CS486C – Senior Capstone Design in Computer Science

Project Description

Project Title: Project SmartFan – Minimal-energy active household temperature control with ambient air	
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Project Overview:

Heating and cooling accounts for 47% of household energy use in the US, and an average household can spend $2,000 on utility bills. Household utilities account for 25% of their carbon emissions in the US, which directly contributes to accelerating climate change (EIA 2009, https://www.eia.gov/consumption/residential/). If a dent could be made in energy consumption in this sector, a real impact on global warming could be realized, as well a being a boon to household financial budgets and poverty alleviation.

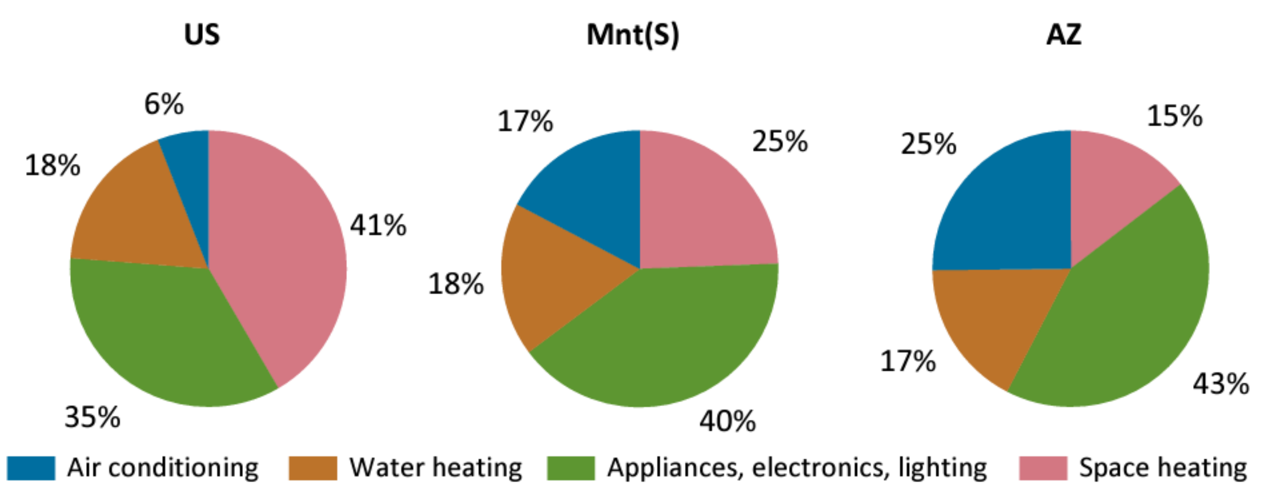

Figure 1. Proportion of total household energy used across 4 categories in the United States, southern mountain states, and Arizona. Arizona's usage of AC is much higher than the rest of the US.

Household energy consumption can be tackled in a number of ways. New construction techniques and materials are much more energy efficient, but older housing stock cannot be demolished and rebuilt, and renovating old housing is usually prohibitively expensive. More efficient machines can be purchased and installed such as heat pumps, geothermal systems, and more modern air conditioners. While often less expensive than renovation, these machines can be expensive nonetheless. That limits their adoption speed and potential.

Surprisingly, *no solution currently exists to leverage the temperature differential between ambient air and household air* to reduce the need for energy-intensive temperature regulation such as heaters and air conditioners. Enter ***SmartFan***.

SmartFan will consist of a set of fans and temperature sensors that will be installed in house walls or windows. These fans will be capable of **creating an airflow through a house**. **By bringing in warm outside air when the house is cold, or cool outsider air when the house is hot, SmartFan will reduce the need for heaters or conditioners to pull the entire load of house temperature regulation**. Throughout the day, ambient air temperature typically cycles between being relatively warm at midday, and relatively cool at night. As long as the maximum ambient temperature is above the household air temperature at some point during the day when warming is needed, or vice versa, SmartFan will be able to contribute.

