Project Summary

Text Box 1: Overview, Keywords, and Subtopic Name

Smart HVAC Furniture: This involves Ecological Furniture: personalizing HVAC furniture with self-control processes in an office space. Keywords include Heating, Ventilation, Air Conditioning, Internet of Things, Embedded Systems, Thermal Comfort, Thermodynamics, and PID controllers. The project requires areas of technical expertise in Mechanical Engineering - provision and construction of suitable furniture for physical and thermal comfort, Computer-Vision - identifying a user at their desk space, and Embedded Systems - the technology used to control the HVAC system provided with the furniture. The project will be applied to the fields of Environmental Sustainability – reducing the cost of energy spent on commercial and residential HVAC systems, and Control Systems – the ability to control the ecological furniture using embedded hardware.This project aims to reduce HFC emissions while providing thermal comfort for individuals, bringing about large-scale change in the HVAC industry.

Text Box 2: Intellectual Merit

This Small Business Innovation Research Phase I project produces office furniture that can accurately predict the comfort of individual users using thermal sensors, a thermal imaging camera, and HVAC and embedded systems. To do so, the embedded system must regulate the transfer of temperature-controlled air from the source (the HVAC) to the user - according to the data produced from the thermal sensors and thermal imaging camera (spotting the user's presence and temperature of the environment respectively). The office furniture will be designed to accommodate in-built AC/Heating for microclimate control around an individual, when present, using said furniture.

Text Box 3: Broader/Commercial Impact

According to the U.S. Energy Information Administration (EIA): in 2012, 4 Quadrillion British Thermal Units (BTU) of energy were being consumed in the commercial sector[1], equivalent to charging approximately 5 billion iPhone 5Ss, for a year. This project aims to reduce this value, as it targets the thermal comfort of an individual, while not cooling the space around said individual. This model also follows the technological trend of home and office automation, and can bring about a change in the culture of heating, cooling and ventilation in the respective industry.

[1] https://www.eia.gov/tools/faqs/faq.php?id=86&t=1

Elevator Pitch

By some estimates, the United States spends approximately 40% of its energy on indoor climate control. Much of this is inefficient because large volumes of indoor space are heated or cooled simply to tend to the individuals in it. This project aims to take on this issue by introducing a new concept that targets the operation of HVAC systems and reduces the impact that they have on the environment.

Eco-Flow is a highly effective system that will tend to individual requests for microclimates. By adding a microclimate, a user's immediate area can be tailored to suit them in a manner of ease. Eco-Flow can solve this, as it embeds an HVAC system within every-day furniture. We create controllable, energy efficient heating and cooling that can target the users directly, thus allowing for customization of ideal comforts in a small area, rather than impacting a large area at the cost of more energy. Thermal sensors and thermal imaging cameras are also embedded into the system to produce an accurate reading of the area, as well as detect the presence of the user. This leads to efficient use of the product as well – The product will switch on when a user is present; cooling or heating the user to their liking, or remain switched off if there is no user detected.

The application of this product will be displayed in the office environment – where Eco-Flow can be embedded into office chairs and desks. This is the ideal environment, as there are a large number of users within a single space, each with reserved unique thermal comfort zones. Those comfort zones are often disturbed, since there is only one heat or cool protocol in the entire facility. Eco-Flow can tend to every user, and eliminate the inconvenience of spending energy and money- heating or cooling a large space only to benefit particular users.

Commercial Opportunity

Eco-Flow affects the commercial and residential sector. The commercial sector contains at least 10 million units, as reported by the United States Census in 2015[2]. Areas such as office space (open or closed) or other areas of enclosed space can have the convenience of Eco-Flow in their environment, providing thermal comfort and reducing cost of energy. New and upcoming firms that are in need of constructing office space need not worry about costs in planning and constructing HVAC infrastructure if they obtain Eco-Flow.

As reported by the Census in 2014, there are at least 100 million residential units that can make use of Eco-Flow[3]. Any person that wishes to reduce their power bill or add consistent room temperatures in a residential area can invest in this product. Although users may already have a central heating/wall attached unit, they can still focus on a smaller climate zone by making use of Eco-Flow. If the resident owner is constructing their new home, Eco-Flow can be considered to reduce costs, increase budget, and increase the area available to the owner outside the home.

Eco-Flow can very well apply itself into lab environments, where users are in need of keeping a designated area at controlled temperatures for set periods of time. The ability to easily modify the temperature of the environment around a research project will greatly alter the way researchers can construct experiments. For instance, the inability to house an incubator can be fixed by applying Eco-Flow into the experiment, thereby producing accurate results.

