fenestra

The Internet of Things enables the window to become an active and smart component of the home HVAC system

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Abstract

Home windows enabled by an internet of things (IoT) device, can utilize weather information to help cool and ventilate homes. Analysis of the data from the Net-Zero Energy Residential Test Facility (NZERTF) helped us explore energy saving strategies. Our insights lead us to design an algorithm which calculates the enthalpy level in outdoor air based on weather conditions. When the enthalpy level of outdoor air is favorable, the system will open the home windows and turn off the A/C. When we applied this algorithm back to the NZERTF data, we calculated savings of 15% in the energy consumed by the A/C during the summer season.

Introduction

The internet of things (IoT) is a revolution bound to transform everything in our lives. We currently have smart thermostats which can learn our usage habits to help us save energy. The doorbells in our homes, can now alert us through our smart phones when somebody is at our door. Home outdoor lights can now be synchronized to turn on and off at the exact time for dusk and dawn. The power of this revolution comes from everyday items gaining access to every piece of data available on the internet and interacting with one another.

The ubiquitous home window has so far been left out of this IoT revolution. The home window can be transformed from a passive item, to an active and smart HVAC component. The window, enabled by our ***fenestra*** IoT device, understands outdoor weather conditions and takes advantage of these conditions.

We all have noticed sprinklers watering a lawn, just as rain is falling. This same thing happens every time we operate an A/C to cool a home, just as the weather outside is favorable. **Our thesis is simple: can we save energy by opening the windows in our home when the outdoor weather conditions are favorable, instead of operating the A/C?**

Problem statement

U.S. homes similar in size to the NZERTF use about 20% of the total energy consumed in A/C[1]. Energy used for residential A/C amounts to approximately $11Billion USD each year and generates 100 Million tons of CO2 each year[2]. Given its magnitude, even small changes can result in big improvements.

Efficiency, at its simplest, means using the available resources in the best possible way. Operating an A/C to cool a home, at the same time when the outdoor air is cooler than indoors, is clearly inefficient.

Proposed solution: *fenestra*

The idea behind ***fenestra*** was born from an observation we made in Germany. *Frische Luft*, German for Fresh Air, is a common phrase used in Germany to describe the daily routine of opening windows. Every day, windows are opened for some time regardless of weather. A closed-up building is regarded as very UN-healthy. Being allergy sufferers, it did not take long for us to realize the power of this simple concept.

The IoT applied to the home window has the ability to capture all of these benefits, eliminate any inconveniences, and optimize its operation. An IoT device like ***fenestra*** can enable the window to track real time weather conditions, to communicate with other IoT devices in the home, as well as the homeowner preferences. Security concerns are addressed by using presence and vibration sensors which provide an alarm system for windows even while open. Lastly, a friendly user interface allows the

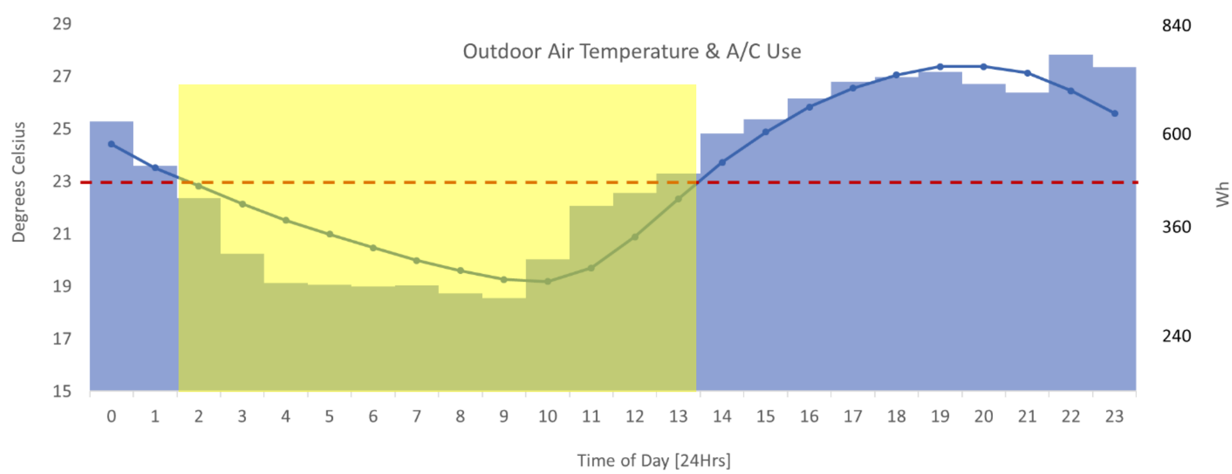
[1] http://nvlpubs.nist.gov/nistpubs/TechnicalNotes/NIST.TN.1767.pdf Figure 5-1
[2] http://energy.gov/energysaver/air-conditioning

