Next Generation NZE: *Inheriting the Good Genes*

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Objectives for today

- Compare the performance of two generations of NZE structures**: 10 to 47% improvement**
- Compare the performance of **innovative energy saving control strategies**
- Demonstrate **user preference & behavior** on **energy consumption**

Project FROG:

"Flexible Response to Ongoing Growth"

Buildings area: 1,280 sf

1st generation - Frog

Kawaikini New Century Public Charter School, Lihue, Kauai (2013)

Ilima Intermediate School, Ewa Beach, Oahu (2010)

Middle and high school classrooms

Buildings area: 1,440 sf

2nd generation - Frog

University of Hawaii at Manoa Campus, Oahu (2015-2016)

Designed to actively engage users while utilizing partially automated controls

K-12 and university classrooms

Features to manage energy and comfort

Energy Efficient Design
- Orientation, insulation, high performance glazing

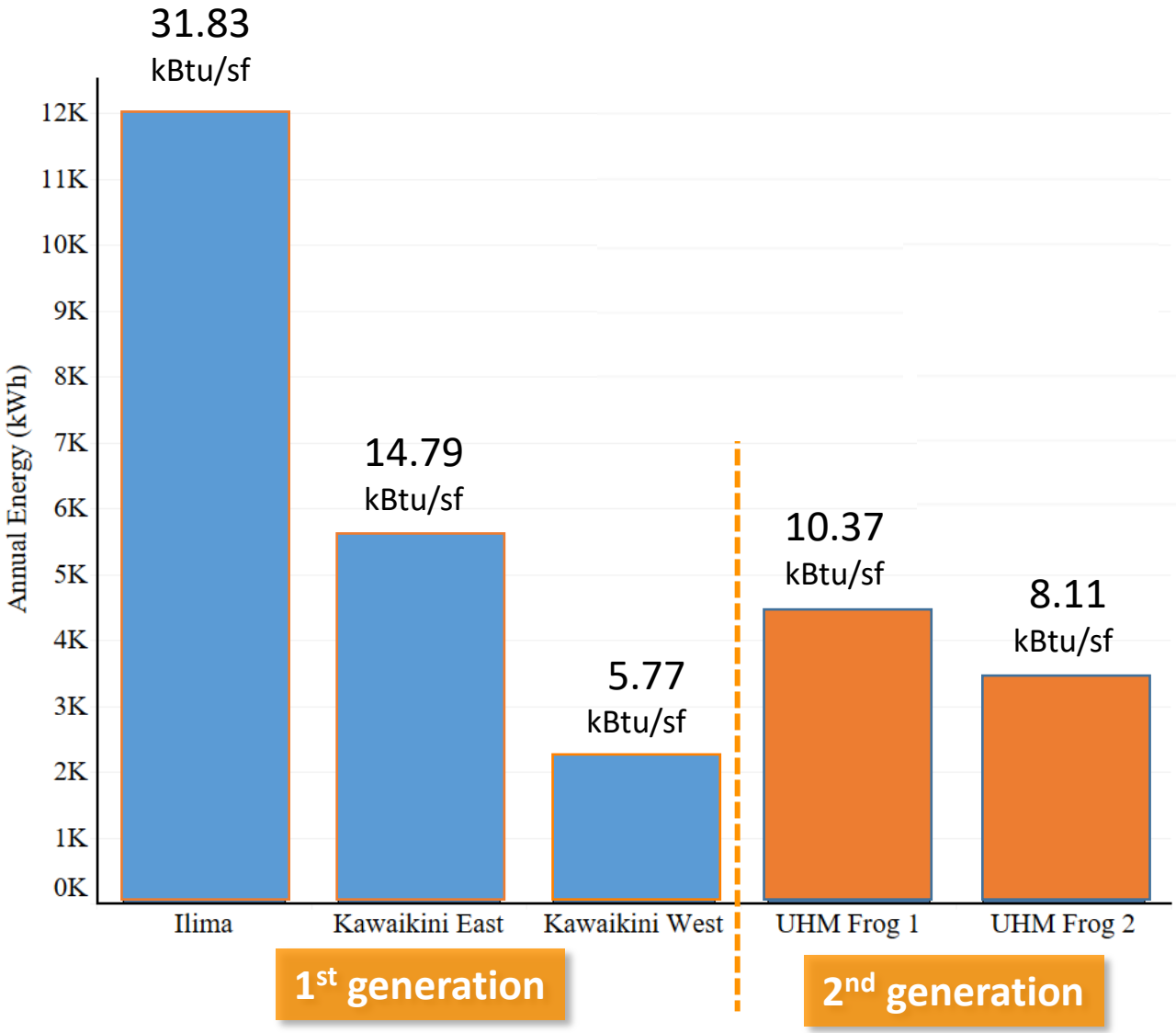
Lighting
- Daylight harvesting LED fixtures w/ O.S.
- Optional during day

