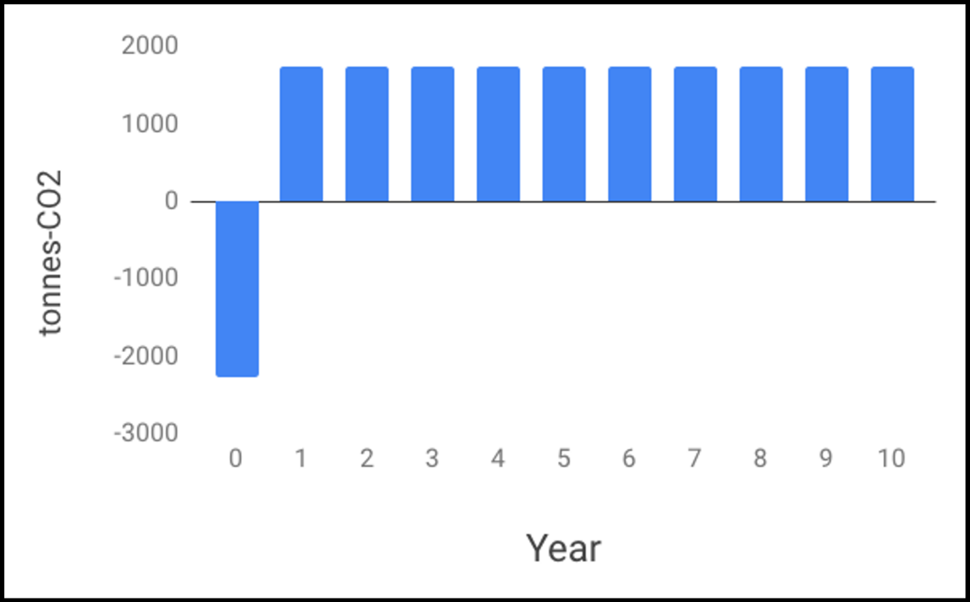
CO_2 Emissions

- Can payback its embodied CO_2 emissions within 1.3 years
- Would offset 1800 tonnes CO_2 annually (6.8% of emissions)



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Section A Analysis

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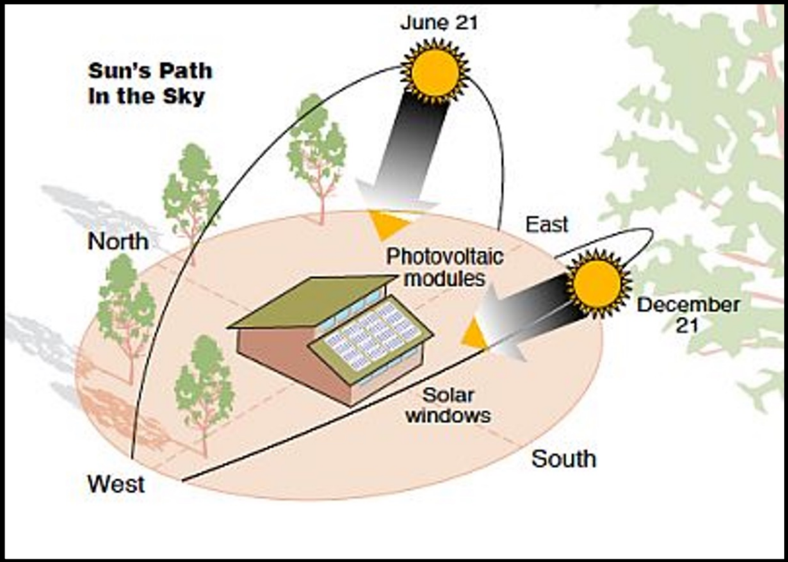
Goals

Goal - not to exceed the baseline electricity usage

- Roof direction
- Certain roofs - not feasible

Energy storage not practical



https://livingonsolarpower.wordpress.com/2013/03/08/how-the-sun-moves-through-the-sky/

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Main Recommendation

- $3.34 M: Solar
- $0.16 M: Residential geothermal

$225 k/yr savings

2.1 GW-hr/yr solar output

15-year payback

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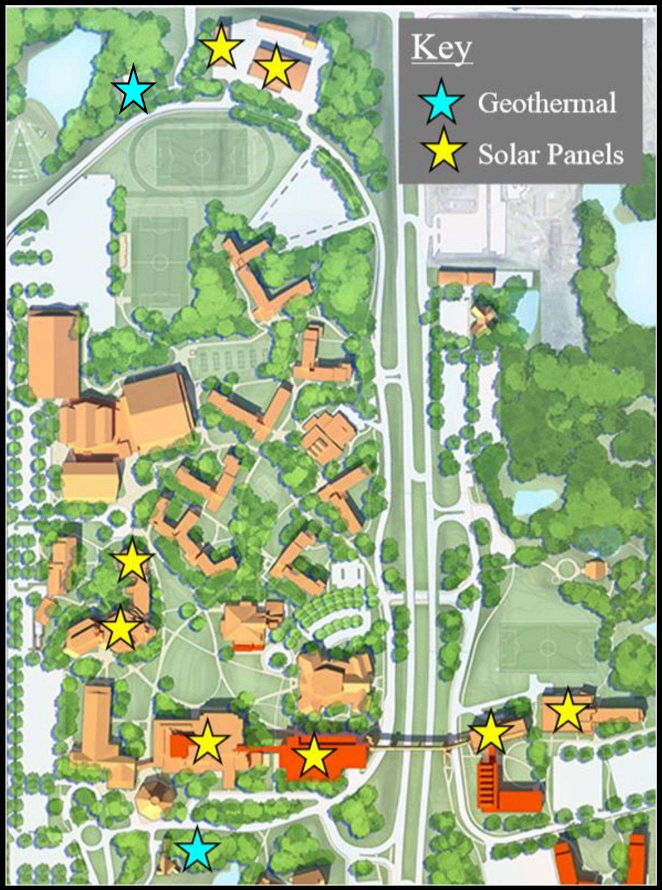

