Sustainable Radon Mitigation through Optimized HVAC Scheduling

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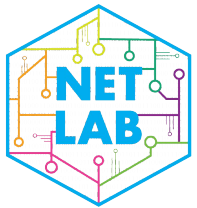

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Outline

- Motivation
- Experiment Design
- Evaluation
- Conclusion

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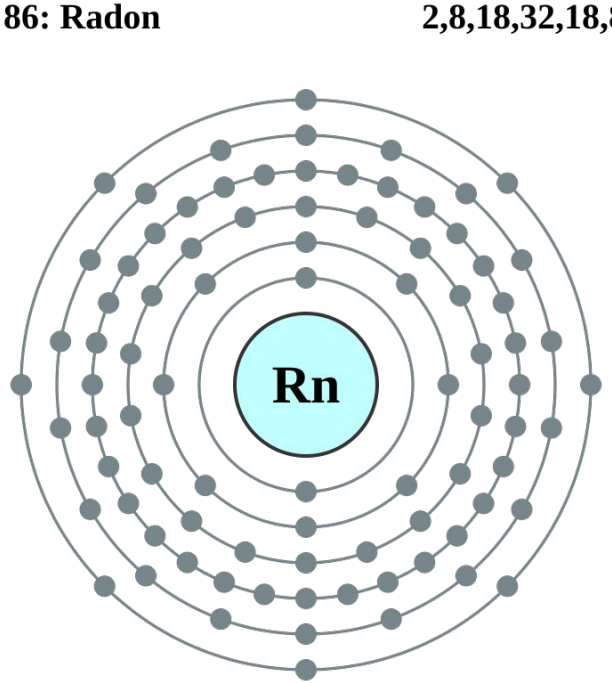
What is radon?

- Naturally occurring, toxic, radioactive gas
- Second leading cause of cancer in US
- Measured in picoCuries per Liter (pCi/L)
- EPA limit of <4.0pCi/L



https://hif.wikipedia.org/wiki/Radon#/media/file:Electron_shell_086_Radon.svg

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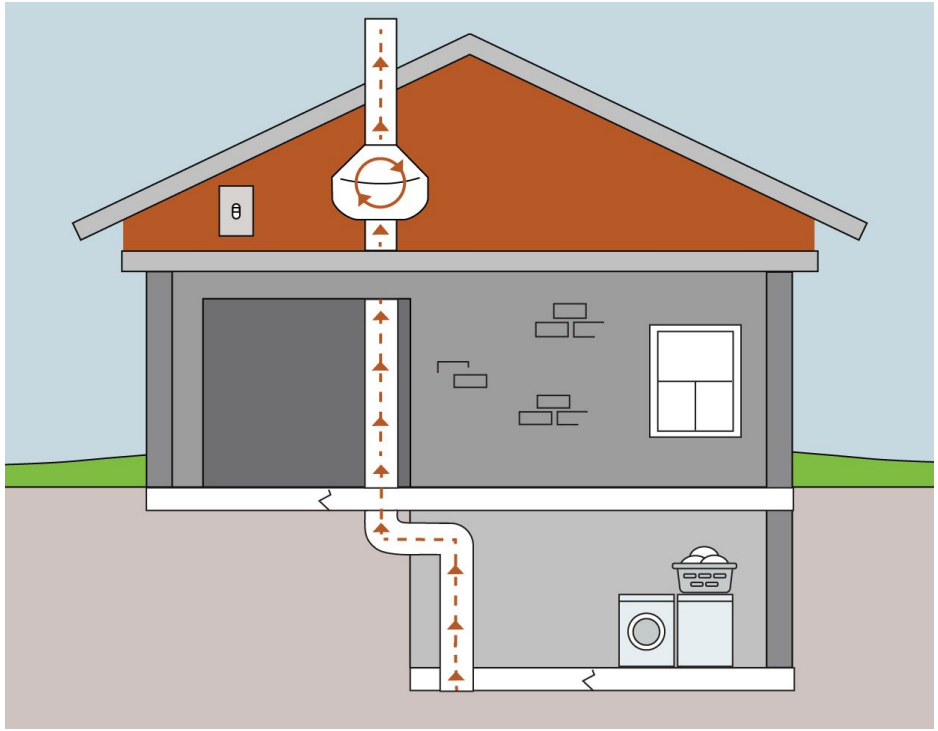
Radon Detection