Windows and daylighting
- Operable windows north and south. High clerestory windows

Ceiling Fans
- Air movement across skin
- Standalone or augments the HVAC

Air Conditioning
- Designed for mixed mode, higher delivery temp; 1 hour *ON-DEMAND* timer/thermostat
- AC will cycle to OFF between classes and not run unless activated

Comparative results



Average EUI

1st generation Frog Average

17.46 kBtu/sf-yr

2nd generation Frog Average

9.24 kBtu/sf-yr

Overall Savings

47.8%

2nd Generation

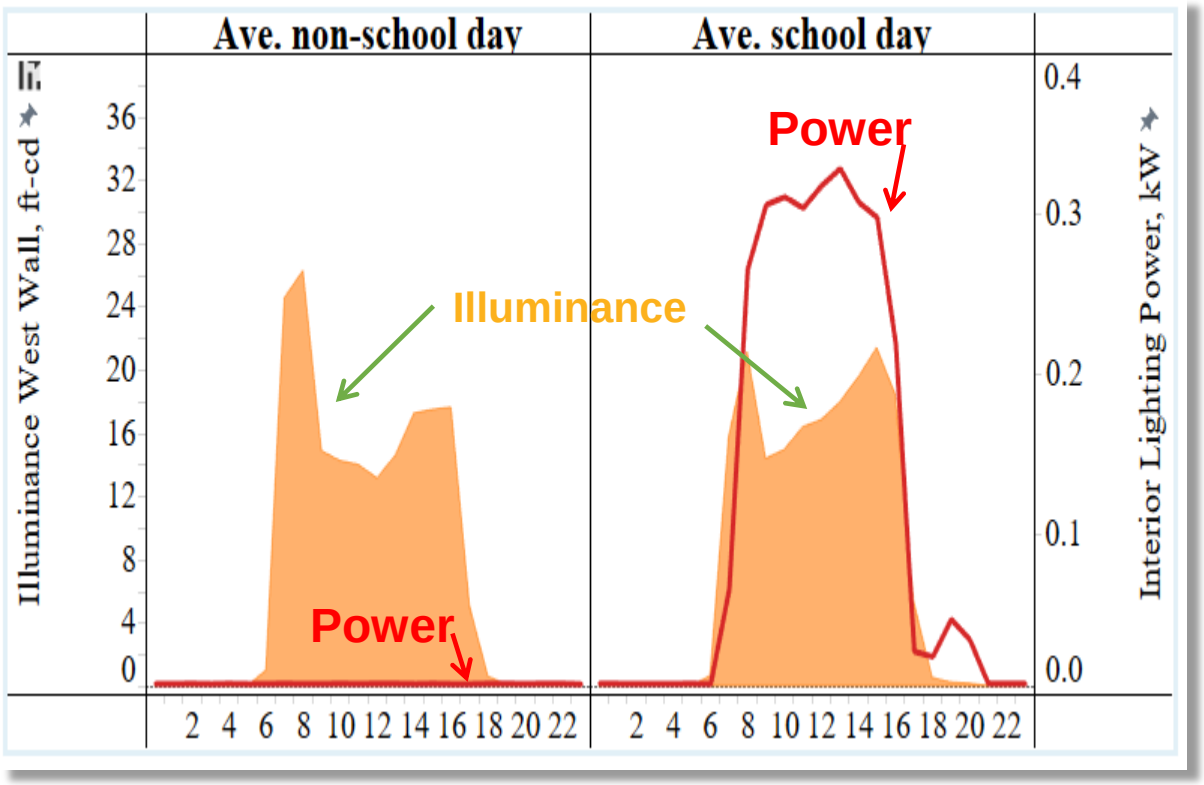
2nd generation Frogs

Designed to actively engage users
integrating partially automated controls:

- **Lighting** – daylight harvesting sensors
- **HVAC** – On-Demand control
- **Ceiling fans** – 100% manual

Daylight harvesting & lighting controls

- Occupancy Sensors
- Daylight harvesting system
  - Energi Savr Node™ lighting management system by Lutron
  - 2 sensors per classroom
- Manual override for 100% daylighting



