Conservation and Generation: Focusing on Energy to Save Money at Calvin College

Trevor Nyeholt, Erik Karlson, Cam Richman, Tyson Butler

Engineering 333

December 6, 2017

Natural Gas Savings Project

ENGR 333-A

Trevor Nyeholt and Erik Karlson

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The Problem

Calvin College spent $836,000 on natural gas in 2016

http://www.wzzm13.com/img/resize/content.wzzm13.com/photo/2017/02/15/Calvin%20college%20sign.3_1487195906153_8522173_ver1.0.jpg?preset=534-401

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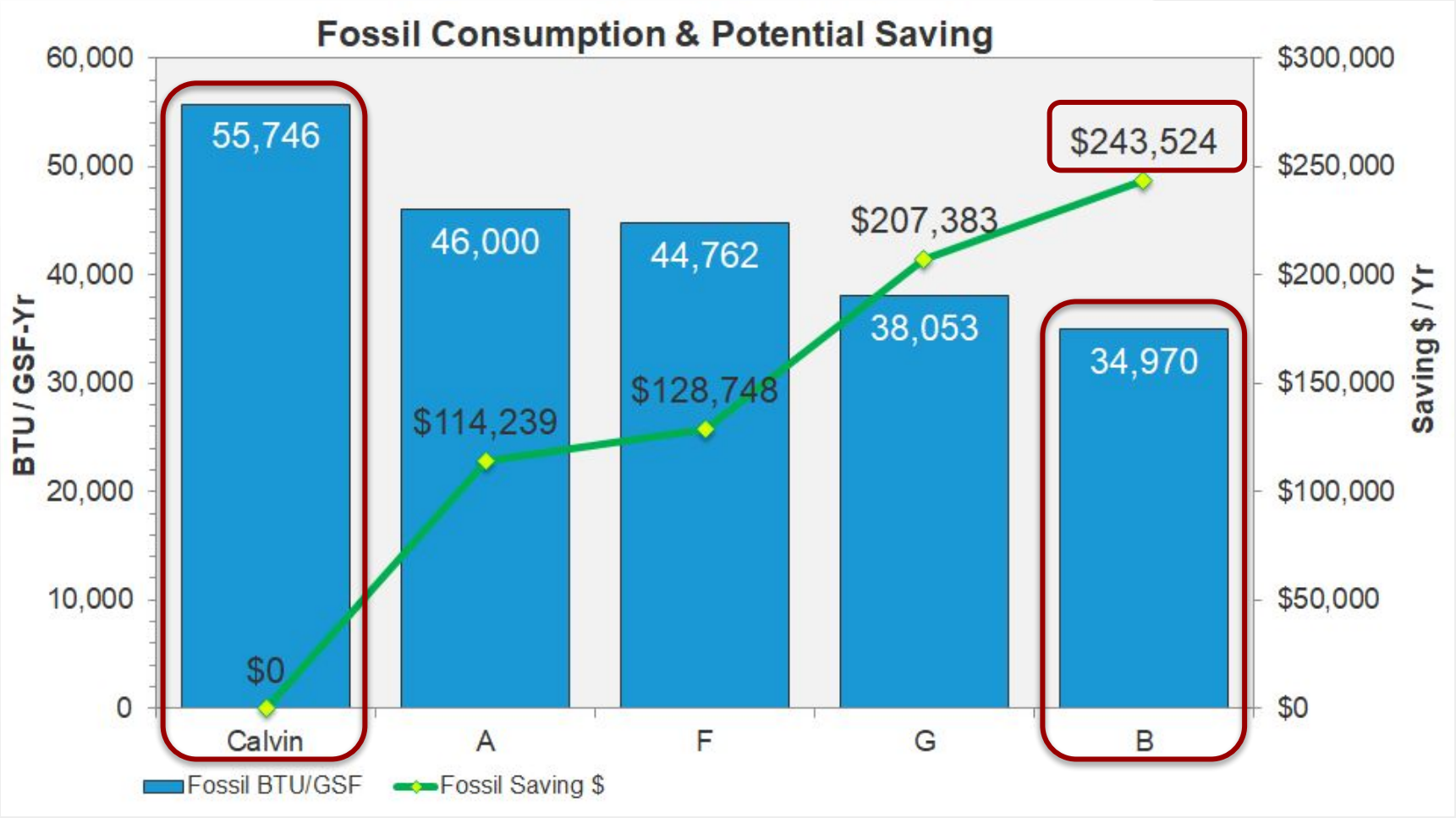

Figure from Sightlines 2017 Report

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What would it take to save Calvin $75,000 per year on natural gas costs?

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Finance

Academic Buildings

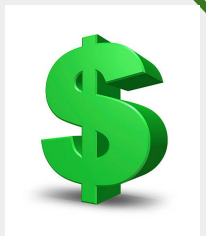
https://calvin.edu/contentAsset/image/869e8731-49b2-4e7e-a1b1-0de4926c709f/

Dorms and Dining Halls

https://static1.squarespace.com/static/507db947e4b046d3434cd164/t/55fad97ce4b081c8

Spoelhof Fieldhouse Complex

http://www.recmanagement.com/images/201005/201005_aw_3d_01.jpg



https://www.istockphoto.

Boilers

https://content.invisioncic.com/r262316/monthly_2017_03/boiler.jpg.ea4907d8f723

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Projects

Boilers

Increase Boiler Efficiency
Replace Kewanee Boilers
--

Academic

Replace Windows
Standard Temp
--

Dorms/ Dining

Additional Roof Insulation
Adjust Radiator Fins
Replace Windows

Fieldhouse

Additional Roof Insulation
Behavioral Changes
Standard Temp

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Best Cost-Saving Projects

- Improving and Replacing the Boilers

https://www.google.com/search?q=boiler&source=lnms&tbm=isch&sa=X&ved=0ahUKEwjht

Best Cost-Saving Projects

- Improving and Replacing the Boilers
- Standardizing Building Temperature

http://www.pgecurrents.com/?attachment_id=13547 By Chip Buchanan

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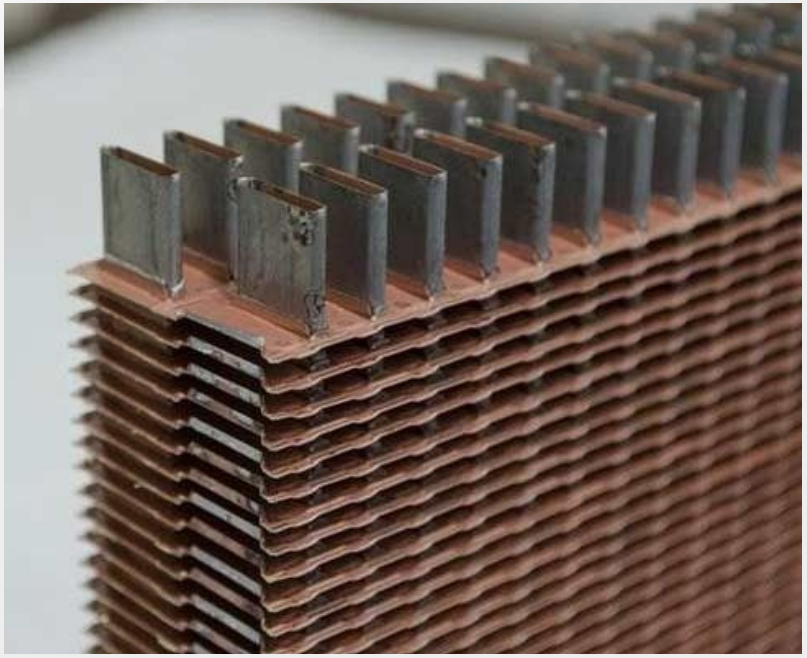
Best Cost-Saving Projects

- Improving and Replacing the Boilers
- Standardizing Building Temperature
- Adjusting the Dorm Radiator Fins



https://4.imimg.com/data4/FT/MB/MY-8338283/industrial-radiator-cores-500x500.jpg

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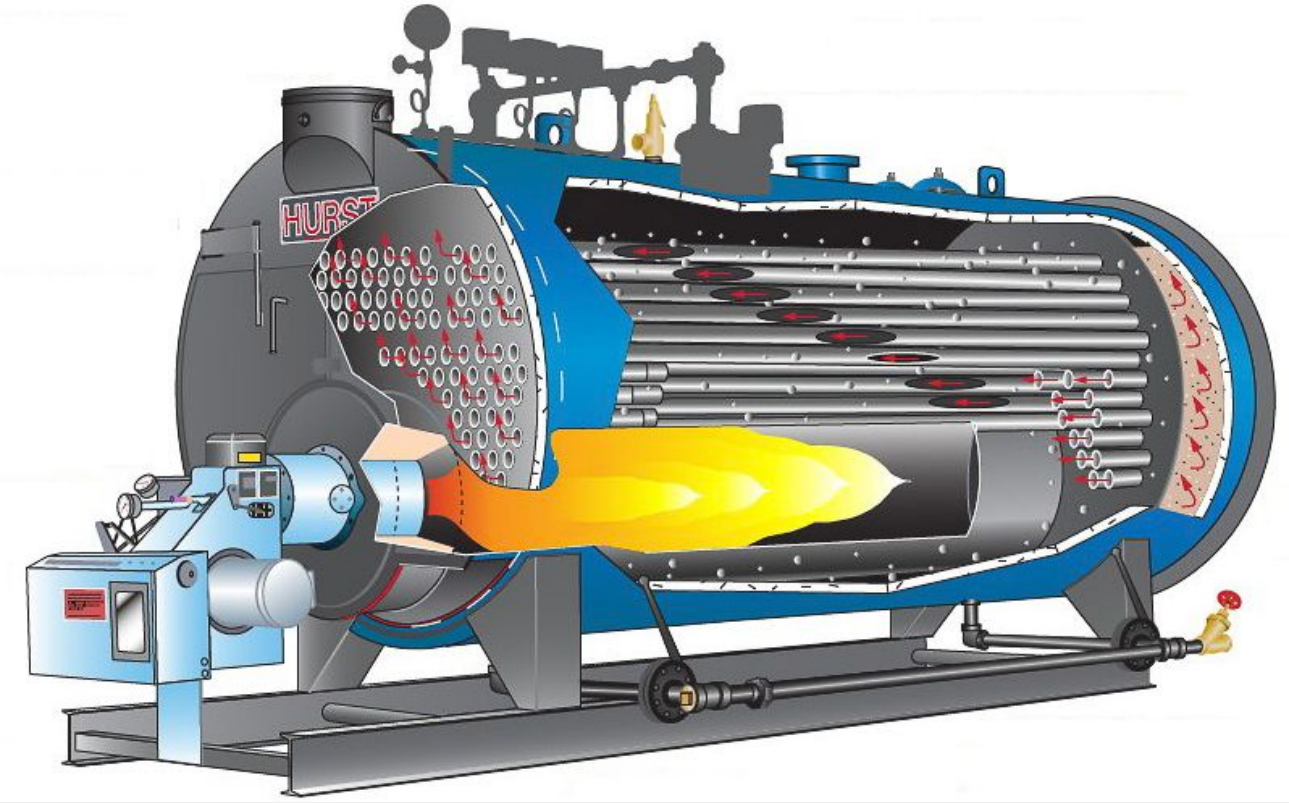
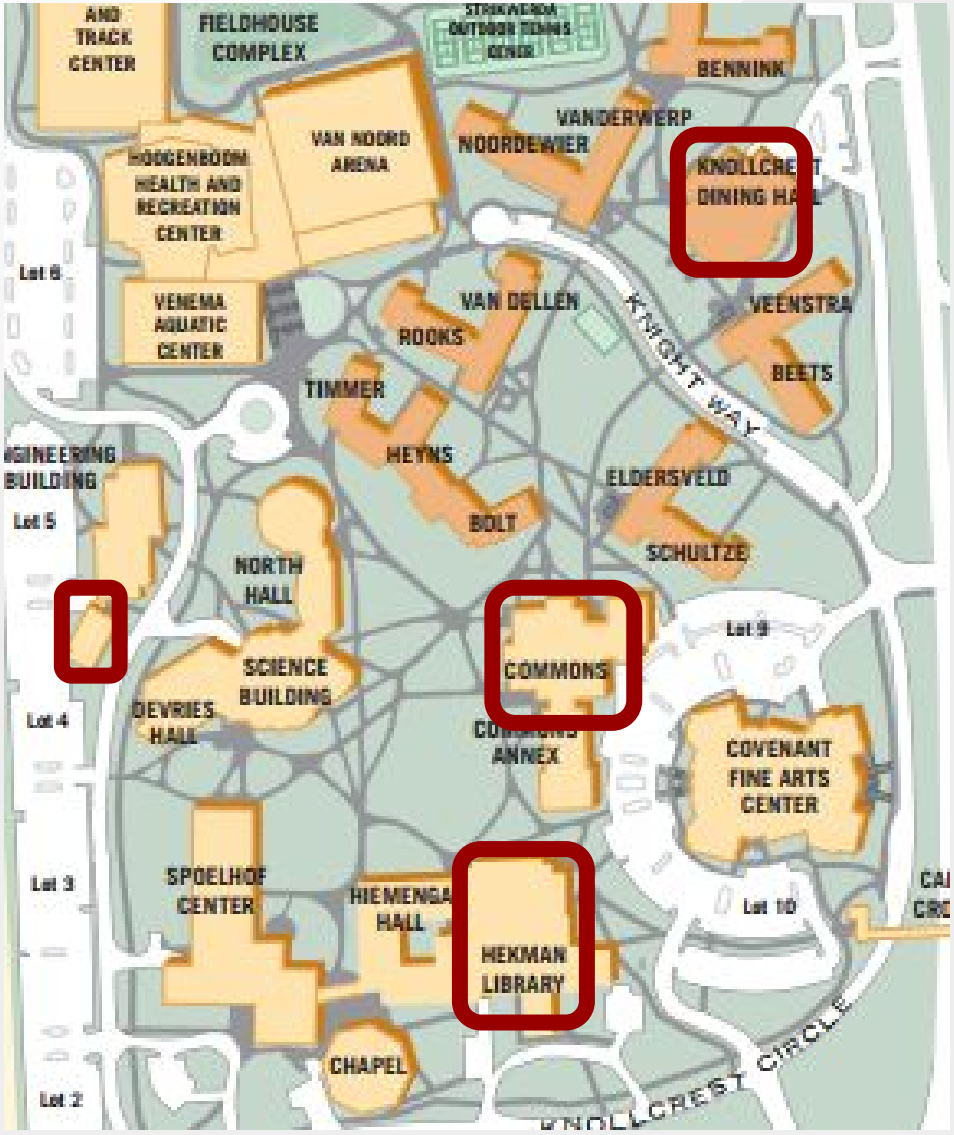
Boilers



http://marinersgalaxy.com/2013/03/different-types-of-marine-boilers-and.html

Boilers-Location



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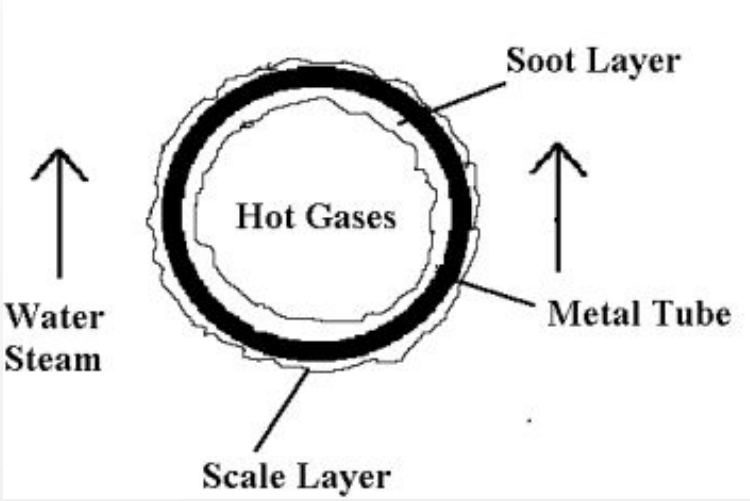
Boilers-Increase Maintenance

Fire Tube (Kewanee)

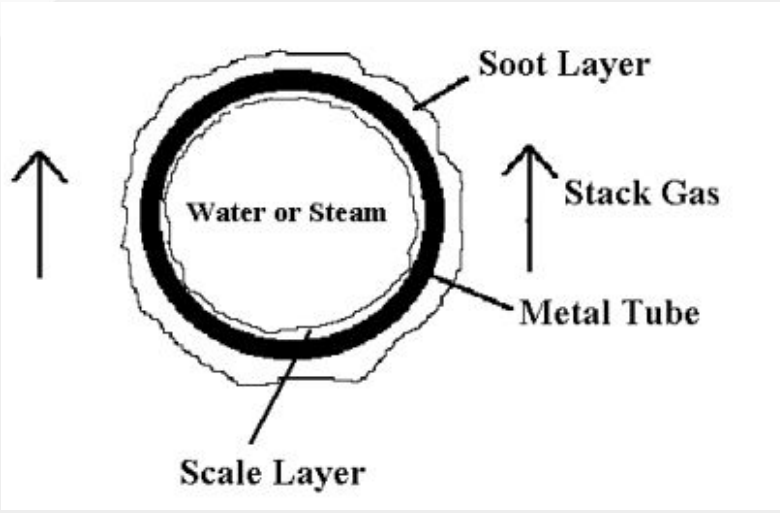


http://heating.danfoss.com/PCMPDF/BC_Kaupp_report_VFGIA102.pdf

Efficiency

65% ⟶ 67%

Water Tube (Hurst)



http://heating.danfoss.com/PCMPDF/BC_Kaupp_report_VFGIA102.pdf

Efficiency

78% ⟶ 80%

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Boilers-Increase Maintenance

http://i2.wp.com/optimiseheatandsteam.com/wp-content/uploads/2015/04/Boiler-Cleaning.jpg?resize=4303%2C3247

