Emission Projection of Using Outdoor Heaters for Dining

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Objective

- To approximate the environmental impact of using outdoor heaters for restaurant dining during the upcoming winter.

- Main Questions:
  - How much energy will be consumed to support outdoor dining during winter?
  - What is the scale of emission associated with the energy cost?

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Background Context

- Practice of outdoor dining due to the pandemic
- Restaurants are investing in outdoor heaters for the winter
- The two main outdoor heaters are powered by electricity and natural gas (propane)
- Environmental Impact analysis

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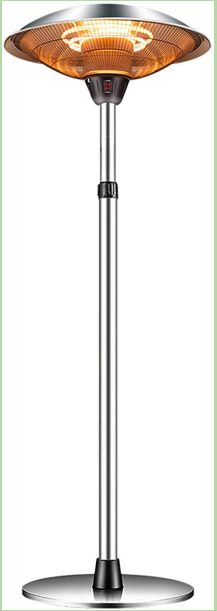

Electric

Propane

Motivation

- From 2010 to 2017, building operation is the most costly in terms of energy and CO_2 emission.
- Emission associated with restaurant operation will increase
- How will the use of outdoor heaters contribute total emissions?

Sector	CO_2e
Buildings & Facilities	1281
Street Lights % Traffic Signals	707
Vehicle Fleet	223
Transit Fleet	51
Employee Commute	779

Princeton's Greenhouse Gas Inventory

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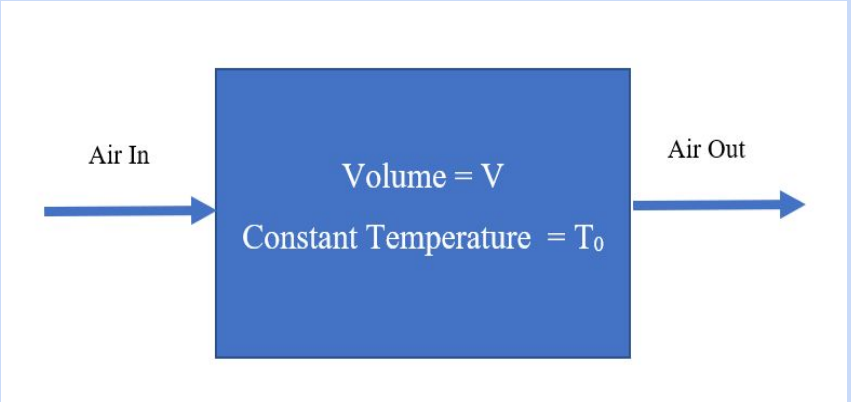
Methods

- Calculate the energy cost associated with its operation
- Heating and maintaining the temperature of a volume of space is related to:
  - How fast the air is exchanging with the surrounding
  - Temperature change
  - Properties of air
- Assumptions about dimension, air exchange rate, and operating hours



Methods (cont.)

- Data
  - 2019 Princeton weather report
  - Quantities associated with air
- $$C_3H_8 + 5\,O_2 \longrightarrow 3\,CO_2 + 4\,H_2O \qquad \Delta H = 2,044.2\ \text{kJ/mol at } 25^\circ\text{C}$$
- Determine the amount of propane is needed to generate the calculated energy demand
- Estimate the CO_2 emission from the quantity of propane

Electric vs Propane

- Electric heaters have issues with wires and outlets
- Propane heaters have fire safety installations
- Propane heaters have a higher output and are more efficient
- Propane heaters are typically cheaper

Type	Output
Electric	5000 BTU
Propane	36000-48000 BTU

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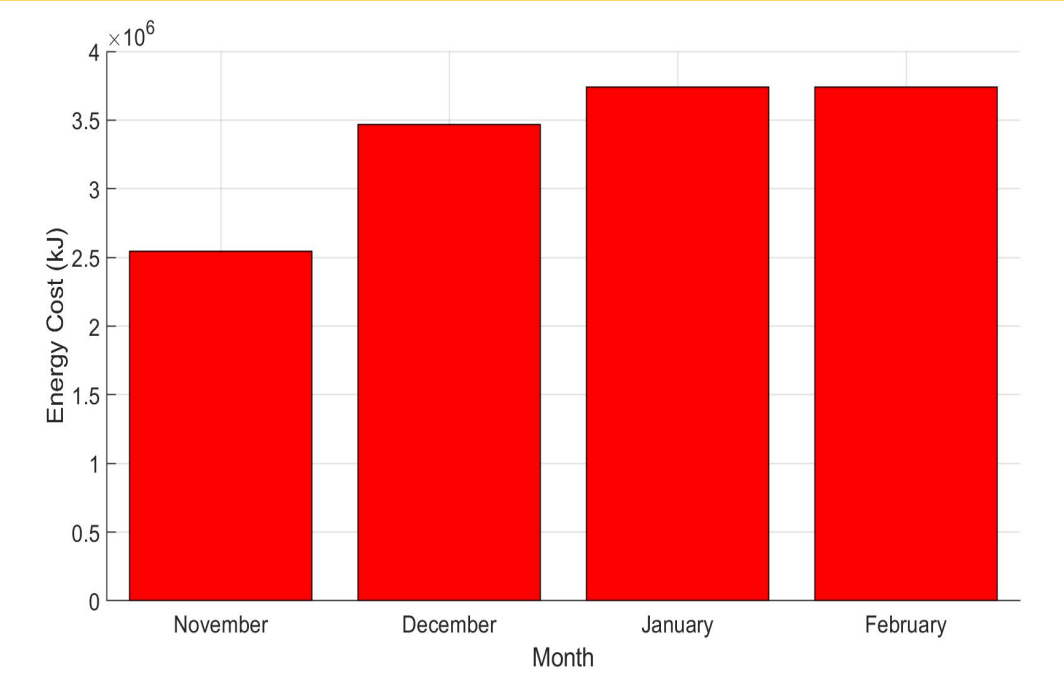
Energy Cost & Emission



Number of Heaters	Total Emission (metric tons of CO_2)
50	43.6

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Sensitivity Analysis

- Efficiency - The heater operates at reduced efficiency under 40 °F (4.44 °C)

- Affects the values for January and February

	95% Efficiency	90% Efficiency
Emissions in CO_2 (metric ton)	44.2	44.9
Percent Difference	1.46%	3.08%

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Conclusions

- 43.6-44.9 metric tons of CO_2 emission is anticipated by the consistent use of outdoor heaters in the upcoming months
- Average household produces about 60 metric tons of CO_2 in a year
- Results can fluctuate depending on operating hours, outdoor environment, and unexpected weather changes

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Thank You!

- Thank you to Christine for consistently providing updates and data for my analysis
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