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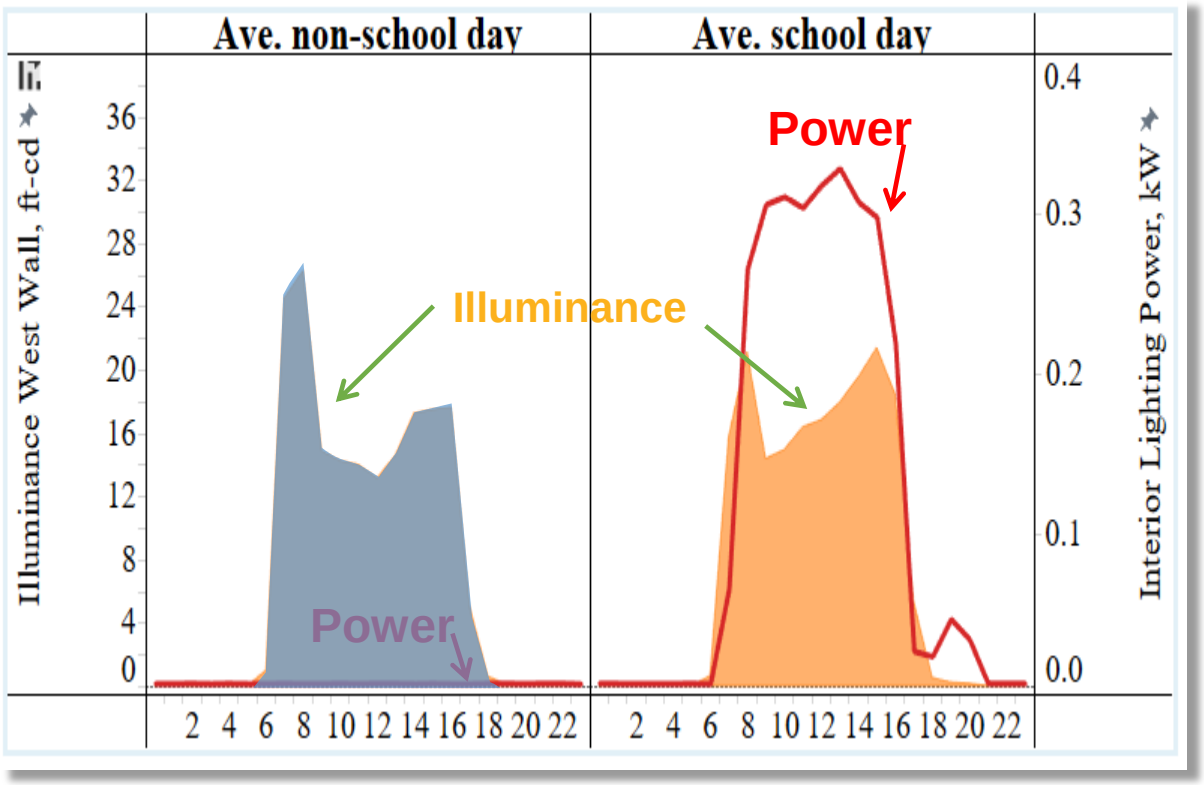
Energy Savings: Lighting



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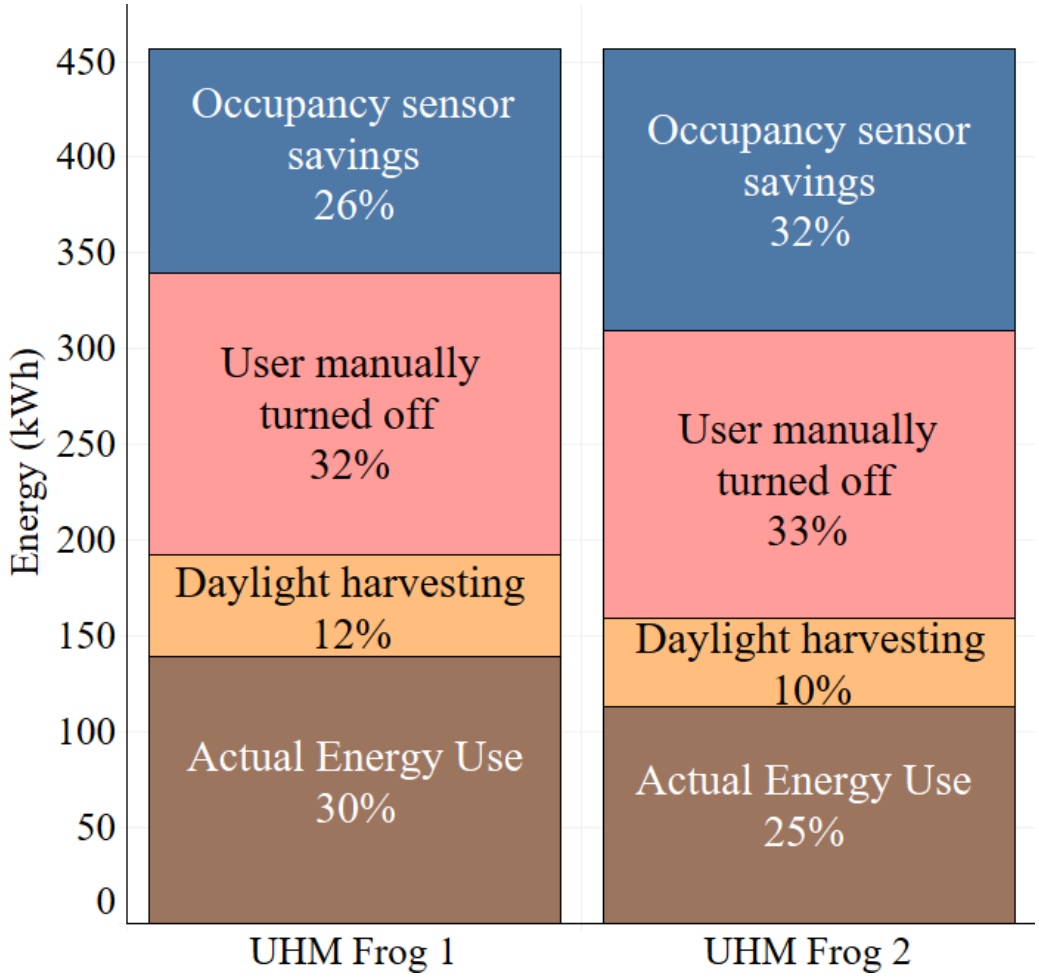
Actual energy used & percentage of savings