https://calvin.edu/master-plan/

Research

GVSU's Solar Garden

- 11,250 solar panels
- 17 acres of land
- 3 MW electricity production
- Commissioned in 2016

Bunker Interpretive Center - Baseline Information

https://www.google.com/maps/

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Geothermal

- Residential vs. commercial
  - Ventilation standards
  - Efficiency reduction
  - Exponential cost growth

http://josephdwalters.com/residential-vs-commercial-power-washing/

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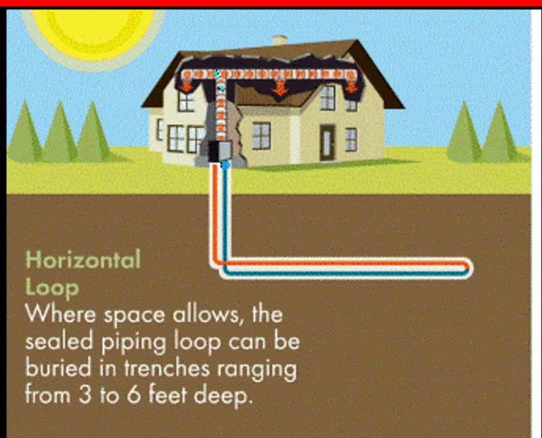
Geothermal



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Geothermal Houses

- $0.16 M initial investment
- Calvin residential homes
  - Manor House and Perkins House
  - Potential growth
- Total savings
  - $15 k annually
  - 10-year payback
- 50-year lifetime


1230 Lake Drive


232 Travis St SE


1807 Observatory


3151 Hampshire


Dewitt Manor


Perkins House

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Commonalities

Base case cost: ~$3.5 M on solar

Solar rooftop area: ~5 acres

Payback period: ~17.5 years

Yearly energy production: ~2.11 GW-hr/yr

Annual savings: ~$200,000

https://cleantechnica.com/2015/05/14/todays-solar-panels-can-power-the-world-mit-study-finds/

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Options & Alternatives

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Section B Option

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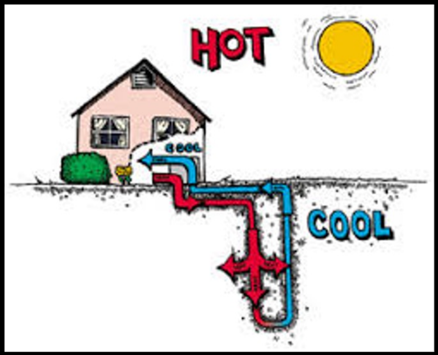
What can we do with $1.3 M?

Small Geothermal System



http://clipart-library.com/clipart/335024.htm

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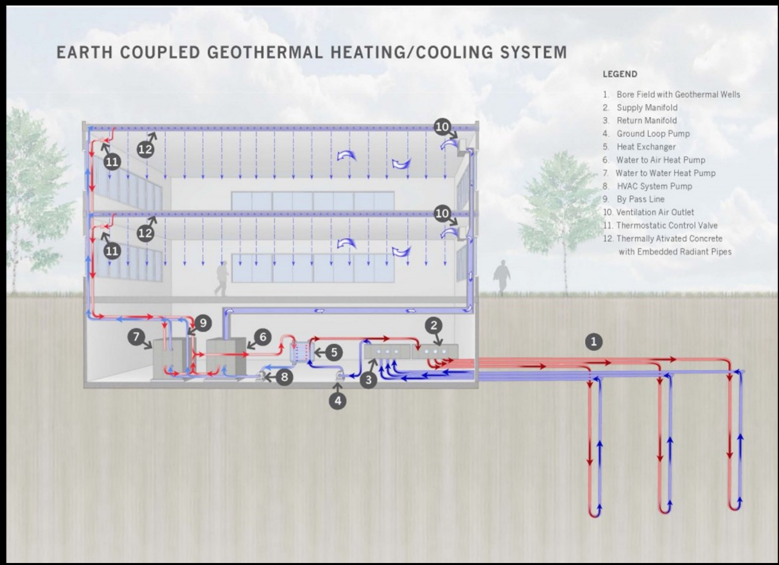
Geothermal

