

## **The University of Hartford:**

### **A Case-study of Implementing Natural Ventilation in Sustainable Buildings**

In the 21<sup>st</sup> century, the world's population is taking new measures to ensure emissions of greenhouse gasses are minimized, while more studies are focusing on the construction of buildings that can be naturally ventilated; thereby reducing overall energy consumptions. As widely reported, the built environment, which includes buildings and transportation systems, accounts for more than two-thirds of all greenhouse gas emissions. As such, there is an increasing need to reduce energy consumption for all newly constructed buildings. "Green building" or "sustainable building" rating systems have been introduced in the USA to promote a healthier built environment. However, in order to achieve these standards, continuing education to ensure professional excellence is required. As such, all design professionals need to be aware of thermal conditions, specifically the importance of traditional and technical forms of building ventilation.

This study explores the use of natural ventilation in the design of sustainable buildings. At the University of Hartford, all architecture thesis projects must meet green building standards set by the design program. In the advanced building systems course, graduate students are required to study climatic impact on building forms and building skins. While there is a tendency to rely on mechanical ventilation in most student design projects, there has recently been an increase in various design proposals that promote the importance of natural ventilation. Innovative building skins have been developed by students that incorporate natural ventilation. These student propositions were evaluated using the Leadership in Energy and Environmental Design (LEED) rating system. Although, other aspects of design are also important in creating a sustainable architecture, the study found that students who engaged natural ventilation could more easily meet LEED requirements for (HVAC) internal thermal conditions. Thus, natural ventilation can be a crucial component in attaining a truly sustainable built environment.

## **The Architecture Thesis Program as a Study in Sustainable Systems**

The University of Hartford's undergraduate Bachelor of Science program was created in 1991, with the Master of Architecture program following in 2002, earning its first accreditation in 2008 under the department chair, Michael J. Crosbie, AIA (Visiting Team Report, 2008). While the graduate program holds the NAAB accreditation, the undergraduate program is advertised as a 4+2 terminal degree, encouraging students to pursue graduate school by either matriculating into the university's program, or attending another school. The M.Arch program has continued to grow over the past 9 years while retaining its accreditation. Currently, 4 of the 7 full-time faculty members are tenured and a number of practicing professionals serve as adjunct faculty, teaching a variety of topics across the curriculum in both required and elective courses to the 10-40 graduate students enrolled annually.

The Master of Architecture Thesis Class is split into two parts, a thesis research component, which takes place in the 3rd Semester, and a thesis design studio, which takes place in the 4th and final semester of the program. Upon entering Thesis Research, students are required to present a project proposal describing an issue in architecture and their intent to resolve it through an original design. The intentions of the course are to 1) Arrive at a well-stated (clear and concise) proposal for a manageable thesis project, 2) Prepare materials in anticipation of the thesis project, 3) Research and analyze the materials necessary to present a cohesive thesis - critical analysis of site, precedent, and theory, 4) Write a considered position paper on the topic of your thesis, and 5) Write a detailed program for a complex building" (University of Hartford (2016))

To be successful, the incorporation of sustainability in architecture needs to span across the entire project. There are opportunities to make eco-friendly decisions in almost every area, from something as large proper site orientation down to something as small as material selection. Through an integrative process, every design decision will affect the next, with goals of sustainability being set in the beginning, the ideals of green construction can easily be incorporated into any project. This paper will explore the creative use of natural ventilation and building skins to achieve LEED certification in a design project and the different design decisions made by several students and discuss how the student learning outcomes prove the method of introducing sustainable ventilation systems in architecture education at the graduate level.

## **LEED Green Building Rating System**

Available for nearly all project types, LEED is the most widely used green building rating system in existence. Certifications from LEED are sustainability achievements that are recognized worldwide and provide verification of a building's green features. Overseen by the United States Green Building Council (USGBC), their mission "is to transform the way buildings and communities are designed, built and operated, enabling an environmentally and socially responsible, healthy, and prosperous environment that improves the quality of life." (LEED Certification).

The system is comprised of impact categories which vary between project types. Sustainable practices that are important to a new construction project may not be relevant to an interior fit-out, and are omitted as such, however, for most project types, the differences are small. The impact categories are further broken down into individual credits, which define the sustainable practices being implemented. Credits are weighted depending on how much their incorporation impacts the project in terms of green building practices. Many of the design decisions made on LEED projects reduce the energy demand or carbon footprint of the resulting building. The number of credits achieved determines what level of Certification the project receives; Certified at 40, Silver at 50, Gold at 60 or Platinum at 80 (LEED Certification).