Full semester & school days

FINDINGS

- 457 kWh with no controls & lights at full brightness from 7:00am to 7:00pm
- The most effective intervention is manual

HVAC Controls

- Mixed Mode
- On-Demand HVAC control
  - ON: Manual override only
  - OFF: Auto-off in 1 hour

- Temperate climate
- Natural ventilation often sufficient
- Class schedules vary
- Ceiling fans augment ventilation to bring into comfort zone

Decisions: To cool or not to cool?

Ex. 1

FROG 1

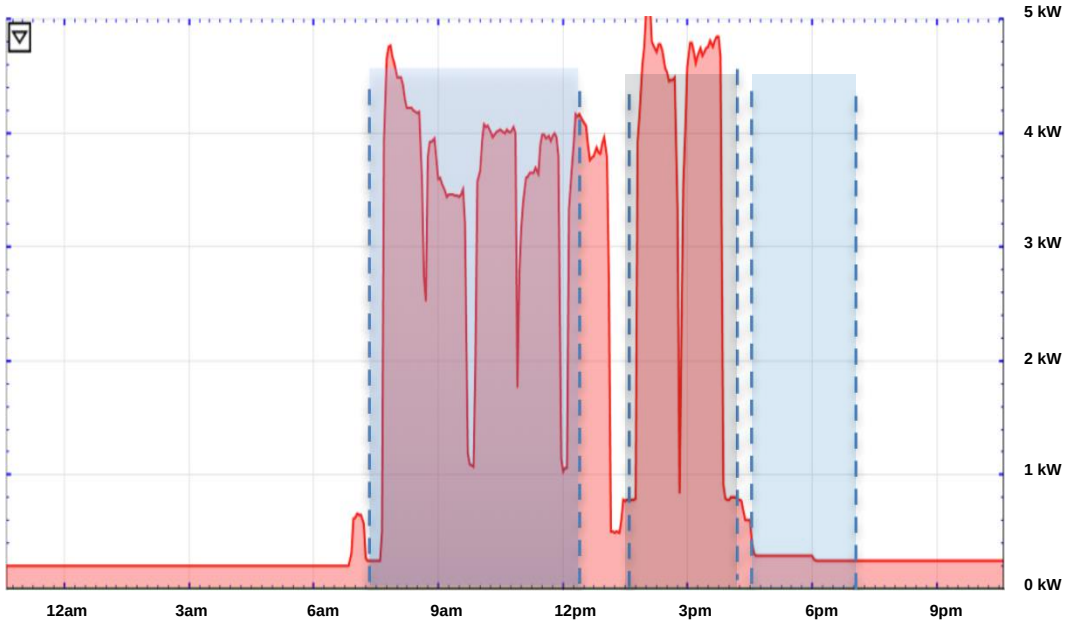
Mon, Aug 28

Occupancy hours: 7.30am-12.30pm; 1:45pm-4:15pm

FROG 2

Mon, Aug 28

Occupancy hours: 7.30am-12.30pm; 1:45pm-4:15pm; 4:30pm-7:00pm



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Decisions: To cool or not to cool?