- Install geothermal system in Commons lawn
  - 75 400-ft. bores
  - Supplement the aging Kewanee boilers (65% efficiency)
  - Replace 11.3% of the Commons power plant capacity
- Service 92,000 ft^2 (the size of BHT)
- Total estimated net savings of $4 k/year



https://www.glumac.com/sustainability/design-strategies/share-resources/

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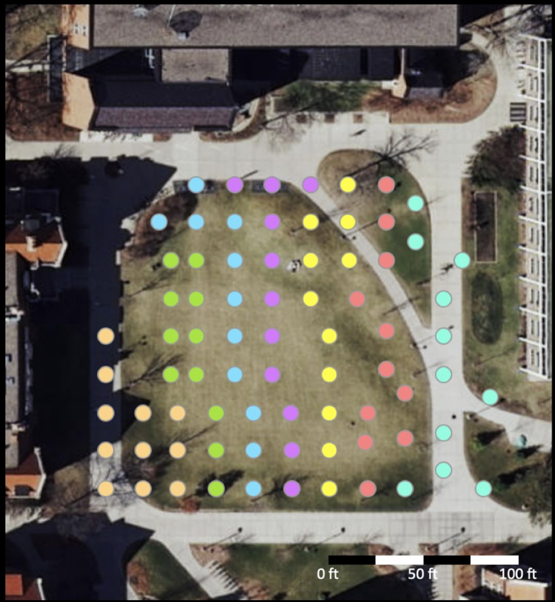
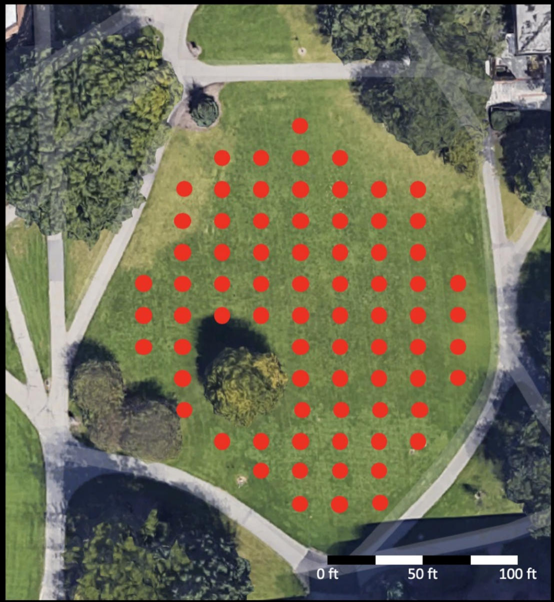
Class B - Option #1 - Geothermal

Carleton College



https://apps.carleton.edu/geothermal/

Commons lawn



https://www.google.com/maps/

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Section A Alternatives

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Section A - Alternatives

How can we maximize savings with the $5 M investment?

Alternative #1

Assumption: Grid buy back

On-Campus Solar

Consumers Energy

https://www.consumersenergy.com/

Alternative #2

Assumption: Off-site location

On and Off-Campus Solar

https://en.wikipedia.org/wiki/New_Mexico

Alternative #3

Assumption: Wind is feasible

On-Campus Wind

https://www.machinedesign.com/

Section A - Alternative #1 - Maximize Solar

Assumption: Michigan allows independent power producers to sell into the grid.

- Best scenario for on-campus production
- Exceed baseline consumption and sell into grid

- $4.48 M on-campus solar
- $157 k residential geothermal

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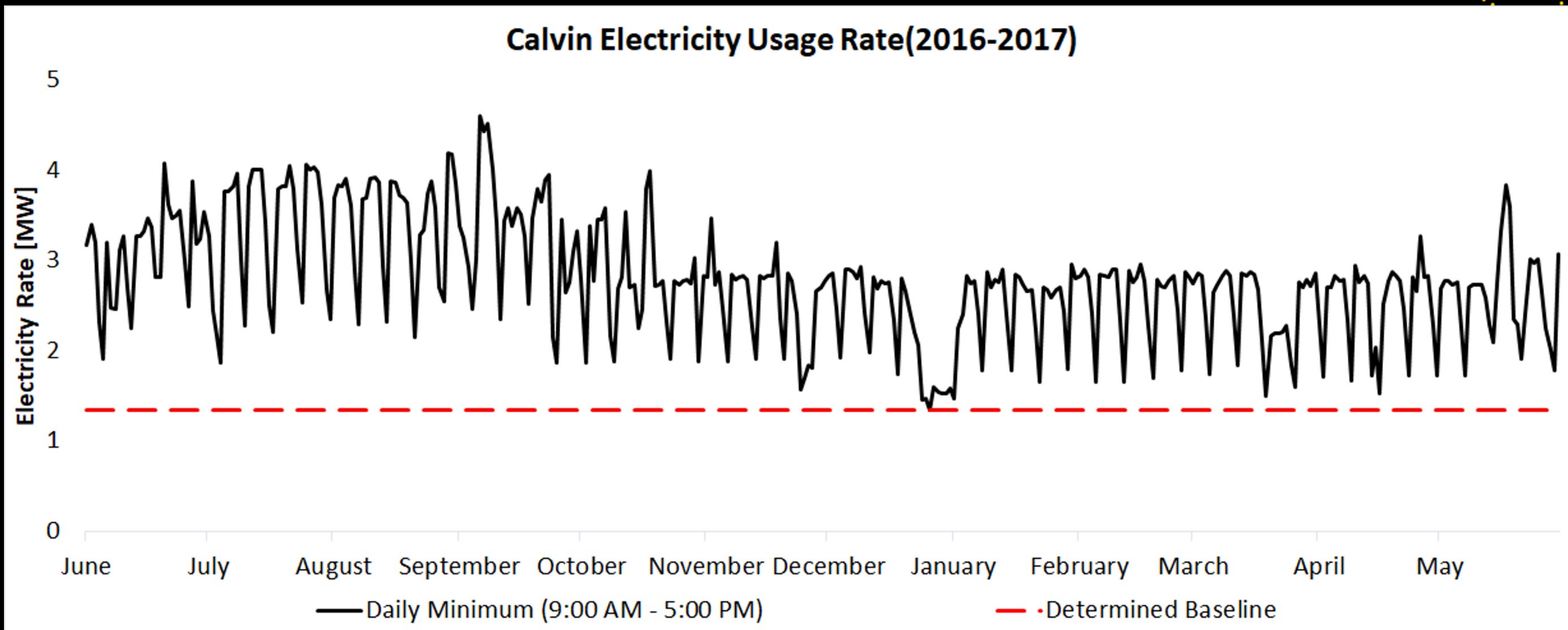
Yearly Electricity Use