homeowner to take control of their windows using a smartphone or tablet anywhere. ***fenestra*** optimizes the *Frische Luft* concept through the use of high technology.

Using the data set collected on the NZERTF we challenged ourselves to design the ideal algorithm to automate the windows of a home using ***fenestra***. As we analyzed the data, we looked for favorable weather conditions. We also had to understand at what times the A/C equipment was running. Lastly, we scanned for periods when both conditions existed at the same time: A/C running while favorable outdoor weather is present.

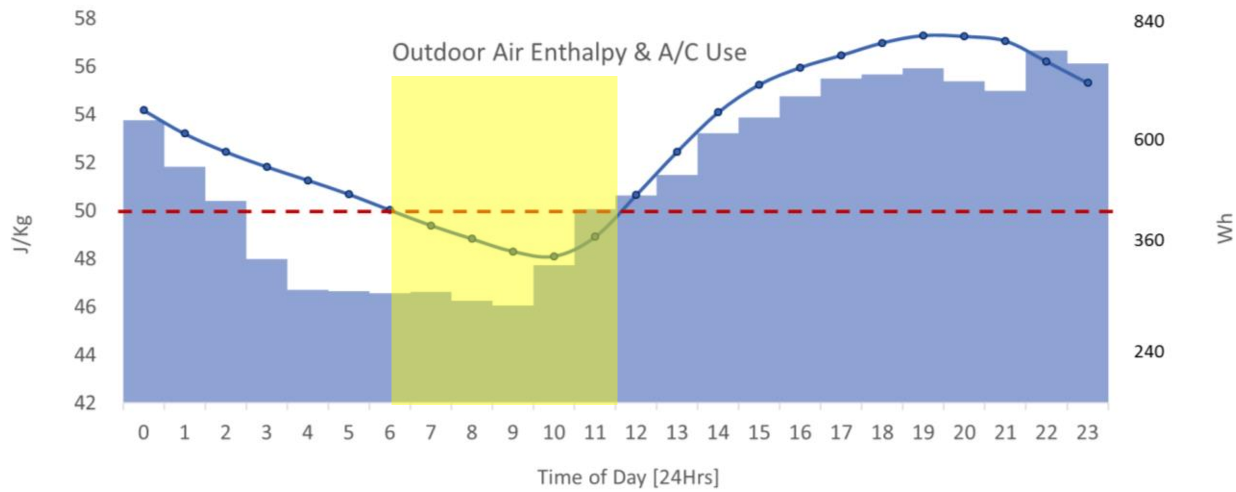
What we learned from the NZERTF data set

The data set from NZERTF gave us ample opportunities to analyze an experiment. We began by analyzing the data and looking for patterns in temperature, outdoor heat energy in the air (enthalpy), and their correlation to energy used for A/C. Having understood these correlations, we designed a very basic algorithm to identify the areas of opportunity. Finally, we experimented and refined our algorithm to make it work with ***fenestra***.