Ex. 2

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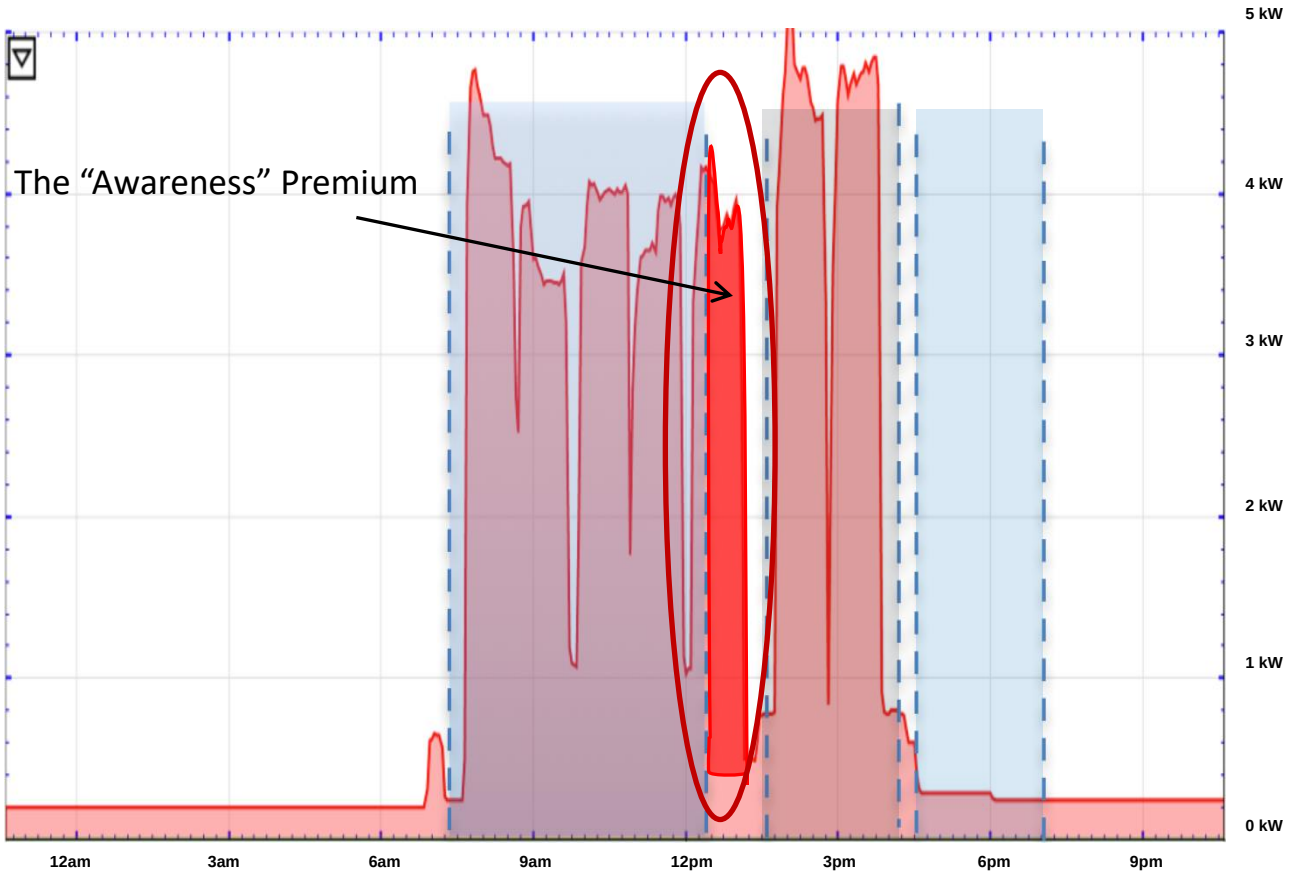
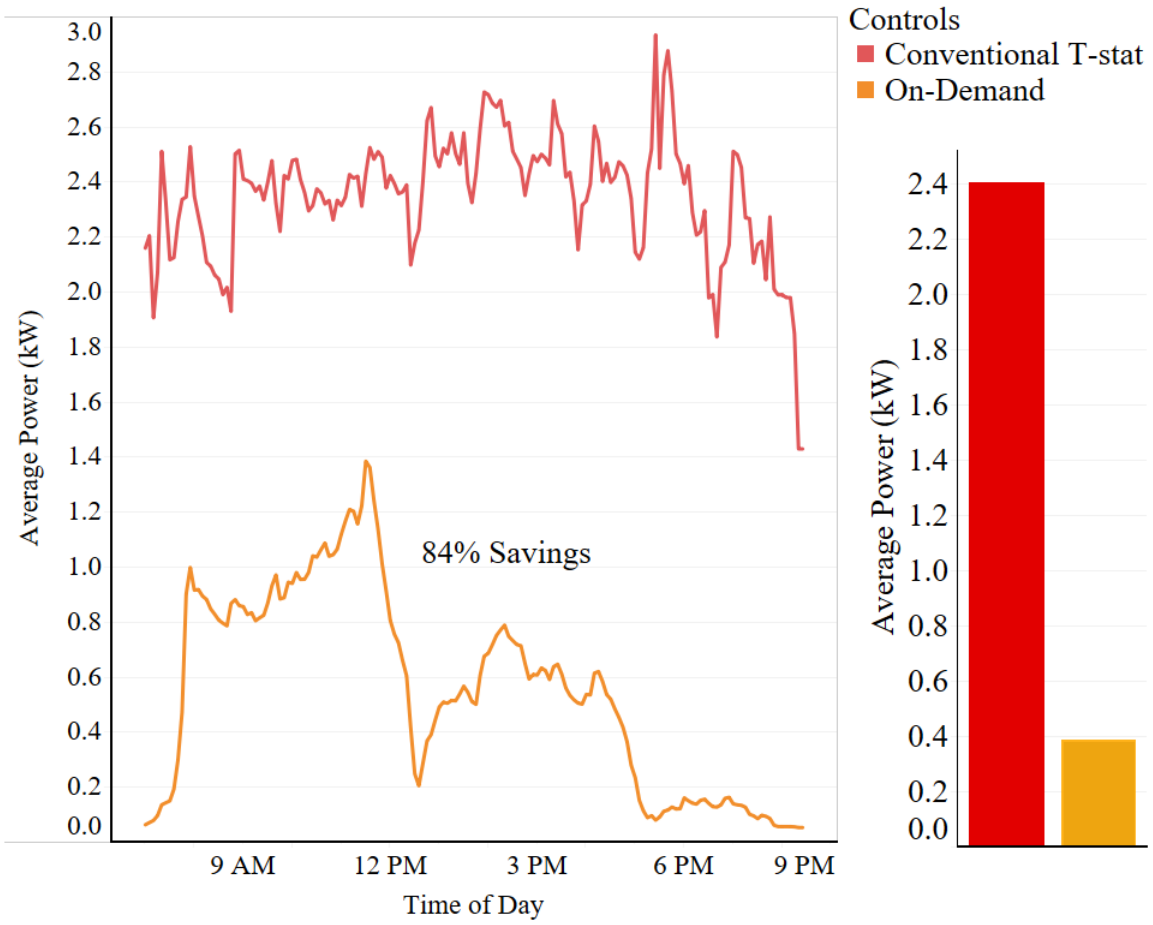
FROG 2