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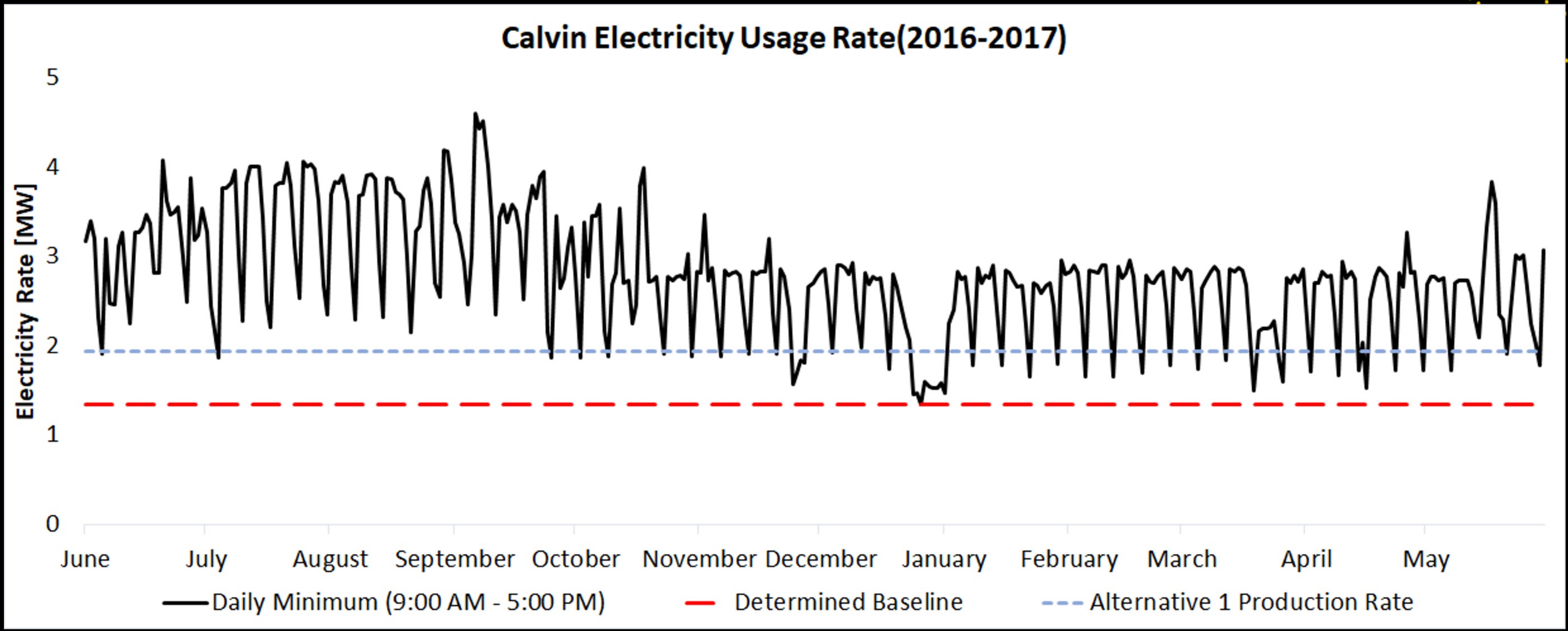
Yearly Electricity Use



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Section A - Alternative #1 - Maximize Solar

- $4.84 M budget for an on-campus solar
- $318 k/yr electricity savings
- 15-year payback period
- 7.41 acres needed
- 3.8 acres clearcut

https://www.google.com/maps/

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Section A - Alternative #2 - Off-Campus Solar

On-campus

- Select roofs that are well displayed
- Shows Calvin's commitment to renewable energy
- $1.2 M (24%) of budget would go on-campus

Off-campus

- More area, and higher efficiency compared to Michigan solar
- Potential partnership with Rehoboth Christian School
- $3.6 M (72%) of budget would go on-campus

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https://www.denverchristian.org/