In the LEED Green Building Rating System, the largest impact category that credits can be earned in is Energy and Atmosphere, with a total of 35 possible credits. This category focuses on energy optimization and measurement, ensuring that building systems are not only efficient, but also take advantage of opportunities to reduce energy demand by incorporating passive systems. "As much as half of the energy used in your home goes to heating and cooling," (Heat & Cool Efficiently) meaning that optimization of these systems will yield both energy savings as LEED credits.

### **Interest**

One of the largest incentives people have to pursue sustainable practices is the financial savings that green buildings bring. While there is a large upfront cost of implementing the technology, the higher energy performance will certainly reduce energy demand, and in turn, the amount of money spent on energy. "A recent study of PNC's bank branches by the University of Notre Dame found that the annual utilities cost per employee in their LEED facilities was \$675.26 lower than in non-green facilities;" (LEED Facts, 2013) additionally, "Employees working in the LEED-certified branches of the same financial institution were found to be 'more productive and engaged in their work'" (The Business Case for Green Building, 2015). Many LEED credits create opportunities for employees to directly partake in energy savings through

lighting and air quality controls. While sensors are often installed for routine regulation, allowing occupants to control their environment and giving them the ability to make eco-friendly decisions increases productivity. Many companies have also found changes in consumer activity as they shift to more eco friendly practices, “73% of corporate leaders expect to attract and retain customers as a direct result of their sustainability efforts,” (The Business Case for Green Building, 2015) as most of the population has a desire to take part in creating more eco-friendly lifestyles.

Green building practices are not just limited to commercial projects, CEOs and homeowners alike can partake in financial and energy savings through similar means. With growing popularity of sustainability technology and awareness of climate change, interest in building green has risen across all project types, “recent studies confirm that that, as of January 2015, the market for houses with green certifications is 10 to 14 percent more than for comparable homes without them” (The Business Case for Green Building, 2015). As the trend grows, the priorities of homeowners has shifted drastically from what previous generations considered important, “73% of single-family builders and 68% of multifamily builders say consumers will pay more for green homes. Harris Interactive poll of over 2,000 Americans found that nearly half (49%) consider eco-friendly features more important than luxury items in a home (31%)” (The Business Case for Green Building, 2015).

### **The need**

When thinking about the future of energy, the discussion often diverts to the generation of clean energy through solar panels, wind farms, and other means of harvesting electricity while matters of conserving energy and maximizing energy efficiency are overlooked. “The residential space conditioning load is responsible for a significant portion of annual emissions of fossil carbon dioxide. These carbon emissions originate either from on-site combustion of fuel or, in the case of electric equipment, from the power stations that generate the electricity consumed” (Ryan). The over reliance on mechanical systems for space heating and cooling is one of the largest sources of wasted energy and greenhouse gasses being dumped into the atmosphere.

- In 2012, over 40% of the world’s electricity was generated from coal (Nuclear Power in the World Today, 2017).
- “A typical coal plant generates 3.5 million tons of CO<sub>2</sub> per year” (Coal Power: Air Pollution).

- Space heating and cooling accounts for 35% of the energy used by commercial buildings (Energy Use in Commercial Buildings, 2017)

In addition to the wasted energy and the production of CO<sub>2</sub>, humanity's reliance on mechanical cooling systems release other harmful substances into the air. For decades, Chloroflourocarbon (CFC) has been used as a refrigerant in cooling systems. CFCs have such a large potential for depleting the O<sub>3</sub> that the use of the compound has been banned under the Montreal Protocol and cannot be used in a project if LEED Certification is being pursued (Refrigerant Management).

Our mechanical systems allow people to occupy the harshest environments on the planet, creating habitable spaces in extremely hot or cold regions. There is no denying the marvelous accomplishment this is. However, not all environments require this. For centuries, humanity has survived the heat and cold of most places through natural means and an understanding of their surroundings. By using appropriate materials and considering the movement of the sun and air, energy demand will drop drastically and the amount of money spent on energy for heating and cooling will follow suit.

