SCHOOL OF CONSTRUCTION AND THE ENVIRONMENT

Building Science Graduate Program

SENSITIVE HOMES: REMOTE SENSING AND MONITORING INTEGRAL TO HOMES

A Pilot Study on First Nation Homes on an Urban Reserve

Homeowner Protection Office
Branch of BC Housing

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Motivation

- Aboriginal families are significantly more likely to live in poor housing conditions than the general population. In Canada, most of these houses are often located in colder regions, which challenge the construction, the indoor air quality and the energy consumption
- Poor housing is related to poor child health outcomes

Causes: Deficient Construction, Lack of Maintenance, Cold Climate, Overcrowding, Lifestyle

Problem: No Performance Data is available in literature

Research Questions

- How do construction, mechanical equipment, climate, & occupant related factors combined affect the quality of aboriginal homes?
  Answer: A judicious application of Building Science principles & use of technologies. However, unique constraints, construction & service life conditions & uncertainties increase complexity
- How to identify & measure these unique conditions & uncertainties?
- How to devise solutions to the aboriginal housing quality problems that incorporate these unique conditions & uncertainties?

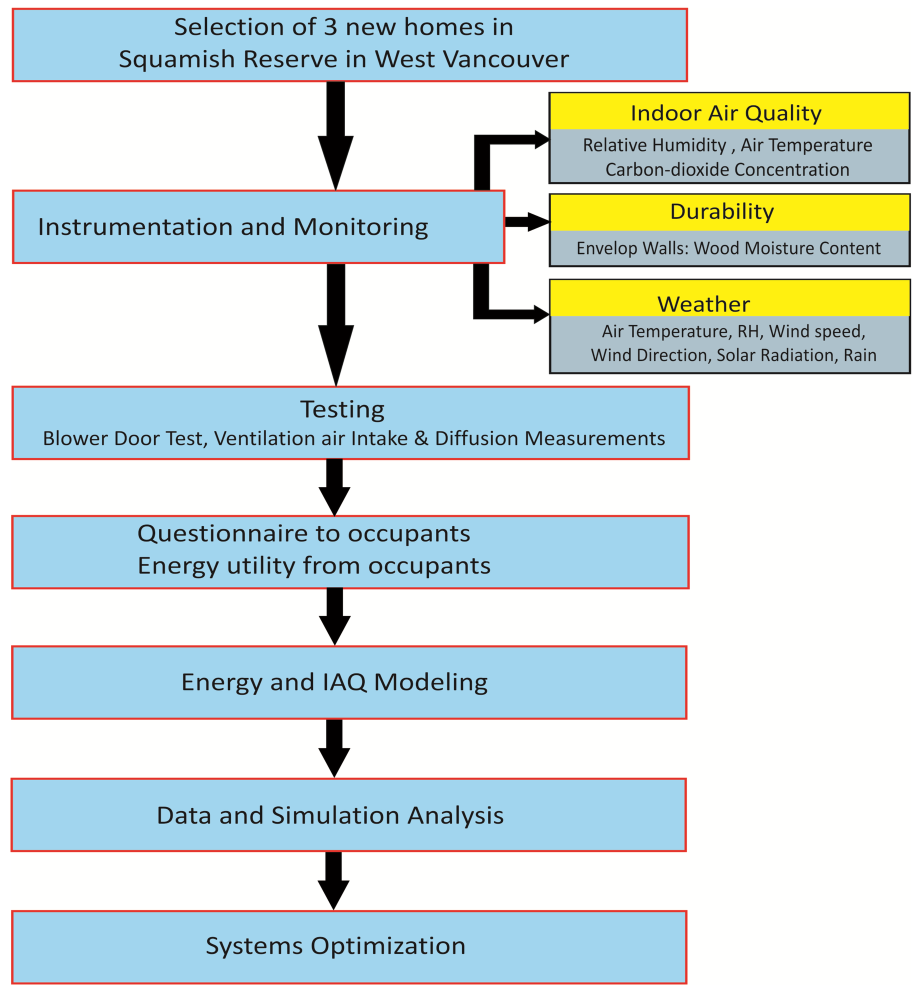
Research Hypothesis

- Aboriginal homes need to be made more resilient & responsive to unique constraints, construction & service life conditions, & uncertainties
- There is an urgent need for actual data to understand the factors affecting the performance of these houses
- Solution should be systems-based. It should consider the construction, the mechanical equipment, climate and the occupants
- Vision: a remote health monitoring system integral to homes acting as early warning to detect problems before they become more serious and sometimes irreversible