Annual Cost: $4,000

Net Annual Savings: $11,000

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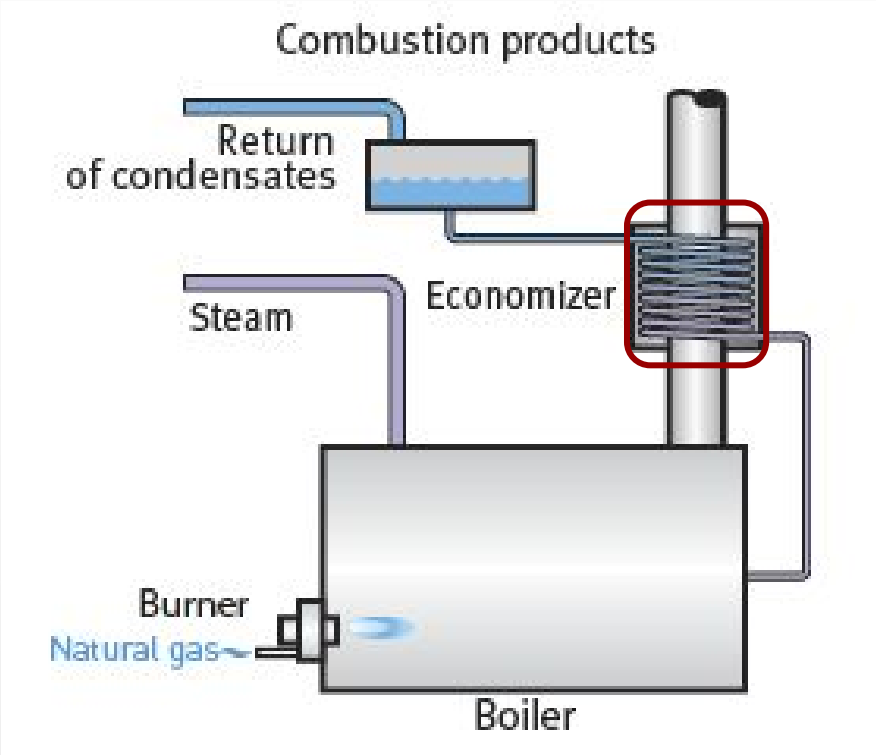
Boilers-Add Economizers and Controls



https://www.energir.com/~/media/Images/Affaires/Gif_appareils/Gif_appareils_ang/Boiler_stack_economizer_en.gif?h=240&la=en&w=279

Implementation Cost: $45,000
Annual Savings: $10,000

Implementation Cost: $5,000
Annual Savings: $5,000

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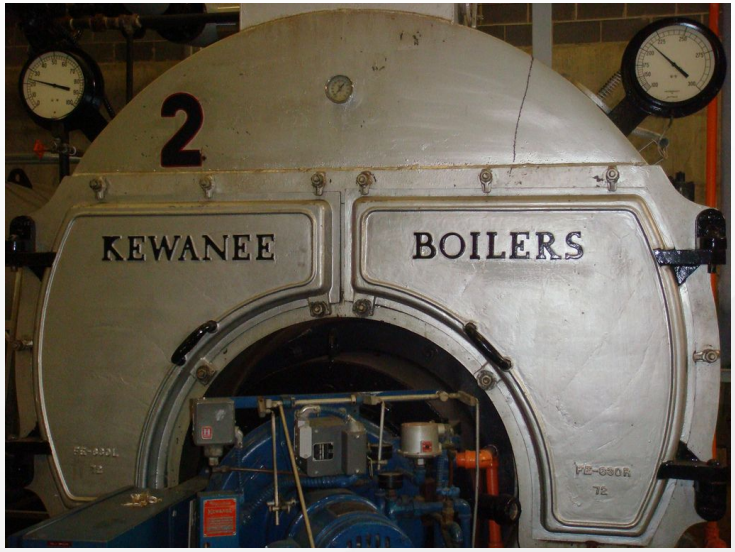
Boilers-Replace Kewanee



https://c1.staticflickr.com/5/4062/4430326044_cc8280f511_b.jpg

https://www.hurstboiler.com/images/ohio-special.png

Kewanee Boilers

- Fire Tube Boilers
- 67% Efficiency

Hurst Boilers

- Water Tube Boilers
- 80% Efficiency

Implementation Cost: $300,000

Annual Savings: $30,000

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Building Temperature Standard

Example:

Grand Valley State University Policy

PROCEDURES

During the winter season the heating controls are set at a **maximum of 70°F.** During the summer season the **minimum cooling temperature will be 76°F.** Facilities Services will respond to hot/cold calls to ensure that systems are running properly, but will not adjust the temperatures to levels outside of the standards

https://www.gvsu.edu/policies/policy.htm?policyId=E677FA8A-E5C3-83

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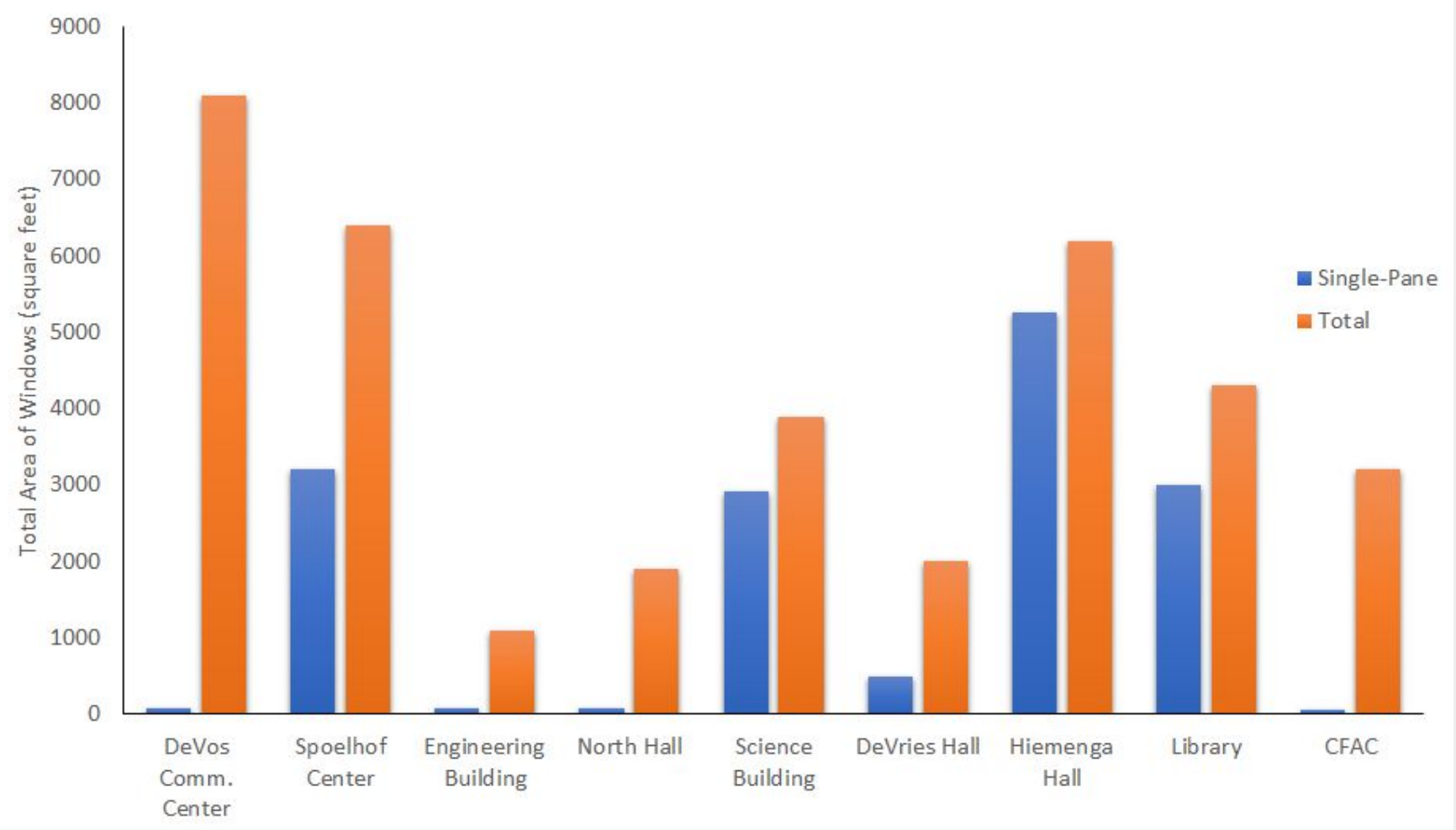
Window Area Totals



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Building Temperature Standard

Academic Buildings
73°F ⟶ 68°F

PE Complex
73°F ⟶ 68°F

Implementation Cost: $0
Annual Savings: $13,500

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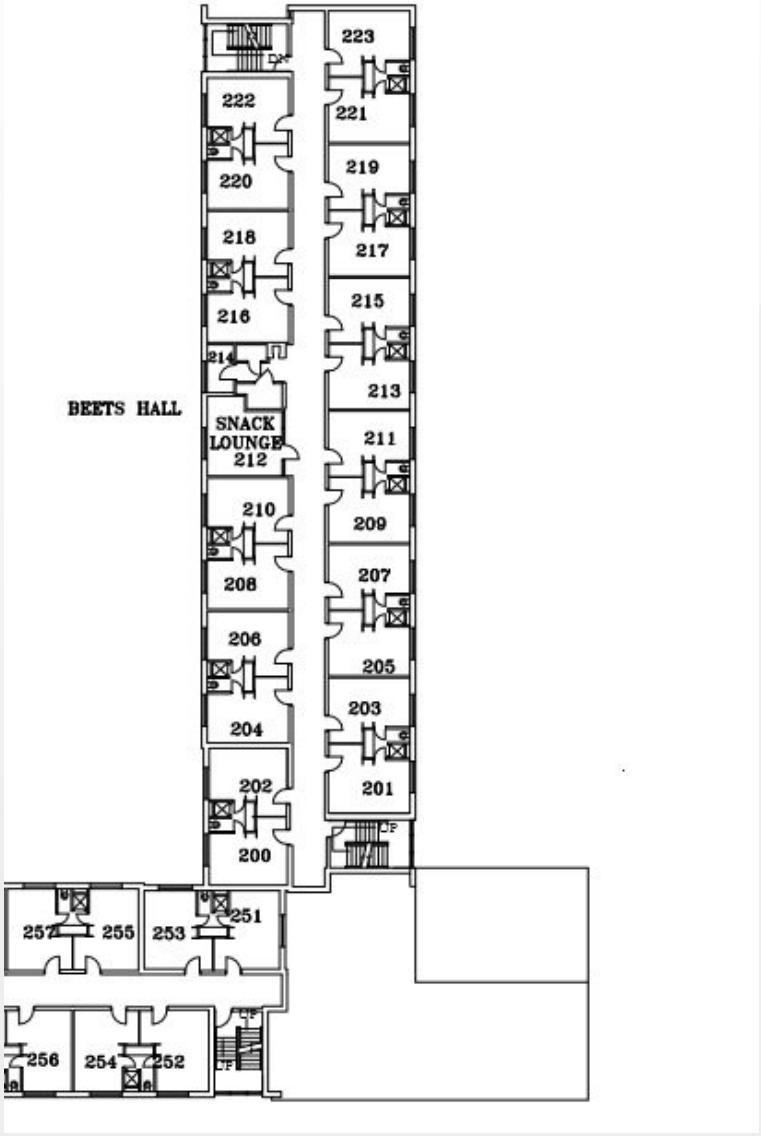
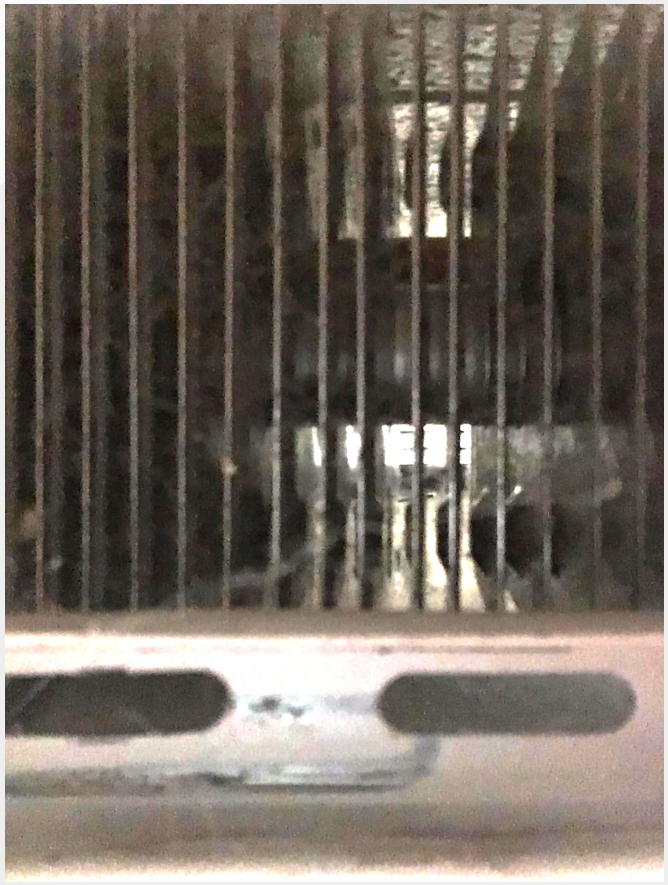
Dorm Radiators



From Physical Plant Floor Plans



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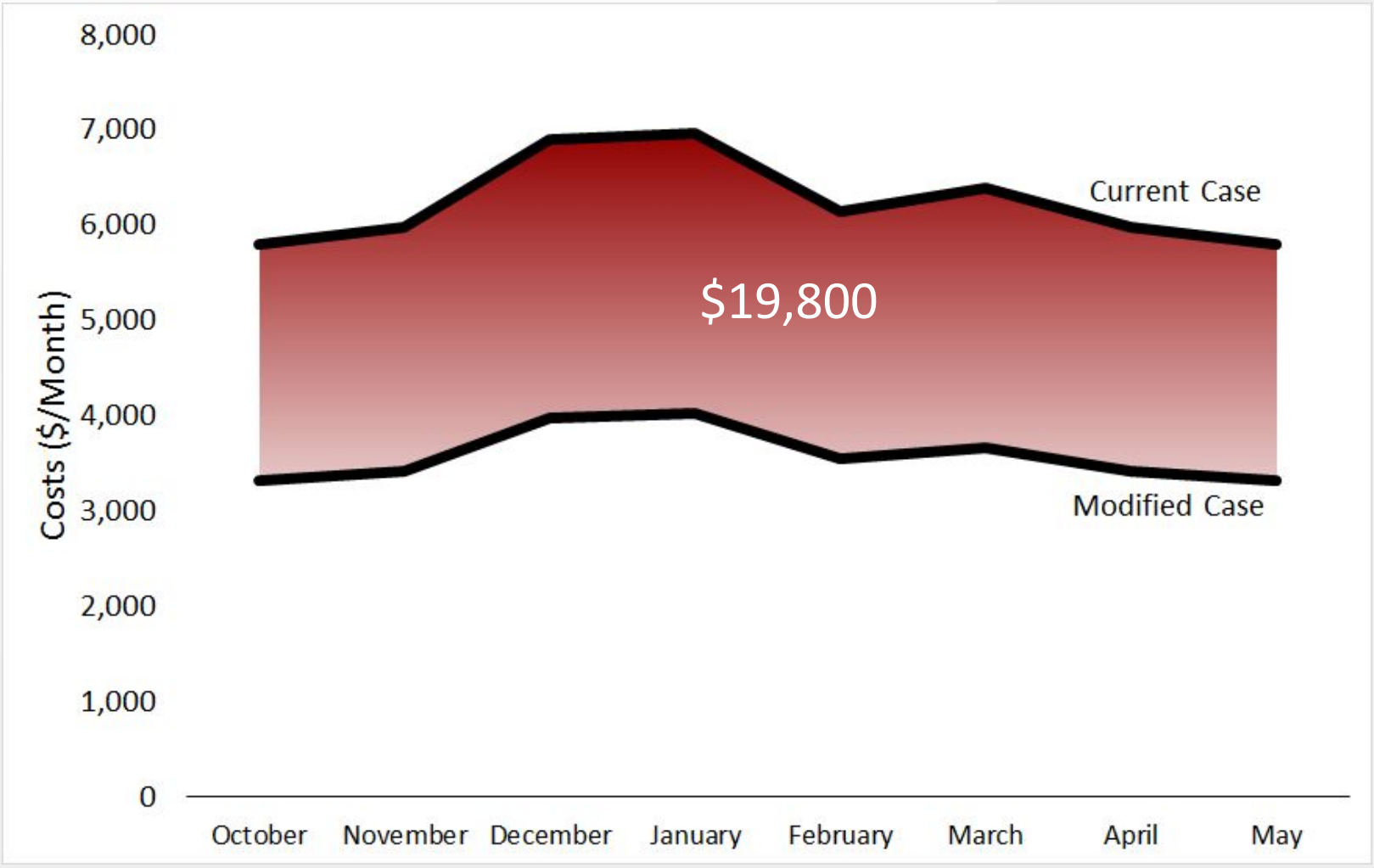
Dorm Radiators



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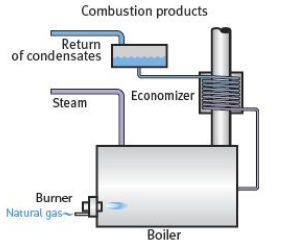
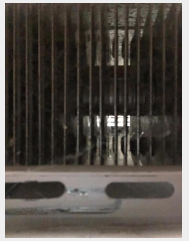


Implementation cost:	$0	$45,000	$5,000
Annual Savings:	$11,000	$10,000	$5,000
Payback:	0 Years	4.5 Years	1 Year



Implementation cost:	$300,000	$0	$50,000
Annual Savings:	$30,000	$13,500	$19,800
Payback:	10 Years	0 Years	2.5 Years

Total Annual Savings ($)	**$89,300**
Implementation Cost ($)	**$400,000**
Payback (Years)	**4.5**