- Passive radon detection
  - Activated Charcoal (short term)
  - Alpha Tracking (longer-term)
- Continuous Radon Monitors (CRM)
  - Every hour after burn-in period

Radon Mitigation

- Active methods
  - Collect and expel radon through dedicated pipes
- Passive methods
  - Sealing the building envelope
- Expensive on larger scale



https://www.protectenvironmental.com/wp-content/uploads/2024/07/Attic-Mitigation-garage.png

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The Problem

- Traditional methods are expensive and complex
  - Bigger footprint
  - Complex building envelope
- Increased exposure to faculty and staff

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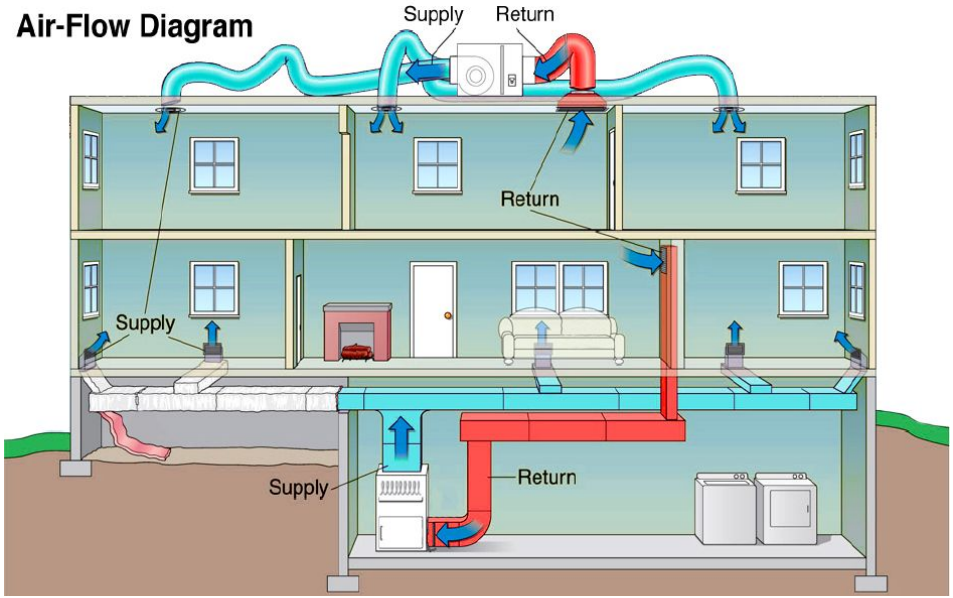
Our Solution

1. Characterize radon with CRMs
2. Identify times with highest exposure
3. Develop optimized HVAC schedule
4. Incur as little extra cost as possible



https://hvacrschool.com/wp-content/uploads/2021/07/airflow.png

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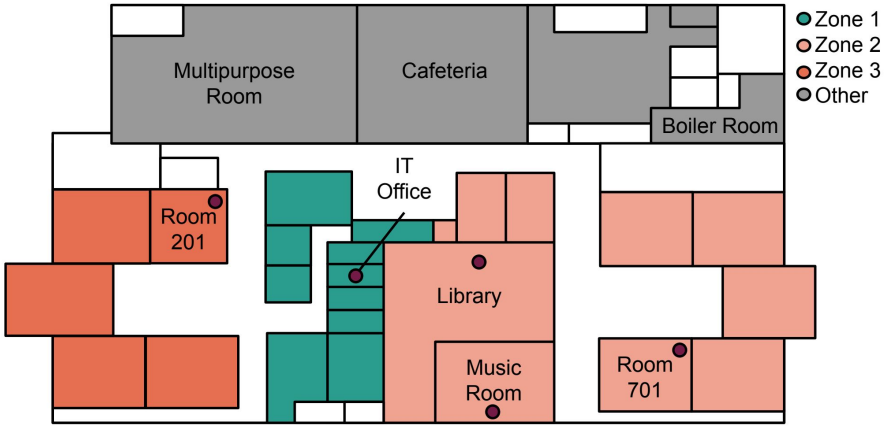
Experiment Setup