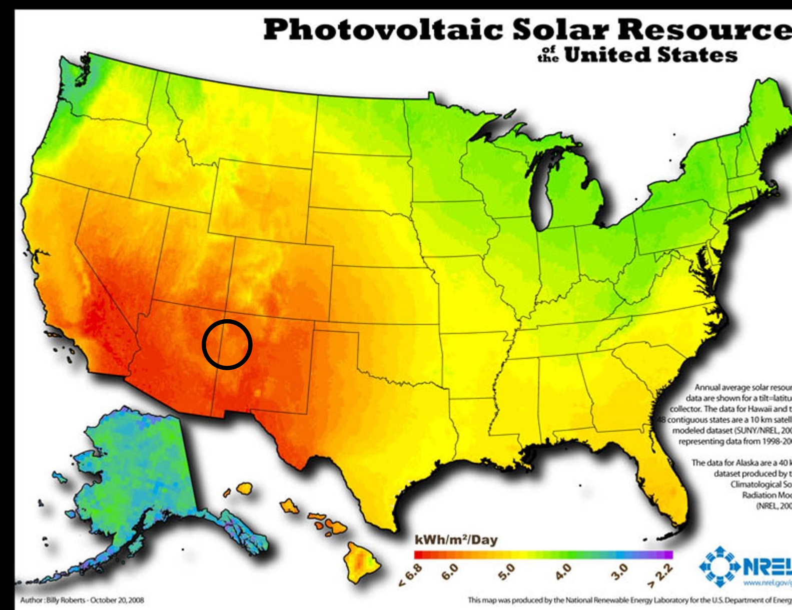
Section A - Alternative #2 - Off-Campus Solar

Rehoboth, NM

- 1.5x more sun
- Increased ROI & payoff
- Rehoboth contact

Unknowns

- Sell back price → annual savings



https://www.eia.gov/energyexplained/index.php?page=solar_where

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Section A - Alternative #2 - Off-Campus Solar

Rehoboth, NM

- 1.5x more sun
- Increased ROI & payoff
- Rehoboth contact

Unknowns

- Sell back price → annual savings

https://www.google.com/maps/

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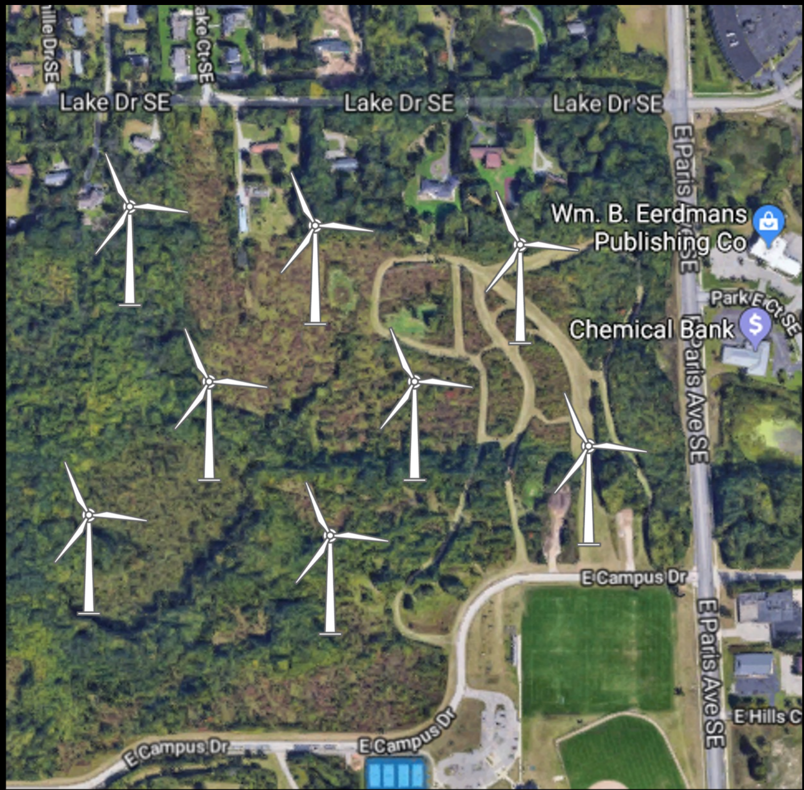
Section A - Alternative #3 - Wind

Assumption: Wind is feasible

- $3.34 M on-campus
- 8 wind turbines
- 25-year payback
- $125 k/yr savings
- 55 acres