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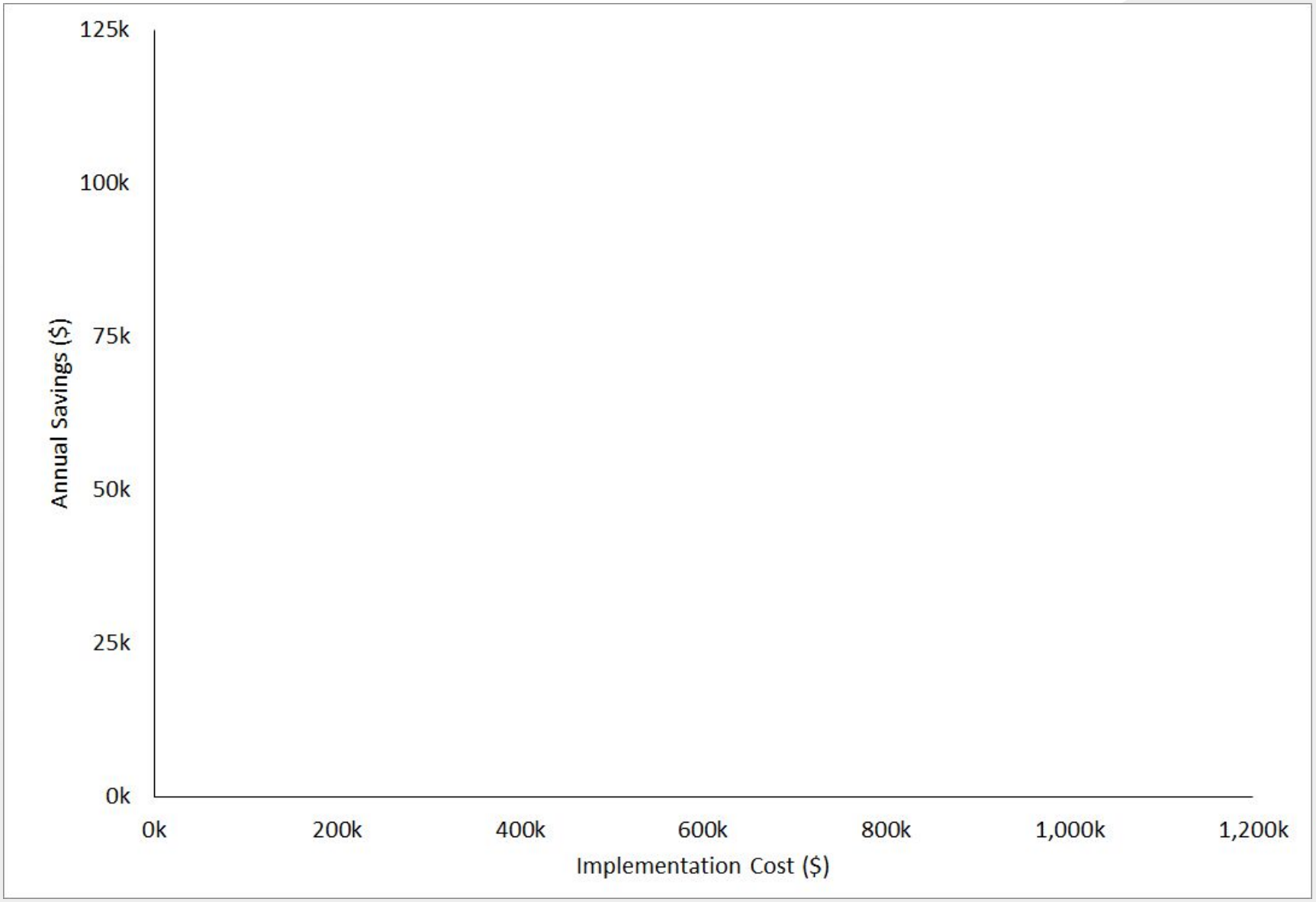
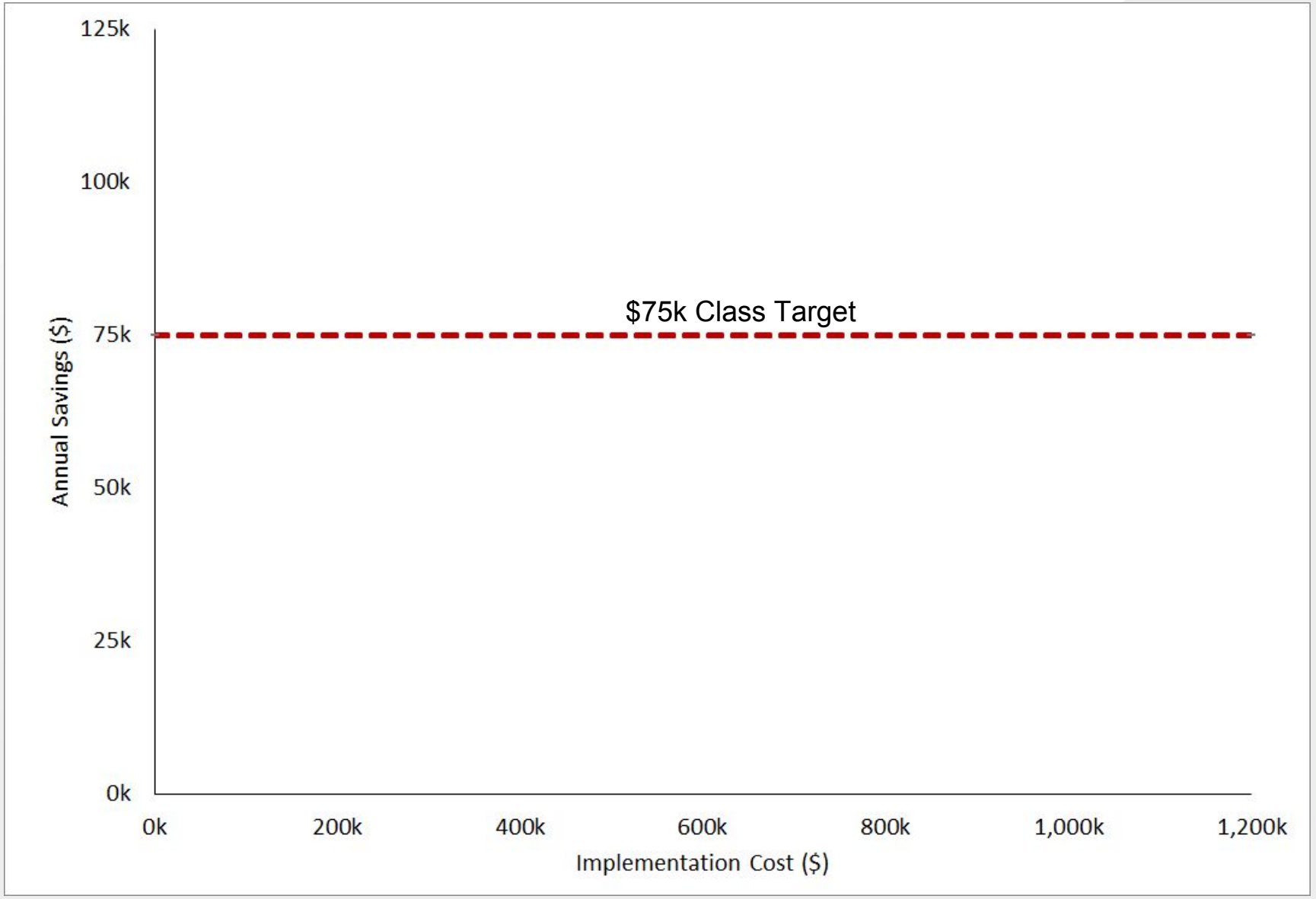

125k
100k
75k
50k
25k
0k
Annual Savings ($)
0k
200k
400k
600k
800k
1,000k
1,200k
Implementation Cost ($)



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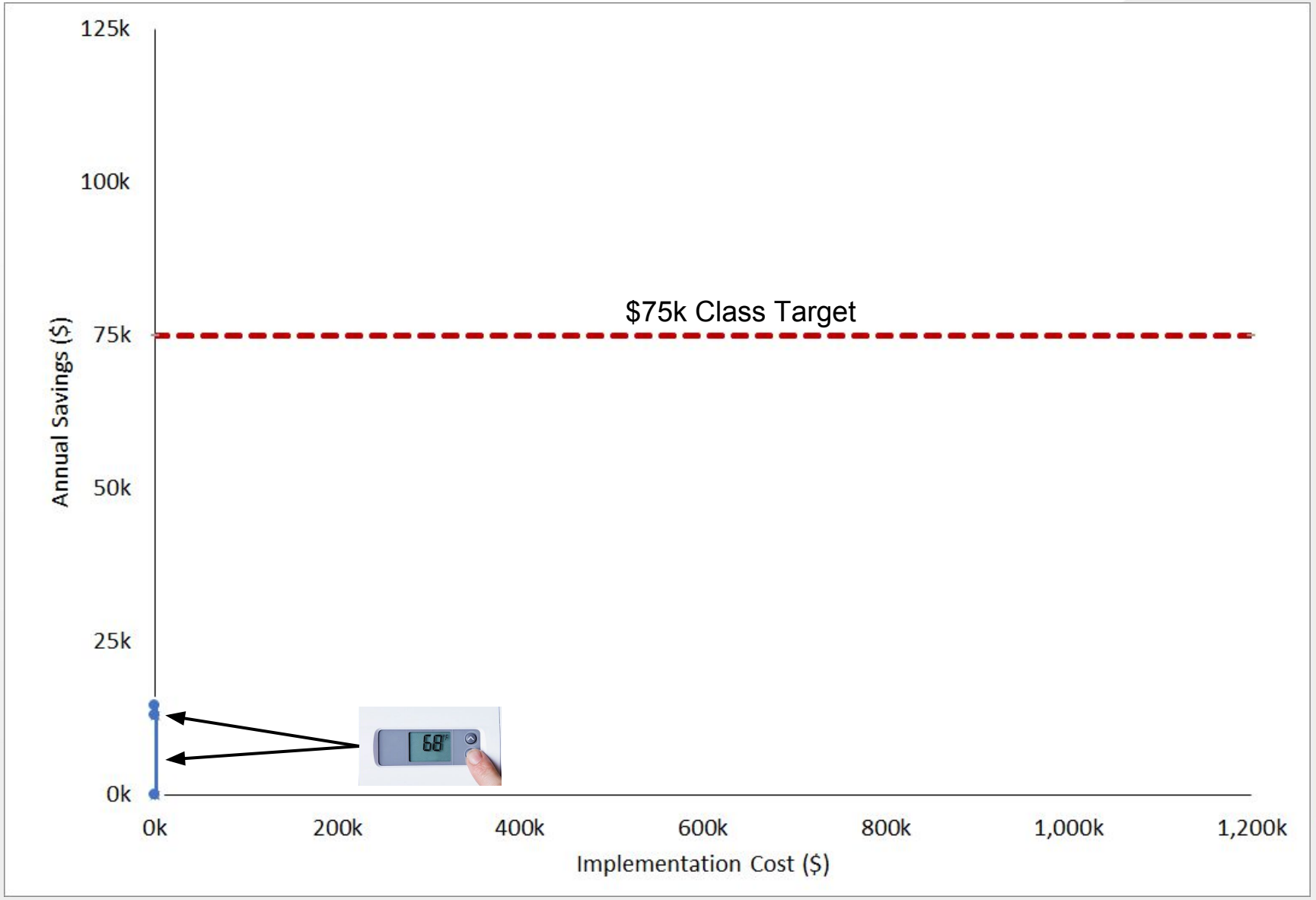
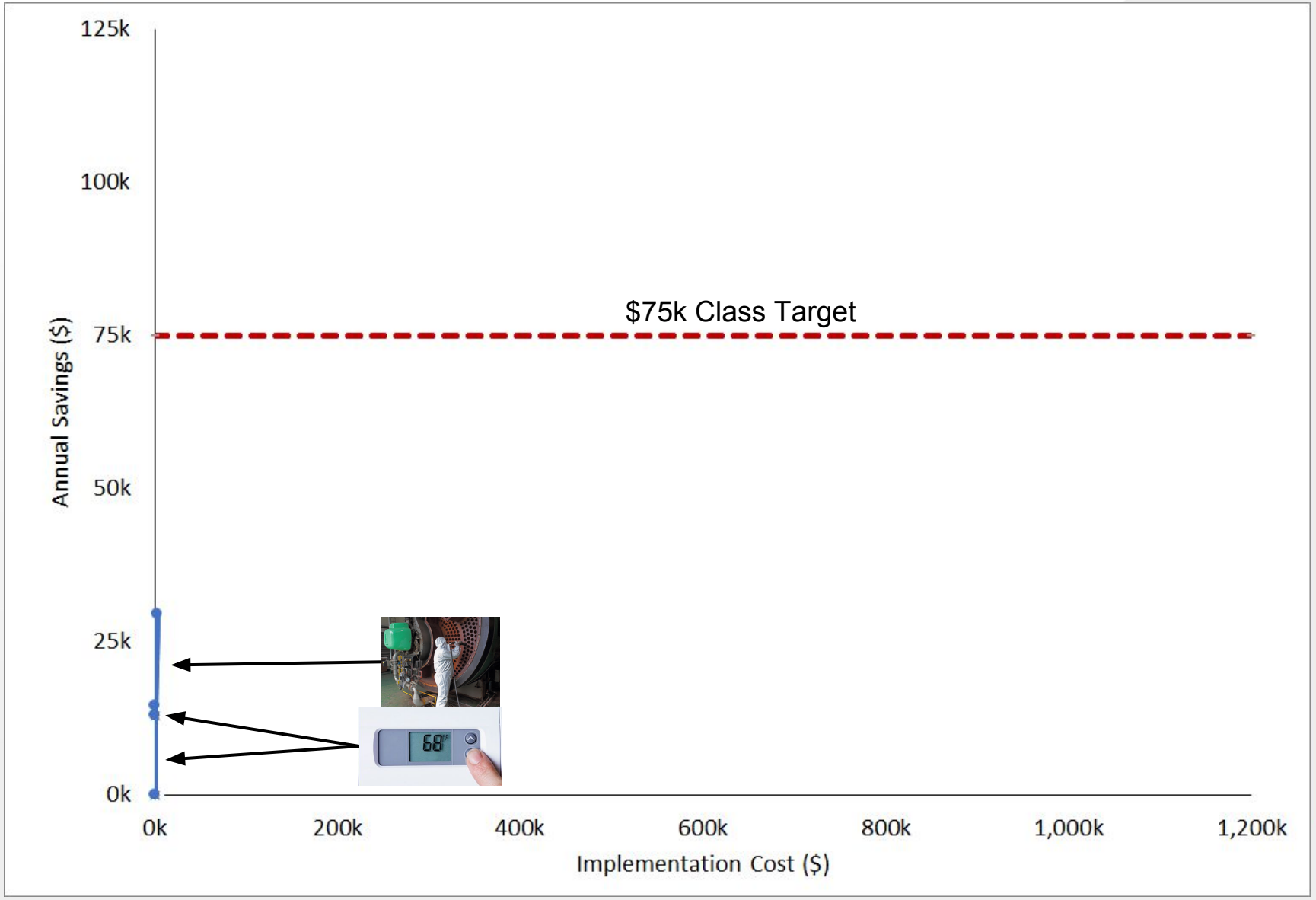
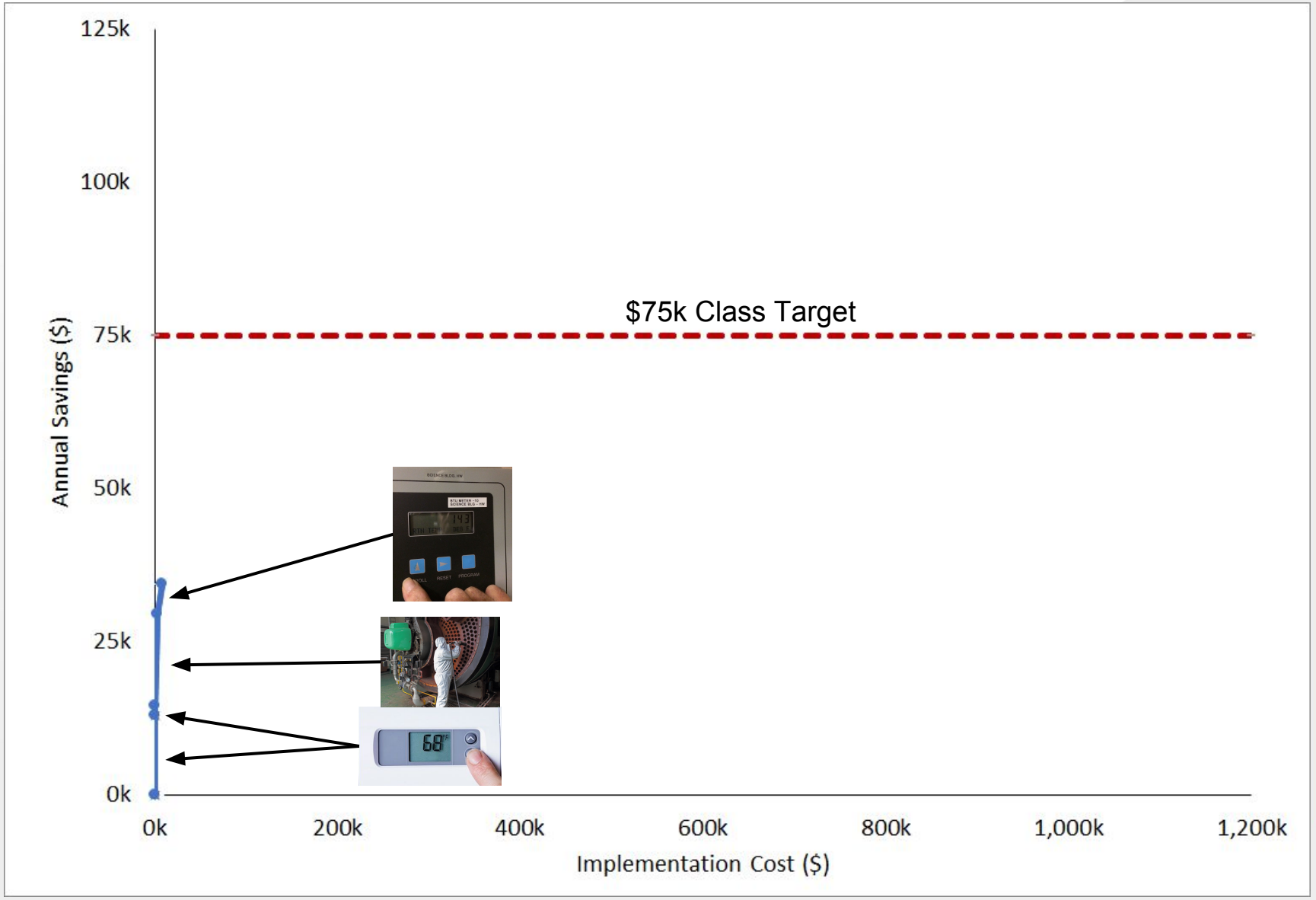