- Place radon sensors in 3 different HVAC Zones



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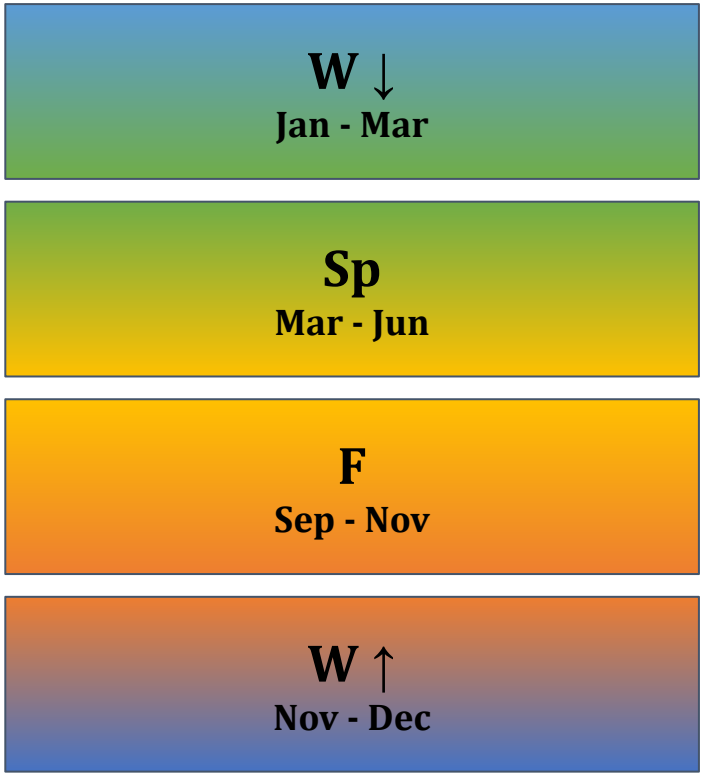
Experiment Seasons

- Place radon sensors in 3 different HVAC Zones
- Measure for a year, excluding summer



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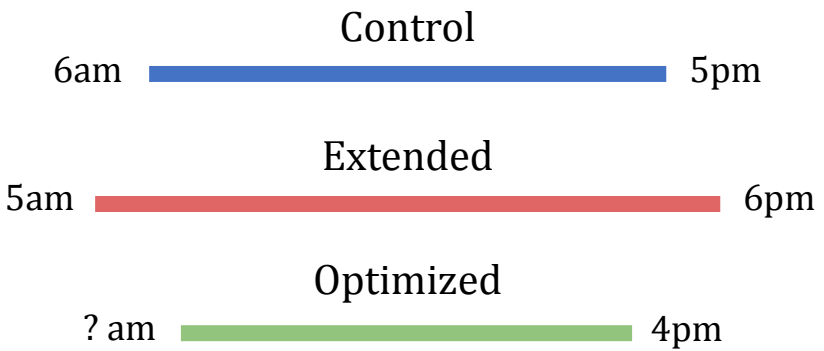
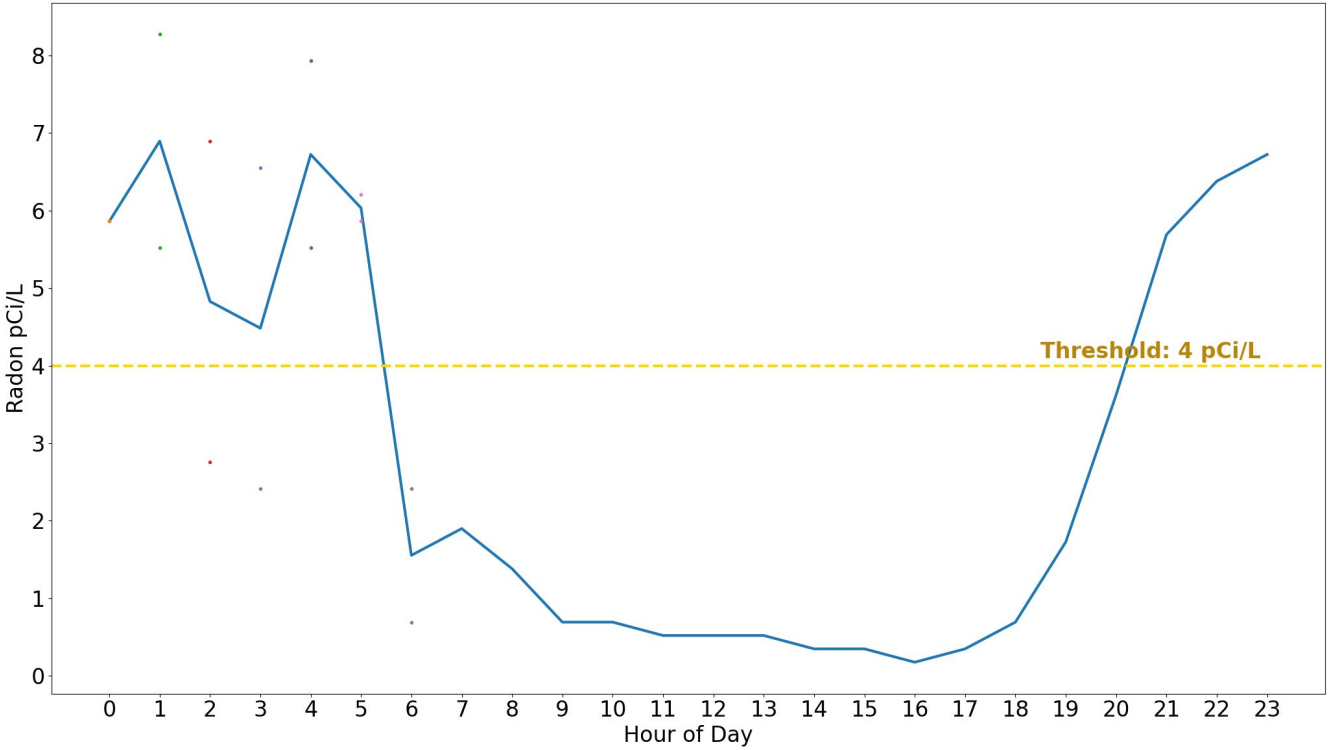
Experiment Schedules