### **Methods of sustainable ventilation**

Mechanical heating and cooling, in terms of the history of architecture, is a relatively new idea; "it is only in the last century that cheap energy and mechanical heating and cooling of the buildings left architecture disengaged" (Brebbia, 20018, p. 11-12). It has proven itself to be extremely effective in making spaces comfortable for human inhabitants. However, throughout most of history, air circulation was heavily dependent on the laws of nature. Consideration of how the project would be situated on the site and the placement of fenestration determined how much air flow could occur in any given structure.

Mechanical heating and cooling can produce the desired results; the process requires a large amount of energy. With the right consideration of design, passive systems can be implemented into building projects that drastically cut down on the need for mechanical systems. There are various natural systems, each with their own pros and cons. Passive heating and passive cooling strategies provide alternative solutions for space conditioning.

There are three primary strategies for passive heating: direct gain, indirect gain, and isolated gain (Grondzik). Direct gain utilizes south facing glazing to heat habitable surfaces. Indirect gain utilizes a trombe wall, which is a wall built on the winter sun side of a building with a glass external layer and a high heat capacity internal layer separated by a layer of air. This wall absorbs heat throughout the day and releases it during the night in order to regulate

temperatures. Isolated gain requires the creation of a space separate from the one that is being heated, which can absorb heat from the sun through glazing, creating large temperature swings. The air in this space must be vented to the main spaces in order to utilize the collected heat. Passive cooling can be a bit more complex than heating. The three main strategies are: cooling the air, cooling the building, and increasing the airspeed (Grondzik). Cooling the air can be accomplished by removing humidity or venting air through underground geo-exchange channels. Cooling the building can be accomplished by allowing heat to escape. Much like solar gain, thermal masses that retain heat can also be used to cool the building. If the mass is allowed to cool at night, it will keep the building cool all day as it works its way back to a neutral temperature, repeating the cycle the following night. Increasing the airspeed will cool the building through one of two means of ventilation; stack driven or wind driven. Stack driven ventilation relies on the natural air flow from low to low pressure. Cool air resides in high pressure areas whereas warm air has low pressure, causing heat to rise. Venting hot air at a high point will play into the natural air circulation as the hot air rises; likewise, an intake at a low point will naturally draw in cooler air to feed into the high air pressure (Grondzik).

### **Sustainability in Thesis**

Students at the University of Hartford are introduced to these methods through the Advanced Building Systems class. Students learn about different types of passive heating, cooling, and ventilation while discussing which methods will have the most effect in different climates. By learning how to use the psychrometric chart, students can determine which methods will be the most effect for their projects and integrate them into the design.

This practice is carried through the design studios and finally tested in the Master Thesis project, where every student selects their own site and building type. This approach to the design curriculum allows for a wide range of independence and a variety of sustainable solutions. Every project in the Master Thesis must earn the 60 LEED credits to receive a LEED Gold Certification. In order to achieve this goal, students research sustainable technology and practices across all aspects of the project, including building orientation, materials, methods of construction, building systems and recent technological innovations. The goal of each student is to earn as many credits as possible. According to the LEED scorecard, the most credits can be attained in the *Energy and Atmosphere* category, so students naturally prioritize these criteria. Depending on the project, students take different approaches to their ventilation. Some projects attempt to simulate the climatic benefits of other regions in order to create a sense of familiarity for the inhabitants.

Drawing on the similarities in climate between Syria and San Diego, California, Twana Aldouri utilized stack ventilation in courtyards outside of residential apartments to create isolated gain shared by several units. An international student from Iraq, she was familiar with typical ventilation techniques used in her homeland. Along with thorough research into traditional Middle Eastern housing prototypes, she fused her personal experience and analysis and translated the results to a new location, with a similar climate. This heterotopian housing complex is intended to simulate the amenities that displaces refugees from Syria would be accustomed to in their homeland. San Diego has been a popular destination for refugees from the Middle East, resettling 1,450 people in the 2016 fiscal year (Parvini, 2017), making it an ideal location to explore this idea.

In her design for a residential apartment block in San Diego, she proposed a relationship where cool air naturally drops into the courtyard from as hot air rises is expelled upwards and away from the units. The air in the courtyard can be drawn in through windows in each apartment, using the same high-to-low pressure movement that the air will naturally make, cooling the apartment. Additionally, mashrabiya screens is applied to the exterior facades of the building, providing sun screening and privacy whilst still allowing air to flow through open windows, aiding the natural ventilation efforts. The mashrabiya screens are wooden or glass screens, perforated with elegant geometry and Arabic ornamentation, typically seen in Middle Eastern countries (Aldouri, 2017). Its incorporation into this project helps to create feelings of familiarity and security for the inhabitants while drawing on the benefits of sustainable natural ventilation. The natural cooling taking place through the means of the courtyard and the exterior screening nearly eliminate the need for air-conditioning (Aldouri, 2017).