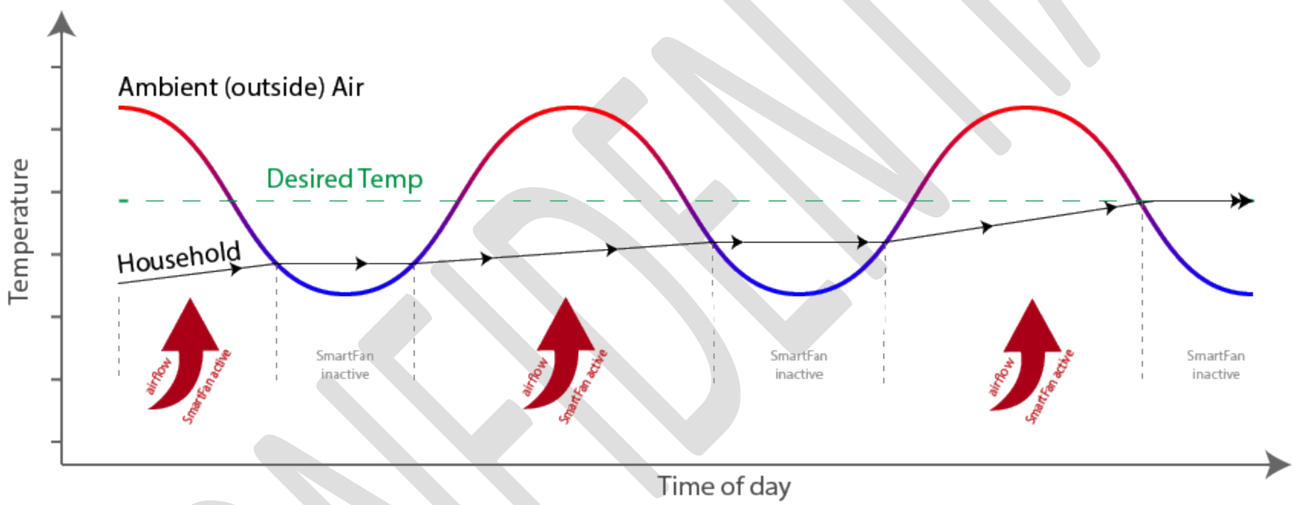

Figure 2. Diagram of hypothetical operation of SmartFan heating a home through a period of time when the outside air temperature fluctuates, given an assumed desired temperature and initial household temperature.

Let us consider an example scenario common in Flagstaff's late Fall season: our houses are too cold without turning on the heat. Yet, during peak daytime hours, the outside air temperature is higher than our indoor temperature. SmartFan would work in the following manner: 1) The user sets a desired temperature (say, 70°F). 2) SmartFan monitors indoor and outdoor air temperature. 3) When indoor temperature hasn't yet reached 70° and outdoor temperature exceeds indoor temperature, SmartFan will turn on its fans, thereby bringing outside air in and heating the house.

SmartFan will work anywhere that daily temperature fluctuation crosses the household temperature line (Figure 2), or stays on the 'desired' side of household temperature. The ideal environment for SmartFan to function is one in which the day/night temperature fluctuation is large, such as in Flagstaff.

A previous EE capstone successfully built and tested the hardware for this project. They used HomeAutomation for the interface, but what is really needed is a custom piece of software built with Python that runs on a raspberry-pi based control panel. This software will implement the algorithms to activate the fans depending on temperatures and user preferences.

If this project is successful, **further research could lead to a profitable business venture that both makes money and combats climate change**.

A bit about me: I study the relationship between forest structure and forest function, mostly in the tropics but also in temperate forests such as those here in Flagstaff. Questions we ask include, for example, how the structure of a forest relates to how much carbon it takes up from the atmosphere, how structure can help forests be resilient to climate change, and how the architecture of individual trees relates to their life history strategies. I use UAV's to study forests from above with hyperspectral optical sensors, and from below with terrestrial LiDAR scanning (TLS), Structure from Motion (SfM), and microenvironmental sensing techniques (see my brief talk about TLS here, and some 3D tree models here). I also have a background in electrical and software engineering (see my CV here). I think a lot about light, heat, and air in forests. This solution occurred to me while sitting in my home in Panama, choosing between sweltering or paying astronomical electricity bills.

Key features for a **minimum viable product** would include:

- Software running on a Rpi-based control panel that makes decisions about when to turn fans on and off, and communicates with temperature sensors and fans to affect those decisions. This includes reading forecast temperature conditions to pre-cool or pre-heat the house intelligently.
- A User Interface on the panel that will accept input from the user to set the desired temperature, and that will display current and forecast temperature conditions.
- Ability to control settings and view conditions via internet.

Stretch goals could include:

- Energy savings estimation.
- Communicates with smart thermostats (Nest, EcoBee, Honeywell, etc) to read the desired temperature.
- API to allow communication and control via HomeAutomation, Hubitat, and other home automation protocols.

A successful project would have lasting impacts on the trajectory of climate change by creating a new low-energy technology to regulate household temperatures.

Satisfaction Standards:

Exemplary: All elements of an MVP done very well, plus two stretch goals.
Good: All elements of an MVP done well.
Fair: All elements of an MVP that do not reliably work.
Poor: Not all elements of an MVP attempted.

Knowledge, skills, and expertise required for this project:

- Interest in developing software for solutions that combat climate change in novel and interesting ways.
- Some knowledge of python and UIs,
- Interest in working with low-power wireless communication protocols (e.g. zigbee, z-wave) and associated hardware and software.

Equipment Requirements:

- Relatively inexpensive chips and parts. Most things have already been purchased.