- Place radon sensors in 3 different HVAC Zones
- Measure for a year, excluding summer
- Three different periods
  - Control
  - Extended
  - Optimized



Optimized Schedule Derivation

- Average radon values by hour of day by day



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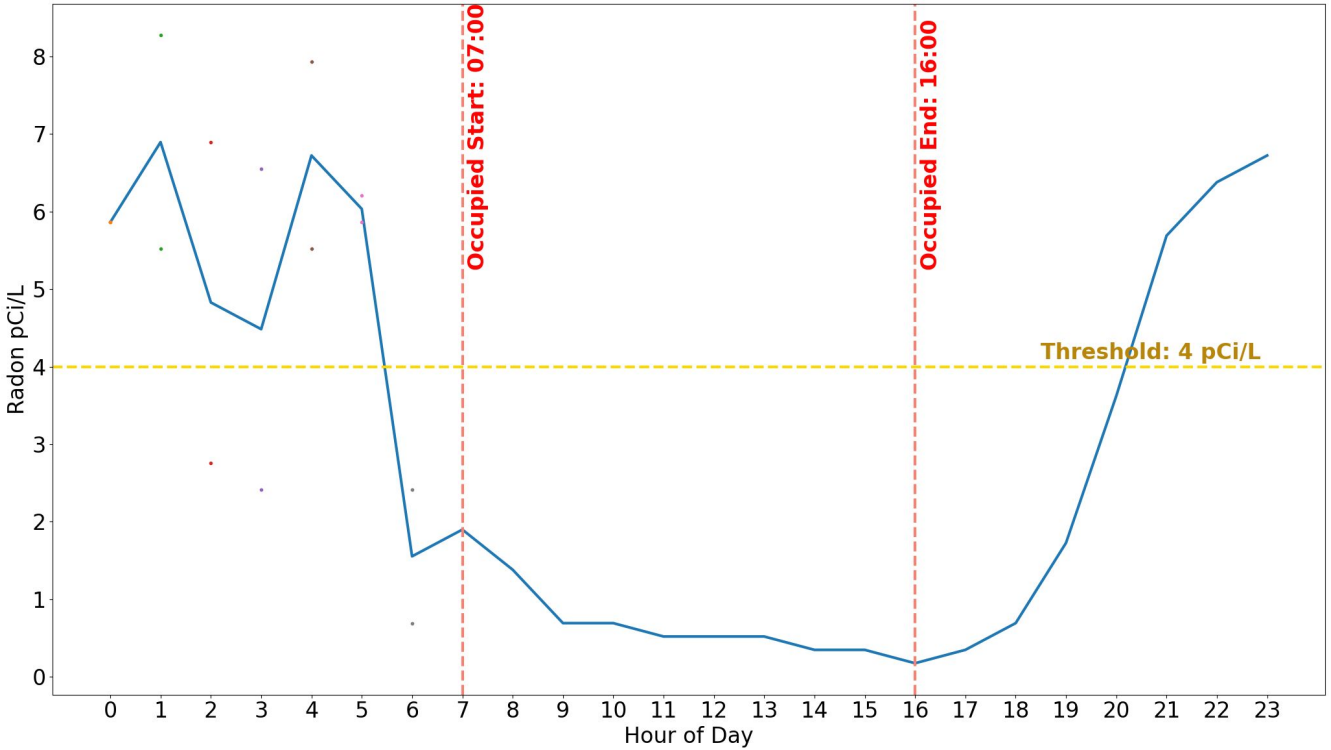
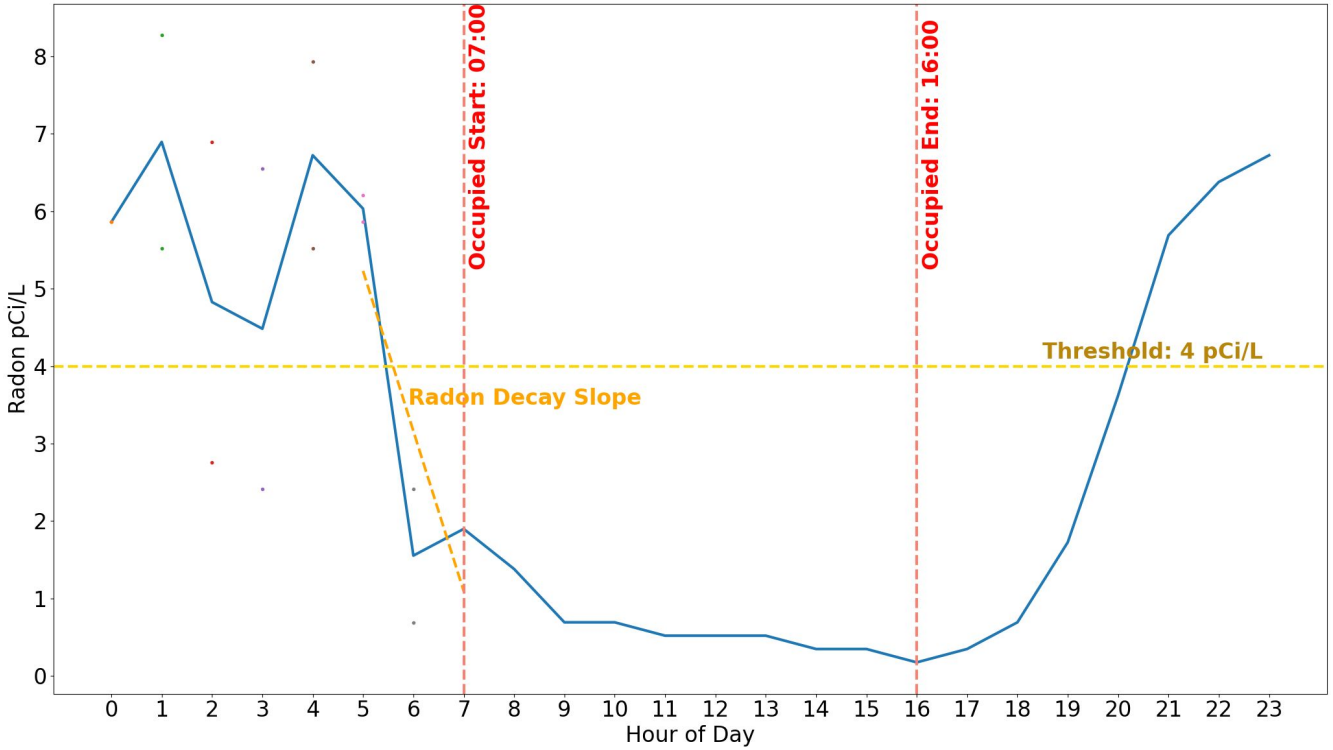
Optimized Schedule Derivation