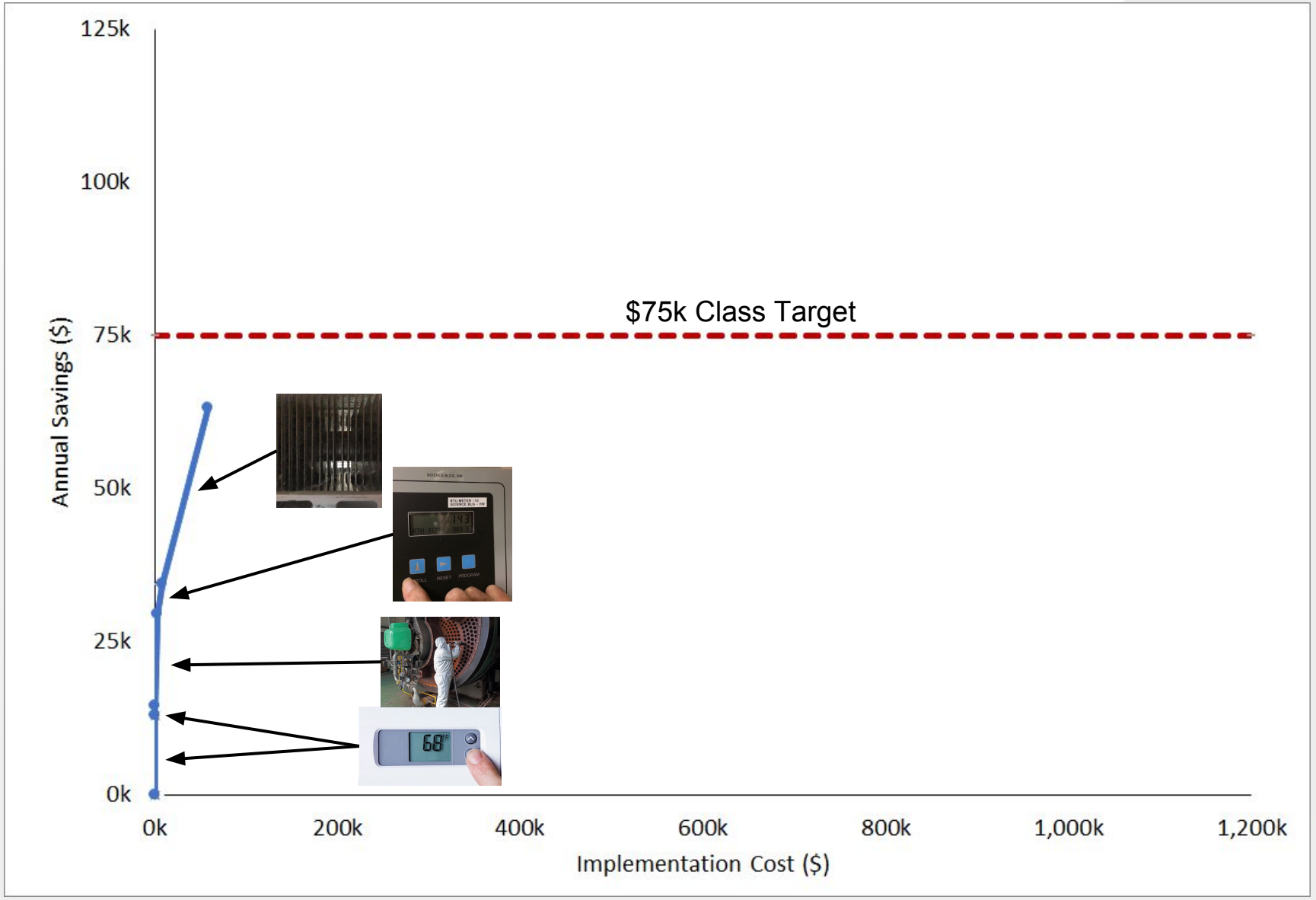
Calvin COLLEGE 1876



Calvin COLLEGE 1876



Calvin COLLEGE 1876



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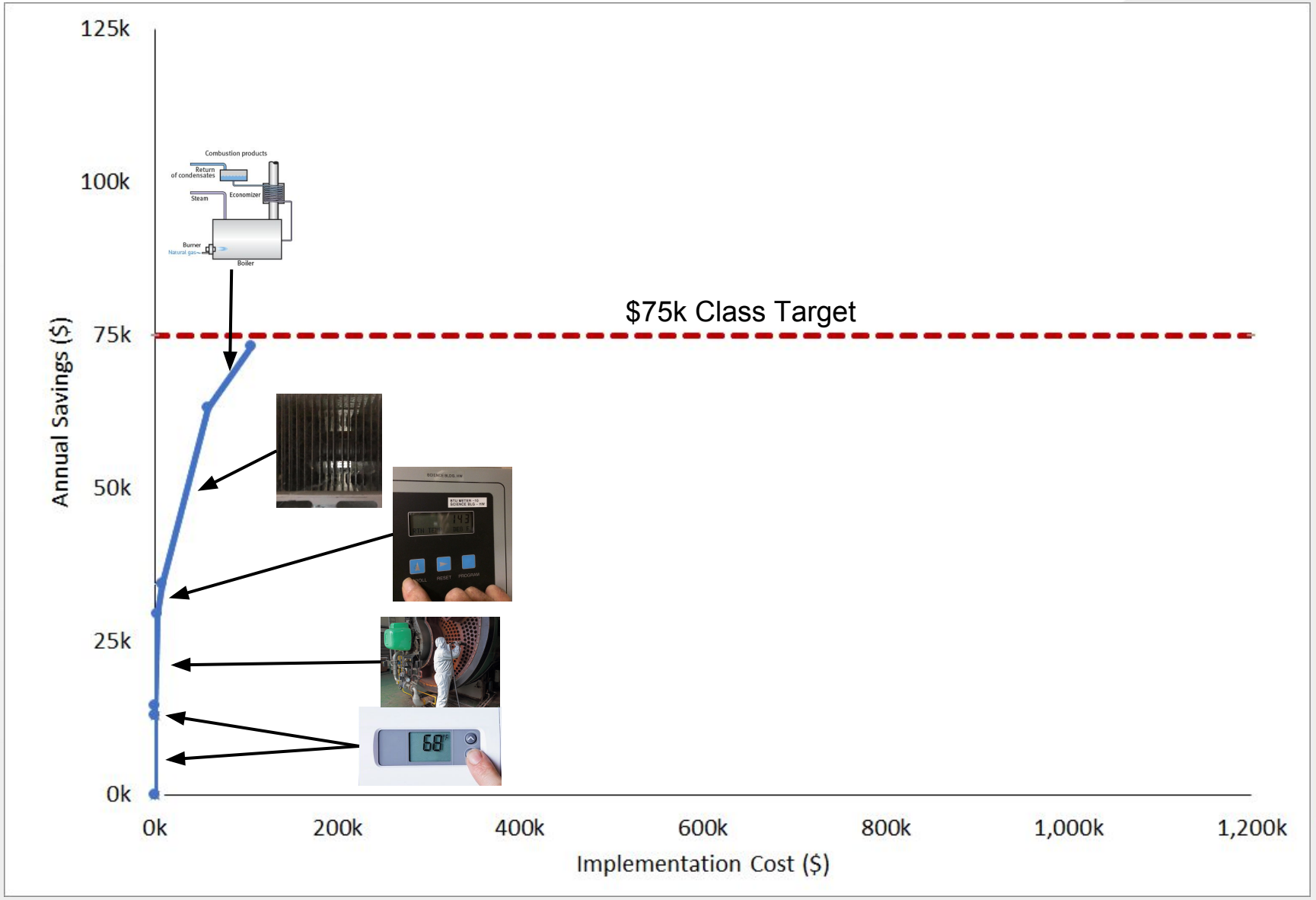

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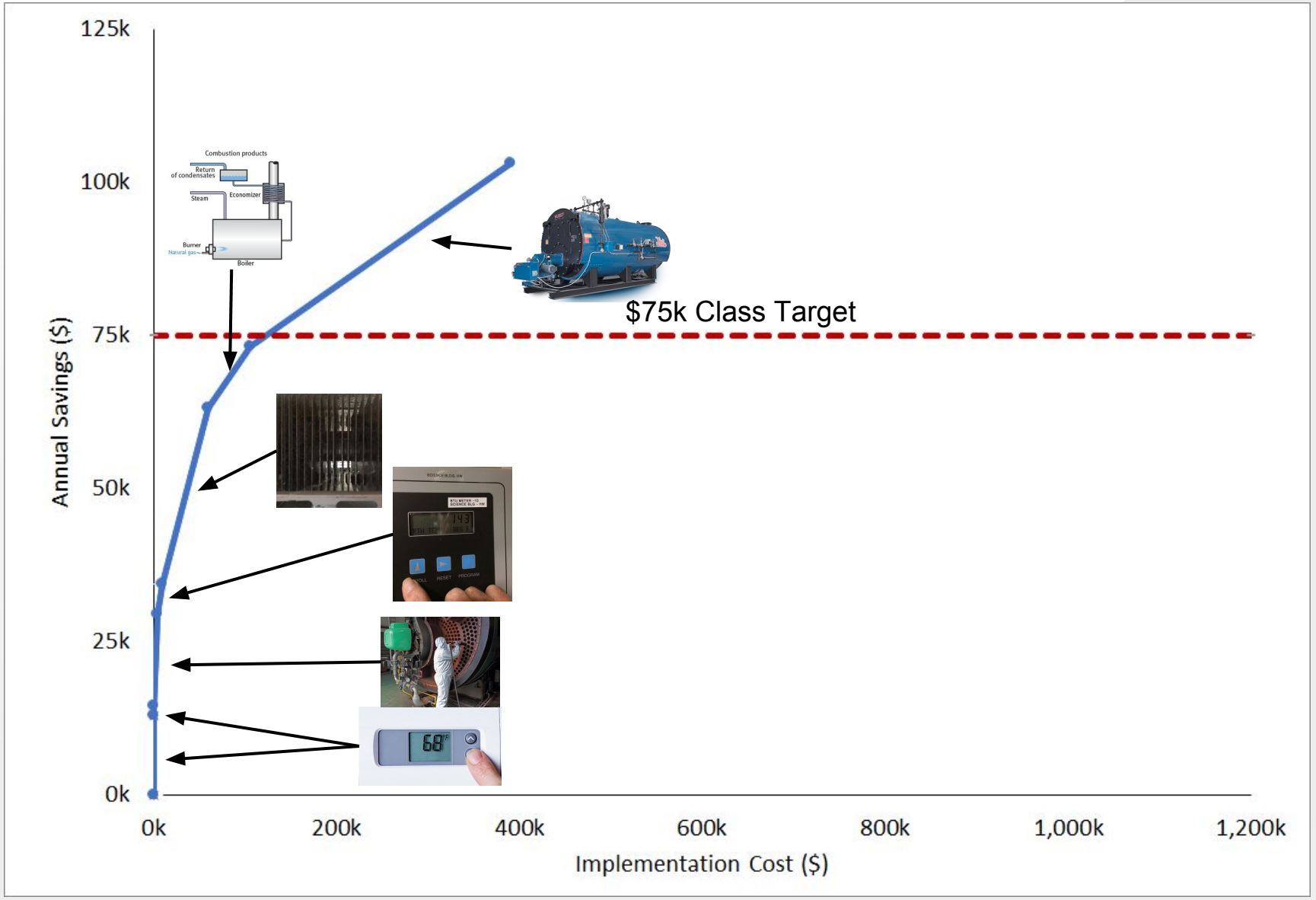

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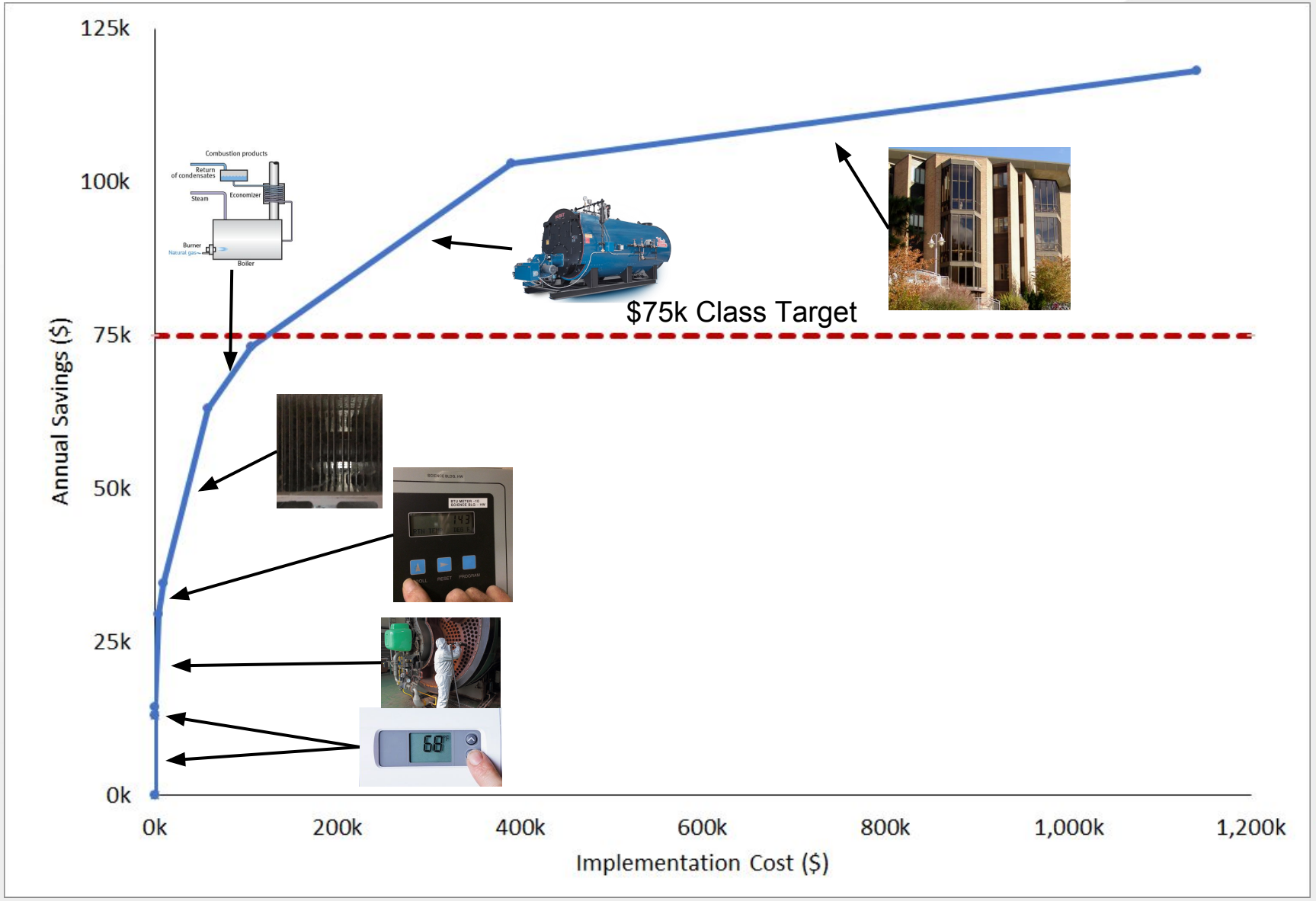

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Co-Gen Plant Energy Savings

ENGR 333-B

Cam Richman, Tyson Butler

What would it take for Calvin to save $150k/year on energy costs using a new on-site co-generation plant?

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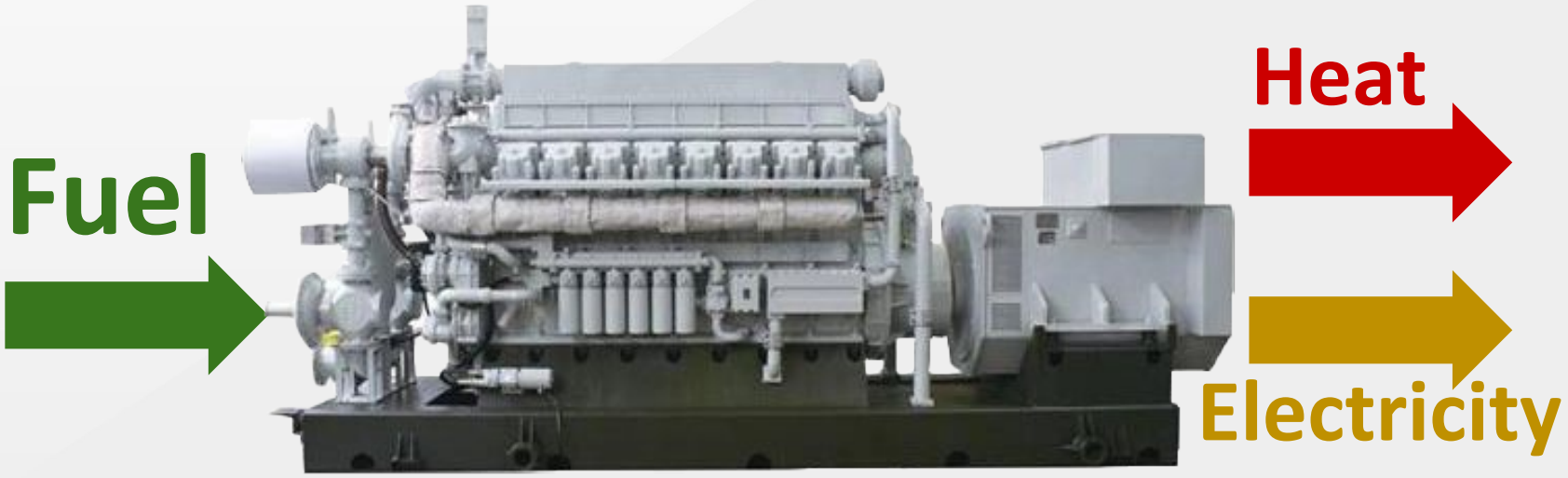
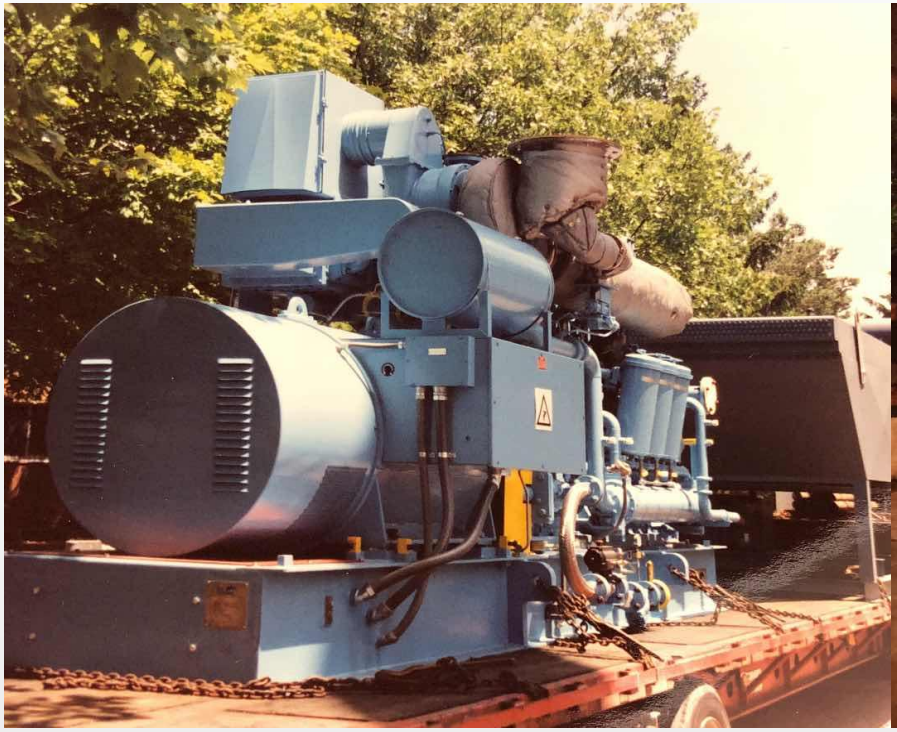
What is a Co-generation Plant?



