PennState College of Education | CSATS Center for Science and the Schools | **Research Experiences for Teachers** | PennState College of Engineering ARCHITECTURAL ENGINEERING

Interaction Between Energy Use and the Indoor Environment

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PROBLEM

How can you improve both energy efficiency and indoor air quality in a building?

RATIONALE

There is much interest in making buildings more energy efficient, if for no other reason than to save money. However, many measures that improve energy efficiency can negatively affect indoor air quality. Since the majority people spend 90% of their time indoors building health is extremely important.

Two pollutants that can be measured to assess air quality are carbon dioxide (CO_2) and particulate matter (PM).

According to Occupational Health & Safety CO_2 levels of 350-1000 ppm are typical found in occupied buildings with proper ventilation. When levels are over 2000 ppm it can cause health impairments like headaches, sleepiness, poor concentration, increased heart rate, and nausea.

The Environmental Protection Agency (EPA) states that PM smaller than 10 µm in can settle in your lungs and possibly enter your bloodstream, causing major health issues including heart problems and respiratory issues. Some studies have cited PM as causing premature death.

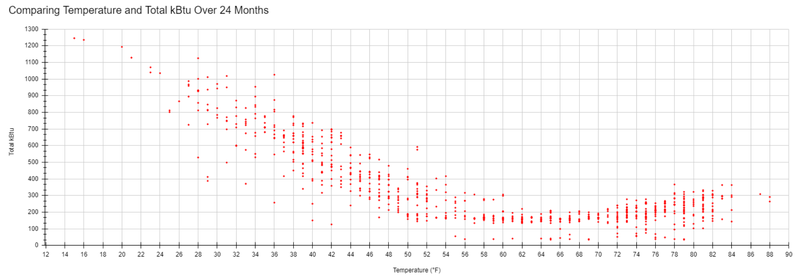
CONDUCTING AN ENERGY AUDIT

An energy audit allows the assessment of energy use in a building. An audit is conducted by taking an inventory of all energy using equipment and reviewing historical data of energy use.

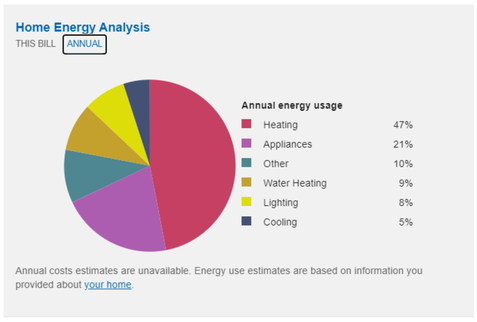
The home used for this study was a 2700 ft^2 single family home. Gas is used for heating and the home has central air. There is a smart thermostat that runs on a schedule. Two rooms have individual heating/cooling systems. The hot water heater is at least 40 years old. Windows are newer. The refrigerator, washer, dryer, and dishwasher are all newer appliances.

Historical data from Delmarva was reviewed for a two year period. Electric and gas use were converted from kWh and CCF, respectively, to kBtu.

FINDINGS OF THE ENERGY AUDIT



On average the annual energy utilization index (EUI) for this home is 47 kBtu/ft^2/yr. EUI is used to compare energy use amongst buildings and estimate utility costs. The graph above shows daily meter reading (kBtu) over 24 months versus temperature (ºF). A multi-point regression curve can be seen with two pivot points, one for heating and one for cooling. There is a steady increase in energy use at temperature both below 50ºF and above 80 ºF.



According to the home energy analysis completed on the Delmarva website almost half of the energy used by this home is for heating.

ASSESSING INDOOR AIR QUALITY

A Purple Air sensor and a HOBO data logger were placed in various locations around the house for 70 hours at a time.

Air Quality Index (AQI) Values	Levels of Health Concern	Colors
When the AQI is in this range:	*..air quality conditions are:*	*...as symbolized by this color:*
0 to 50	Good	Green
51 to 100	Moderate	Yellow
101 to 150	Unhealthy for Sensitive Groups	Orange
151 to 200	Unhealthy	Red
201 to 300	Very Unhealthy	Purple
301 to 500	Hazardous	Maroon

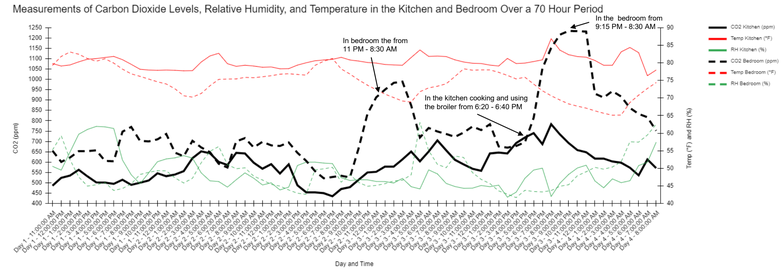
The Purple Air Sensor measured PM smaller than 2.5 µm and calculated the Air Quality Index (AQI) value at regular intervals.

The HOBO data logger measured CO_2 (ppm), relative humidity (%), and temperature (ºF).

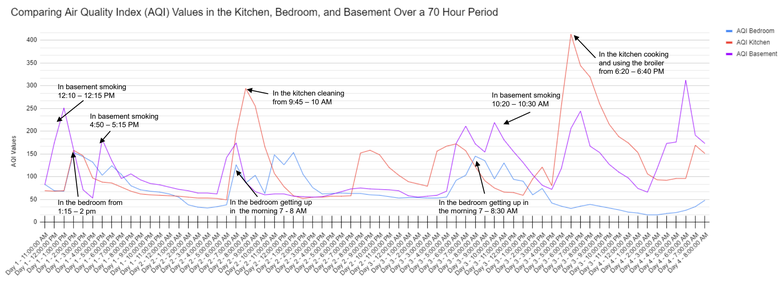
While data was not collected on the same dates for each location It was collected during corresponding times. Anecdotal notes were taken regarding activities happen in the rooms while the sensors were present.

RESULTS OF AIR QUALITY STUDY

Carbon Dioxide - There seemed to be limited correlation between daily activities and CO_2 levels. Times when activities seemed to correspond to changes in levels are annotated on the graph below. Data for the basement was not included due to a calibration malfunction with the sensor.



Air Quality Index Values - The bedroom had the healthiest AQI values. The AQI fluctuated between Good and Moderate 77% of the time. The kitchen was the least healthy room in the house with AQI values that were Moderate to Mildly Unhealthy 67.5% of the time and Unhealthy, Very Unhealthy, or Hazardous 31% of the time. The highest AQI value of 413 directly corresponded to when the broiler was in use. The basement had the most unhealthy spikes but overall seemed to rate better on the AQI than the kitchen. Values were Good to Moderate 56%, Mildly Unhealthy 18%, and Unhealthy, Very Unhealthy, or Hazardous 30% of the time. Spikes seem to correspond with times there was smoking in the basement.



RECOMMENDATIONS

Some simple recommendations to improve energy efficiency include: sealing air leaks, blocking drafts around doors, installing blinds or curtains on windows, vacuuming coils behind the refrigerator, cleaning around heating and cooling vents and AC units, upgrading to smart outlets, and replacing light bulbs with LEDs.

In regards to indoor air quality, the first three ways listed to improve efficiency might degrade quality due to decreased ventilation. It is important that windows are opened to allow fresh air into the home whether possible. A way to do this would be to open downstairs window at night when the central air is turned off since an individual unit is run unit in the bedroom.

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