Objectives

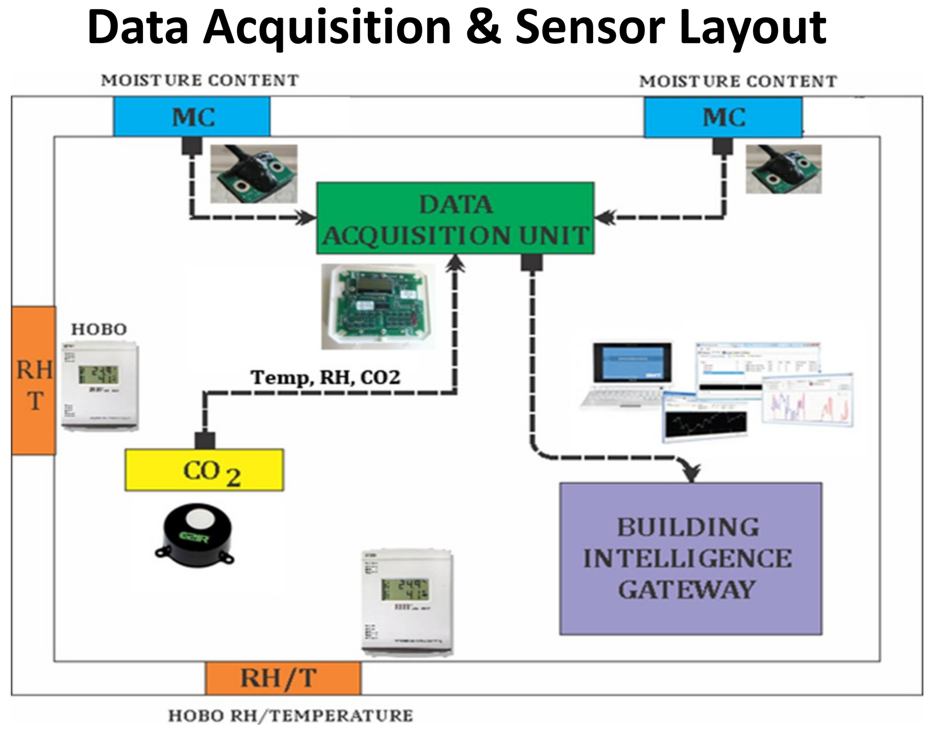
- **Short Term—Pilot Study**
  - Monitor a group of urban aboriginal homes to obtain preliminary durability, indoor air quality and energy performance data
  - Use this data to propose a cost-effective solution to optimize the quality & resiliency of these homes
- **Long Term**
  - Study remote communities in the far north and investigate construction systems and Technologies that are resilient and responsive to the unique conditions