In another residential project, Laura Crowley utilizes a series of sustainable concepts to not just provide natural ventilation, but also regulate interior environments, diminishing the need for space conditioning. Across several programmatic elements, a mixed use apartment building requires different cooling and privacy elements for each space. Proposed for downtown Southington, Connecticut, considerations must be taken for all four seasons as temperatures range from 17 degrees Fahrenheit in the winter to 85 degrees Fahrenheit in the summer (Southington, Connecticut). In order to defend against these drastic temperature differences, air-tight thermal insulation in the exterior walls is imperative. Walls with high R-values will prevent heat transfer between interior and exterior spaces, allowing conditioned spaces to maintain the desired temperature longer by limiting the heat transfer from outside.

By utilizing elements such as sun shading, which allows solar gain in the winter and blocks it in the summer, and high R-value building skins, the indoor quality is easily maintained;

however, the spaces still need to be conditioned to the appropriate temperatures. Laura Crowley incorporates mechanical heating and cooling to accomplish this; the supplemental sustainable elements drastically reduce the energy demand of the project allowing spaces to be heated and cooled efficiently. To lighten the mechanical conditioning load, heat pumps are used to move heat either in or out of the building. As opposed to typical electric resistance heaters, a heat pump does not generate heat, it simply moves heat in the desired direction, inside for heating, outside for cooling and operate between 200%-300% typical HVAC efficiency. Further decreasing energy demand, Laura specifies energy recovery ventilation (ERV) that recovers most of the energy of the air exiting the building into the air entering the building through heat and moisture transfer. While the two air streams do mix slightly, about 10% (Holladay, 2010), the air entering the building needs only slight conditioning, saving about 94% of the energy typically used (Crowley, 2017, p. 47). Operable windows allow occupants further control over the temperature of individual spaces as well as additional fresh air intake.

Kalkidan Zerfu explores how sustainable practices can benefit developing nations where building materials are not in abundance through the design of a student center. This building type speaks to the educational quality of her study of the sustainable aspects of bamboo while also allowing for a variety of programmatic elements to be taken into consideration. As an international student from Ethiopia, her gravitation to bamboo allows the project to relate back to her home country which has “the largest area - over one million hect-acres - of commercially untapped bamboo in East Africa” (Zerfu, 2017, p. 12). Bamboo, as a renewable and naturally sustainable resource, only taking a few years to grow to usable height (How Does Bamboo Grow?, 2017). To prove the material’s resilience, she proposed the project be constructed on the Westminster School campus in Simsbury, Connecticut, where the climate would allow for a multitude of passive strategies to be tested, proving the material to be beneficial universally.

Kalkidan Zerfu utilized a direct gain in order to heat her building by collecting solar radiation. The heating effect is extended through the night with the use of thermal masses, which collect heat throughout the day via the direct gain consideration, releasing the heat into the building at night as the building maintains temperature equilibrium. With the incorporating a stack ventilation system, the heat is naturally drawn across the building and expelled out the top of the atrium because. As heat is released out the top, more air is drawn in that direction because there is less air pressure at the exit point, dragging the hot air across the building and effectively heating every space along way. The same concept is used to cool the building in the summer. Sun screening effectively halts the solar gain, and operable windows allow cool air to

replace the hot air as it rises and exits the building. This full-building ventilation is heavily dependant on airflow, making operable windows and skylights essential to the design.

### **In Conclusion:**

The challenge of building sustainably is an ever growing issue that will have a massive impact on humanity's future. Rating systems such as LEED provide guidelines and incentive for pursuing green building practices, however, it is the responsibility of educators immerse students in the ideas and processes so that a more sustainable future can be created. Looking back on the history of architecture, before the convenience of mechanical heating and cooling, natural and passive strategies had been the industry standard for space conditioning. The shift towards mechanical systems has burdened our energy supply and caused massive amounts of pollution to enter the atmosphere. This paper has discussed a small portion of the ideas that students are exploring as design solutions

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