https://www.google.com/maps/

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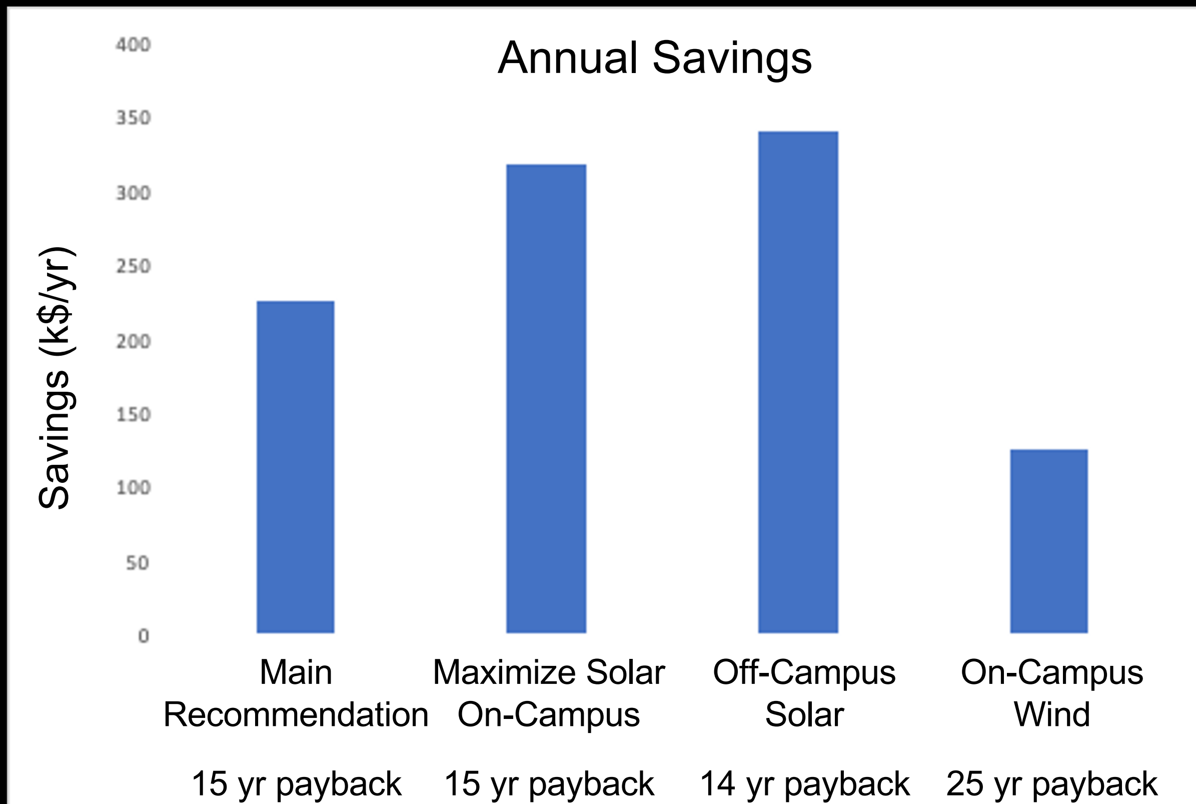
Section A - Cost Savings



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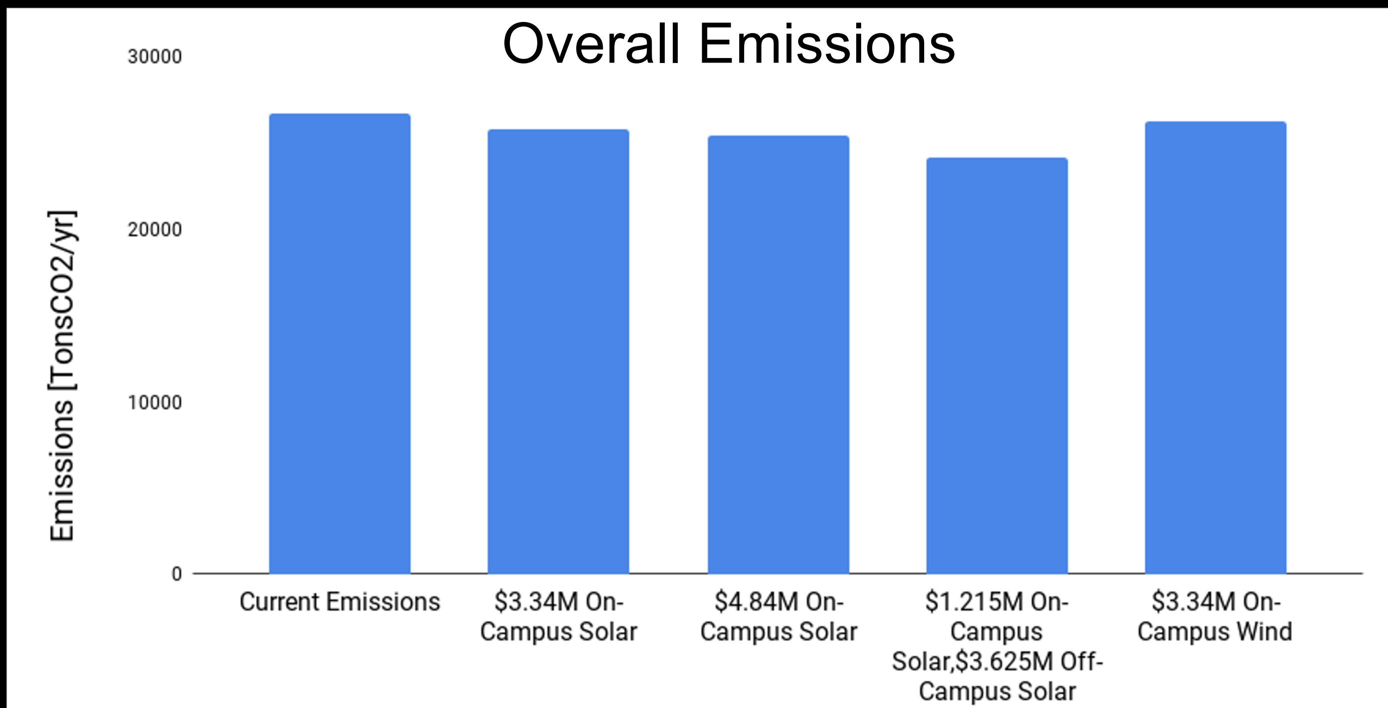
Section A - CO_2 Emissions