- Use building's occupied time as frame of reference



Optimized Schedule Derivation

- Characterize radon decay by linear regression



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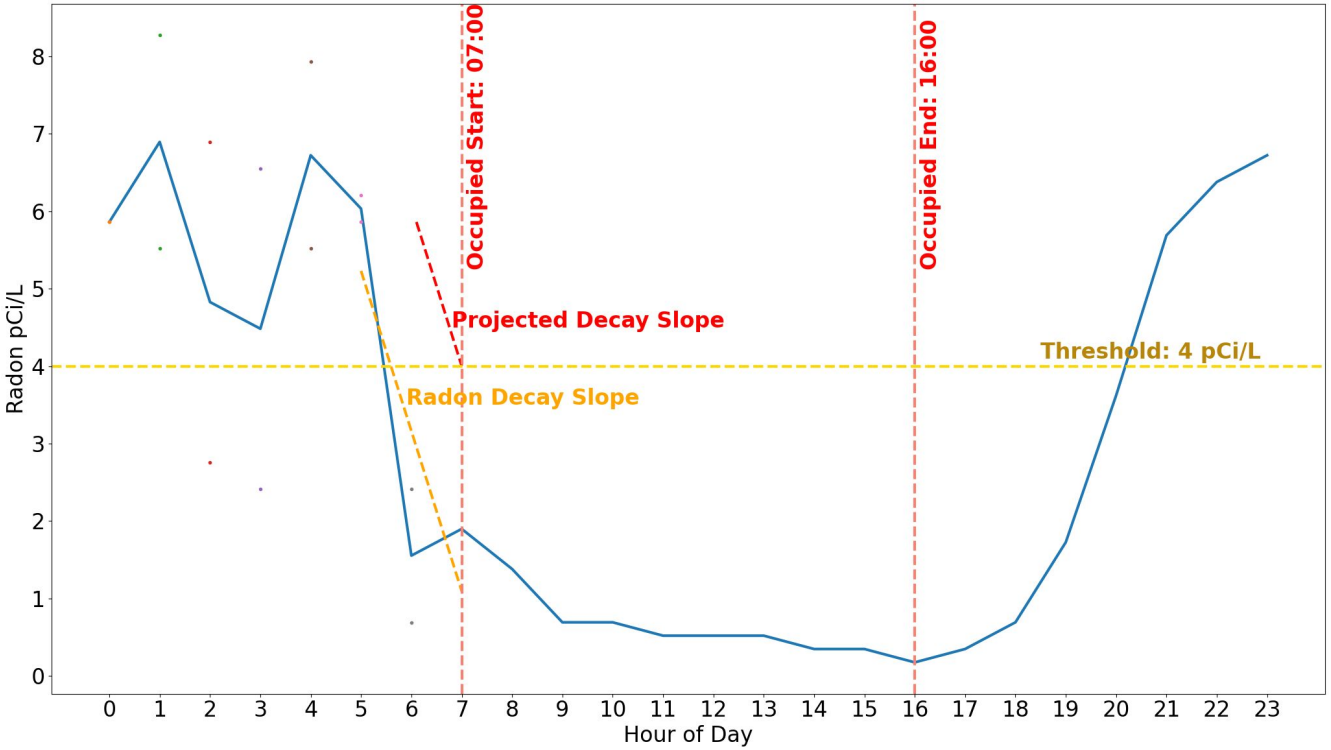
Optimized Schedule Derivation