https://www.google.com/search?biw=1385&bih=803&tbm=isch&sa=1&ei=WeklWsmQIcvKjwT1qqnYBA&q=coge

Calvin's Old Co-generation Plant



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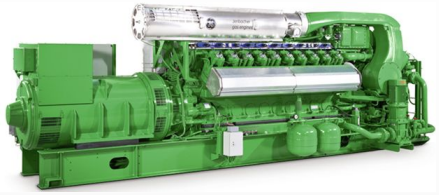

https://www.google.com/search?q=ge+

Engine Selection

https://www.google.com/search?q=

Interconnections

Consumers Energy

https://www.google.com/search?q=consumers+ene

Natural Gas /Electricity Savings

https://www.google.com/search?q=

CO_2 Savings

https://www.google.com/search?q=finance+pict

Finances

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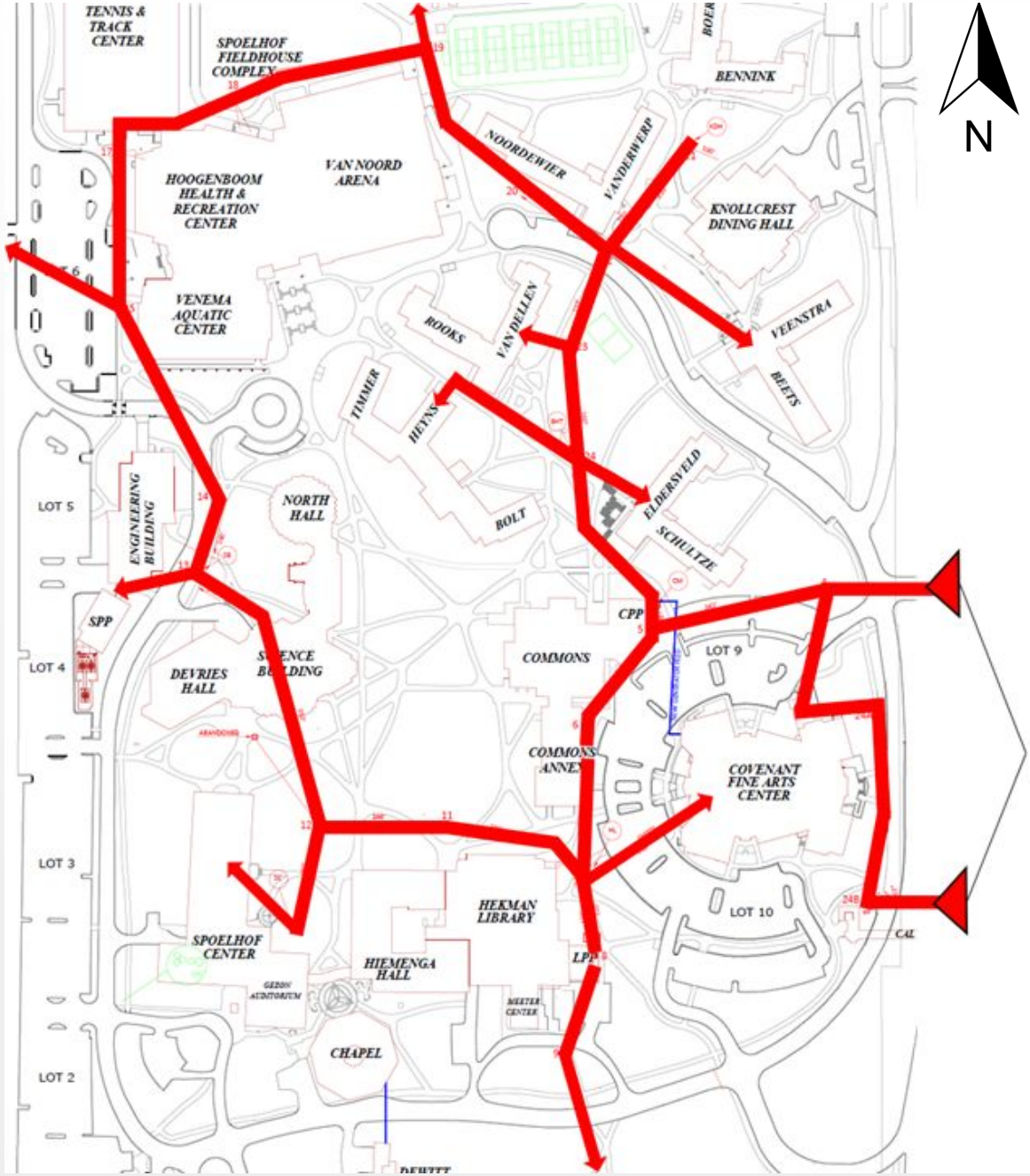

Main Electricity Loop

From Burton St. Substation

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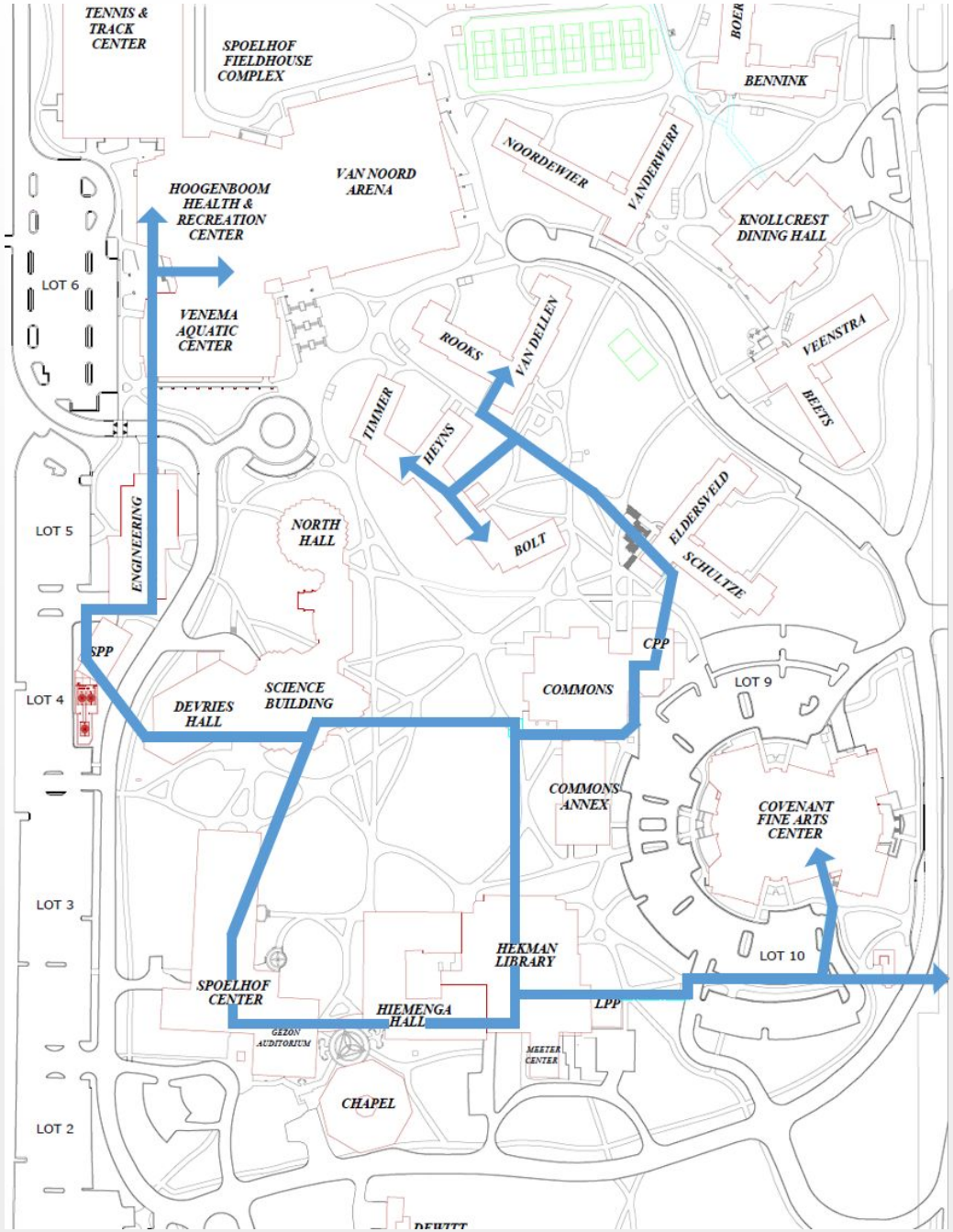

N

Main Heating Loop

To DeVos and Prince

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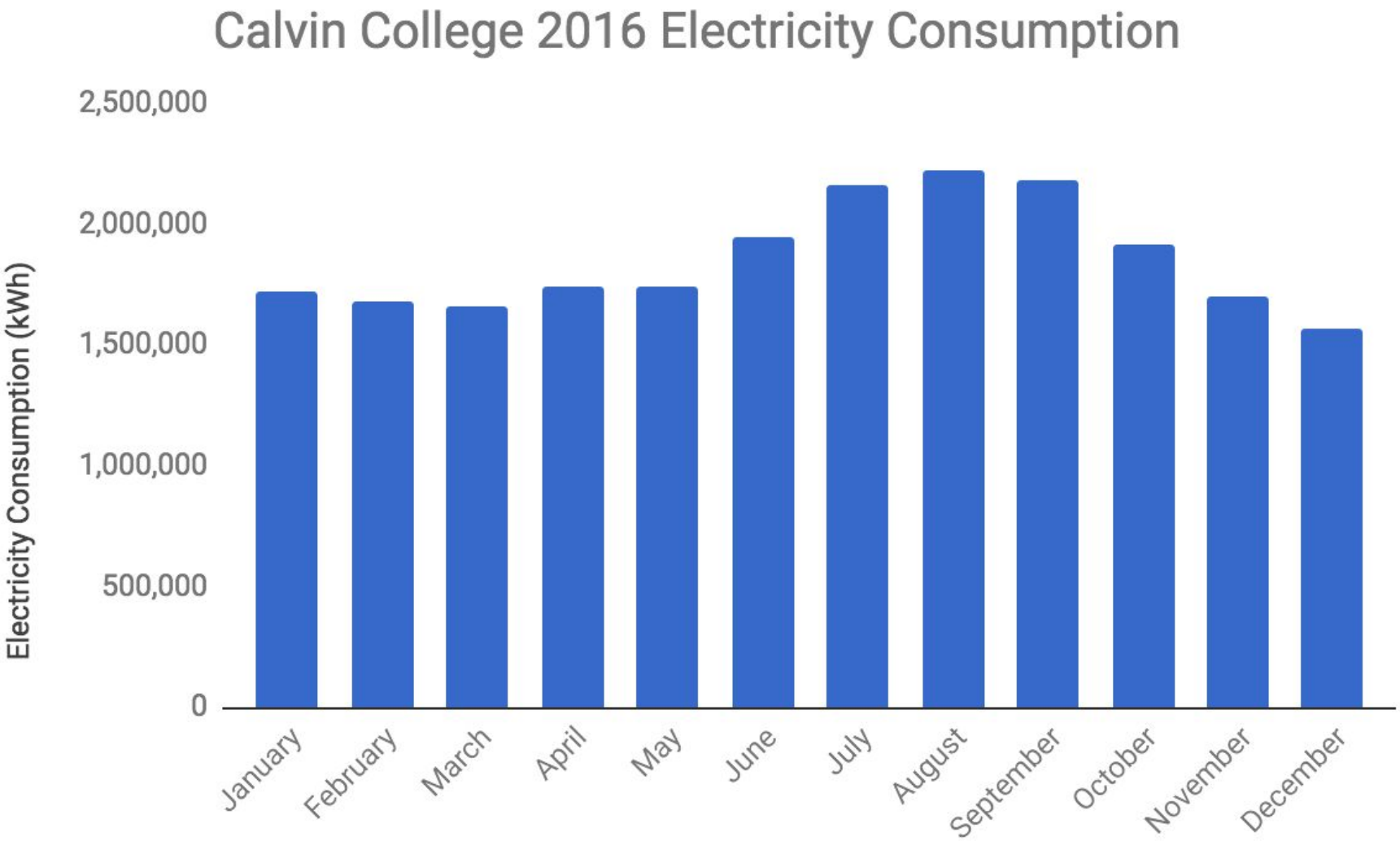
Calvin College 2016 Electricity Consumption
Electricity Consumption (kWh)
2,500,000
2,000,000
1,500,000
1,000,000
500,000
0
January
February
March
April
May
June
July
August
September
October
November
December

Calvin College Electrical Consumption

https://calvin.edu/news/archive/under-the-lights

2010-2016 Data:

- Electricity: 25,000,000 kWh/yr
- Peak usage: 5250 kW
- Min usage: 1340 kW

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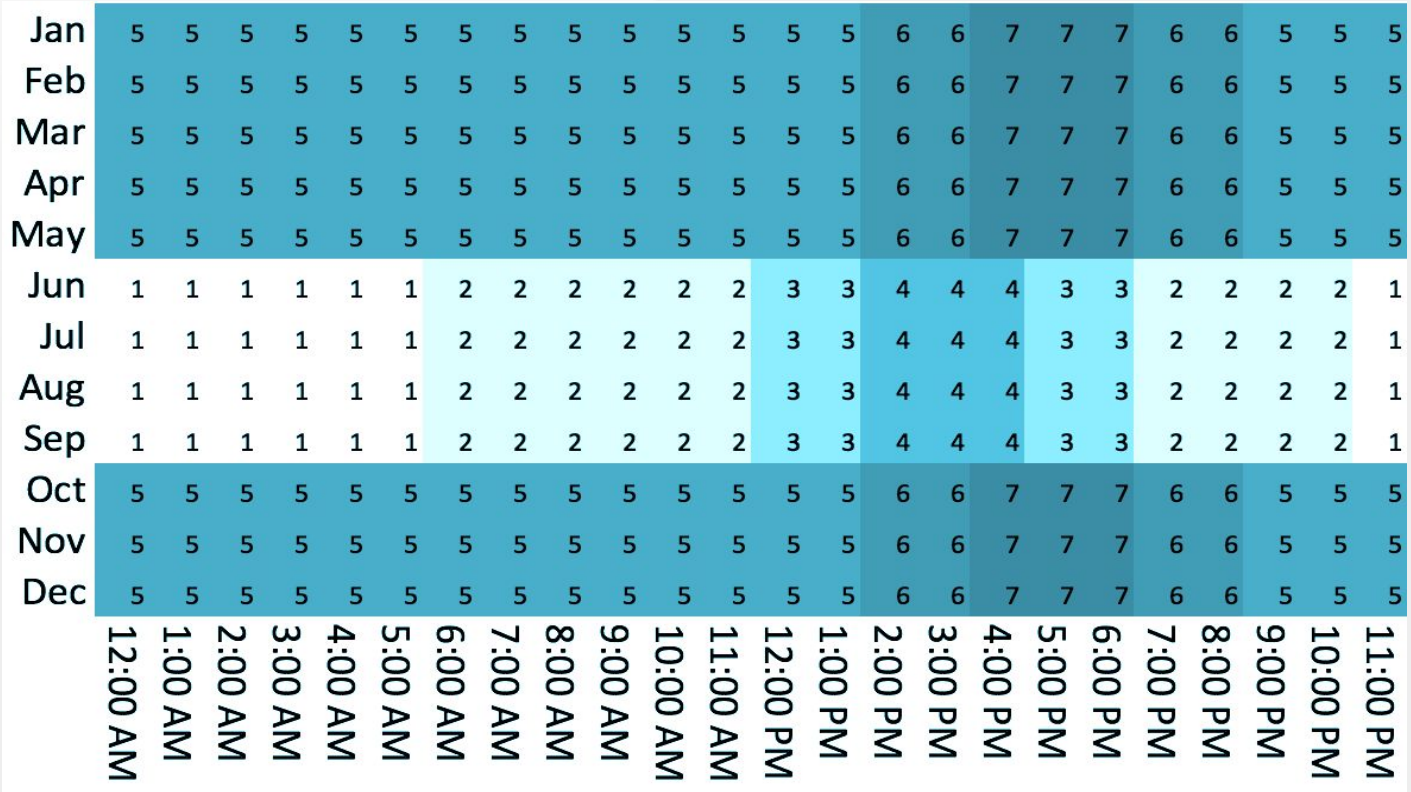
Electrical Price Variation

- Simplified Electricity Cost
  - Off-peak $0.07/kWh (7pm-11am)
  - Peak summer $0.14/kWh (11am-7pm)
  - Peak winter $0.09/kWh (11am-7pm)