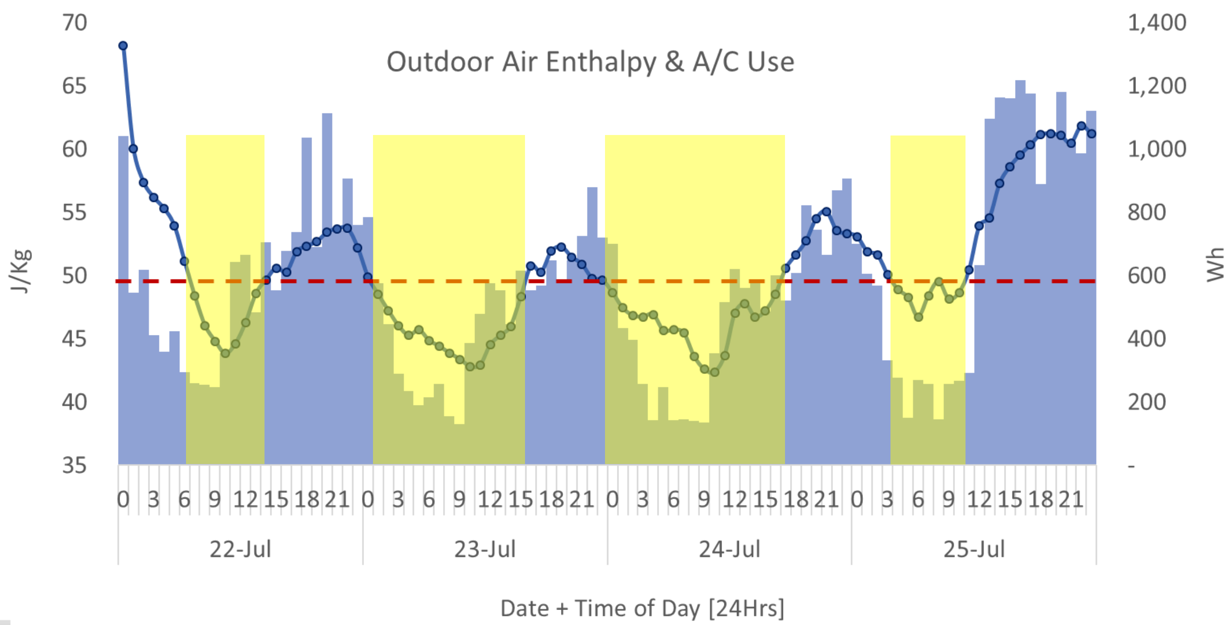


Our first graph shows an average summer day in the NZERTF. The light blue solid bars represent the power consumed by the A/C, while the dark blue line shows the ambient temperature. The yellow shaded rectangles show the times at which ***fenestra*** would open the windows. This graph clearly shows that for several hours, the temperature outdoors is lower than the thermostat set-point. During this time, the A/C is working relatively light, still it does so for many hours.

As we scrutinized the data in closer detail, and studied the thermodynamics of A/C, we went further and decided that temperature was not the correct criteria for opening the windows. As we all have experienced, humid air "feels" warmer than dry air; the reason for this is enthalpy, or the amount of heat energy in the air. The revised graph below shows how this new criterion reduced the time available to open the windows, due to the humid weather in Maryland.