- Shift the slope to reach threshold at occupied start



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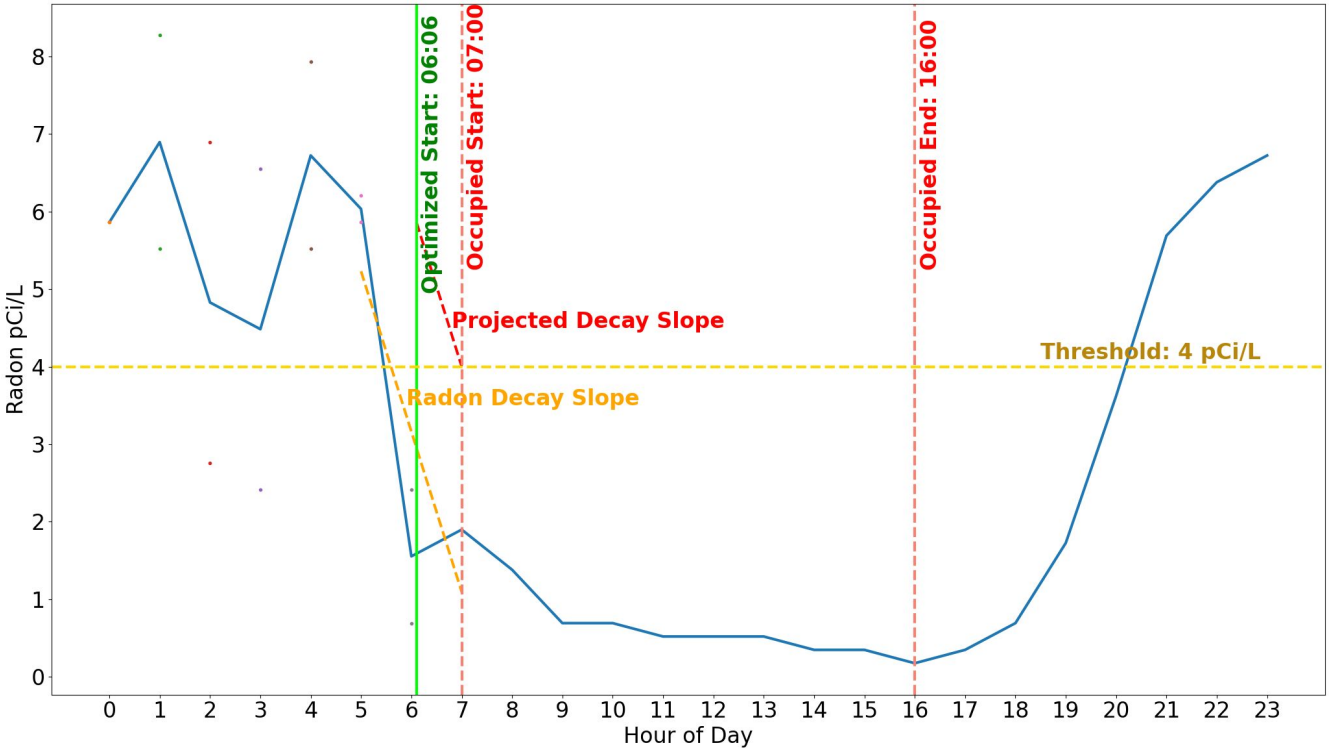
Optimized Schedule Derivation

- Determine start time from projected decay slope



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HVAC Start Time

- Compare control start times with optimized start times
- Saved multiple hours per week

DoW	M			T			W			Th			F		
Zone #	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
W ↓	**05:33**	06:55	07:00	06:23	06:44	07:00	**05:48**	7:00	07:00	**05:38**	07:00	07:00	06:12	07:00	07:00
Sp	**05:15**	**04:40**	07:00	07:00	07:00	07:00	06:49	06:49	07:00	07:00	07:00	07:00	**05:12**	07:00	07:00
F	07:00	07:00	07:00	07:00	07:00	07:00	07:00	07:00	07:00	07:00	07:00	07:00	07:00	07:00	07:00
W ↑	07:00	**05:08**	07:00	07:00	07:00	07:00	07:00	07:00	07:00	07:00	07:00	07:00	07:00	07:00	07:00
Saved	0:42	**-0:17**	4:00	3:23	3:44	4:00	2:37	3:11	4:00	2:38	4:00	4:00	1:24	4:00	4:00