Mon, Aug 28



Conventional vs On-Demand HVAC control



5 minute average data

FINDINGS

- 84% savings over conventional thermostat
- Usage floats with existing class schedules and outdoor conditions

Education, behavior and engagement

Tragedy of the commons

"Individual users, acting independently and rationally according to their own self-interest, behave contrary to the common good of all users."

- Garrett Hardin -

Engagement

Training Users:

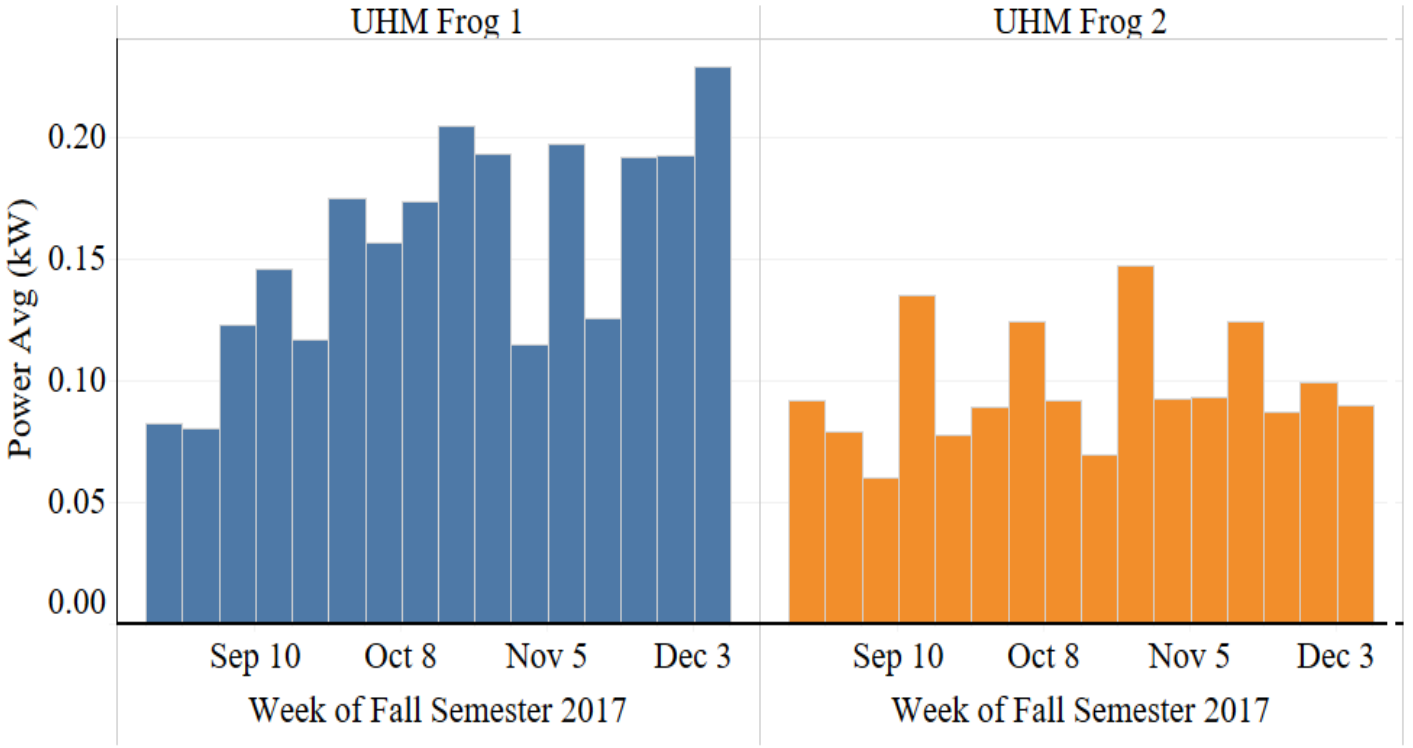
"What the heck is *Mixed Mode* anyway?"