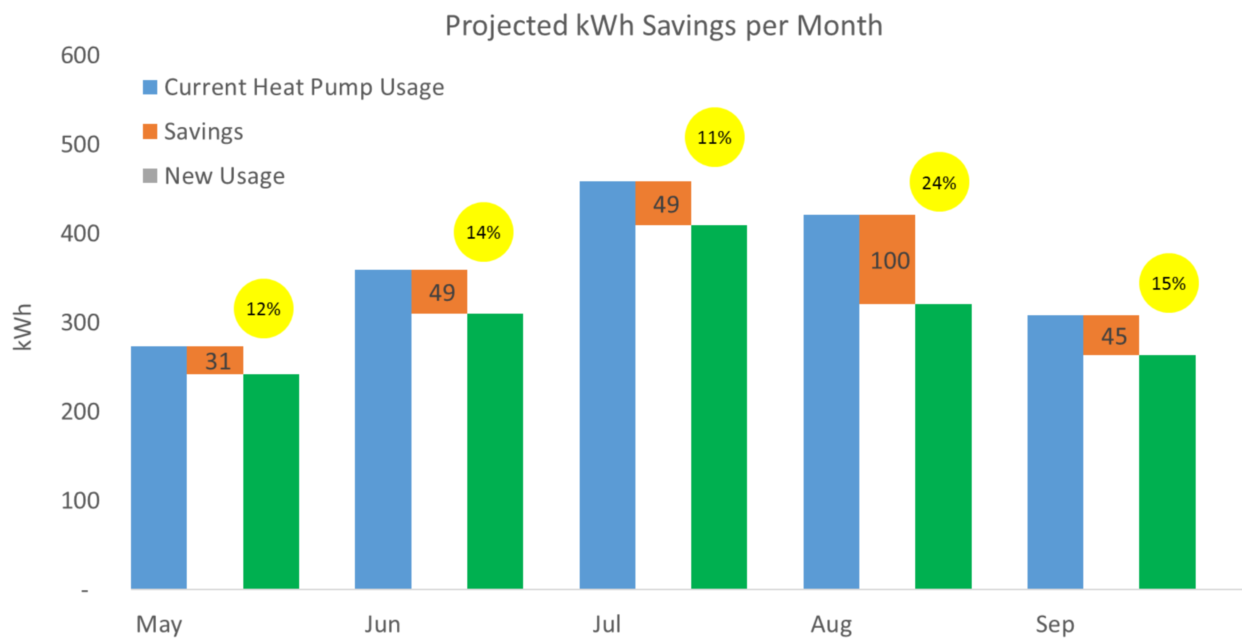


Working with averages provided us with insights and the ability to spot patterns, but many times, averages can be deceiving. Our last challenge was to design an algorithm that could deal with the noise in the data and efficiently operate ***fenestra***.



The graph above shows four days, right in the middle of summer, and it perfectly illustrates the algorithm at work. Whenever the amount of heat in the air drops below 50J/Kg, we can take advantage of favorable outdoor weather conditions. The intersection between the solid bars (A/C operating) and the yellow rectangles (***fenestra*** open window) represent the savings expected.

From one average day, to four days; how would the algorithm work for the complete summer season? The graph below shows the amount of energy used for A/C each month, followed by the opportunity our algorithm identified, and finally the projected energy use. The yellow balloons show the percentage savings expected for each month.