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Engine Considerations

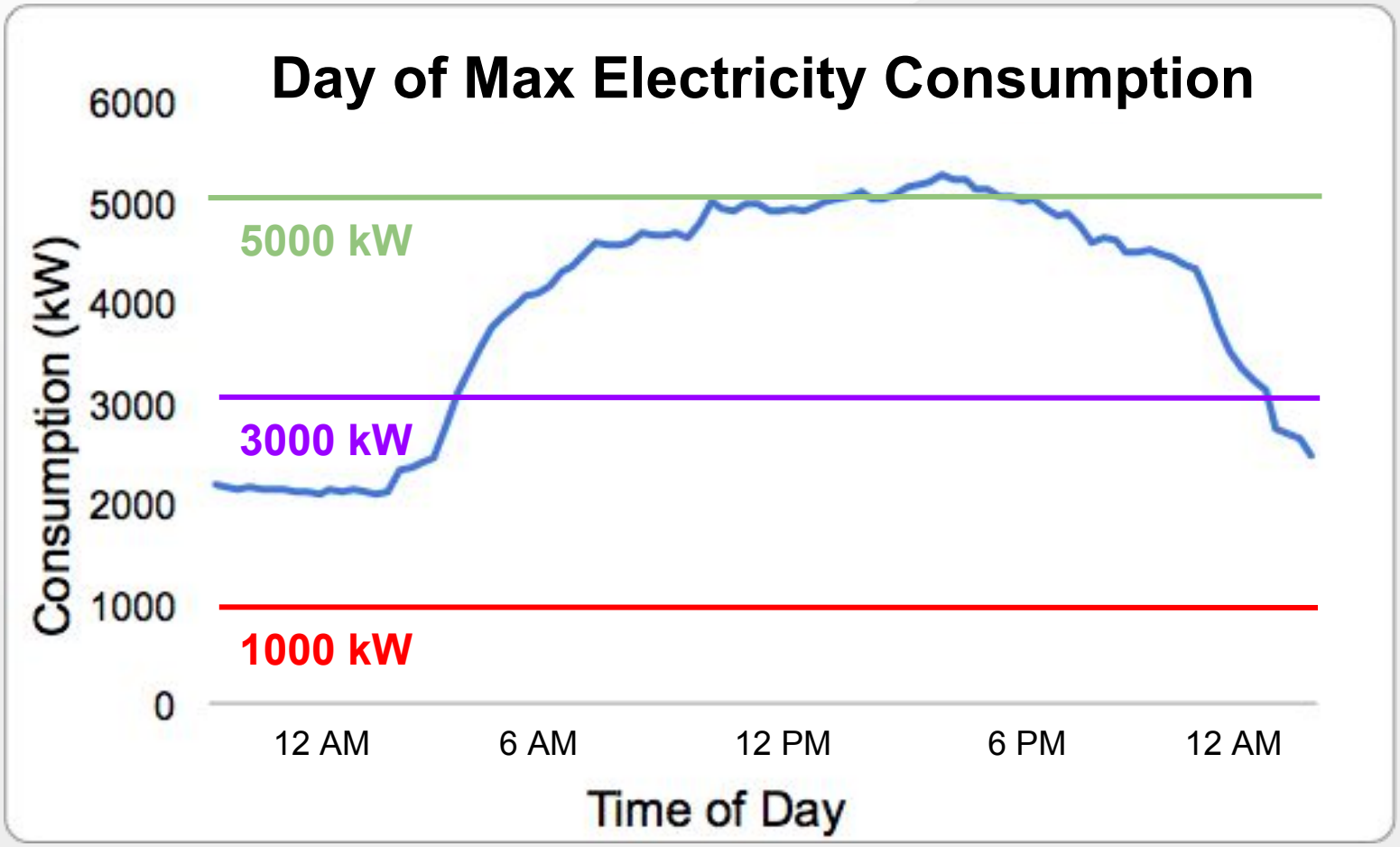
- Engine cycle type
  - Brayton or Otto
- Company
  - GE
  - Enerblu
  - Kawasaki

https://upload.wikimedia.org/wikipedia/commons/thumb/f/ff/General

https://pbs.twimg.com/profile_images/850053964322164736/nR5qG5Bh_400x400.jpg

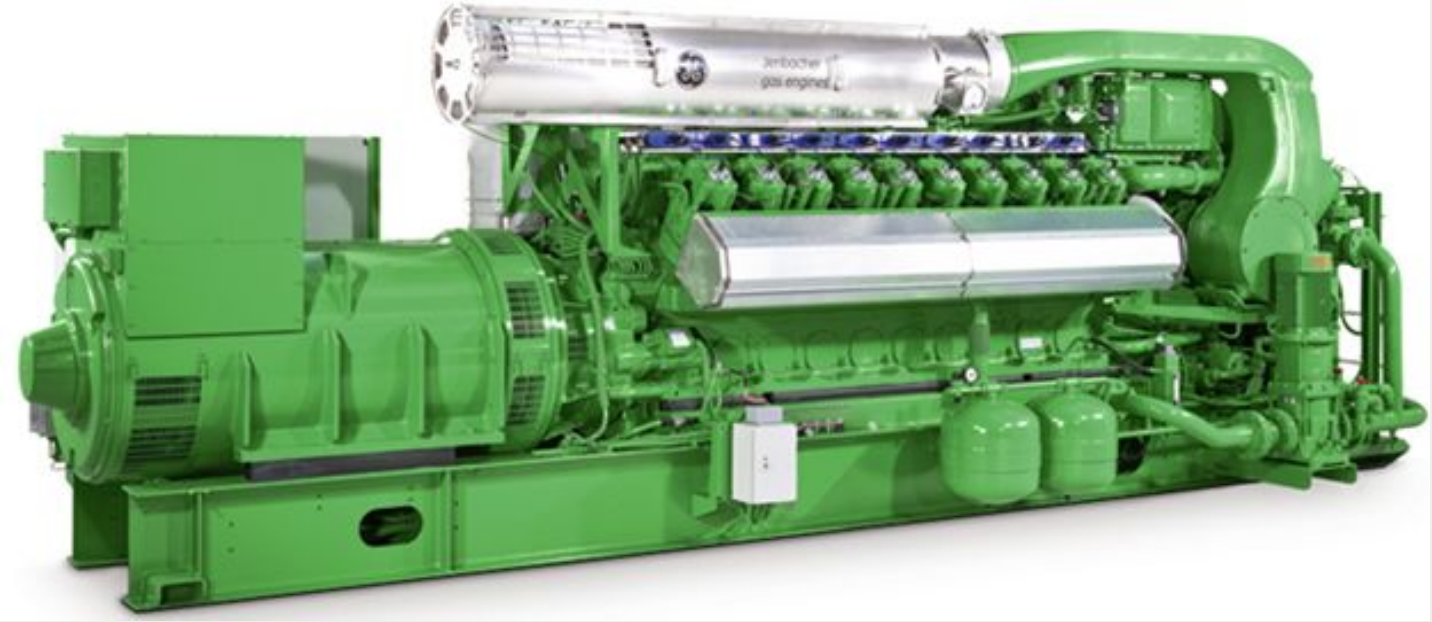
https://www.google.com/search?q=kawasaki+logo&source=lnms&tbm=isch&sa=X&ved=0ahUKEwiej9KsvenXAhWC8YMKHVHEBNgQ_AUICigB&biw=1

Engine Considerations

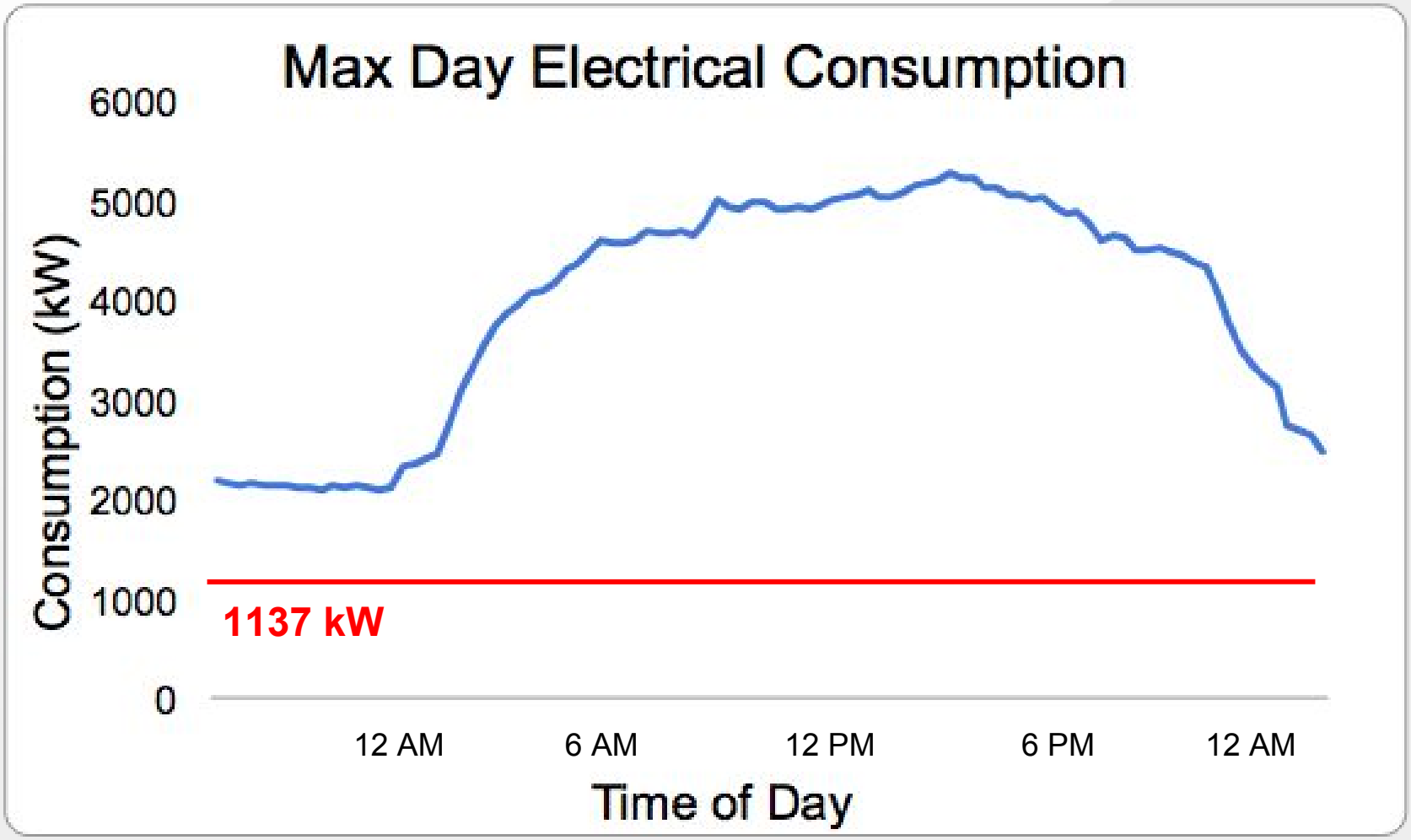


Final Engine Selection

- Model: GE's Jenbacher 4 J416 GS-B86
- Power: 1137 kW
- Fuel Cost: 3.8¢ /kWh
- Cost of Installed Engine: $1.4 million



https://www.google.com/search?q=ge+jenbacher+j416&rlz=1C1GCEA_enUS773US773&source=lnms&tbm=isch&sa=X&ved=0ahUKEwjG7


Max Day Electrical Consumption
6000
5000
4000
3000
2000
1000
0
Consumption (kW)
1137 kW
12 AM
6 AM
12 PM
6 PM
12 AM
Time of Day

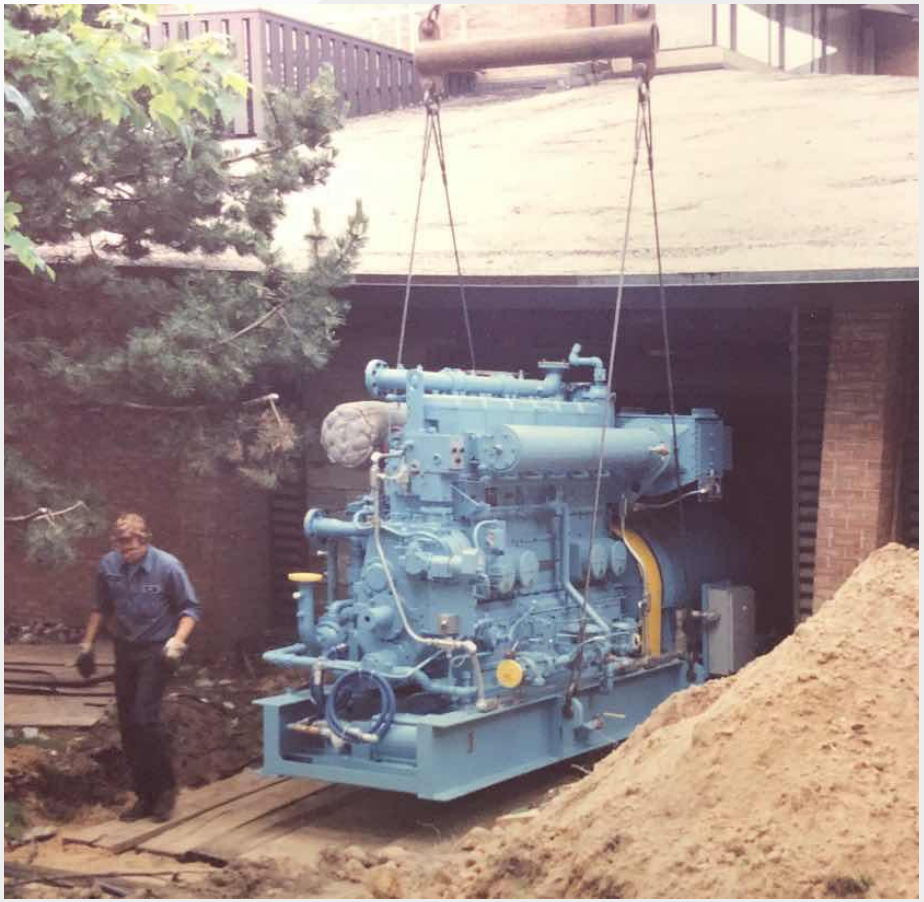
Installations

<u>Option 1:</u>

Previous Co-gen Location

- Pros:
  - Existing infrastructure

- Cons:
  - Size constraints
  - Installation
  - Maintenance

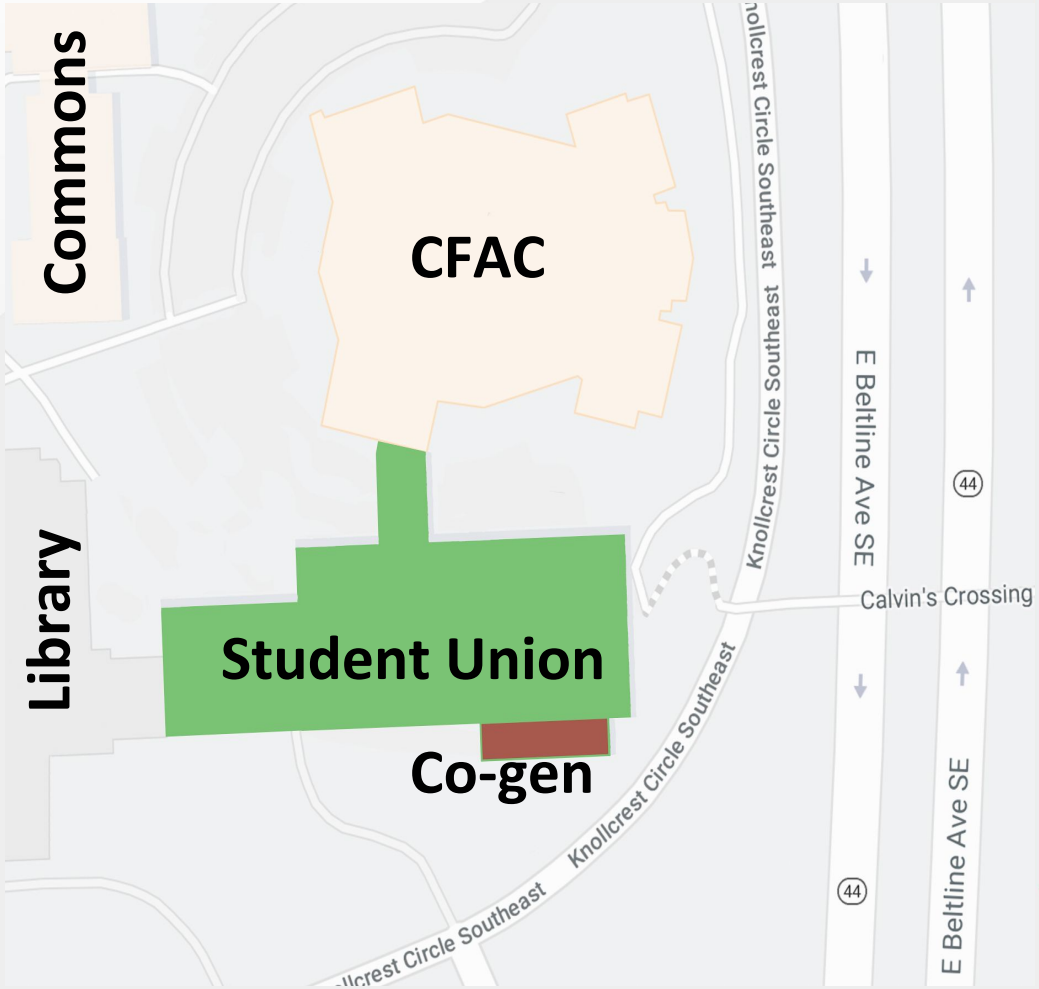


Installations

Option 2:
Student Union

- Pros
  - Expansion plans
  - Redundancy

- Cons
  - Infrastructure
  - Eyesore



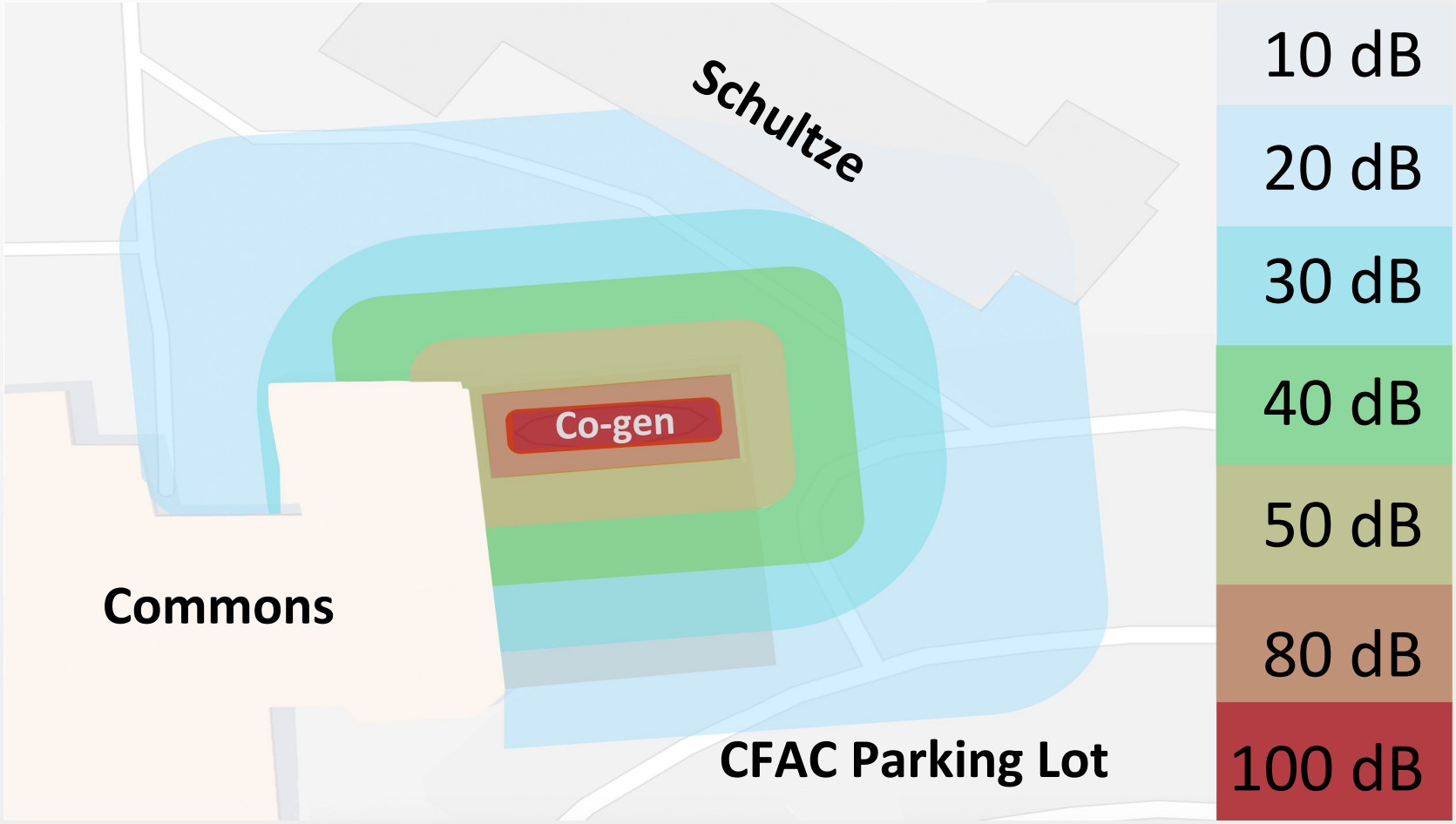
Proposed Location

<u>Option 3</u>:
East of Commons

- Pros
  - Expansion plans for loading docks
  - Heat/electricity loop availability