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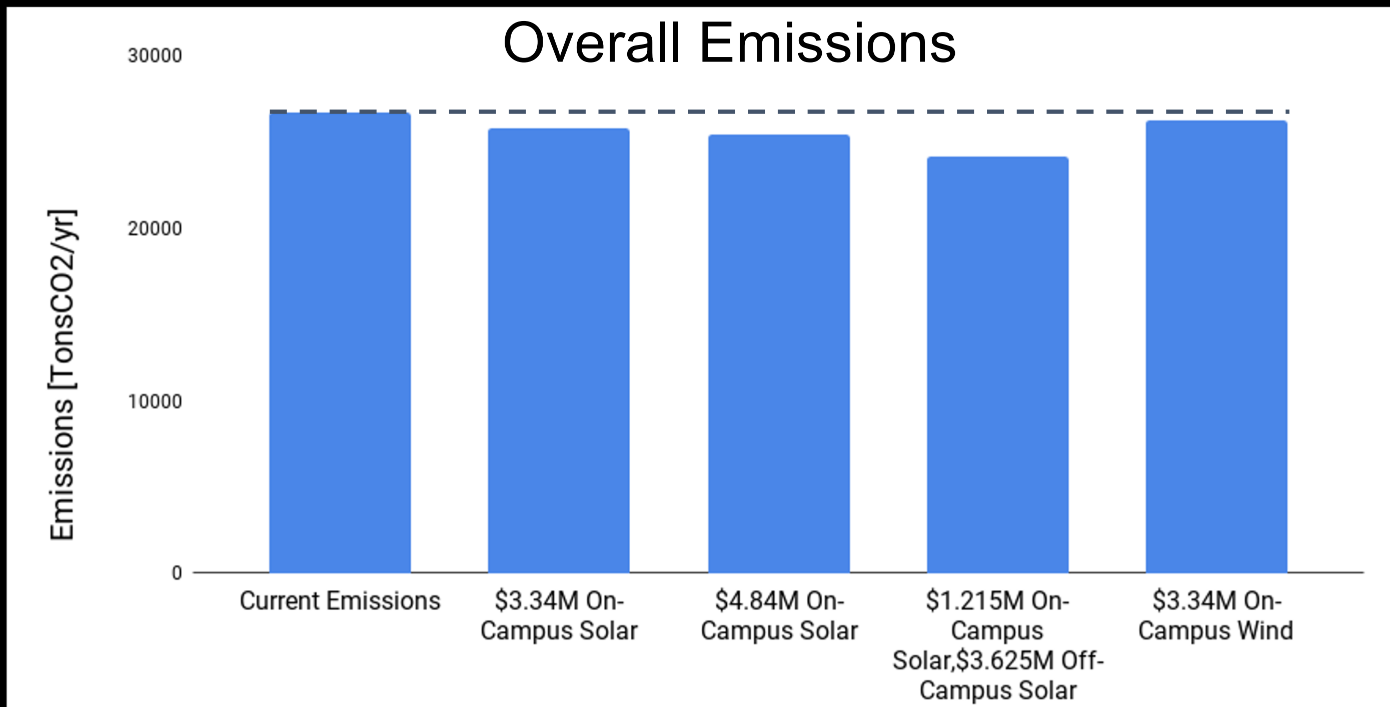
Section A - CO_2 Emissions