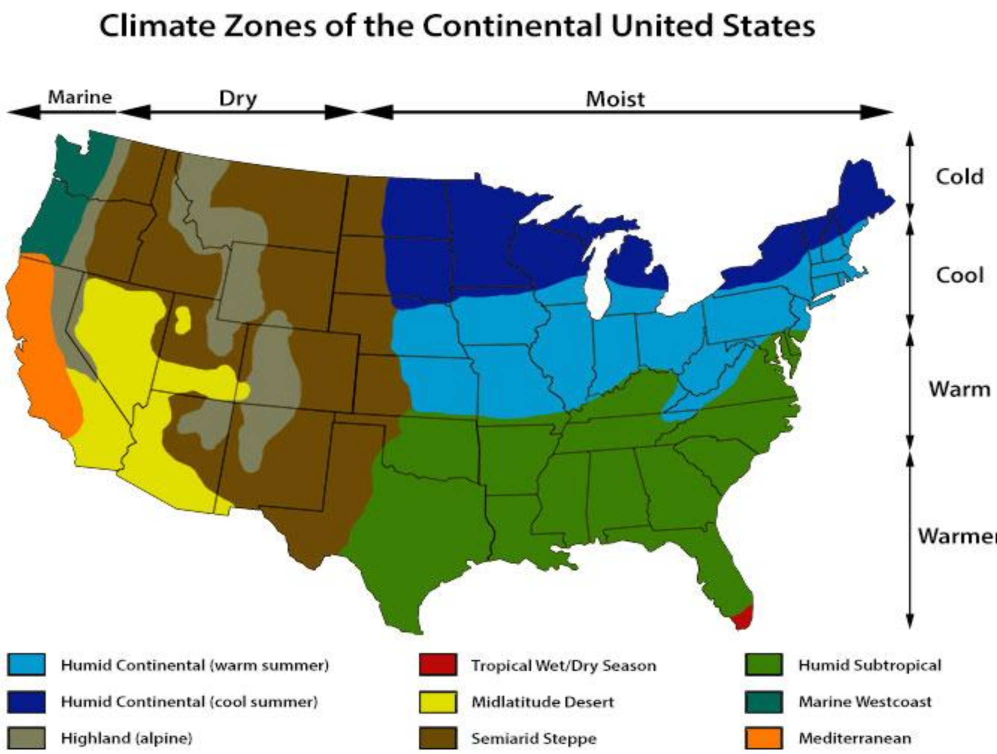


Taking the complete summer, the projected savings added to 15%. In the case of the NZERTF, these savings would amount to 275kWh or $41.35 for the summer season. At first hand this might seem like a small amount, but let's go back to our initial figures: $11Billion USD and 100 Million tons of CO2; 15% of this equates to $1.65 billion USD and 15 Million tons of CO2, not a small amount.

Next Steps

We have learned plenty throughout this exercise, but we still have two questions we want to research further. Our first interest is to extrapolate our analysis to all of the United States. Our current analysis applies to the NZERTF, and could easily be extrapolated to the surrounding climate region. But, how would ***fenestra*** work on more favorable climates? Our second research interest would be to predict the home temperature and A/C use, given outdoor weather today, **and** tomorrow. We currently react to favorable weather, but could we open the windows proactively and further improve the results?

The continental United States has nine climate zones, and each one represents different challenges and opportunities for ***fenestra***. The NZERTF is located on a warm and humid area, which is not the ideal weather, since humidity traps the heat throughout the day, and can hold most of it during the night. On the other hand, dry and Mediterranean climate zones have very low humidity levels. This means that as soon as the sun goes down, the heat in the air dissipates quickly; the temperature swing between the warmest and the coolest time of the day is very large. This should present an ideal opportunity for ***fenestra*** to bring larger energy savings



Learning how the home heats and cools with weather changes and how the events of opening the windows changes this response, offers challenging but very interesting possibilities. As ***fenestra*** operates, it can gather important information on the thermal characteristics of a home. This thermal behavior data, together with weather forecasts, and sophisticated algorithms, could enable ***fenestra*** to open windows proactively. If on a given day we have temperate weather, but the forecast anticipates a very warm day to follow, ***fenestra*** could avoid some A/C use, by overcooling the home and "banking" cold air. Sophisticated smart thermostats are already exploring similar methods for the A/C operation. ***fenestra*** could bring in additional intelligence and possibilities to the HVAC system and provide even more efficiency gains.

Conclusions & Thanks

We at ***fenestra*** are passionate for the tremendous efficiency improvement opportunities that the IoT revolution brings. We believe that sustainability not only makes economic sense, but that it should be a goal in and of itself. We hope, and we are working very hard so ***fenestra*** can make the jump from idea to reality, and contribute if even a tiny bit to sustainability.

We want to thank the Department of Commerce for their support. We had been looking for data correlating the thermal behavior of a home to outdoor weather from the very early days of ***fenestra***. We had contacted NREL, and they did share some data with us, but nothing like what the NZERTF provided to us. Special thanks to Pri Oberoi and Laura McGorman for their continued support, and for answering all our questions and numerous emails.