- Cons
  - Sound Pollution

Sound Considerations



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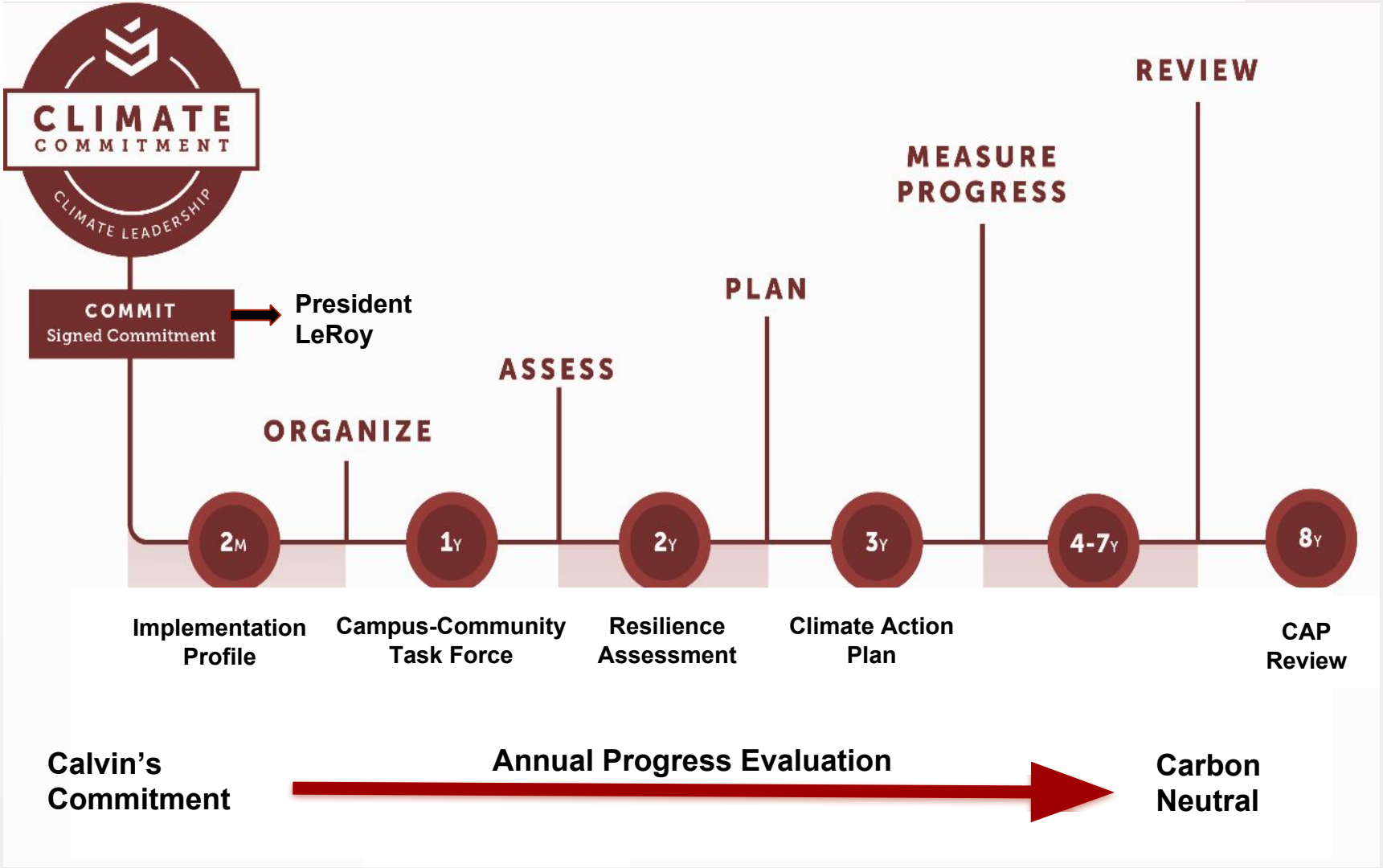

http://secondnature.org/wp-content/uploads/Commitment-Timeline_Climate_Orange.png

"The earth is the LORD's, and the fullness thereof; the world, and they that dwell therein."
Psalm 24:1 (KJV)

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CO_2 Emissions

https://d2v9y0dukr6mq2.cloudfront.net

http://www.financeapprise.com

Primary Emissions

- Substances/waste gas streams emitted directly; through on-site practices

Secondary (Embodied) Emissions

- Substance/waste gas streams emitted indirectly; through off-site practices

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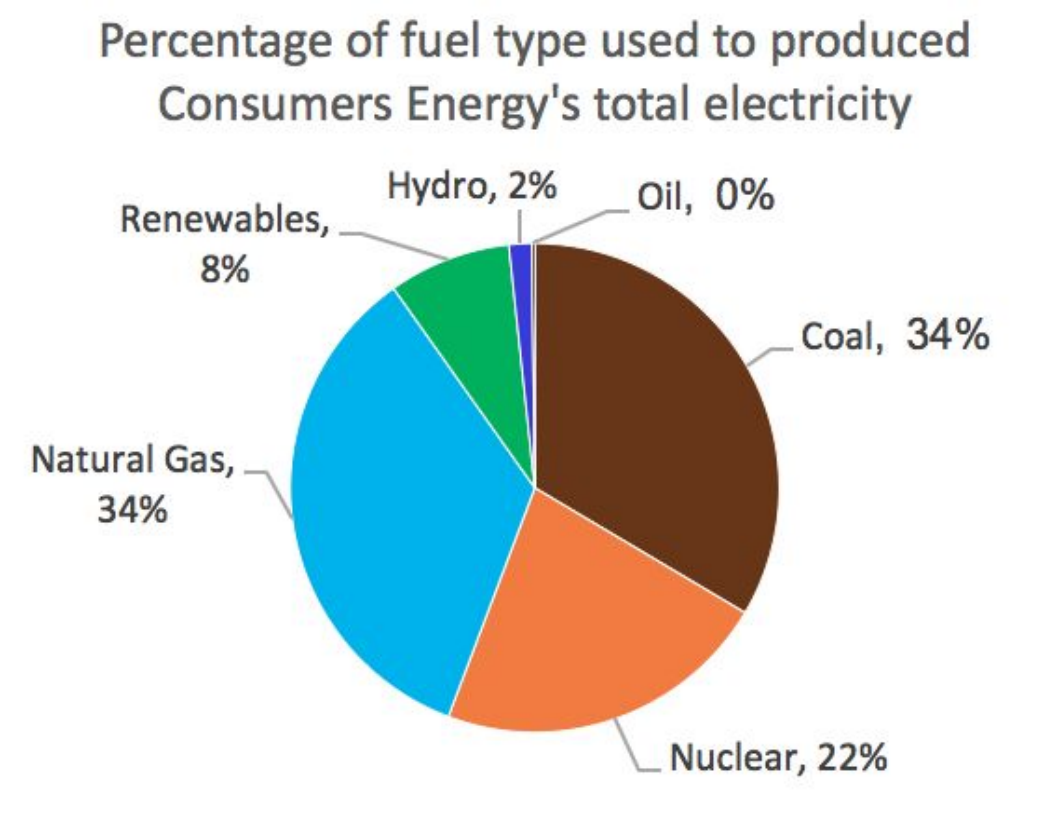
Present CO_2 Emissions

Currently at Calvin College

- 100% of electricity sourced from Consumers Energy

Consumers Energy CO_2 Emissions

- **0.758 kg CO_2 /kWh**



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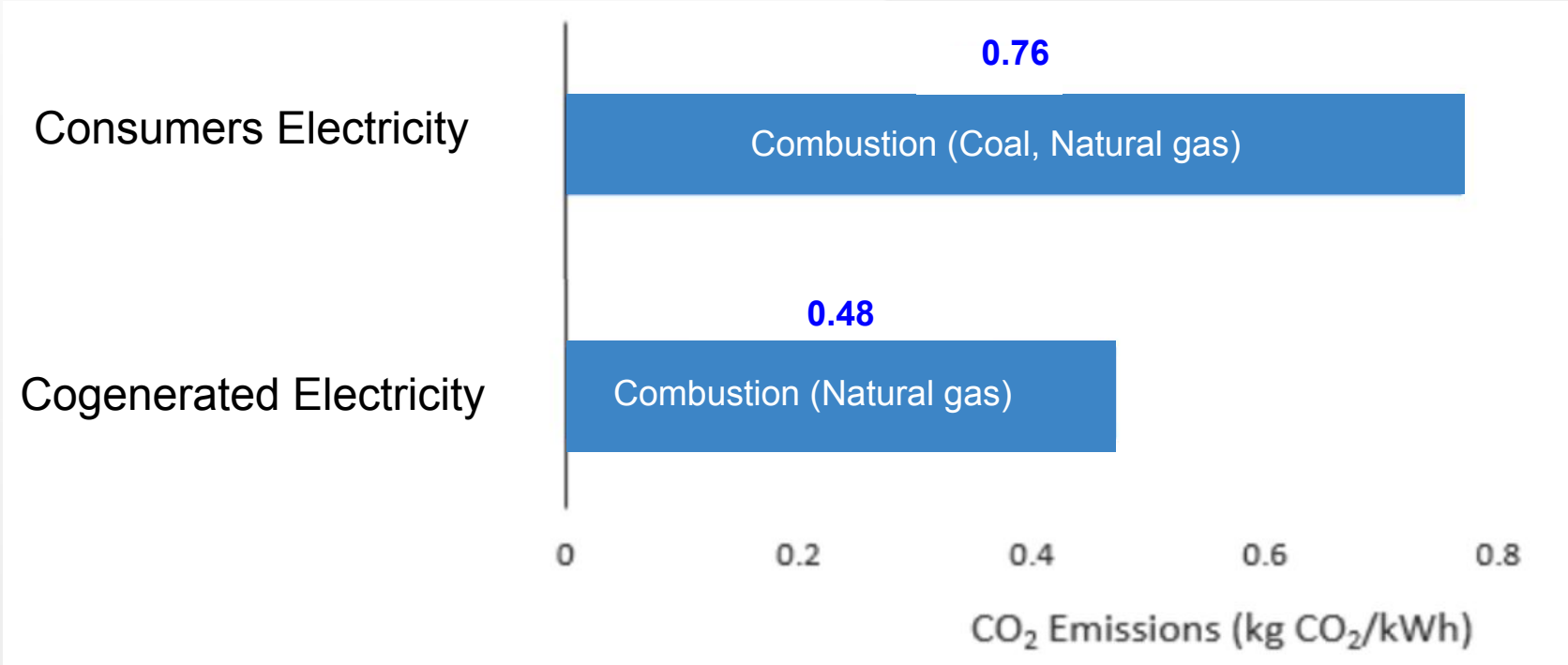
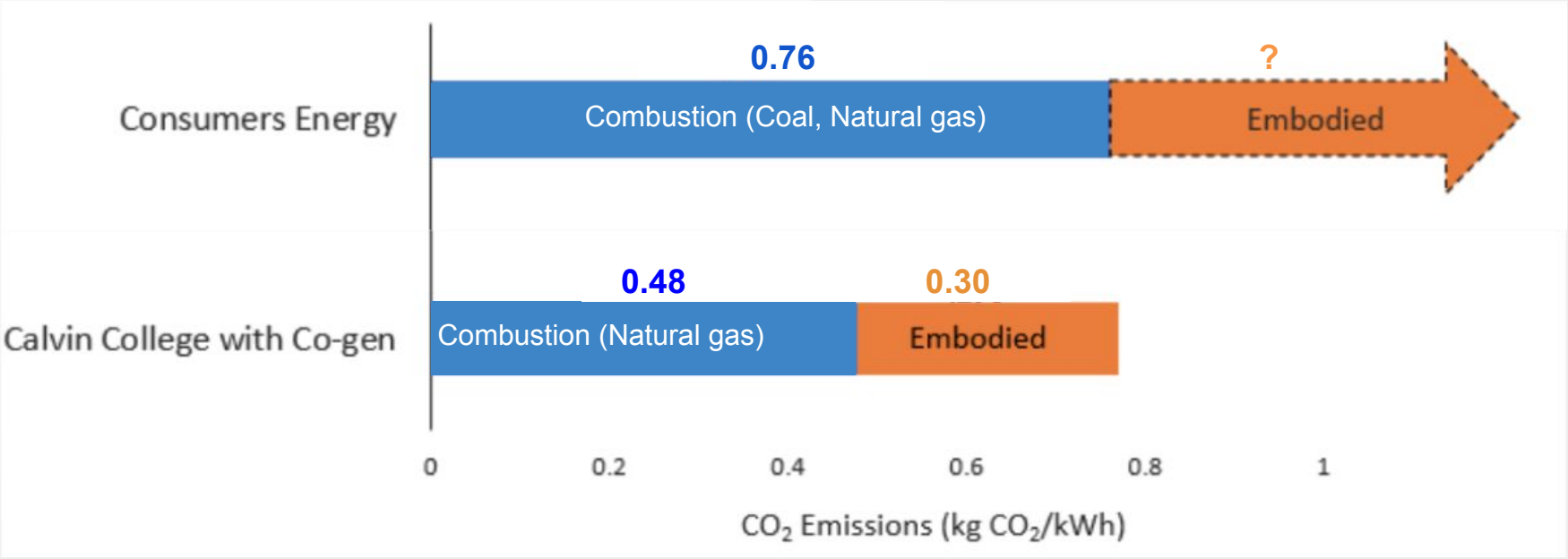
Cogeneration Emissions



Cogeneration Emissions



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Offset of Boiler Emissions

- “Waste” heat from Co-gen
- Reduce boiler operations
- Minimize boiler exhausts

https://www.google.com/search?q=boiler&source=lnms&tbm=isch&sa=X&ved=0ahUKEwjht

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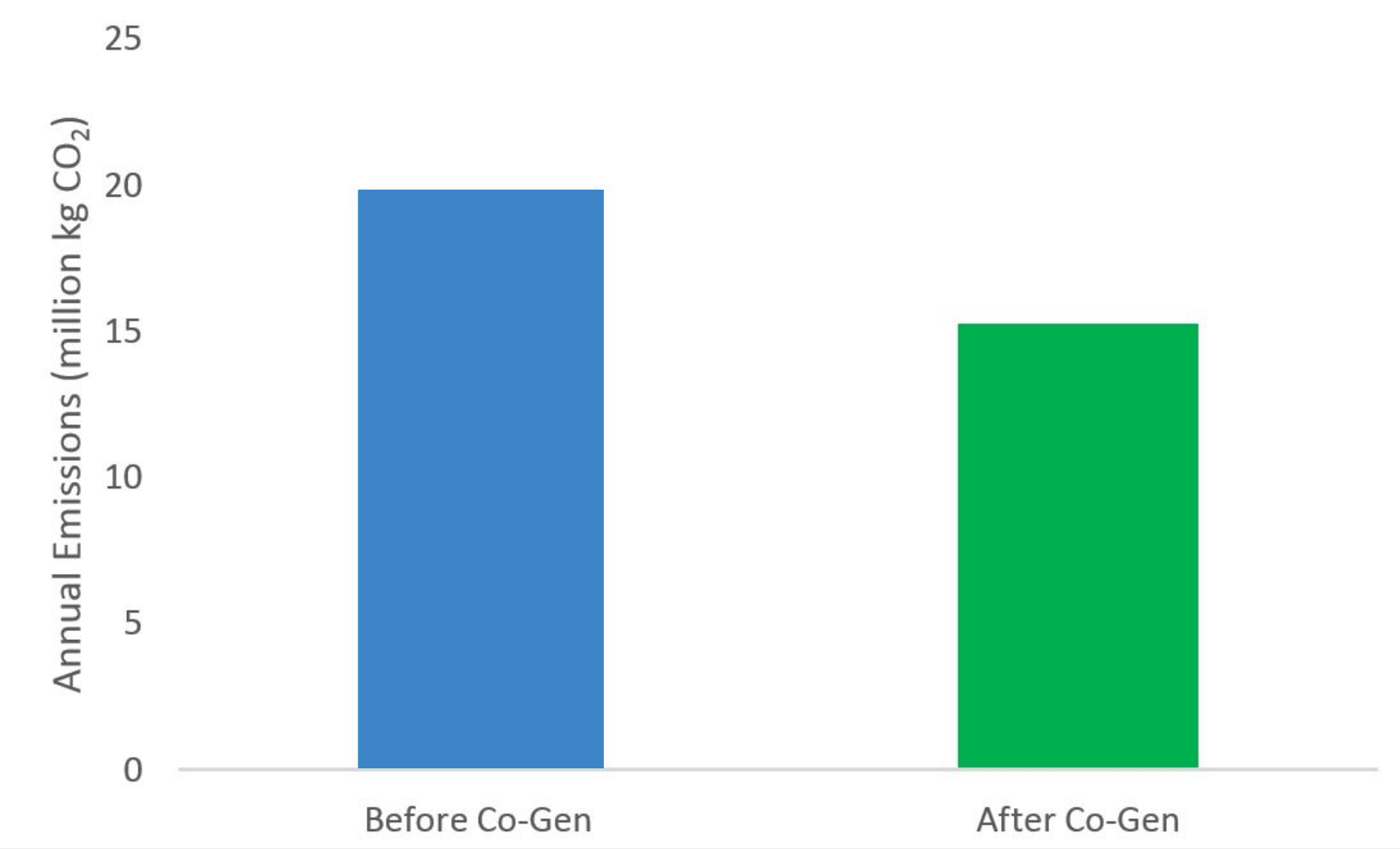
Cogeneration Emissions