The United States have societal, market, industrial and technological drivers to go green, and Eco-Flow can further this movement. As of this year, the United States have also left the Paris Climate Agreement, and have lowered the budget for the Environmental Protection Agency, which provides a much more crucial ground to have a smaller carbon footprint. Citizens must have a way to reduce their impact, and Eco-Flow can provide a step towards this cause.

Energy Star's federal tax credit incentivizes those to have HVAC products that consume less energy[4]. For example, they advocate an Energy Efficiency Ratio (EER): the higher the EER rating, the more energy efficient the product is. This results in lower energy costs. Individuals can be convinced to lower their costs by investing in Eco-Flow, a product that may have energy savings.

In the Commercial Sector, companies are often enticed to conserve energy with the help of the United States Green Building Council (USBGC). They provide what is called the Leadership in Energy and Environmental Design (LEED), the most widely used green building rating system. Building owners that make use of this project can have an easier time establishing the LEED certification.

Eco-Flow keeps up with the ongoing technological trends today. Like many others that are adapting, we apply it to the Internet of Things (IoT) - where individuals integrate technology into their everyday lives. With Eco-Flow as a smart HVAC, it can easily fit into smart home technologies. As the demand for smart home appliances increase[5], more individuals will be inspired to invest into Eco-Flow, in which they can control from their computer and/or smart device.

Like the market, we break down our customers into the commercial and residential sector. For the residential users of our product, we provide another method for controlling an HVAC product. Traditionally, HVAC products only have the ability to be switched on or off. Eco-Flow, on the other hand, has a state in-between on or off. Rather than depending solely on the temperature around the machine, we also depend on the presence of the user. Thus we provide a 'sleep' mode. When the user

---

[2] https://www.census.gov/data/tables/2015/econ/susb/2015-susb-annual.html

[3] https://www.census.gov/housing/hvs/data/histtabs.html

[4] https://www.energystar.gov/about/federal_tax_credits_consumer_energy_efficiency_definitions

[5] https://technology.ihs.com/549694

returns, the machine can resume its work in cooling the user without being switched off. This will provide as a method of saving energy. Eco-Flow will only switch off when the user has not been present for a while, or the user switches the machine off manually.

By only depending on the temperature around the machine, like many HVACs do, it can result in uneven temperatures. In wall-attached units for instance, the HVAC will attempt to cool the room, but only affect a minute area. Once that area has obtained the ideal temperature, the machine will switch off. In reality, the temperature around the machine has been affected, but the rest of the area it attempted to cool will still be at the original temperature. If Eco-Flow is to be used in a wider area, it can make use of its Central Sensory Network (CSN) in accordance to other Eco-Flow units. Much like that of the AC unit in cars, Eco-Flow can detect what areas are at the right temperature and what area is not. Eco-Flow will adjust their units and cool/heat the incorrect areas accordingly.

Business and commercial building owners would greatly benefit from these functions as well. In the office space in particular, there are various unique "thermal comfort zones" that each employee would have. Since there is a large ratio between the number of employees to the options in central heating (typically only one), there would usually be a large amount of discomfort present. As a result, workers would have to either bring their own comfort clothing (which may not be up to standard in the workplace) or, possibly, reduce their productivity, due to the distraction of being too hot or too cold.

According to reports by news sources, HVAC systems in the commercial sector have been reported to be rather "biased" in heating and cooling temperatures: in particular, to men rather than women[6]. To expand, heating and cooling in central heating had a calculation being practiced. Based on the metabolic rate of a 154 Lb, 40 year old male, the cooling and heating system would adjust to this, times the number of workers present. This was done in the 1960s, before women were present in the workforce. Now that women are as equally employable as men, this method is outdated, and it is possible that some commercial buildings have not adjusted to this system.

Eco-Flow can assist these issues by providing comfort to each individual worker's preferred microclimate. Rather than settling on a calculated value to have the central AC running to satisfy a few, Eco-Flow can satisfy all by adjusting to each personal preference to generate the ideal microclimate. As a result, there could be an increase in productivity in the workplace, as there are little to zero distractions on how hot or how cold the temperature is. Eco-Flow can also be retrofitted for each user's particular need, whether it can be for a larger nozzle for airflow, or possibly a longer network of tubes from the originating HVAC module. Eco-Flow caters to each customer's desired need and structure.