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Conclusions

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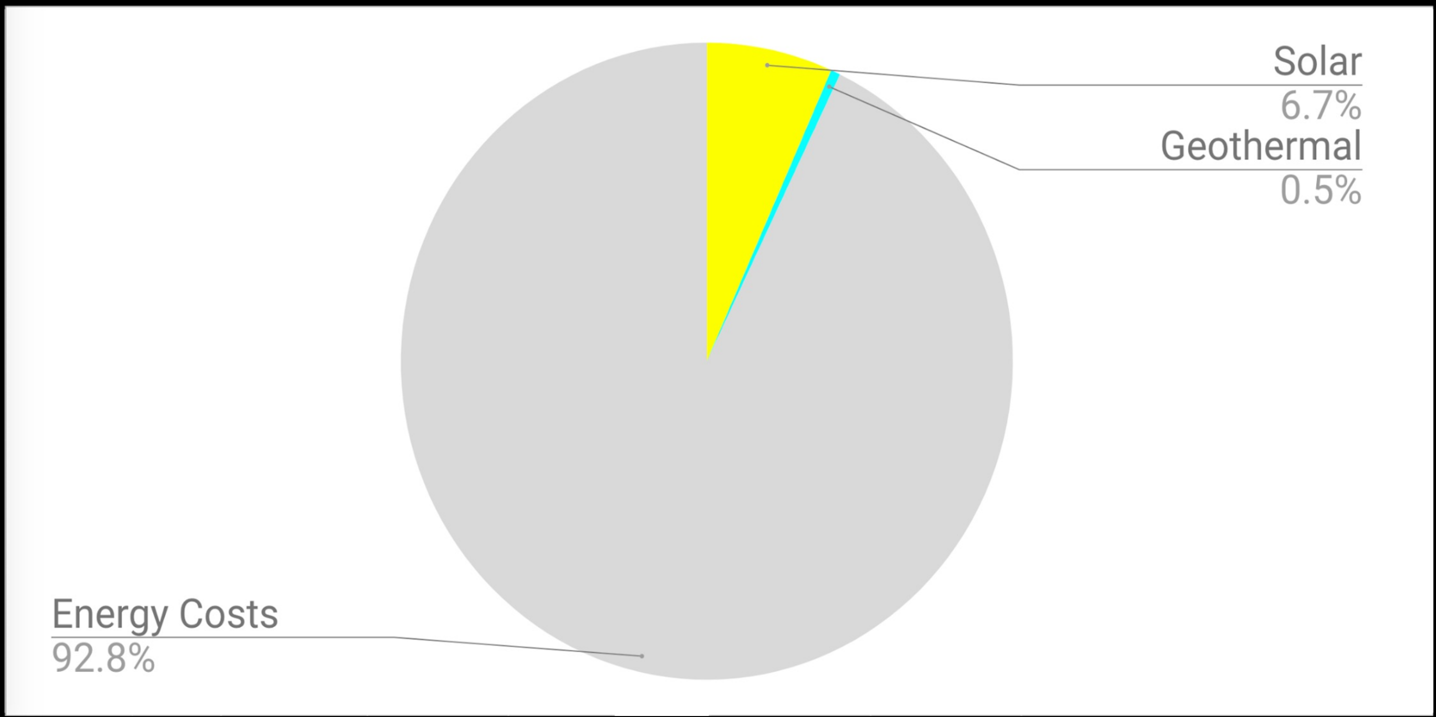
Financial Summary



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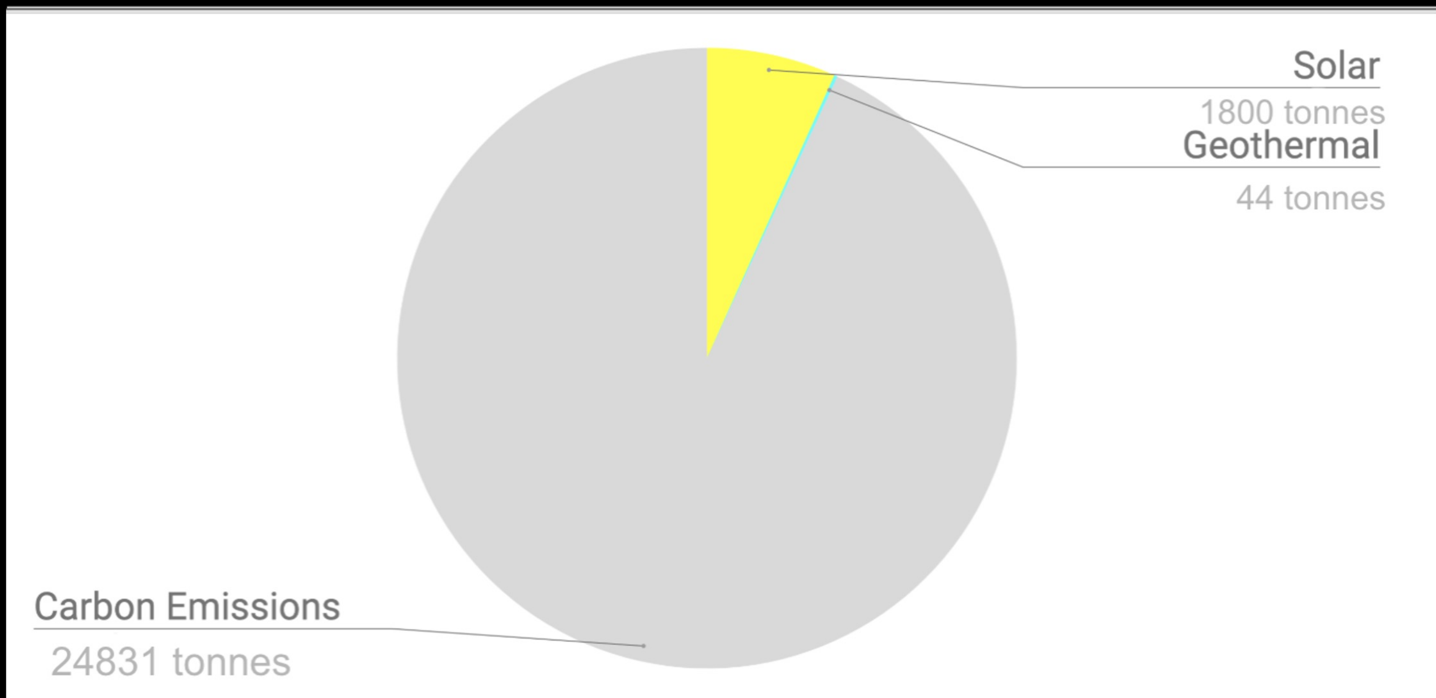
Carbon Impact



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What's next?

- Consider renewables for future buildings
- Detailed study of solar options on campus
- Wind study

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Acknowledgements

Russell Bray - Director of Physical Plant

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