Research Methodology

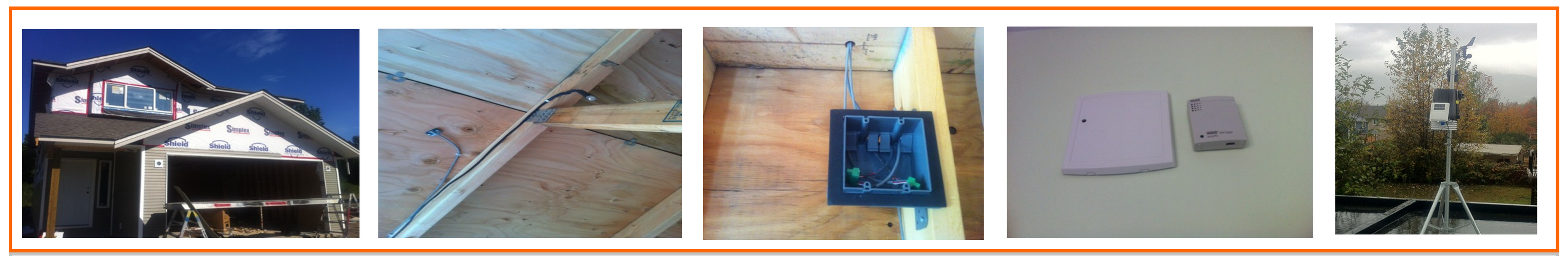


SMT Research Monitoring System

Data Acquisition & Sensor Layout

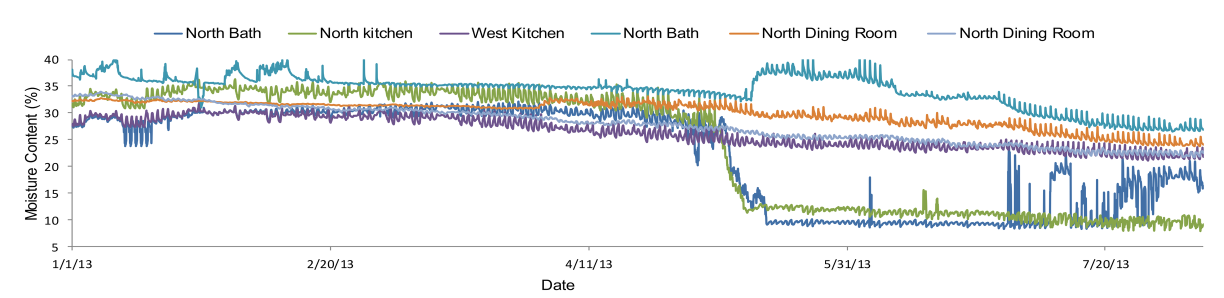


Monitoring System Installed

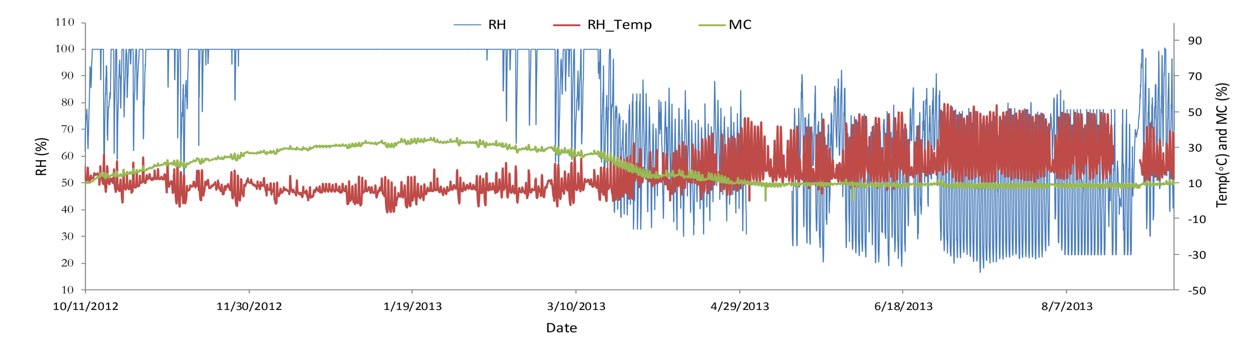


Data Analysis: Durability

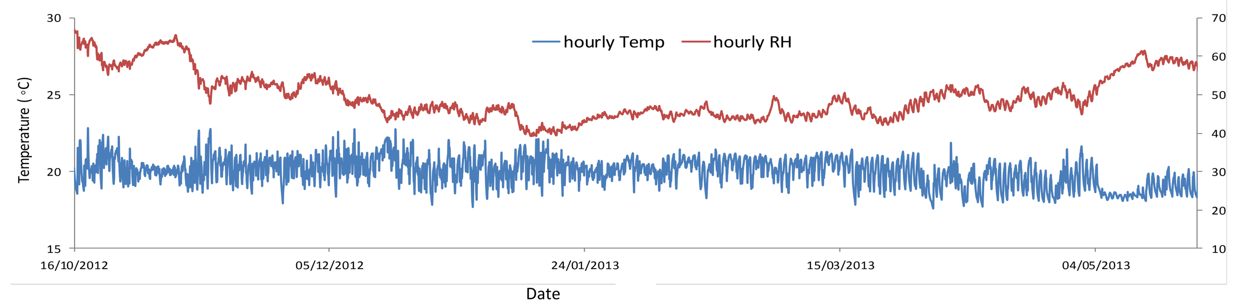
Hourly Moisture Content on Various Elevations