By combining the residential and commercial sector together, we obtain a large availability of customers in the market to advertise Eco-Flow to. In addition, by making strong use of the market drivers available, we can provide a strong business value behind Eco-Flow while providing a formidable alternative to the currently available HVAC units in the market. Through channels such as Home Depot, Amazon, Apple, Brookstone and our own distribution website, Eco-Flow can be sold in-person or online to individuals based on their preference. Not only do we want to satisfy customer's needs to purchase the product, but a relationship between the customer and the company must be established. To meet these requirements, Eco-Flow intends on having an account management representatives for enterprise. This individual caters to customer's sales questions and preferences, as well as provide benefits to customers (discounted sales, giveaways or other promotional benefits). Eco-Flow will also be providing customer support for those that undergo difficulties in setup or inconveniences caused by malfunctions behind the product. If the issues are common, Eco-Flow would provide a list of "Frequently Asked Questions" (FAQ) on our website. This website would also be providing an "About Us" page, where we can educate possible users on our products in a clear and concise manner. With the addition of white papers, we can provide additional information for customers to educate themselves further.

---

[6] https://www.today.com/health/office-air-conditioning-cold-women-science-reveals-why-t36476

The revenue generated will originate from sales online or in-store. This in turn will pay for research and development, technological infrastructure behind Eco-Flow as well as products and salaries provided to the workforce. As a business, our key activities include further research and development for innovating Eco-Flow further, the provision of specialized talent behind the company, customer support and education (through white papers and resource libraries available to users). These are also key resources behind Eco-Flow, with the addition of intellectual property and sales force. Our key partners include those in distribution along with governments to advocate for a greener, healthier alternative to current HVAC systems through tax incentives.

Our competition is limited to the current HVAC industry plus Nest and Dyson, two major competitors, and EcoVent, a startup with a similar approach. Both EcoVent and Nest apply smart logic to current HVAC systems. With additional research and development, both companies can produce their own smart HVAC unit, similar to our approach. Dyson, on the other hand, provides ergonomic, attractive, standalone heating and cooling units but do not have smart logic applied to them. With the addition of smart logic to their products, they can very easily become direct competition with Eco-Flow.
Although Eco-Flow can provide innovation that can change the market, there are associated risks. Eco-Flow advertises for thermal comfort, in which the user is satisfied with the provided temperature setting for their microclimate. However, this is resulted from physiological and psychological comfort. There is no 100% guarantee that consumers will feel complete comfort in our product. Eco-Flow must also maintain energy efficiency to promote itself as the ideal alternative to HVAC units. If it cannot provide this standard, then the product cannot provide itself as a greener alternative. The market must also cater to the value of Eco-Flow as well. If priced too high, it may not receive great recognition and lose value in name. If key competitors decide to release a product similar to Eco-Flow, the likelihood of Eco-Flow gaining speed in the market is limited to possibly none.

As it stands, Eco-Flow currently has an advantage as the only unique smart HVAC unit. With additional research and development, we create a working, successful prototype. With this working prototype, we will devise how to mass-produce Eco-Flow products and budget the manufacturing process. Once we are able to produce promising products, we will be able to promote and receive revenue from the market.

Economically, we provide an open alternative to HVAC units, innovating others to compete and build alternatives to Eco-Flow, providing for a greener future ahead. This is with the initial assumption that Eco-Flow will save a percentage more of energy than typical HVAC units that are currently in the market.

Eco-Flow tackles the issues of global warming and carbon dioxide emissions by attempting to reduce the footprint that current HVAC units have. ARPA-E recognizes this as a grand challenge program, and acknowledges that HVAC systems could further save energy by going in the direction in which we as Eco-Flow pursue[7].

If Eco-Flow is introduced to the market, there can also be a shift in the HVAC workforce. Due to Eco-Flow's goal of reducing costs to HVAC infrastructure, there could be less of a need for HVAC technicians to be present to maintain and repair large HVAC units. All building structures are affected, therefore all individuals may be influenced by this day-to-day product. However, it must be noted that Eco-Flow will still consume electricity and still emit HFCs to the environment, contributing to the greenhouse effect. Eco-Flow is not appropriate as a children's toy, nor should the product be tampered with, as this may lead to injuries. If used wrongly, Eco-Flow could provide an unwanted environment to sensitive individuals, which can lead to excessive discomfort. Eco-Flow will be addressing this issue by only providing temperature differences up to 15 degrees Celsius. Eco-Flow cannot be used without an

[7] https://arpa-e.energy.gov/sites/default/files/documents/files/DELTA_ProgramOverview.pdf

electrical outlet or power source. Therefore, if there is no outlet available for the user, Eco-Flow will be unable to provide them comfort.

Eco-Flow's mission is to provide less harmful emissions to the environment, while still providing the necessary cooling or heating effect for all individuals. It is becoming more crucial to save on energy and protect the environment. By leaving the Paris Climate Agreement this year, it is more important than ever to invest on greener alternatives to ongoing wasteful products. The HVAC industry can be considered an untapped market that is not up to date with current technological trends. Through ownership of an Eco-Flow product - a smart HVAC unit for all - it can provide a much more personalized, efficient, and immediate airflow for a user without the worries of energy wastage and cost.