- Familiarize with controls
- Provide real time feedback
- Embed NZE as a "culture"

Ex. 1 Indoor lighting

Decision:

Do we need the lights?



Weekly average lighting power for afternoon class session for occupied hours

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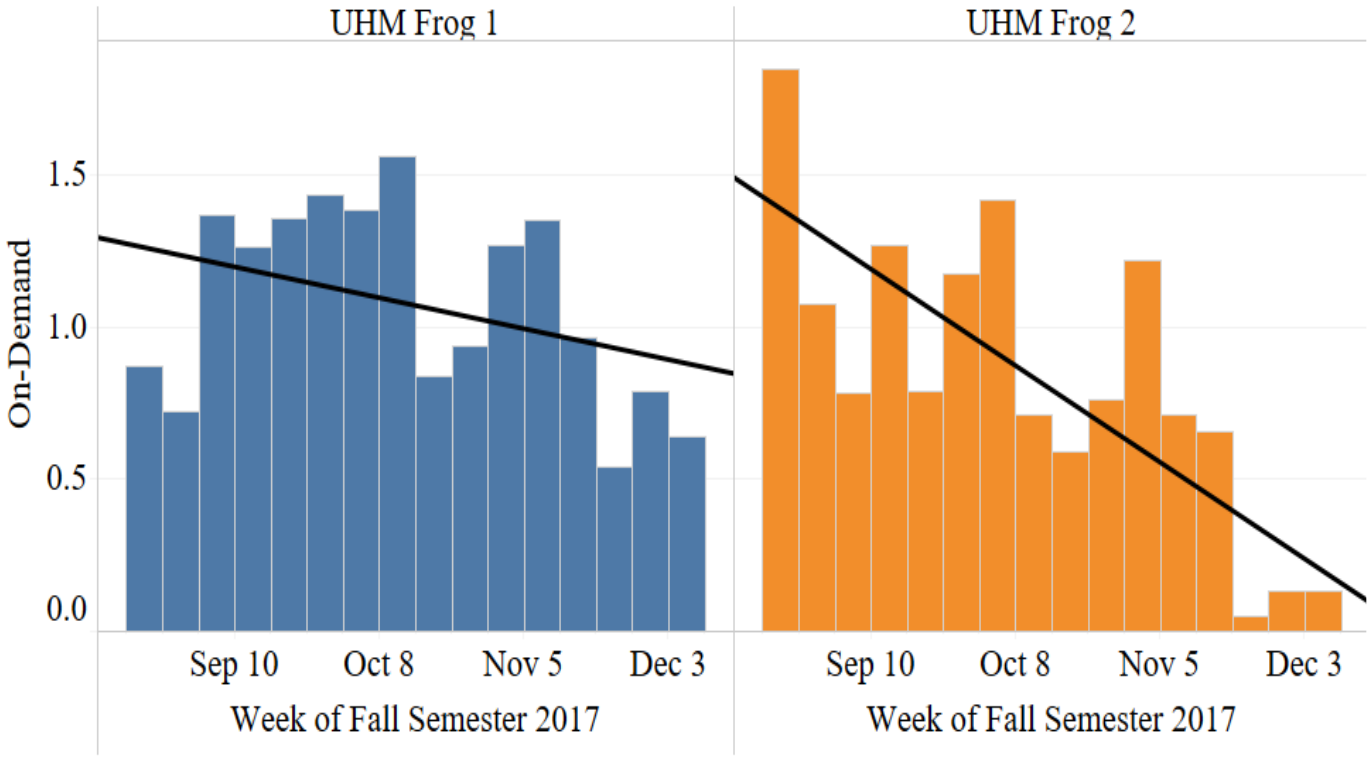
Ex. 2 Air conditioning

Decision:

Do we need the A/C?