Hourly temperature, Relative Humidity and Moisture Content in the Attic

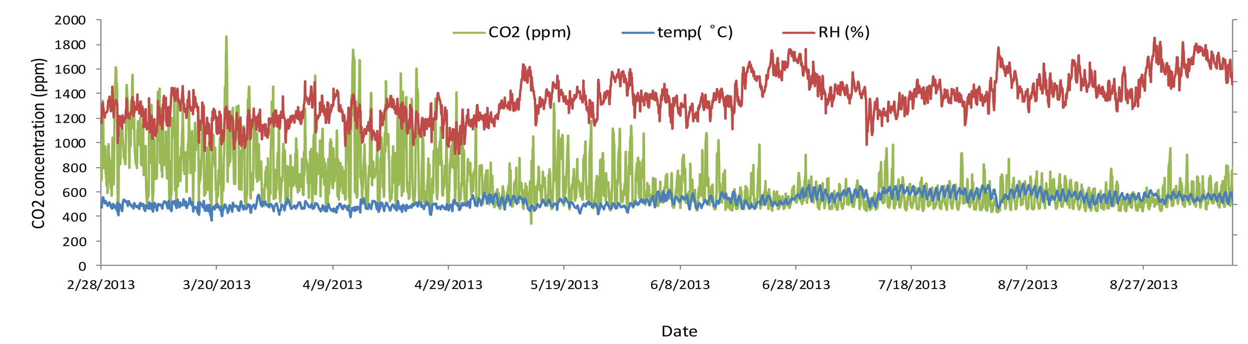


Hourly temperature and Relative Humidity in the crawlspace



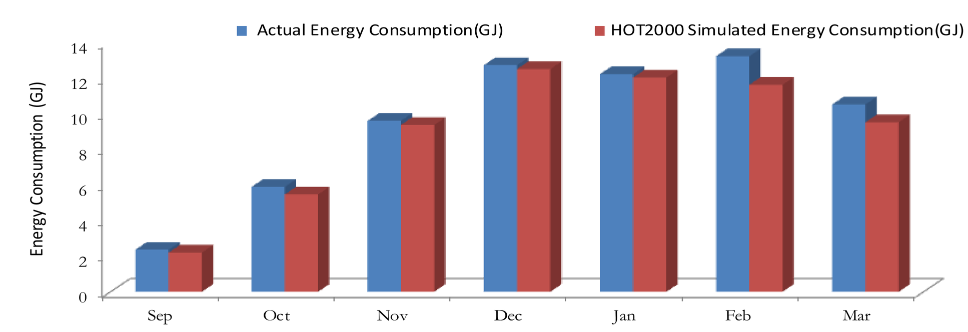
Data Analysis: Indoor Air Quality

Hourly temperature, Relative Humidity and CO2 level in Master bedroom



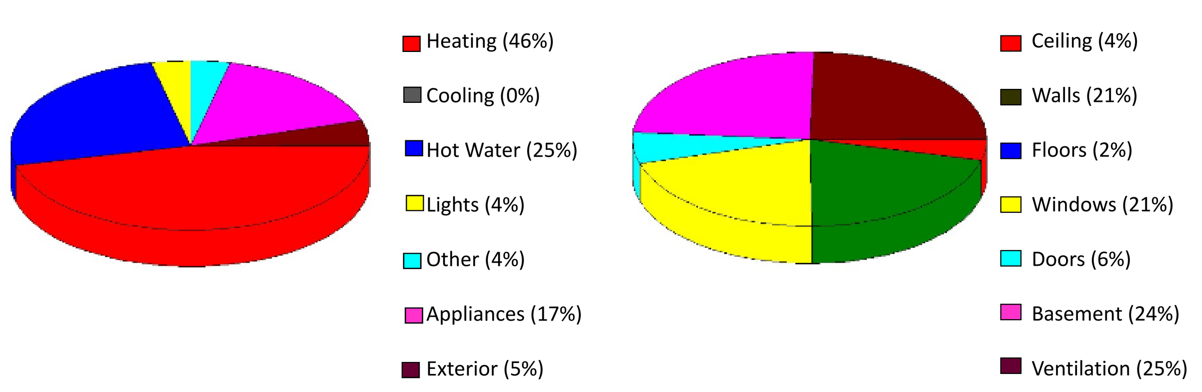
Data Analysis: Energy

Comparison of Simulated Vs. actual energy consumption

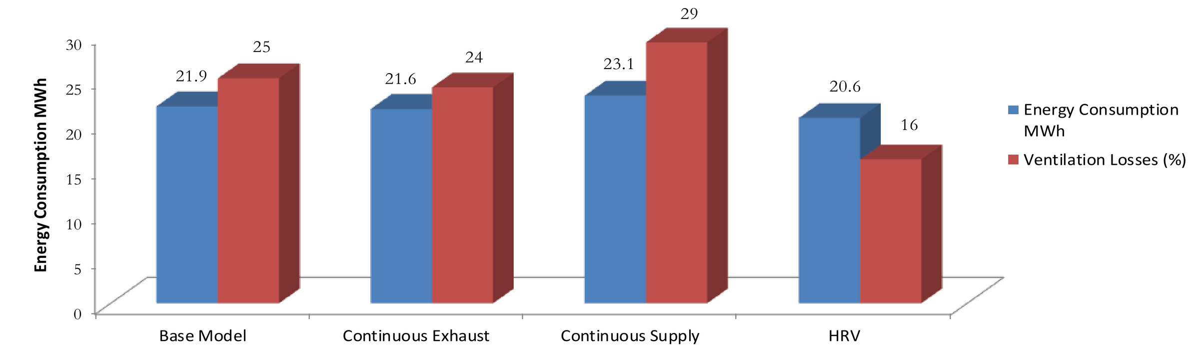


Components of Annual Energy Consumption

Components of Annual Heat Loss



Comparison of Alternative Ventilation Systems



Lessons Learned From the Pilot Study

Envelop Moisture

- **Warning:** Some walls particularly north walls are not drying out as expected.
- **Warning:** Attics are extremely wet during winter. However, they dried out in summer, but seem to be getting wet again as fall begins
- Crawlspaces show stable RH/T.

Indoor Air Quality

- Forced air heating system is distributing air to the rooms uniformly when operational.
- CO2 levels are within limits but occasionally jumps towards higher values (>1400 ppm) due to increased occupancy.
- RH/T data indicates there is no risk of microbial contamination within the living space.
- The data analysis combined with calibrated multi-zone CONTAM airflow modeling pointed towards potential indoor air quality problems due to insufficient ventilation rates and possible risks of airborne contamination from the building enclosure
- **Warning:** In the long term, mould spores from walls and attic may migrate indoors. To minimize the risk, a balanced ventilation system is desirable