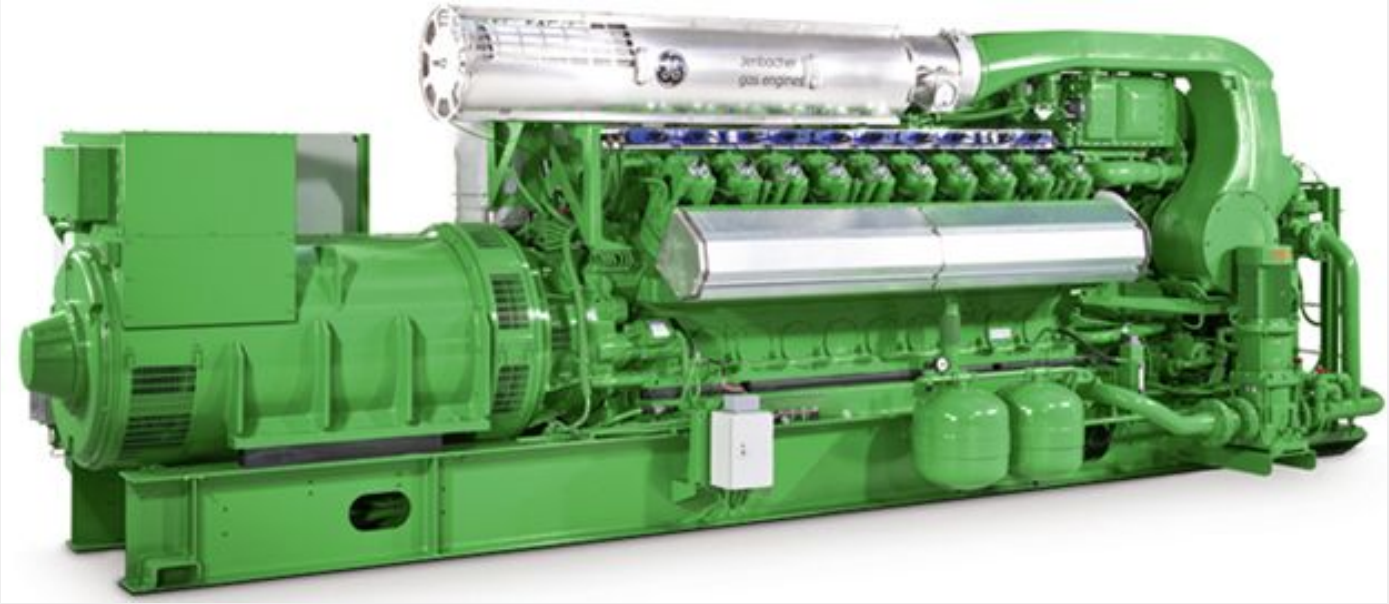


Engine Finance

Total upfront Engine Cost : $1,400,000

Assumptions

- Includes lifetime spare parts
- Calvin Installation



https://www.google.com/search?q=ge+jenbacher+j416&rlz=1C1GCEA_enUS773US773&source=lnms&tbm=isch&sa=X&ved=0ahUKEwjG7

Interconnections Finance

Total Infrastructure Cost: $95,000

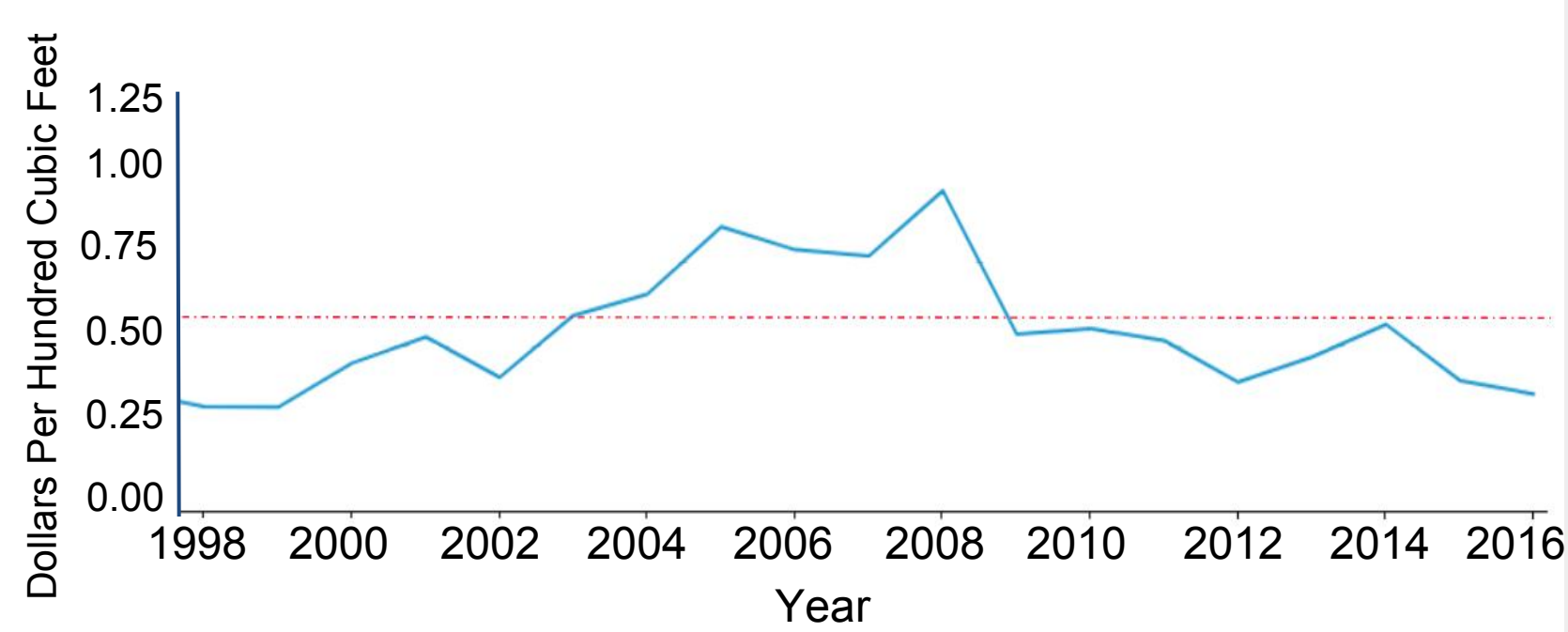
Expensive Components

- Concrete
- Cinder Blocks
- Roofing
- Gas Line
- Piping

https://www.google.com/search?q=building+materials&rlz=1C1GCEA

Gas Price Fluctuations

- Cost of natural gas
  - $0.53 /100 ft^3 ⟶ $0.038 /kWh



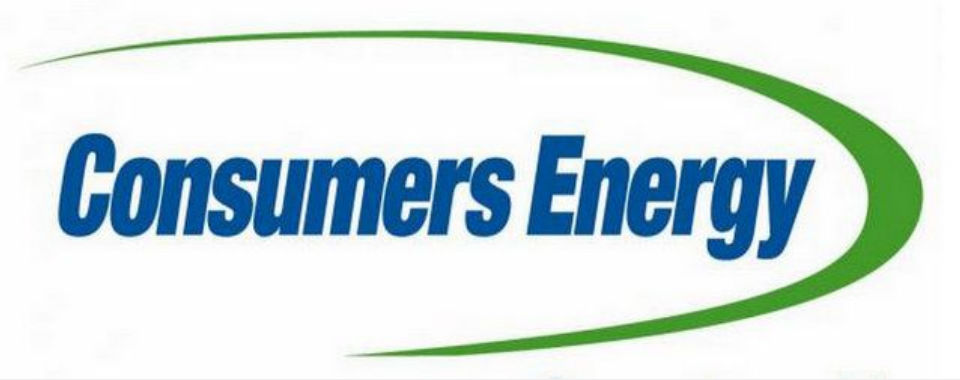
Cost Savings Calculations

Electricity Savings

- Considerations
  - Peak and Off Peak Rates
  - Winter and Summer Peak Rates
- 90 Percent Utilization

Gas Savings

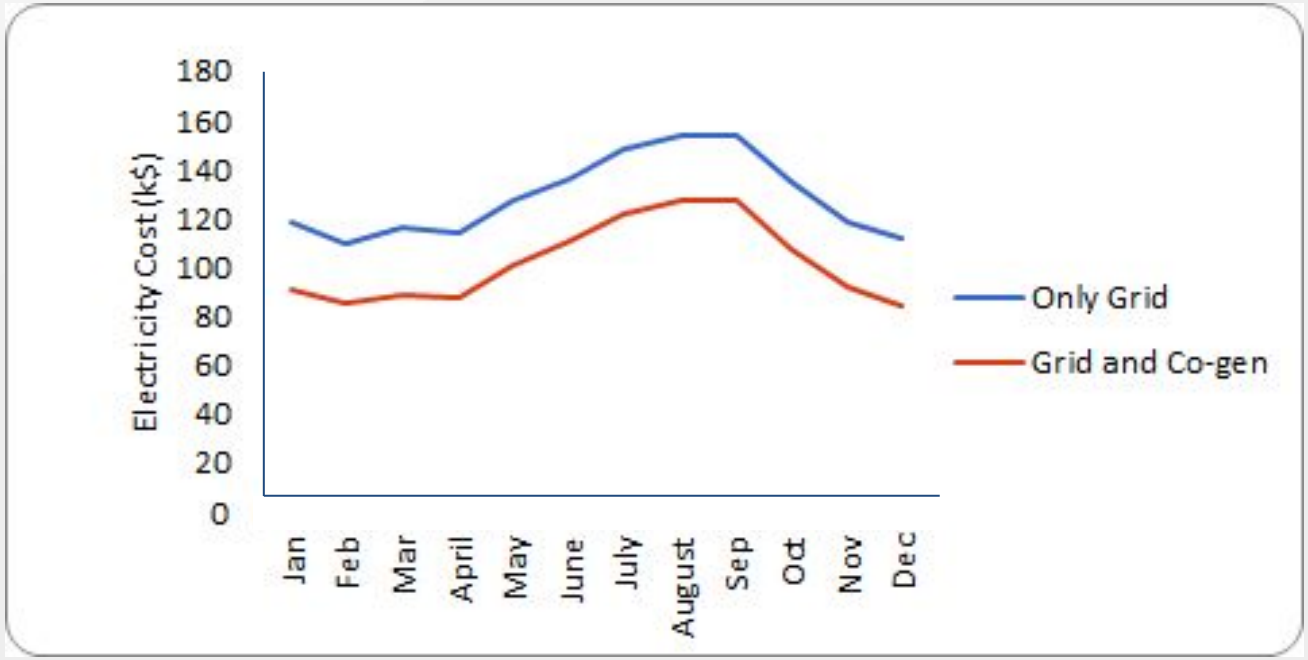
- Boiler Usage



https://www.google.com/search?q=consumers+energy+logo&rlz=1C1GCEA_enUS773US773&tbm=isch&s

Total Savings

Electricity Savings:	$319,000 /yr
Natural Gas Savings:	$187,000 /yr
Calvin Maintenance Cost:	($2,000) /yr
Total Savings:	**$504,000 /yr**



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Conclusion

	Goal	CO_2	Energy
Section A:		906 MT/yr	$89,000/yr
Section B:		18,950 MT/yr	$504,000/yr

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Acknowledgements

- Phil Beezhold, former Director of Physical Plant at Calvin College
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- Professor Richard De Jong, Sound/Vibrations Consultant
- Jared Cherni, GE Power Sales and Business Development Manager
- Professor Matthew Heun, ENGR 333 Instructor
- Engineering 333 Classes

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Questions?

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Appendix

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Section B: Co-gen Energy Savings

Financial Savings

Option 1: Fully Funded Co-gen

Annual Savings:
$504,000

Option 2: Bank Loan

Bank Loan: 4 years, 5% interest
Life of Cogen: 20 years

Avg Annual Savings:
$420,000 (4 year payback)

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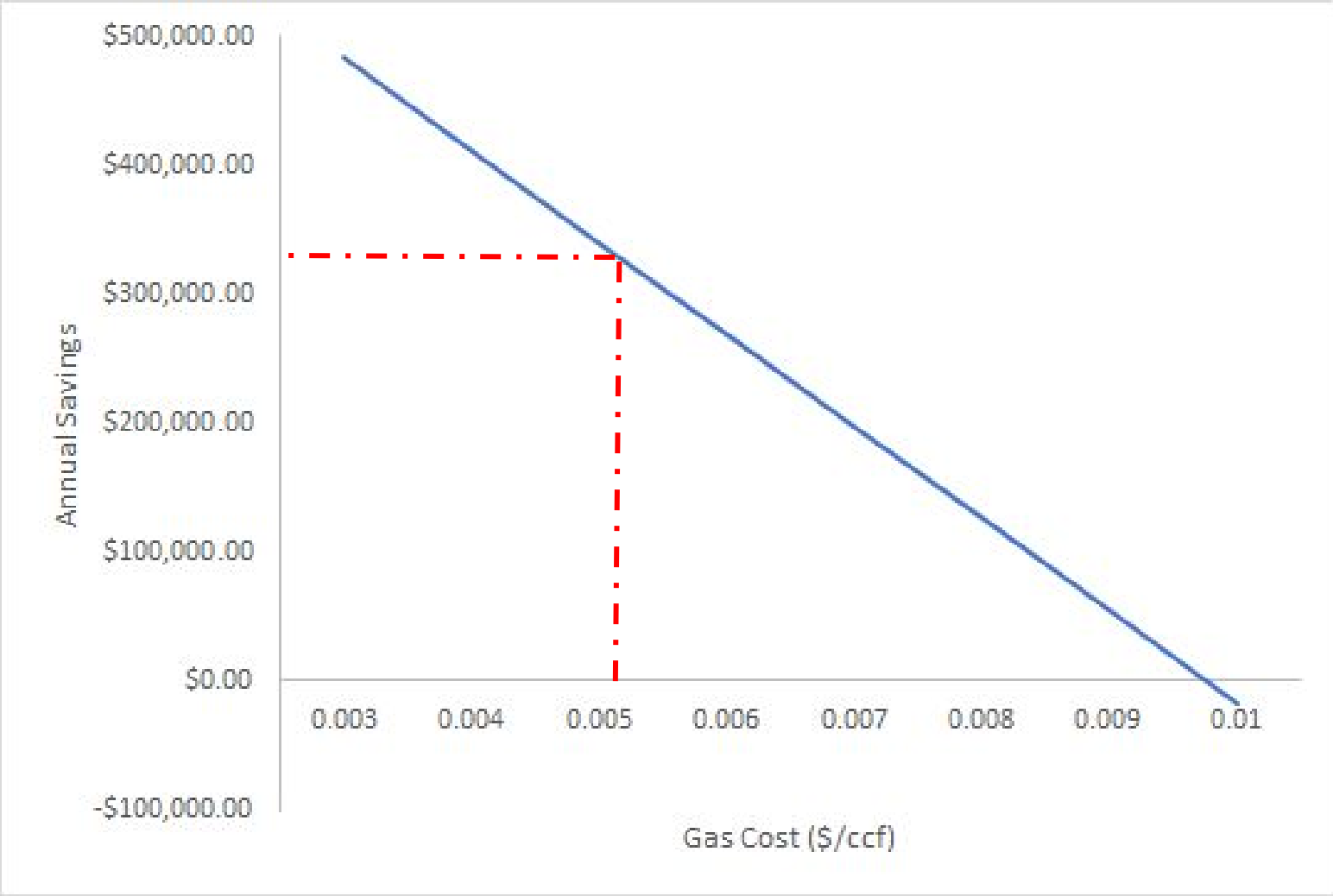
Electricity Savings Sensitivity



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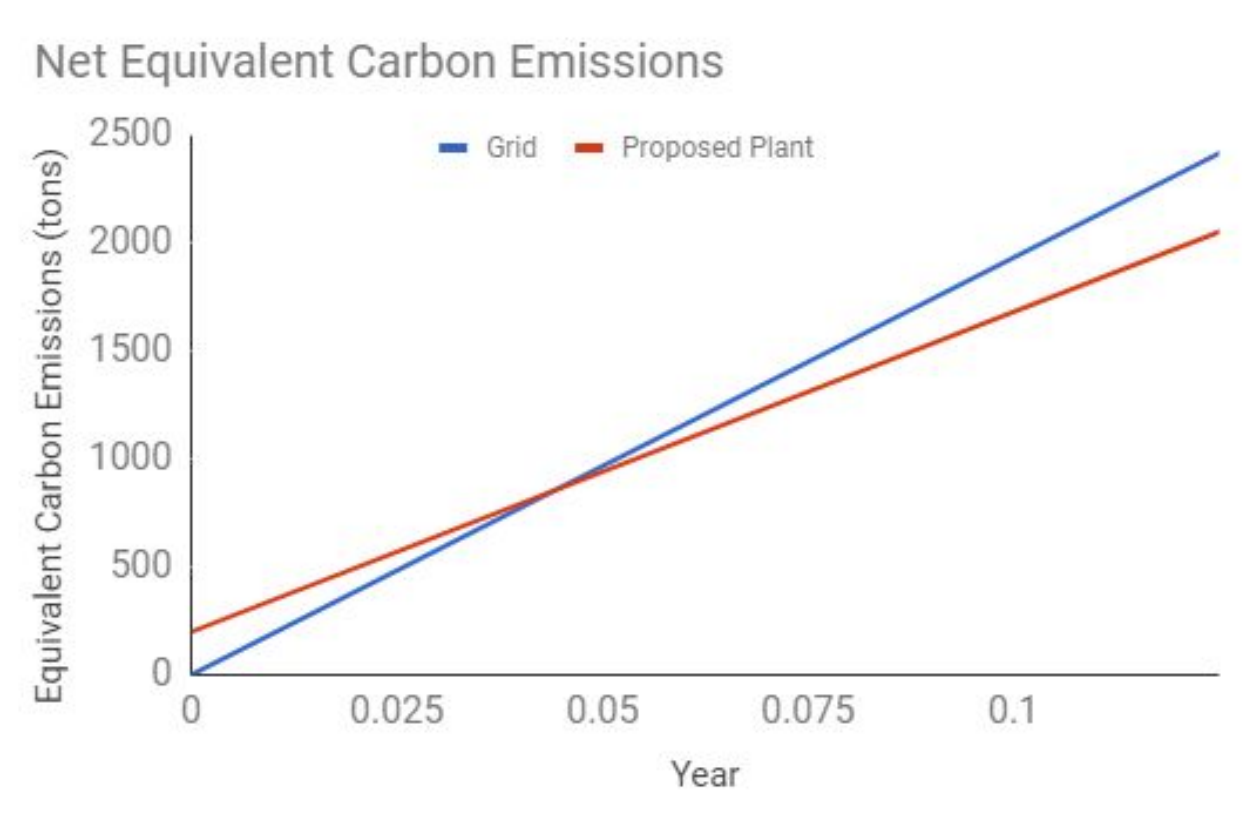
CO_2 Finances



- Carbon Difference
  - + 199 tons (Installation)
  - - 4,498 tons/year (Operation)
- Emission breakeven point
  - 16.1 days

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CO_2 Finances

- Total Savings
  $22,000 per year

- Astumptions
  - $5/ton carbon trade value

https://www.google.com/search?q=co2+images&rlz=1C1GCEA_enUS773US773&tbm=isch&source=iu&ictx=1&fir=0kTxaI62UWr98M%253A%

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