Weekly average of HVAC power for morning class for occupied hours

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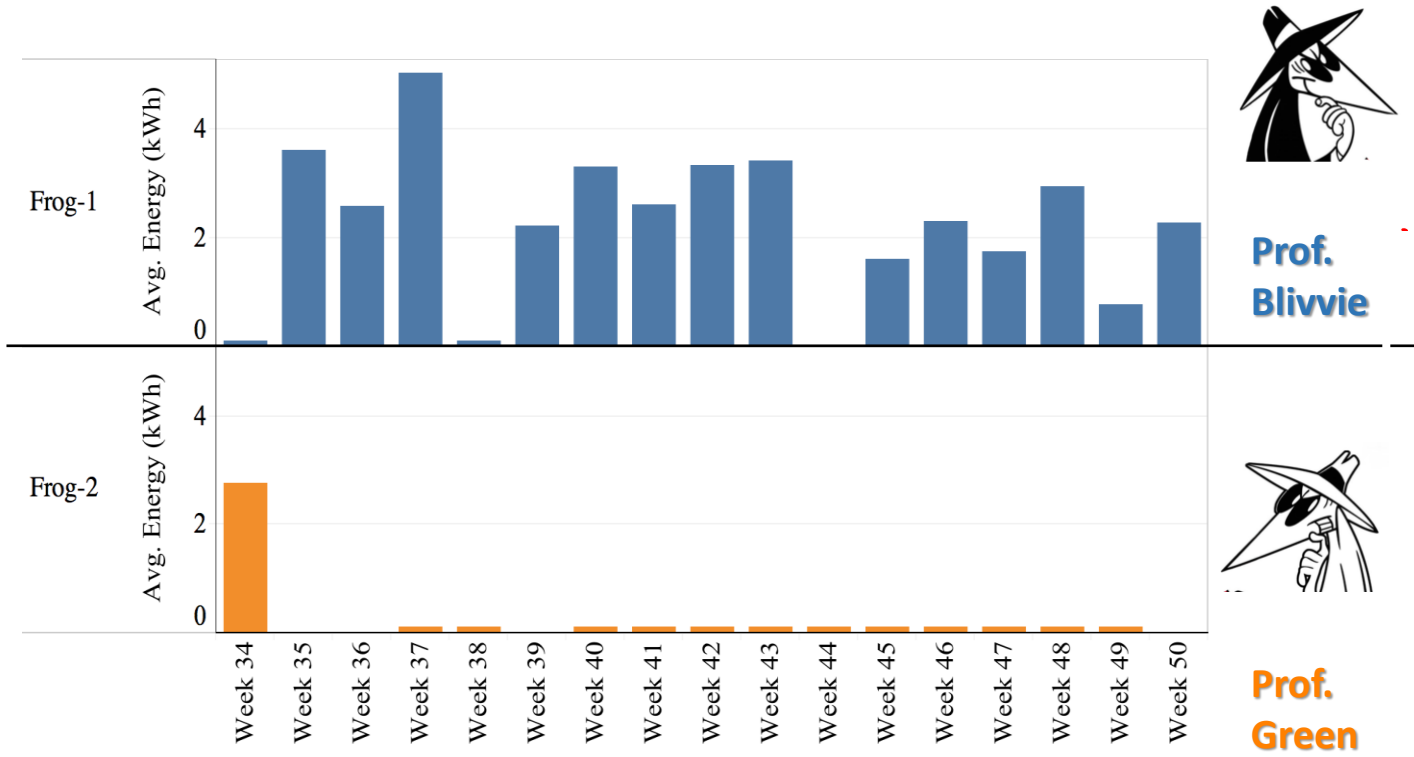
Ex. 2.1 Air conditioning

Decision:

Do we need the A/C?



Ave. Weekly HVAC energy (kWh) for single class period

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Conclusions and Recommendations

- **Balance user engagement and sense of control with automation**
  - Training, education and awareness
- **Keep it Simple…**
  - Offer cues and *clarity*
- **Predictive modeling is useful during design …**
  - But for that pesky behavior

Lessons Learned:

Complex Interactions Impact Performance

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Thank you

- Automated or manual controls?
- Should performance be dependent upon user awareness?