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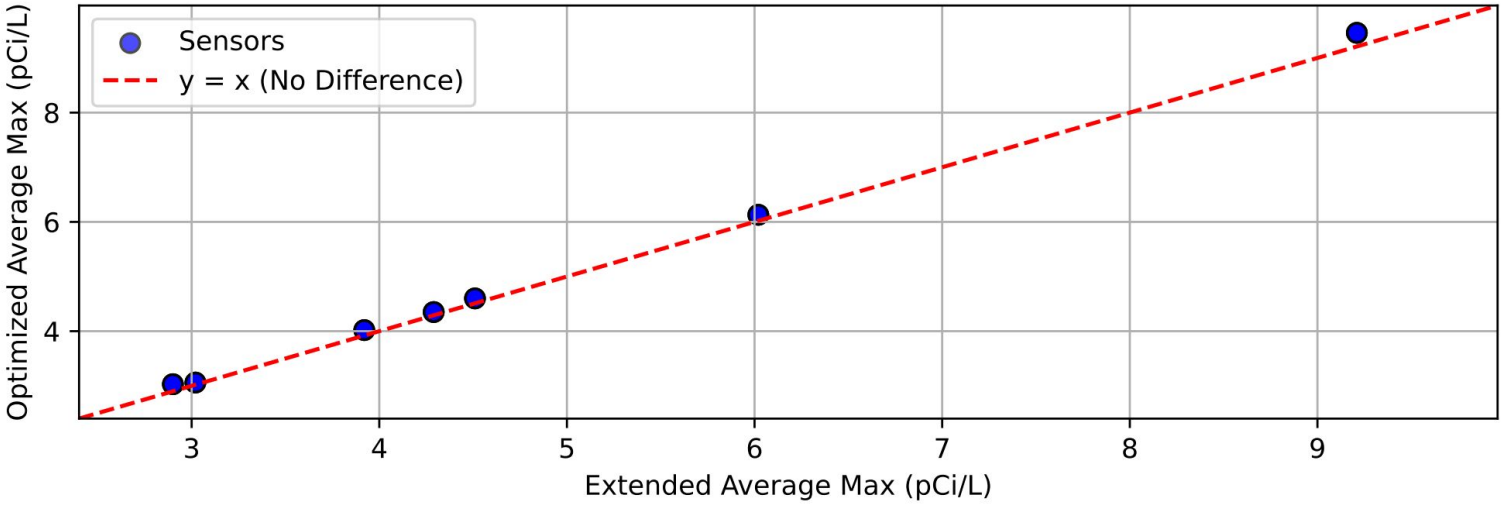
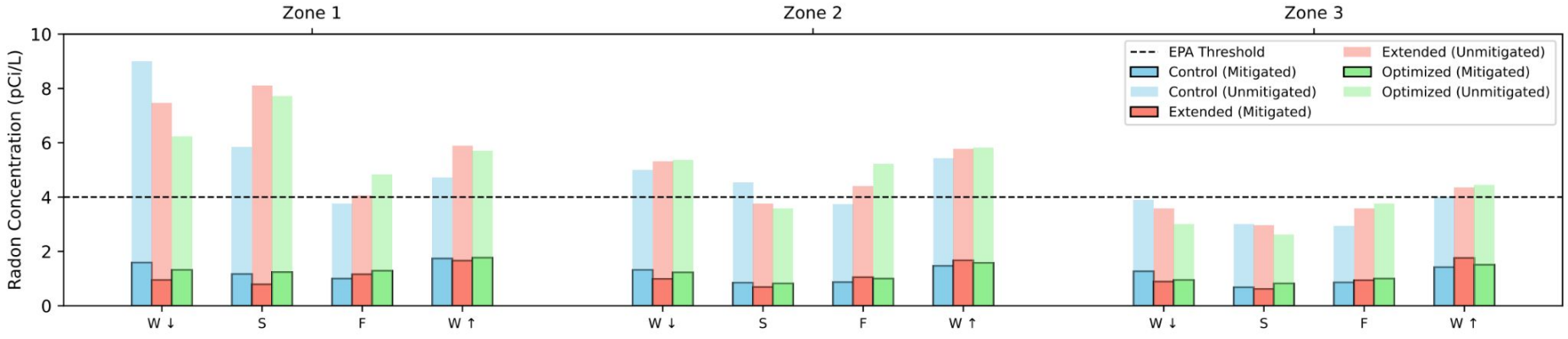
HVAC End Time

- End times make no difference on radon saturation
- Saved additional hour of operation time per day



Health Impact

- Overall radon exposure decreased with active mitigation across all zones and seasons



Obstacles Encountered

- Not allowed to automate
  - Person-in-the-loop
  - School schedule
- Optimized schedules can make people uncomfortable
  - Either too warm/cold if too early/late

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Conclusion

- Our framework successfully provides a targeted approach to mitigating radon with the HVAC
- Saves time and energy
- Designed to fully integrate into schools with any level of access to HVAC system

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Questions?

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