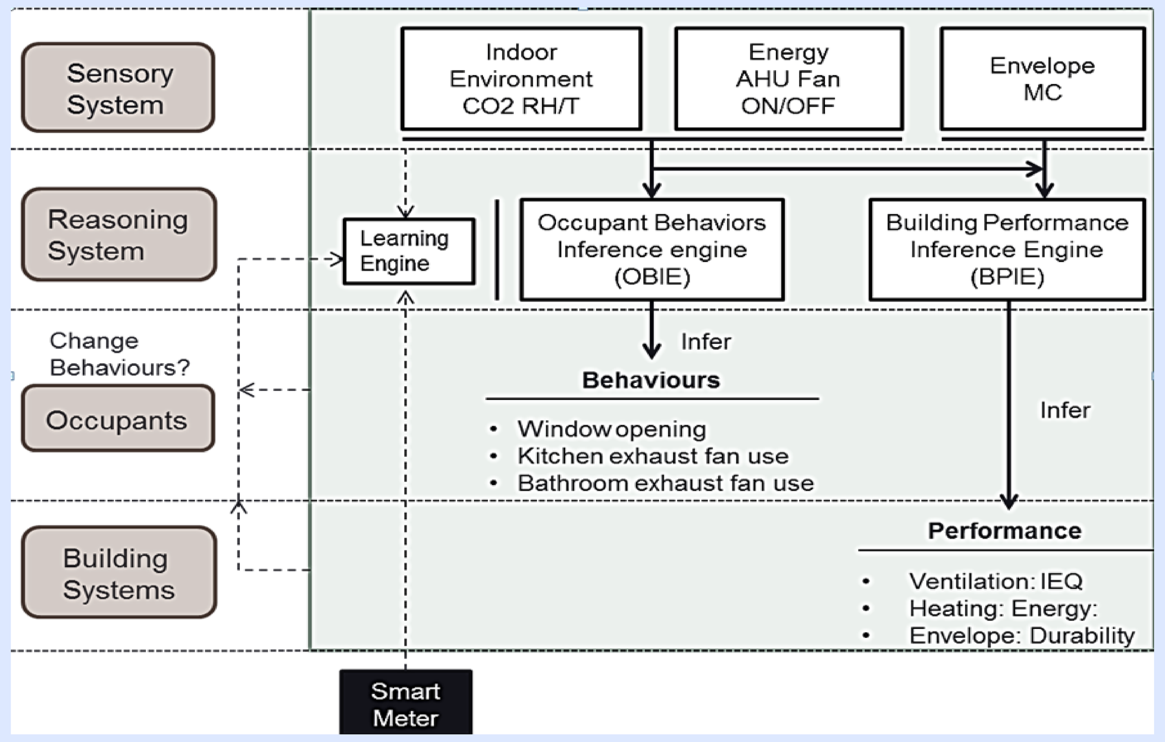
Energy

- Heating and ventilation drive the energy consumption.
- **Warning:** Occupants are opening windows in winter and are unaware of the energy penalty

Conclusions From the Pilot Study

- Important knowledge can be gained from a well planned and deployed sensing system integral to homes.
- This knowledge can be used to provide feedback to occupants on durability, indoor air quality and energy
- In residential buildings, occupants have more impact on the indoor environment, durability and energy than in commercial buildings
- Occupant behaviour is critical for the design of any resilient residential indoor environmental system
- A residential monitoring system has potential to act as an early warning system to detect problems before they become irreversible.

Conceptual Architecture: A Health Monitoring System Integral to Homes



Main Features:

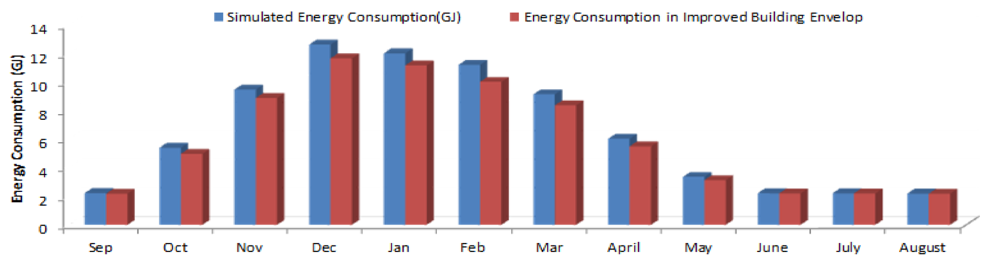
- Infer performance knowledge from monitoring data
- Minimize the need for numerous sensors & data acquisition through monitoring intelligence
- Statistical algorithms coupled with building science knowledge & principles
- The algorithms are calibrated by memorizing characteristics of time-series generated by sensor data during a learning phase where the building is assumed to behave normally
- This phase subsequently helps identify anomalous behaviour

Outcomes

Short Term Outcomes

- **Recommendations to improve existing homes with simple and affordable solutions**
  - Increase air tightness
  - Simulations predicted 8% reduction in energy consumption
- **Recommendations to improve construction, and heating and ventilation systems in future homes based on HOUSE AS A SYSTEM concept**
  - Dedicated controlled supply ventilation system (Central Integrated Fan Supply Ventilation system)
  - Increased insulation in the attic
  - Feedback to homeowners and builders: Energy and IAQ

Comparison of energy consumed in existing vs. improved building air-tightness



Long Term Outcomes

- Collaborations with the industry to optimize heating and ventilation systems for improved energy efficiency & IAQ
- Advanced automated control systems for improved ventilation
- Permanent real-time home quality monitoring/response platform
- Partnership with First Nation homes

Conclusion

- Important Knowledge gained from the pilot study
- Sensing System gives valuable feedback
- However, remote sensing technologies are still evolving
  Problems faced: cost, reliability, durability, autonomy, communication

Future Work

- Study a larger group of houses, more representative of remote, not urban, communities
- Work with manufacturers to test alternative heating and ventilation technologies
- Work with researchers to develop intelligent sensing systems & control algorithms

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